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A SYSTEM DYNAMICS APPROACH TO MANAGING PROJECT RISKS IN THE ELECTRICITY INDUSTRY IN SUB SAHARAN AFRICA

by

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ABSTRACT

A SYSTEM DYNAMICS APPROACH TO MANAGING PROJECT RISKS IN THE ELECTRICITY INDUSTRY IN SUB SAHARAN AFRICA

In Africa, major projects are presently in progress to upgrade and expand energy sector infrastructure. Many such projects have run into delays, quality problems and cost overruns. To overcome these challenges, Governments in the region have devoted effort and resources in seeking to improve the management of energy sector projects in many countries in the continent. The objective of this research was to develop a means and method by which risk can be better managed in projects in the electricity energy sector in Kenya and the Sub Saharan Africa region. The research focused on risks prevalent in the electricity sector projects in the region from which a System Dynamics model that mirrors the prevailing dynamics in the sector was developed. Views from key stakeholders in the industry in Kenya such as contractors, utility companies and the Ministry of Energy officials were solicited through an exploratory study that gave rise to the conceptual System Dynamics model developed in this research.

The primary motivation of the research was to expand the understanding of the dynamic interaction of risks in the electricity energy sub-sector by focusing on the dynamics of projects in the electricity power industry in Sub Saharan Africa. System Dynamics was chosen as the modeling and simulation tool based on insights from literature that revealed that projects in the electricity industry can be framed as complex dynamic systems since they comprise multiple interdependent and dynamic components, and include multiple feedback processes and non-linear relationships. A qualitative research approach was used in the research study, designed as a guided participative cooperative enquiry based on active interviewing as well as use of archival data from previous projects.

The new basic model developed in this research was presented to a workshop comprising experts in the power industry in Kenya, where the model structure and the simulation results were shared with the participants in a discussion forum. The results from the workshop indicated that the simulation results from the model mirrored the reality of project dynamics in the industry in Kenya, and by extension, the wider Sub Saharan Africa region. The results indicated that the forces that cause project delays and quality challenges in the electricity sector in Kenya include a shortage of testing / commissioning engineers that lead to multitasking and late discovery of tasks that require rework. Political risk, unforeseen technical difficulties as well as below average project management skills also featured prominently during the workshop discussions.

Various policy scenarios arising from experimentation on the new model were explored and analyzed in the research. The results of the policy scenario analysis show that by employing more competent project managers and engaging of skilled testing and commissioning engineers in adequate numbers, projects in the sector will likely finish on time and with improved quality. The study also reveals that inclusion of an insurance component in the procurement process for the project contractors can be used to mitigate the effects of political risk, and that spreading the workforce, rather than having a skeleton workforce at the beginning of the project, would be more desirable as it would help eliminate effects associated with multitasking that contribute to project delays. This research contributes to new knowledge by expanding and extending the previous model by Richardson (2013) through the inclusion of political risk, project management competence, unforeseen technical difficulties and an insurance index to derive scenarios that can be used to reduce project delays and improve on quality of the completed project.

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TABLE OF CONTENT

PART 2: THE EMPIRICAL RESEARCH

LIST OF TABLES

LIST OF FIGURES

PART 1: THEORETICAL RESEARCH

CHAPTER 1: Introduction / Background to Managing of Risks in Electricity Industry Projects

1.1 Introduction

Developing countries offer abundant opportunities for high return and high growth potential investments, such as in critical infrastructure that removes bottlenecks to growth. Economies in sub-Saharan Africa are growing at an average rate of 5 percent a year, and this makes the sub-continent attractive as an investment destination (Pole et al, 2010). With a growing population, emerging middle class, and strong GDP growth, the region consisting of 48 nations is poised to continue the impressive growth and evolve into an increasing business destination. Roxburgh et al (2010) note that Sub-Saharan Africa is presently the third-fastest growing region after Asia and Middle East, and this strong growth pattern is supported by the World Bank (2015) which states that the GDP growth in Sub-Saharan Africa improved to an average of 4.6 percent in 2014, up from 4.2 percent in 2013, mainly supported by infrastructure investment and consumer spending.

While reporting for the IMF, Pani (2015) also states that the IMF's regional economic outlook for Sub-Saharan Africa projects the economy of the region will register another year of solid performance, expanding at 4.5 percent in 2015, and further notes that Sub-Saharan Africa will remain among the fastest growing regions of the world in 2015. This is also supported by the report from the African Economic Outlook 2015, an annual report from the African Development Bank which predicts that the economic growth in Sub-Saharan Africa will reach 4.6 percent in 2015 and increase to 5.4 percent in 2016. Most of the growth has come from the desire of the countries in the sub-Saharan Africa region to upgrade their infrastructure consisting of new roads and highways, telecommunications projects and the ongoing scale up of electricity generation and distribution projects. However, many such projects have run into delays, quality problems and cost overruns, which have become a major challenge to projects in the region.

To overcome these challenges, enormous efforts have been devoted to the planning and control aspects of construction management. Pathak and Srivastava (2015) however note that in real life engineering projects, uncertainties such as management experience, labor skills and weather conditions are usually at play and end up affecting the duration and cost of project activities. Widely adopted approaches for planning and control in the construction industry include the use of network-based tools, such as Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), and Earned Value Method (EVM). However, because these tools inherently utilize a static approach that may provide users with unrealistic estimations, they often ignore prevalent multiple feedback processes and nonlinear relationships of a project (Lyneis et al, 2001). Systems thinking and the system dynamics approach has proven useful in project management planning activities where it has been applied and has been suggested by Bendoly (2014) as a critical driver of a range of beneficial organizational behaviors that will add value to the management of construction projects. This view is supported by Han et al (2014) who state that system dynamics has received relatively little attention despite its great potential to address dynamic complexity in construction projects, which also involve multiple feedback processes and non-linear relationships.

Several researchers have carried out research related to construction project management with the use of system dynamics modeling, as shown in table 1.1.

Table 1.1: Applications of system dynamics in research into construction project management (Boateng et al, 2012)

Researchers	Year	Summary
De-Marco, A. & Rafele, C.	2009	A feedback process to understand construction project performance
Nasirzadeh, Afshar and Khanzadi	2008	An approach for construction risk analysis
Ogunlana, Sukhera and Li	2003	Performance enhancement in a construction organization.
Love, Holt, Shen, Li and Irani	2002	The need for understanding of how particular dynamics can hinder the performance of a project management system.
Chritamara. S and	2002	Modeling of design and build construction projects

Ogunlana. S.		
Rodrigues, A. and Bowers, J.	1996	A comparative analysis between two approaches to project management.

However, and despite these efforts, little or no research has been done aimed at understanding the dynamics at play in project risks specific to the electricity industry in Sub-Saharan Africa. This research identifies the risks present in electricity projects in Sub Saharan Africa, reconstructs the dynamics at play using feedback loops and employs system dynamics modeling to study the project dynamics in electricity sub-sector projects in Sub Saharan Africa. The aim is to derive suitable policies that would benefit such projects in future.

1.2 Background of the study

Engineering and Construction industry caters for projects that design and build facilities. These projects require capital investment on which the client seeks to generate a satisfactory return. Clients understandably want to achieve for their projects the best cost performance in combination with the best schedule performance. In this setting, change is common and often includes changes to performance specifications, changes in project scope, changes in design features, changes in vendor-supplied equipment, as well as changes in schedule targets (Cooper and Lee, 2009). These types of changes create uncertainty in the project environment, and often lead to risks that create challenges to the attainment of project goals. The project as a whole stand to gain if these risks can be managed well.

This is true for the electricity power industry in Sub Saharan Africa which is undergoing a period of rapid expansion with many large scale projects covering power supply generation scale up, new transmission and distribution network construction as well as upgrade of the existing substations. However, many of these projects have faced unforeseen risks and uncertainties, and end up running into lengthy schedule delays and substantial cost overruns. This has the combined effect of slowing development in the region and frustrating investors in the region who have to bear with irregular and unreliable power supply, power rationing and high power tariffs occasioned by use of expensive short term thermal power brought in to fill the gap.

1.3 Problem Statement

Infrastructure comprising transport, water, energy and information and communications technology, has become the single largest business line for the World Bank Group, with $26 billion in commitments and investments in 2011 as a result of a major scale up since 2003 (Kyte et al, 2015). There is consensus that energy is directly linked to the key global challenges that the world faces today and as such, the development of sustainable and long-term solutions to meet these growing, diverse and urgent energy challenges assumes special significance for developing countries in general and countries in Africa in particular. International Energy Agency (2008) reports that Africa continues to face critical challenges related to its energy sector, and that the current energy policies and systems have failed to provide the platform needed to support the economic development of the majority of Africa's poor.

In the recent past, there has been a remarkable growth in the number, size, and complexity of large-scale Infrastructure projects in many developing countries. Across sub-Saharan Africa in particular, Bray (2015) notes governments are facing growing domestic pressure to increase power capacity to meet the needs of their populations through such projects. Othman (2013) notes that mega construction projects represent a strategic option towards achieving sustainable development objectives in developing countries. Management of these projects inevitably requires dealing with risks and uncertainties that arise during the course of the projects. These uncertainties contribute to project delays and decline in organizational performance. Key issues in Africa's energy sector include low access and insufficient capacity, poor reliability and high costs. In a study conducted to investigate effectiveness of risk management practices across countries and industries, Zwikael and Ahn (2011) found that environmental context determines the level of perceived project risk. Specifically, they found that the perceived level of risk, and hence risk management planning, are lower in countries characterized by low levels of uncertainty avoidance.

In Kenya, the government has embarked on a target of moving the country to a middle income country economic level by year 2030, and this requires that the country maintains sustained economic growth of at least 10% from 2012 and beyond. This level of economic growth has not been attained yet, and Odero et al (2015) report that the GDP growth in Kenya amounted to 6.9%

and 5.7% in 2012 and 2013 respectively, while the 2014 estimate and the 2015 projection show economic expansion of 5.3% and 6.5% respectively. One of the key pillars to the attainment of these economic goals is the availability of adequate, reliable and affordable electricity throughout the country. The government embarked on ambitious projects aimed at scaling up electricity generation in the country and enhancing power supply distribution and substations upgrades. However, many of these projects have been delivered behind schedule, with quality challenges while some of the projects have been over budget. Documentation and archival data from past projects reveals that a majority of these projects have faced unforeseen risks and uncertainties. Dealing with uncertainties and risks that cause project delays and cost overruns is therefore important so as to ensure future projects in the energy sector in Kenya and by extension, the sub-Saharan Africa deliver value. The fact that uncertainty is at its highest and the cost for making amendments at its lowest during the early stages illustrates the great potential for improvements in the pre-planning and planning phases of projects.

The primary motivation of this research is to expand the understanding of the interaction of risks and uncertainties affecting projects in electricity power industry in Kenya and by extension, the wider Sub Saharan Africa region. The purpose of the new model is to generate new insights and improve understanding of project dynamics in the electricity power industry in Kenya, to explore policies that can be implemented by the government of Kenya and the electricity utility companies to minimize project delays in the sector and improved ways of managing projects in the sector. The results of this study should be of benefit to all the stakeholders involved in the sector including the investors in the energy sector in Kenya and the Sub Saharan Africa region.

1.4 Research Objectives

The aim and purpose of this research was to develop a means and method by which risk can be better managed in projects in the energy sector, specifically in projects in the electricity utility industry in Kenya and the Sub Saharan Africa region. This was done by identifying risks that prevail in the industry and investigating interactions of these risks in a dynamic setting. In doing this, perspectives from key stakeholders in the industry such as contractors, Kenya power and Lighting Company Limited project staff and Ministry of Energy officials, were included so as to create harmony and reduce disputes which are common amongst the key players. Lack of harmony amongst key stakeholders often causes delays and increases uncertainty in projects. The key objectives were: -

(1) To review existing literature on uncertainty and risks, systems thinking and system dynamics in projects, and using insights gained from the literature, solicit opinions from stakeholders in the energy sector in Kenya on prevalent risks in the industry.

(2) Develop a System Dynamics conceptual model of interacting project risks based on knowledge gained from the stakeholders and literature.

(3) Using a systems approach, to develop a suitable System Dynamics simulation model that mirrors the present reality and project dynamics in infrastructure projects in the electricity power industry in Kenya.

(4) To test the model and carry out policy analysis to generate policy scenarios

1.5 Research Questions

This research sought to answer the following questions:

(1) What are the project dynamics in the electricity industry in Kenya?

(2) How do the prevalent risks and other elements interact with each other in a dynamic project set up?

(3) What policy scenarios derived from the resulting model are available that can help stakeholders in the sector to better manage such projects so as to deliver value?

The main questions were answered with the help of the following sub-set of questions:

a) What are the prevalent project risks in electricity infrastructure projects in Kenya and the region?

b) How can the interaction of project risks in the electricity sector in Kenya be studied and analyzed in a dynamic setting?

c) What research strategy and paradigm can be employed in studying project risks in the electricity sector

d) What forces create the problems that lead to project delays and quality challenges experienced in projects in the electricity sector in Kenya?

e) What policy scenarios derived from the project dynamics in the electricity sector in Kenya can be used to improve project delivery time?

f) What policy scenarios derived from the project dynamics in the electricity sector in Kenya can be used to improve the quality of the delivered projects?

The sub-set questions 1.5 (a) and 1.5 (b) were used in answering the first research question; "What are the project dynamics in the electricity industry in Kenya?", while the sub-set questions 1.5 (c) and 1.5 (d) were used to answer the second research question; "How do the prevalent risks and other elements interact with each other in a dynamic project set up?" The two sub-set questions 1.5(e) and 1.5(f) were used in answering the third research question; "What policy scenarios derived from the resulting model are available that can help stakeholders in the sector to better manage such projects so as to deliver value?"

1.6 Motivation of the study

Construction activities are an index of the economic and social progress of a country and management of these projects inevitably requires dealing with uncertainties that may arise from these projects. These uncertainties contribute to project delays and decline in organizational performance (Ofori1991; Ogunlana et al. 1996; Xiang et al 2012; Gheorghi et al 2014; Tran and Molenaar 2014; Chatzimichailidou et al 2015). Local governments and individual firms are therefore concerned about enhancing organizational performance for their survival in the competitive and increasingly globalized construction market.

Many organizations are now adopting management by projects as a general approach. However, as projects become more complex, project failure is unfortunately another major trend (Pugh Roberts Associates, 1993). Overruns are common, many projects appear as failures and are often completed later or over budget, do not perform in the way expected, or are cancelled prior to their completion after spending considerable sums of money. While problems encountered during construction are fundamentally dynamic, they have been treated as static problems within a partial view of a project (Lyneis et al, 2001). As a result, schedule delays and cost overruns are common in construction projects in spite of advances in construction equipment and management techniques (Park and Pena-Mora, 2003). The rapid rate of expansion in the electricity industry in most parts of Sub Saharan Africa has led to an environment in which an increasing amount of business in the industry is delivered through projects (Findt et al 2014; Herscowitz et al 2014; Castellano et al 2015). In this environment, schedule pressure is pervasive; uncertainty is common while resources assigned to projects are scarce.

The primary motivation of this research is to expand the understanding of the dynamic interaction of risks in the electricity energy sub-sector by focusing on the dynamics of projects in the electricity power industry in Sub Saharan Africa. This understanding is captured in a system dynamics model of the factors and risks at play in projects of this nature in the sector. The new model will be used to derive suitable policies that are likely to reduce project delays and quality challenges.

1.7 Scope and Limitations of the Study

The research is focused on how to manage risk and uncertainty in projects in the electricity industry in Sub Saharan Africa. The research will include perspectives of key players in project performance in Kenya, particularly project personnel the electricity distribution company, Kenya Power and Lighting Company Limited, contractors and government officials in the energy sector. The prevailing sector conditions in Kenya is used as representative of the Sub Saharan Africa region, and therefore it is presumed that the model developed in this research will assist practitioners to better manage risk and uncertainty in projects in the industry in the entire Sub Saharan Africa region. This assumption derives from the similarities in culture and project delivery structures in many parts of Sub Saharan Africa. The results of this research are therefore presumed to be beneficial to Sub Saharan Africa, and developing countries at large.

1.8 Importance of the study

The results of the study are expected to improve project planning and the understanding of project dynamics, and will likely result into better project risk management in the electricity industry in Sub-Saharan Africa. This should in turn help the utilities deliver infrastructure projects with better success rates, and hence further improve on the efficiency of project delivery in the region. The results will also be beneficial to investors in the energy sector in Africa and developing countries that share similar operating environments, and will be especially useful during the formulation of procedures for new projects for engagement with the funding recipients. Overall, this should improve economic growth in the region and reduce wastage of resources.

1.9 Organization of the Research

The research is organized in three parts and eight chapters. The first part is the theoretical part comprising the first three chapters. It begins with chapter 1 which introduces the whole thesis, highlighting the subject, purpose and scope. Chapter two focuses on the literature review on project risks, feedback systems, system thinking and system dynamics with the aim of capturing previous research findings and presenting trends in the area. Chapter three covers an overview of mental models, their strengths and weaknesses, and hence the need for computer models. Thereafter, a review is done of existing models and methods relevant and beneficial to risk mitigation during the planning phase of projects.

Chapter 4 describes the scientific procedure or methodology which will be used in this research. This chapter describes the research strategy and the choice of research method. Then, it describes the research paradigm used in this study, followed by the system dynamics hypothesis and an overview of the system dynamics modeling process followed by the validation process used. This is followed by a discussion on the empirical setting of the research, research design and data collection methods. Chapter 5 addresses the new model development using system dynamics approach, while chapter 6 covers analysis and testing of the new model and policy design. Chapter 7 discussed the overall results of the thesis, while the last chapter, which is chapter 8, gives the concluding insights gained from the thesis as well as implications for future research and the electricity power industry in Kenya and by extension, the Sub Saharan Africa region.

Figure 1.1 is a diagrammatic representation of the structure of the thesis showing the linkages between the chapters.

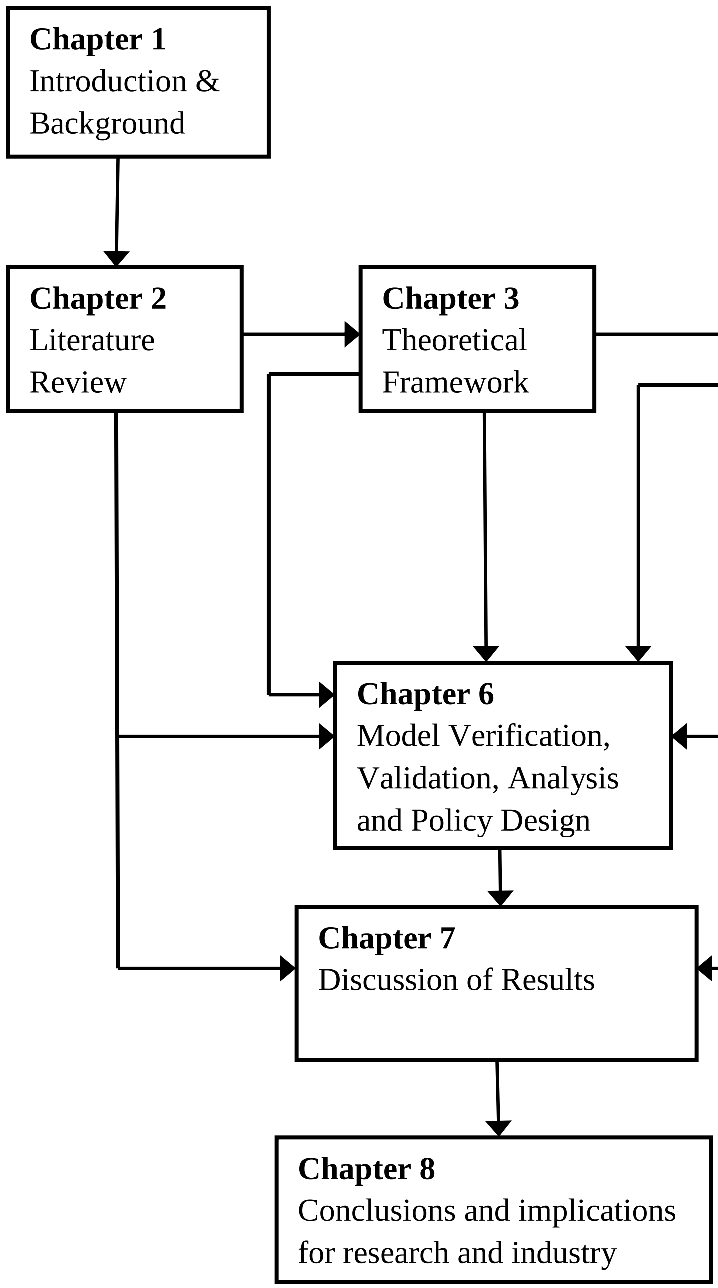

Figure 1.1: Structure of the Thesis showing the linkages between the chapters

1.10 Summary of main findings

In summary, the rate of economic growth in Africa in the recent past has picked up and this has led to more utilities in Sub Saharan Africa into expanding their electricity infrastructure. Most of this expansion is done through projects, and many such projects are affected by project delays, cost overruns, and quality challenges that can be traced to the project dynamics at play. Many such projects are fairly complex and carry risks that may interact with each other, and therefore a holistic systems approach is advocated rather than a sequential approach to managing these projects. This research project has developed a model that will likely help reduce uncertainty in the electricity utility projects in Sub-Saharan Africa, and should be beneficial to the energy sector players in Africa and in other developing countries as well.

The following chapter explores in greater detail past literature and theory on project risks, systems thinking and the systems approach in project management. This helps shed light on the critical factors to be considered in the planning stage of construction projects. The findings in the literature review will be used as the yardstick and reference upon which this research will be conducted.

CHAPTER 2: Literature Review of project risks, feedback systems, system thinking and system dynamics

2.1 Introduction

In this chapter, literature and theory on project risks in general as well as risks common to infrastructure projects are explored and reviewed with the aim of capturing previous research findings. Further, system engineering and its value in project management is expounded while systems thinking, systems dynamics theory and their relevance to projects in the energy sector are explored and explained. The fundamentals and significance of system dynamics theory are also explored, while the system dynamics approach to strategic project management is highlighted. Past and current literature on political risk and its influence on projects in the electricity sub sector is presented and examined, while the phenomenon of interacting project risks is also explored. The place of system dynamics modeling in strategic project management is discussed and its relevance highlighted.

Knowledge gained from this chapter is used in the exploratory study as described in section 4.5.4, so as to aid in answering the sub-research question in section 1.5 (a) namely; "What are the prevalent project risks in electricity infrastructure projects in Kenya and the region?", which is later used in chapter 4 in answering the first research question "What are the project dynamics in the electricity industry in Kenya?".

2.2 Project risks in the construction industry

According to ISO 31000 (2009), risk management refers to a coordinated set of activities and methods that is used to direct an organization and to control the many risks that can affect its ability to achieve its objectives. Project Management Institute (2008) defines project risk as 'an uncertain event or condition', which highlights that uncertainty is a necessary condition for a risky situation and that in practice, project risk and project uncertainty are interlinked. Risk management's objective is to assure uncertainty does not deflect the endeavor from the business goals (Antunes and Gonzales, 2015). Literature has widely acknowledged the positive effects of risk management by focusing primarily on the project level across various industries (De Bakker et al, 2011). In a study on risk management in project portfolios, Teller et al (2014) found the interaction between risk management practices on different management levels to be highly relevant in determining project portfolio success.

The conceptual phase of a new construction project is most important, since decisions taken in this phase tend to have a significant impact on the final cost. It is also the phase at which the greatest degree of uncertainty about the future is encountered. In response to this type of situation, risk management can play an important role in controlling the level of risks and mitigating their effects. However, its adoption by industry has been rather slow, and the construction industry in particular has been slow to realize the potential benefits of risk management (Simister, 1994, Ward et al, 1991). This view is supported by Wu and Olson, 2009 when they state that construction projects are marred by risks which delay the completion of projects on time or result in excessive cost overruns, and such losses are multiplied if the size of the project and investments made are huge. These risks may include unavailability of materials, erratic weather changes, lack of funds, and low quality of sub-contractors.

This is further reinforced by Nasirzadeh et al (2008) when they state that construction projects involve a large number of risks which have a complex structure, are highly dynamic in nature resulting from the various feedback processes involved throughout the life cycle of the project, and that the success or failure of a construction project may vary depending on the approach that is adapted towards managing such risks. Figure 2.1 illustrates the conditions to be fulfilled for an event to be classified as a risk.

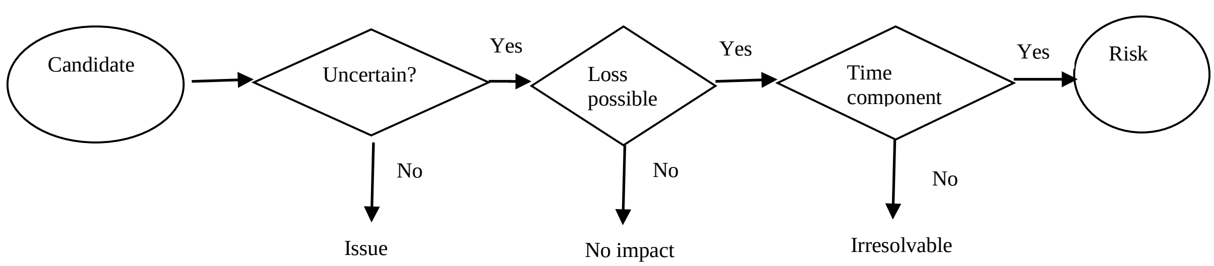

Figure 2.1: The Three Components of a Risk (Smith & Merritt, 2001)

Though managers realize the importance of these risk factors and the need to mitigate them, they fall short of an objective method to manage these risks based on a priority basis (Martin, 2006), and mostly use ad-hoc or unscientific methods like rule of thumb to analyse and manage risks in the absence of a proper risk management framework. However, Shen et al. (2006) have argued that as the construction projects become more uncertain and complex, intuition and tested rules of thumb often fail to anticipate and respond effectively to the extent of uncertainty and risk in construction projects. According to Prasanta (2002), large-scale construction projects are exposed to uncertain environments because of factors such as planning and design complexity; presence of various interest groups like project owner, owner's project group, consultants, contractors and vendors, resource issues; climactic environment; the economic and political environment and statutory regulations. This is illustrated in Table 2.1. These observations reinforce the fact that large scale projects such as those found in the electricity industry are complex in nature, and therefore risk management is important for the success of these projects.

Table 2.1: Risks in Large scale construction projects (Prasanta, 2002)

Technical Risks	Scope change, technology selection, implementation methodology selection, equipment risk, materials risk and engineering and design change
Acts of God	Normal natural calamities and abnormal natural calamities
Financial, Economic and Political Risk	Inflation risk; fund risk; changes of local law; changes in government policy and improper estimation
Organizational Risk	Capability risk of owner's project group; contractor's failure; vendor's failure and consultant's failure
Statutory Clearance Risk	Environmental clearance; land acquisition; And other clearance from government Authorities

Similarly, Hodge (2004) states that infrastructure projects involve a wide range of risks, and he gives in table 2.2 the risks that affect infrastructure projects. This compares well with the risks as listed in table 2.1, with the additional rider that in infrastructure projects, finance, construction, and ownership risks are mostly borne by the public sector in traditional construction projects while operation risks, design and development risks are mostly shared between the public sector and the contractors.

Table 2.2: Risks and risk allocation for traditional infrastructure projects (Hodge, 2004)

Risk category	**Risks**	**Comment**
Finance	Securing finance Maintaining finance Interest rate and tax amendments Tax rulings Price escalation in capital components	Risks mostly borne by public sector in traditional construction projects
Design and Development	Design suitability Development problems Testing problems Design and development variations Delivery of design	Risks shared in traditional construction projects
Construction	Fixed time and cost to complete Delivery schedule Planning approvals Environmental issues Disruption to existing services Site preparation Design and construction variations Industrial disputes	Risks mostly borne by private sector in traditional construction projects
Operation	Asset/service performance Asset/service availability Repairs and maintenance cost variations Security Staff training Cost of keeping existing assets operational Latent defects in existing assets Changes in demand	Risks mostly shared in traditional construction projects
Ownership	Uninsurable loss or damage to the assets Technology change or obsolescence	Risks mostly borne by

	Federal and state legislation/regulation changes Public/third-party liabilities *Force majeure* Realization of the residual value of assets	the public sector in traditional construction projects

2.2.1 Project risks at the institutional level

Marrewijk et al (2008) noted that risks at the level of institutional arrangement include opposition to project; the multidisciplinary nature of projects under discussion; political conflicts; administrative bottlenecks that constrain approvals that would facilitate project development and implementation; and over-optimism of involved politicians with respect to effectiveness of projects. Baydoun, M. (2010) while reporting on a research paper on risk management of large scale development projects in developing countries notes that at the level of project environment and institutional arrangement, the identified categories of risk are as given in table 2.3. It is noteworthy that while this generally compares well to the risks as listed in table 2.1 and 2.2, it specifically brings out the fact that in large scale projects in developing countries, risks such as possibility of armed conflict need to be considered, while legal risks may arise from difficulty due to some local laws. It also brings out the fact that some required expertise in facilitating projects may lack in the public authorities in developing countries, while processes to facilitate approvals may also lack, and this could expose the projects to unforeseen delays. This makes early identification of these risks critical at the front end planning when dealing with projects in developing countries.

Table 2.3: Project Environment & Institutional arrangement Risks: Baydoun (2010)

Risk Type	**Details**
Market risks	Risks under this category are related to changes in market assumptions about either the cost or revenue side of the project
Financial risks	These are correlated to risks of not securing necessary financing for the project
Management risks	These are related to the risks of managing complex processes of large-scale development

	projects
Technical risks	These are related to risks that might emerge from the technical complexity of large-scale development projects
Operational risks	These are associated with risks of improper functionality of the project
Armed conflicts	These are related to risks that might emerge from armed conflicts
Legal risks	These are related to impracticality of some existing local laws and regulations in the country of the project
Multidisciplinary expertise	Unavailability of a wide range of required expertise in public authorities can create communication gap between the developer and such authorities
Conflicts	Conflicts between different authorities or within individual authorities can undermine development and implementation of projects
Lack of approvals facilitation	Risk arises from absence of mechanism in the public sector that would facilitate project approvals, particularly when authorities that do not benefit from the project might not have interest in facilitating procedures for project approval
Delay of incentives	This applies when and where projects are dependent on special incentives like tax or customs exemptions. Delays in the implementation of these incentives pose risk to project management.

Iyer and Sagheer (2010) note that governments world over are entering into partnership with private sector for making provision of public goods and services. They state that public private partnership (PPP) has been widely recognized as an innovative institutional mechanism to leverage the private sector's efficiencies in public services. It enables a win-win situation for all stakeholders and blend public objectives with marketability and profitability. A simple way to distinguish PPPs from traditional forms of government contracting is to define them as risk sharing relationships in which a legal contract assigns public service delivery responsibilities to a private entity (United Nations Economic Commission for Africa, 2011). In PPP, the private sector entity provides public goods and services such as power, water utilities and transport infrastructure. The concept of PPP is founded on the cardinal principle that risks should be borne by the party who can best manage it. Most of the future increase in demand for electricity is likely to come from emerging market economies, but sufficient private funds will not flow into those countries unless the risk profile in energy projects can be reduced.

Heldeweg et al (2015) note that an important avenue toward a proper transition through regional and local projects is for government to collaborate with private sector organizations especially in the energy sector, because these latter organizations are often already involved in private to private partnerships for collaboration. They however note that where collaboration between public and private parties is used in an unregulated area as a means to make a much desired smart and sustainable energy transition in regions, applicability of public law values and norms nevertheless calls for critical reflection on how this collaboration takes shape, especially with a view on how public values and norms are properly safeguarded in a framework of good energy governance.

Hilmarsson (2012) states that Energy projects often require partnership between the public and the private sectors utilizing public private partnerships (PPPs), and that efficient allocation of risks among the different partners in PPPs is key to success and generally results in more profitable projects, with benefits to each of the parties involved. On the other hand, Muzenda (2009) reports that more than two-thirds of countries in Sub-Saharan Africa are currently experiencing power shortages which is the result of many factors such as strong economic growth, which has in turn led to the rapid increase in electricity consumption and urbanization;

and poor planning in boosting generation and distribution capacity and maintaining infrastructure. Capacity impediments include the lack of skills among public officials to manage Public Private Partnerships (PPPs) since most local judicial systems do not have the capacity to handle complex contracts or disputes.

Possible initiatives for tackling these impediments include streamlining public agencies to minimize bureaucracy, hiring and developing individuals who have experience in PPPs, and strengthening regional PPP capacity and cooperation. This is supported through a paper by the United Nations Economic Commission for Africa (2011) which notes that PPPs have made a steadily growing contribution in projects in Africa. Much more technical expertise is needed to assist governments with project preparation, without which some large projects in low-income countries in Africa are still likely to proceed, if only because of the desperate need of some governments to address infrastructure service inadequacies. However, the overall costs of preparation, and the time needed for preparation, are likely to increase substantially, matched by a parallel decline in project quality.

2.2.2 Interaction of different project risk types

Martin et al (2012) note that there is currently a gap in the risk assessment tools available to project planners because the traditional risk assessment tools do not provide the ability to identify interaction between distinct events. This view is supported by Franck et al (2013) when they state that projects are dealing with bigger stakes and facing stronger constraints and moreover, projects must cope with an ever-growing complexity while risks have increased in number and criticality. They further state that existing techniques are mainly mono-criteria, based on risks parameters such as nature or criticality value and limits have appeared since project risk interactions are not properly considered.

Similarly, Denys et al (2015) note that construction projects are subject to numerous risks that could have consequences on project achievement and involve numerous stakeholders whose interests and demands need to be considered in the managerial decision-making process to ensure the success of the project. They state that risk management is a dynamic process and multiple interactions have been identified between risks.

Eden et al (2000) state that it is the interaction between different types of risk that can cause the most damage to a project. It is therefore important to consider not just the risks themselves, but also their impact on one another. Moreover, because one risk may occur at the same time as other risks, they can form a portfolio where the impact of the whole is greater than the sum of the parts (Eden et al, 2007). In addition, when one risk occurs, it may have the consequence of reinforcing the likelihood of other risks occurring, causing a complex chain of outcomes. Boating et al (2015) also state that megaprojects are complex and expensive projects that often involve social, technical, economic, environmental and political challenges to project management and conclude that while some degree of cost and schedule risks are considered during project planning, the challenge of modeling risks interactions and impacts on project performance still remains.

Other researchers express similar views (Young and Zhou, 2014, Franck, 2014). It is therefore evident that a more holistic approach has to be considered as compounding effects exacerbate the systemic nature of risks on the project. In taking a systemic view of risks, investigation of the interactions between risks is encouraged, as well as the management of the causality of relationships between risks, rather than just risks. This brings out the importance of systems thinking when considering project risks, and further reinforces the need for the system dynamics approach in analyzing risks in a way that not only considers the individual risks, but also takes into account the interaction of the risks.

2.2.3 The risk management and resolution process

Fisher and Robinson (2006) illustrate in figure 2.2 a logical process of risk management that begins with risk identification, when tools such as brainstorming, ‘SWOT’ or ‘Delphi’ are used to list and describe all possible risks. Risks are then classified by type and impact. Risks are analyzed or assessed qualitatively by detailing and prioritizing, often using a probability-impact matrix. Risks may also be analyzed or assessed quantitatively, for example, by applying sensitivity analysis and probability simulations. Risks are then monitored and controlled. Similarly, ISO 31000:2009, risk management, Principles and guidelines, provides principles, framework and a process for managing risk. It can be used by any organization regardless of its size, activity or sector. Using ISO 31000 can help organizations increase the likelihood of achieving objectives, improve the identification of opportunities and threats and effectively allocate and use resources for risk treatment.

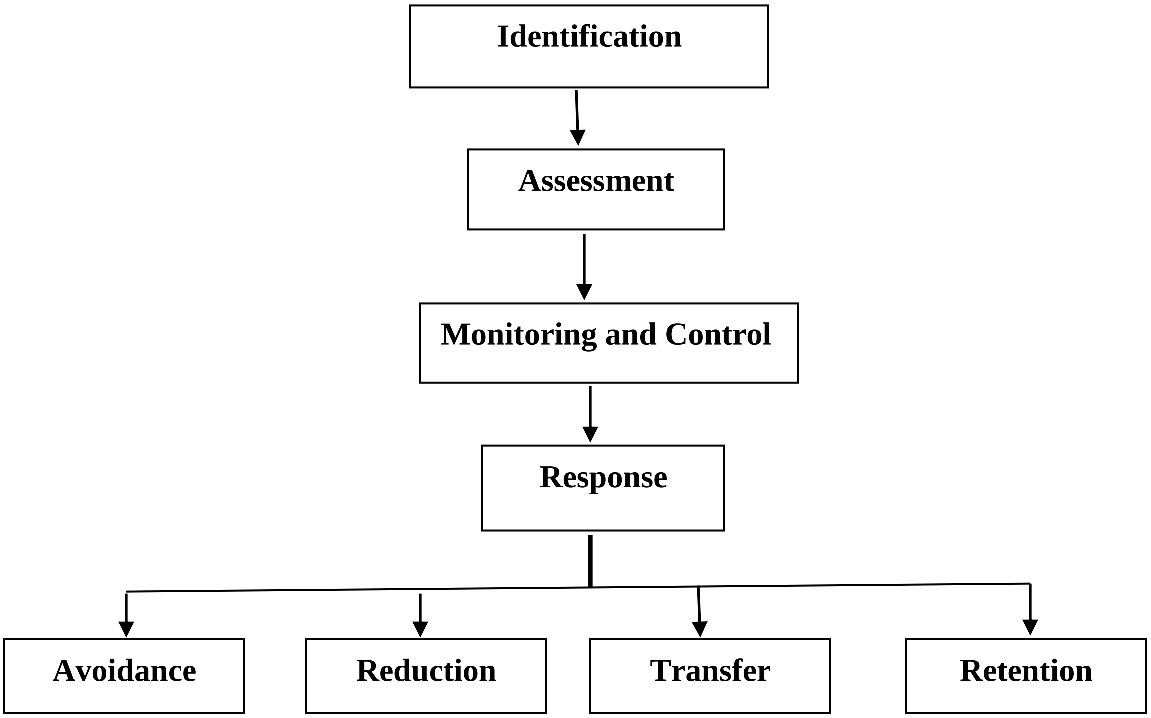

Fig.2.2: The Management of Risk (Fisher and Robson, 2006)

Figure 2.2 compares favorably with the risk resolution process by Smith and Merritt (2001) in figure 2.3, with the addition in figure 2.3 of the elaborate process of risk mitigation to cover provision for redundancy as well as a choice of risk mitigation measures. ISO 31000 recognizes the importance of feedback by way of two mechanisms. These are monitoring and review of performance and communication and consultation. Monitoring and review ensures that the organization monitors risk performance and learns from experience. Communication and consultation is presented in ISO 31000 as part of the risk management process, but it may also be considered to be part of the supporting framework. Fig. 2.4 gives an outline of the ISO 31000 risk management process.

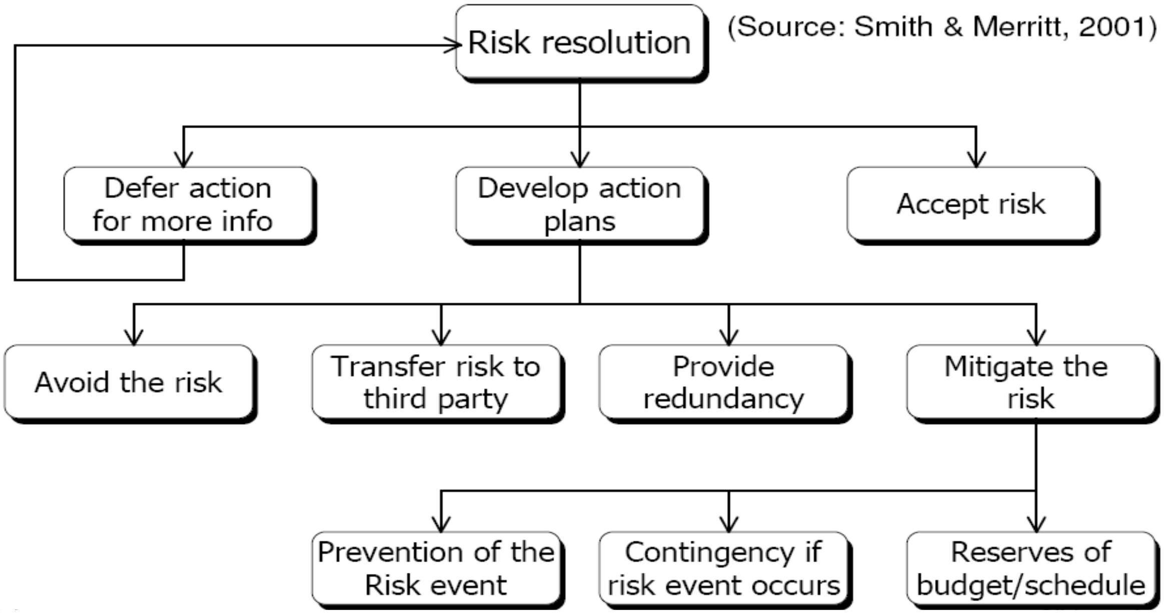

Figure 2.3: Risk resolution process (Smith and Merritt, 2001).

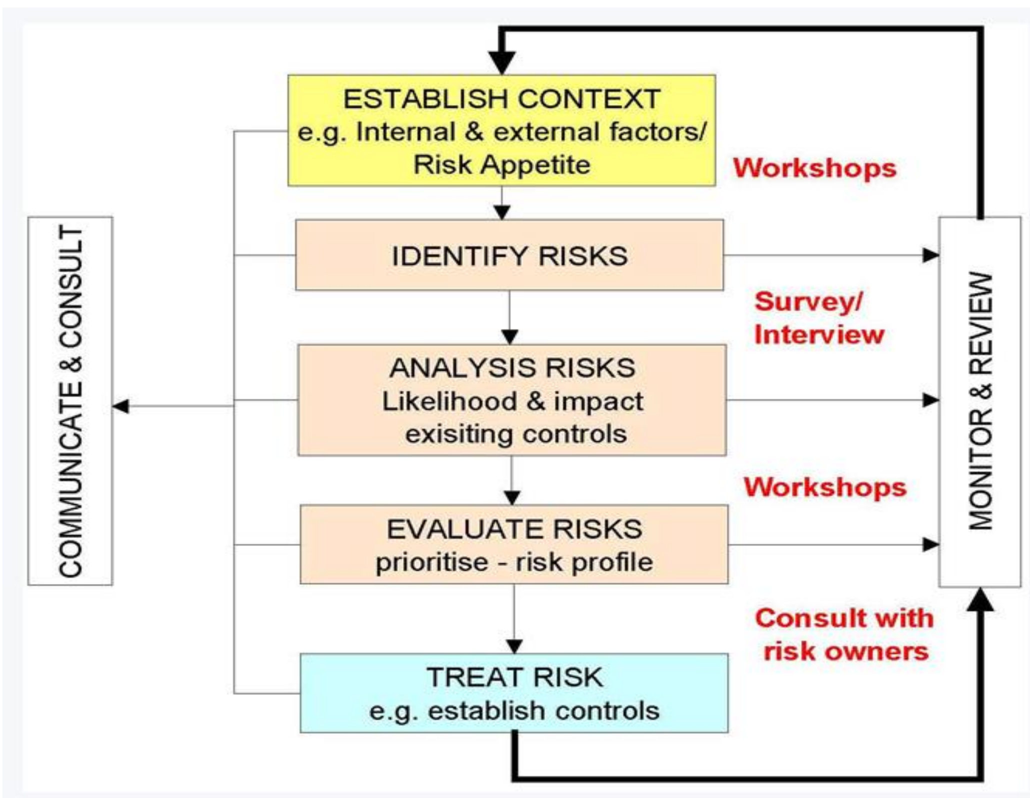

Figure 2.4: Risk Management Process (ISO 31000).

Prasanta (2009) reports that the conventional project risk management approaches in the project feasibility stage emphasize on managing business risks and often ignore operational risks, while project failure can occur because of operational risks such as technical complexities, contractors' and suppliers' incapability and government red tape which often remain unidentified until they occur. He further states that construction projects often fail because of wrong technology selection, a poor environmental management plan, political red tape, poor design specification, wrong implementation methods, poor performance of contractors, and lack of documented materials delivery schedule by the suppliers.

Chapman and Ward (2008) while reporting on a research paper about developing incentive and risk sharing contract, note that the simplest approach to contracting is using a bidding process to obtain the lowest offer of a fixed price contract for a risk efficient choice so long as the client knows exactly what they want and when they want it. This also requires the client to have the expertise necessary with an effective marketplace with contractors who are competent, rational, able and willing to bear the risk. Chapman and Ward (2008) conclude that in many projects, contractors are often willing to bear risk but not able to do so at times, and so contractors will accept contracts which will cause them to go bankrupt if serious risk is realized.

This is a common occurrence in electricity industry projects in Kenya where the World Bank (2014) rates the risk to project implementation for the energy sector recovery project as substantial. In Kenya, many contractors bid with the aim of winning the bid, but are later unable to mitigate risks that arise. Jin and Doloi (2008) report that many governments now recognize that privatization is a partnership in which they must retain some risk, rather than transferring all risks to the private sector. They note that sometimes, risks will inevitably be allocated to the party least able to refuse them rather than the party best able to manage them, especially when the government maintains maximum competitive tension.

2.2.4 Political risk and its effect on infrastructure projects in Sub Saharan Africa

Political risks are due to changes and discontinuities in the business environment due to political changes. Effects of political risks may be macro, affecting all businesses; or micro, affecting only selected industries, firms, or projects (Robock and Simmonds 1983). Kapila and

Hendrickson (2001) defined political risk as the possibility that political forces may result in drastic changes in a country's business environment affecting a firm's profit and other goals. Examples of macro political risks include revolutions, civil wars, nationwide strikes, protests, riots, and mass expropriations. Examples of micro risks include selective expropriations, discriminatory taxes, and import restrictions directed at specific firms. Risk is something that exists when a threat and vulnerability overlap. Jacobsen (2010) reports that despite the fact that most developing countries now generally welcome multinational companies, political risk still represents a huge concern for international business. In fact, multinational companies today probably face a much broader array of risks than during the nationalization wave of the 1960s and 1970s.

Bonacek et al (2014) note that political risk can be associated with exposure to losses due to man-made institutional constraints that discriminate among economic agents, striking a bias in the allocation of resources and therefore is a factor that acts beyond traditional economics as an interference of political institutions in market-based economies. Some political risks such as a resurgence of “resource nationalism” (MIGA, 2010) and unfavorable annulment or change of the terms of foreign investment (Barthel et al, 2010), continue to pose a great challenge to foreign investors in developing markets. In addition, recent high profile and massive casualty terrorist attacks not only stress the prevalence of political violence and the importance of political risk as a challenge to foreign investors, but also highlight that even developed countries are not immune to political risk and violence (Bael and Qian, 2011).

According to MIGA (2013), Sub Saharan Africa and South Asia have shown healthy growth in 2013, achieving 19 percent and 21 percent increases in FDI inflows respectively, and within the range of political risks, breach of contract and regulatory risks are of major concern in the two regions. On a similar note and in a study conducted on the impact of political risk on FDI flows in a Sub Saharan Africa context in Nigeria, Osabutey and Okoro (2015) found that political risk has a significant influence on the inflow of FDI into developing economies in the region such as Nigeria. For Kenya, the World Bank's Kenya Country monitor (2015) paints a positive economic growth outlook for the country, but emphasizes that macroeconomic risks remain significant. GDP growth is expected to remain strong on the back of sustained public investment in infrastructure across several sectors, and key projects that will benefit include communications, transport, and energy. Kenya's productive capacity is expected to improve significantly over both the short and long terms as a result of its targeted public investments to address prevailing infrastructure bottlenecks.

A risk process is usually considered to begin with a risk event and end in a risk consequence (Deng et al, 2014). Political risk formation in international construction projects evolves through a process as presented in Fig. 2.5. Governments are extremely influential actors in international business. To the host-government, as explained by Brink (2004), international projects can represent an important source of funds, technology and expertise that could help further national priorities such as regional development, employment, import substitution and export promotion. The government of a country, on the other hand, may also intervene in the business environment for a variety of reasons such as protecting national industries from external competition; limiting foreign exploitation and increasing national welfare.

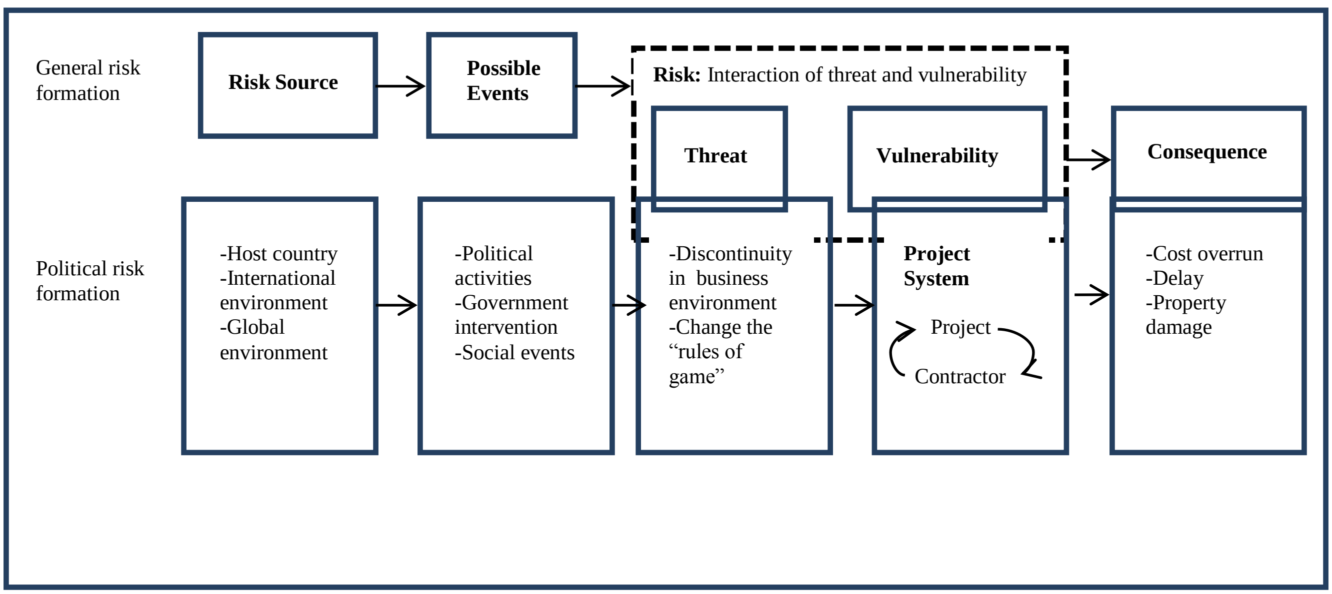

Fig. 2.5: Political risk process (Deng et al, 2014)

A host-government can pursue actions such as taxation restrictions; currency inconvertibility; contract repudiation; import and/or export restrictions; ownership and/or personnel restrictions; expropriation and/or confiscation and industrial espionage. These risks can be categorized as host-government risks, since they are originated by host-governments and can have unfavorable consequences upon international projects. Political risk, as suggested by Brink (2004) and Stosberg (2005), arises not only from governmental, but also societal sources.

2.2.5 Nature of project risks in the electricity industry in Kenya

According to Banaitiene and Banaitis (2012), construction projects can be extremely complex and fraught with uncertainty. Flanagan et al, (2006) add that risk and uncertainty can potentially have damaging consequences for construction projects. Irwin et al (1999) note that infrastructure subjects' private investors to major risks because the investments are often large and their costs can be recouped only over long periods of time. They state that two special features of infrastructure create additional risks. First, the investments are largely sunk; the assets cannot be used elsewhere except at great cost. Second, infrastructure projects often provide services that are considered essential, and are provided by monopolists. As a result, services are highly politicized and this combination of factors makes investors especially vulnerable to opportunistic government actions. This holds true for electricity infrastructure projects in Kenya where the government of Kenya is a major shareholder in all the institutions and utilities that are involved in major electricity expansion projects in the country.

Barbalho (2015) reports that as the world looks to the private sector to take the lead in delivering infrastructure needs throughout Africa, investors and lenders are often wary of entering these relatively untested markets, and the risks that concern investors often relate to low confidence in the judiciary systems, weak or untested regulatory frameworks, poor governance, corruption, lack of enforcement of contracts, political instability, and macroeconomic instability. He further notes that while the Kenyan power sector has gone through relatively successful reform since the late 1990s, with a number of long-term power purchase agreements (PPAs) supported by international investors, private-sector investment and long-term commercial bank financing has remained difficult, partly due to the perceived country risk after the civil disturbances following the 2007 election.

To protect themselves from such risks as nonpayment by purchasers, cost overruns, and low demand, private investors often ask the government to provide extensive guarantees in which the government enters into some form of arrangement that results in the net wealth of the government, not the private investors, varying with the risky outcome. From the discussions on the nature of project risks and risk management in projects, it is clear that apart from risks themselves, the interaction between different types of risks is equally important and worth focusing on as they can cause problems to a project. Risks exhibit a systemic nature, and this calls for a holistic approach to managing of risks that involves investigation of the interactions between risks and management of the causality of relationships between risks.

2.3 System Engineering and its value in Project Management

System engineering emphasizes the systems approach view to dealing with problems, and is defined as an engineering discipline whose responsibility is to create and execute an interdisciplinary process to ensure that the customer and stakeholders' needs are satisfied in a high quality, trustworthy, cost and schedule efficient manner throughout an entire system's life cycle. The system engineering process is not sequential, as the functions are performed in a parallel and iterative manner (INCOSE, 2004). Systems engineering encourages the use of modeling and simulation. Blanchard (2004) notes that the traditional business as usual approach to doing projects has had a negative impact on the systems that have been developed, and the problems noted have been a direct result of not applying a disciplined "systems approach" to meet the desired objectives.

System Engineering is also defined as an interdisciplinary approach governing the total technical and managerial effort required to transform a set of customer needs, expectations, and constraints into a solution and to support that solution throughout its life. (ISO/IEC/IEEE 2010). It integrates all the disciplines and specialty groups into a team effort, forming a structured development process that proceeds from concept to the production stage, and finally onto operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. (INCOSE 2012). Systems engineering as defined by NASA (2012) requires the application of a systematic, disciplined engineering approach that is quantifiable, recursive, iterative, and repeatable for the development, operation, maintenance, and disposal of systems integrated into a whole throughout the life cycle of a project or program.

The emphasis of systems engineering is on safely achieving stakeholder functional, physical, and operational performance requirements in the intended use environments over the system's planned life within cost and schedule constraints. Blanchard (2008) notes that systems engineering management utilizes some common project management framework features such as work breakdown structure, project organization, and management plan in the form of system engineering management plan. Moti et al (2011) define Systems engineering as an interdisciplinary field of engineering that mainly, but not only, relates to design and management of complex engineering projects. They note that systems engineering overlaps with both technical and human centered disciplines such as electrical engineering, mechanical engineering, computer science, control engineering, industrial engineering, organizational studies, and project management.

Despite the vast amount of project management and systems engineering literature available, about two-thirds of all projects still fail, reports the Standish Group (2009), and their reviewing both project management and systems engineering standards, papers, books, conference proceedings, and tool manuals, reveals that most of this material focuses on processes. They suggest focusing instead on people, project managers and systems engineers. Sharon et al (2011) note that systems engineering and project management are two tightly intertwined domains, and as systems engineering management is the practice that couples the system engineering domain and the project management domain, the successful implementation of system engineering requires not only technical but also managerial traits. Systems engineering managers must rely on a combination of technical skills and management principles that address both complex technical and managerial issues. Yang et al (2006) state that the planning, scheduling and controlling of a construction project is an example of a complex system engineering problem.

Hester and Adams (2013) state that systems engineering as is traditionally understood, is founded on a process, and can be categorized as systematic engineering, where systematic connotes the methodical process based nature of standards for systems engineering. They note that while systematic thinking is appropriate for machine age systems, it loses its effectiveness when problems increase in complexity as is common in the systems age. They give the main differences between systematic thinking and systemic thinking as appears in table 2.4. The machine age mentioned by Hester and Adams (2013), as well as Ackoff (1974) is distinguished from the "second machine age" as mentioned by Brynjolfsson and McAfee (2014) when they state that there have been two big turning points in human history, with the first being the industrial revolution, where machines replaced muscle power, and the "second machine age" which refers to the time when machines are now able to take over a lot of cognitive tasks that humans can do, and started around the time IBM's "Deep Blue" computer in 1997 beat Gary Kasparov in a chess match.

Table 2.4: Comparing Systematic vs. Systemic thinking, Hester and Adams (2013)

	Systematic thinking	Systemic thinking
Age	Machine	Systems
Unit of Analysis	Problem	Mess (system of problems)
Stopping criteria	optimization	Satisficing
Goal	Problem solution	Understanding
Underlying philosophy	Reductionism	Constructivism
Epistemology	Analysis	Synthesis
Discipline scope	Multidisciplinary and interdisciplinary	Trans-disciplinary
Approach	Prescriptive	Exploratory

Ackoff (1974) used the terms "machine age" and "systems age" to refer to eras that were concerned with two different types of systems problems. The machine age was concerned with simple systems, and the systems age is concerned with complex systems. He recognized that the technical perspective of the machine age was inadequate for coping with what he termed the messy situations present in the systems age, where human activity systems were predominant. According to Hommes et al (2010), the machine age focused on reductionism, in the belief that everything can be reduced, decomposed, or disassembled to simple indivisible parts which can be analyzed to come up with the function of the whole. Cause and effect in the machine age relied on deterministic thinking and mechanization of work, which took prominence during the industrial revolution whereby machines were used to substitute people for physical work.

Ackoff (1974) notes that in the systems age, things are looked at as part of larger wholes rather than as wholes to be taken apart, and adds that this is the doctrine of expansionism, which brings with it the synthetic mode of thought, much as the reductionism mode brought about the analytic mode. In analysis, the explanation of the whole is derived from the explanation of its parts. In synthetic thinking, something to be explained is viewed as part of a larger system and is explained in terms of its role in that larger system. This view is supported by Hommes et al (2010) when they state that the systems age focuses on expansionism, with the belief that all objects and events, are parts of larger wholes. They note that cause and effect in the systems age relies on stochastic thinking, and the whole is not considered as equal to the sum of its parts, sometimes it's more, sometimes less. Figure 2.6 illustrates the value of systems engineering efforts, which reduce cost and schedule overrun when applied early in the concept and design phases of projects.

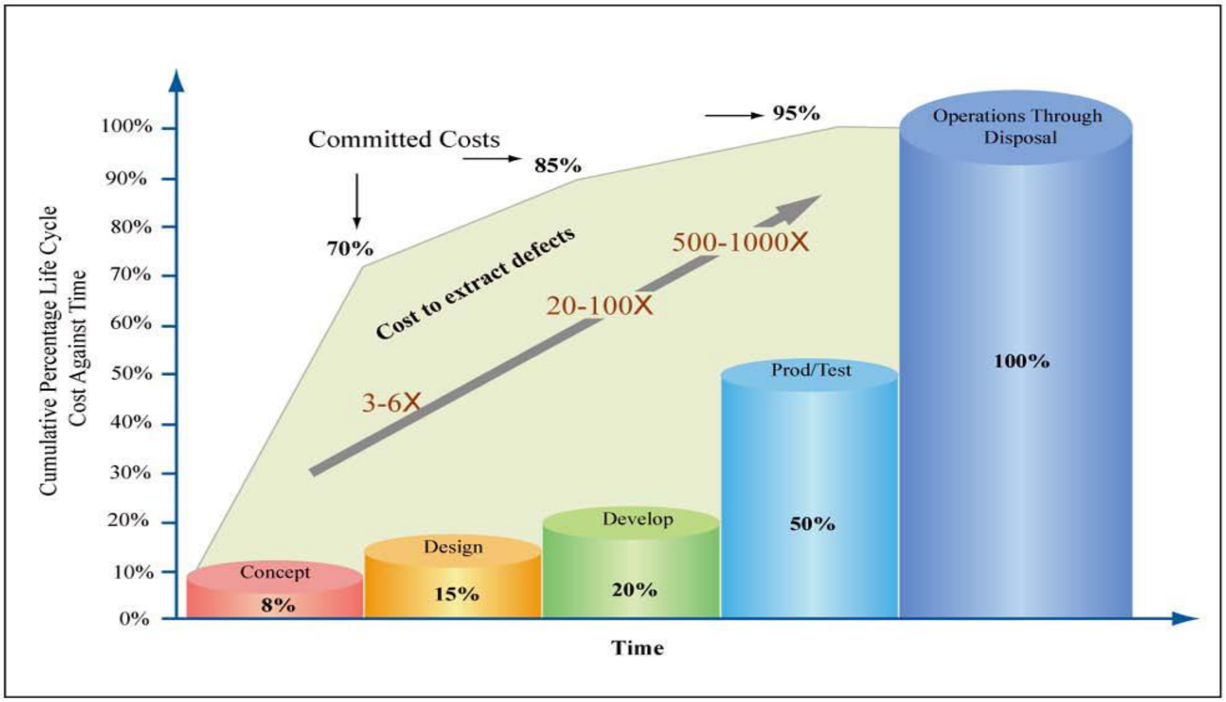

Figure 2.6: The Value of Systems Engineering (Hommes et al, 2010)

Blanchard (2004) further states that for many systems, there has been an imbalance between the cost side of the spectrum and the effectiveness side, as illustrated in Fig. 2.7. In the electricity infrastructure projects delivered in Kenya, incidences of reliability and quality challenges have occurred in many completed projects, resulting into the need for expensive equipment replacements and downtime on the delivered facilities, and this could be traced to the project execution and management philosophy adopted at the time. These findings raise the importance of considering the whole system including construction, operation and maintenance during the front end planning of projects so as to improve the effectiveness of the overall systems built.

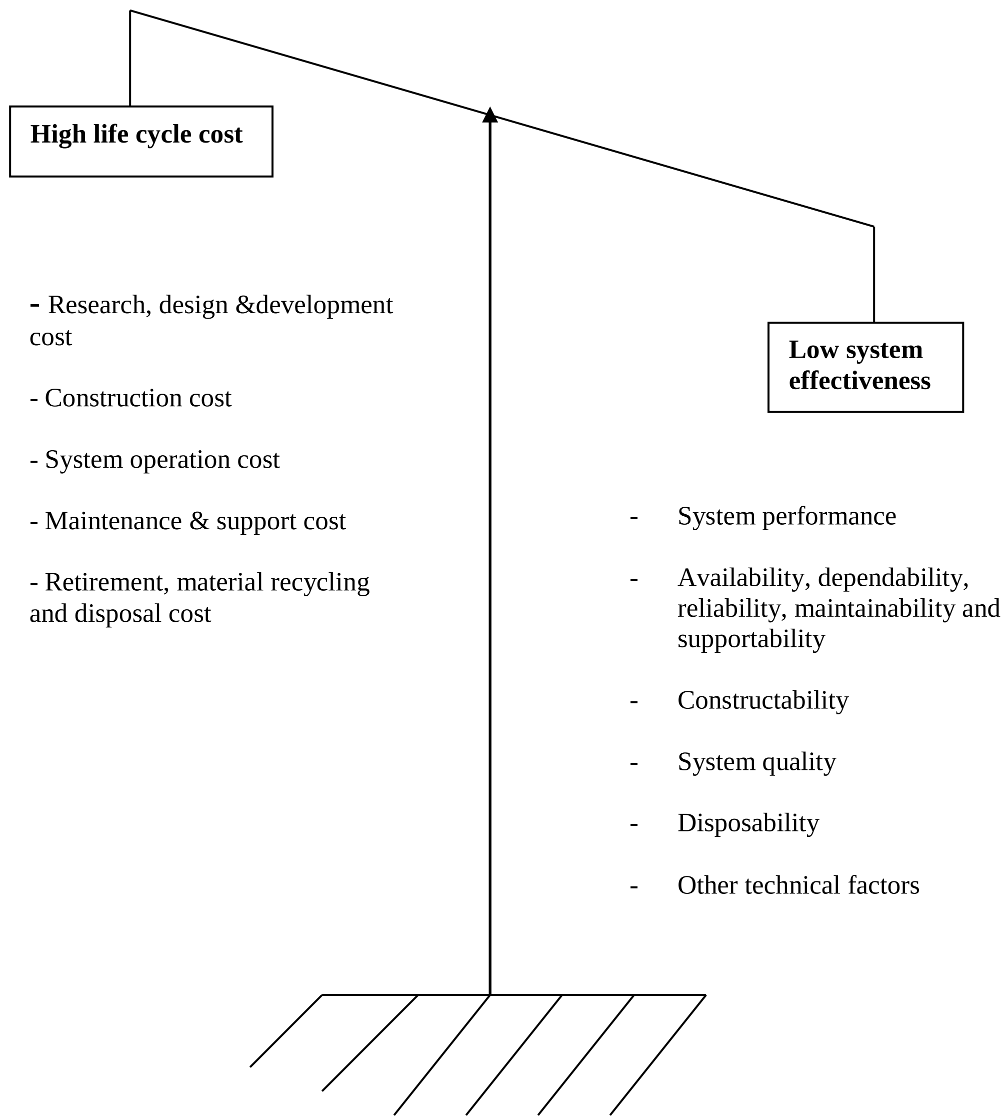

Figure 2.7: The imbalance between system cost and effectiveness factors: Blanchard 2004

2.4 Event-Oriented Thinking vs. feedback approach

According to Morecroft (1997), an event-oriented perspective is pragmatic, action oriented, alluringly simple and often myopic. Fig. 2.8 depicts this mind-set, reflecting the belief that problems are sporadic, stemming from uncontrollable events in the outside world. The typical thinking style here is linear, from problem as event to solution as fix. However, there are limitations to this open-loop, fire-fighting mode of intervention as experience shows that the problem often recurs after the fix. Unexpected dynamics often lead to policy resistance, which is the tendency for interventions to be delayed, diluted, or defeated by the response of the system to the intervention itself (Sterman, 2000). This is a common occurrence in projects in the energy sector in Africa.

A feedback approach is different from event-oriented thinking because it strives for solutions that are "sympathetic" with their organizational and social environment. Problems do not stem from events, and solutions are not implemented in a vacuum. Instead problems and solutions coexist and are interdependent (Morecroft, 1997).

Fig. 2.8: Causes of Policy resistance, the serial view: Event oriented world view (Sterman, 2000)

2.5 Systems thinking and its relevance in electricity infrastructure projects

Ackoff (1994) states that the performance of a system depends on the performance of its parts, but an important aspect of a part's performance is how it interacts with other parts to affect the performance of the whole. Therefore, effective system management must focus on the interactions of the parts rather than on their actions taken separately, and the defining function of a system cannot be carried out by any part of the system taken separately. A system is a set of things, people, cells, molecules, interconnected in such a way that they produce their own internal dynamics. The system may be buffeted, constricted, triggered, or driven by outside forces. But the system's response to these forces is characteristic of itself, and that response is seldom simple in the real world (Meadows, 2008).

Richmond (1994) defines systems thinking as the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure, while Senge (1990) states that systems thinking is a way of addressing complex problems and designs, which can be applied in any discipline or practice, and goes on to define systems thinking as a framework for seeing interrelationships rather than things, for seeing patterns rather than static snapshots, a set of general principles spanning fields as diverse as physical and social sciences, engineering and management. Systems thinking is a way of thinking about, and a language for describing and understanding, the forces and interrelationships that shape the behavior of systems. This discipline helps us to see how to change systems more effectively, and to act more in tune with the natural processes of the natural and economic world (Senge, 2006).

Jaradat (2015) notes that systems thinking is a critical capability for individuals who must design, analyse, and transform complex systems, formulate its governance and address its derivative problems, and conclude that effectiveness in systems thinking is a critical skill for addressing some of the most vexing problems of the 21st century. On the same subject, Pan et al (2013) state that reductionism is the belief that human behavior can be explained by breaking it down into smaller component parts, while holism emphasizes the whole rather than the parts, such that the whole is greater than the sum of the parts, thereby creating a system that provides value. They note that as two diametrically distinct basic views of the world, reductionism and holism guided the development of nature and social science in many fields, and the theoretical debate between them concerns every area of study in various scientific disciplines.

Systems thinking involves holistic consideration of our actions and is needed to deal with the complexity of our world, whose elements are interrelated (Siddiqi, (2011). Everything people know about the world is a model, and these models usually have a strong congruence with the world (Meadows, 2008). However, she notes that these models fall short of representing the world fully because people sometime draw illogical conclusions from accurate assumptions, or logical conclusions from inaccurate assumptions. To navigate well in an interconnected, feedback-dominated world, one must look for long-term behavior and structure. Meadows (2008) further notes that the behavior of a system is important in understanding the underlying system structure. This behavior can be derived from the systems performance over time comprising its growth, stagnation, decline, oscillation, randomness, or evolution. The structure of a system is its interlocking stocks, flows, and feedback loops, and system structure is the source of system behavior.

Clauter et al (2015) note that the early problem definition phase in projects requires an application of systems thinking with adequate modeling tools and methods, while Godfrey (2010) states that to improve the sustainability of the built environment, there will be unintended consequences of good intensions and outcomes that will be difficult to interpret because "cause and effect" are not necessarily closely related in time, actions may appear to be ineffective because we will see symptoms rather than causes, and the problems will likely be complex needing a framework of dependable models. He identifies system dynamics as a suitable modeling approach. The goal of systems thinking and system dynamics modeling is to improve our understanding of the ways in which an organization's performance is related to its internal structure and operating policies, including those of customers, competitors, and suppliers and then to use that understanding to design high leverage policies for success. (Sterman, 2000).

This observation is especially useful in the context of public corporations and utilities involved in the electricity industry in Kenya, where at the planning stage, the culture tends to encourage focus on the project cost and the expected deliverables, while ignoring risks and the role of other stakeholders such as local authorities who eventually have to give permits for portions of the work to proceed. In this research, the dynamics at play in the electricity infrastructure projects in Kenya are identified, including the feedback loops that connect the various elements involved in the process.

2.6 Fundamentals of System Dynamics

Lane (2000) reports that system dynamics was created by Jay W. Forrester at MIT in the late 1950s and involves the modeling of social systems using computer simulation, with practitioners working closely with problem owners to structure debate about long-term policy, and its main ideas are found in a range of publications (Forrester, 1958, 1961, Richardson and Pugh, 1981). As a modeling approach, system dynamics has three characteristics. First is the concept of information feedback loops. These involve the collection of information about the state of the system, followed by some influencing action which changes the state of the system. These closed loops of causal links involve delays and non-linearities as well as processes of accumulation and draining.

The second characteristic is computer simulation. Although humans can conceptualize such loops, they lack the cognitive capability to deduce the consequent dynamic behaviour without assistance (Sterman, 2000). Computer simulation is therefore used rigorously to deduce the behavioral consequences over time of the hypothesized causal network. The shifting interplay of loops means that different parts of a system become dominant at different times. The third characteristic of system dynamics is the need to engage with mental models. The most important information about social situations is only held as mental models, not written down. These mental models are complex and subtle, involving hard, quantitative information and more subjective, or judgmental aspects of a given situation (Doyle and Ford, 1998). Such models are the basis for organizational decision making.

Pretorius and Benade (2011) state that a system can be seen as consisting of interacting components or sub-systems, and a system can also form part of other systems, leading to the notion of the “system of systems” (SOS) or even “super systems”. The behaviour of systems is generally complex and time-dependent, and systems can be physical or conceptual, or a mix of the two such as a computer used in a risk management system, and system behaviour is generally non-linear. While systems thinking is the process of understanding how things influence one another within a whole, Forrester (1994b) notes that it will change few of the mental models people have. In contrast, system dynamics modeling is learning by doing, a participative activity in which one learns by trial and error as well as practice, and this has the capacity to change mental models. The field of system dynamics gave rise to and serves as the bedrock for the field of systems thinking. While system dynamics lays emphasis on simulation modeling, it is generally seen as the more rigorous, academic field (Radzicki, 1997). Systems thinking takes the principles of systemic behavior that system dynamics discovered and applies them in practical ways to common problems in organizational life.

While on the same subject, Richardson (2001) states that system dynamics is a computer aided approach to policy analysis and design, and it applies to dynamic problems arising in complex social, managerial, economic, or ecological systems, literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality. System dynamics is also described as a method to describe, model, simulate and analyze dynamically complex issues and / or systems in terms of the processes, information, organizational boundaries and strategies. Quantitative system dynamics modeling, simulation and analysis facilitates the redesign of systems and design of control structures (Wolstenholme 1990, as cited by Erik Pruyt, 2013). System dynamics is in fact the application of the principles and techniques of control systems to organizational and social-economic-environmental problems.

Richardson (2011) states that systems thinking is the mental effort to uncover endogenous sources of system behaviour, while System Dynamics is the use of informal maps and formal models with computer simulation to uncover and understand endogenous sources of system behavior. System Dynamics practitioners use systems thinking, management insights, and computer simulation to hypothesize, test, and refine endogenous explanations of system change, and use those explanations to guide policy and decision making. Sterman (2000) defines System Dynamics as a method to enhance learning in complex systems. Just as an airline uses flight simulators to help pilots learn, System Dynamics is, partly, a method for developing management flight simulators, often computer simulation models, to help us learn about dynamic complexity, understand the sources of policy resistance, and design more effective policies (Sterman, 2000).

Siddiqi (2011) defines System Dynamics as a method that helps us learn and understand complex systems. It is fundamentally interdisciplinary and brings together tools and theories from a wide variety of traditional disciplines such as economics, social psychology and other sciences. At its core, its foundations are on nonlinear dynamics and mathematical feedback control theory. System Dynamics uses computer simulation modeling, using special software programs such as Vensim to figure out how a system's behavior might play out over time if certain changes are implemented. Vensim (Ventana, 2010) is a visual system dynamics simulation modeling tool which allows users to conceptualize, document, simulate, analyze, and optimize models of dynamic systems. Vensim provides a simple and flexible environment for building simulation model from the causal loop diagram, as well as presenting it using stock and flow diagram. By connecting words with arrows, relationships among system variables are entered and recorded as causal connections. The model can be analyzed throughout the building process, looking at the causes and uses of a variable, and also looking at the loops involving a variable. After completion of the model development, the model can be simulated and user can thoroughly explore the behaviour of the model.

Bray (2015) reports that across Sub Saharan Africa, governments are facing growing domestic pressure to increase power capacity to meet the needs of their populations, and increasing sums of money are being committed to address this energy gap, while there is no shortage of companies competing to play their part in bringing these projects to fruition. However, potential investors in the power sector in Africa face myriad risks, and the African power sector is a particularly complex investment proposition for many companies. He concludes by proposing that an effective, compliance-driven approach should include well-developed internal anti-corruption policies, appropriate due diligence checks on third parties, and anti-bribery training and continued monitoring of partners. International Energy Agency (2014) also notes that Sub-Saharan Africa is rich in energy resources, but very poor in energy supply, and making reliable and affordable energy widely available in the region is critical to the development of a region that accounts for 13% of the world's population, but only 4% of its energy demand. Many governments are now intensifying their efforts to tackle the numerous regulatory and political barriers that are holding back investment in domestic energy supply, but inadequate energy infrastructure risks putting a brake on urgently needed improvements in living standards.

Major electricity infrastructure projects are known to be complex in nature, involving construction of power lines over huge stretches of varying terrain while incorporating many stakeholders as an example. At play are varied interests including international and local contracting firms, government institutions, local municipalities and indigenous tribesmen who are all stakeholders and who seek to influence the project. System Dynamics modeling is therefore suitable in modeling the project dynamics at play in electricity infrastructure projects in the Sub Saharan Africa setup.

2.6.1 Non-linear behavior of Systems

Sterman (2000) states that systems are nonlinear, and effect is rarely proportional to cause, while what happens locally in a system often does not apply in distant regions or other states of the system. This view point is supported by Meadows (2008) when she states that a nonlinear relationship is one where the cause does not produce a proportional effect, and therefore the relationship between cause and effect can only be drawn with curves, not with a straight line. Gleick (2008) notes that linear relationships are easy to think about while linear equations are mostly solvable. He notes that nonlinear systems on the other hand cannot generally be solved or are difficult to solve, nonlinearity means that the act of playing the game has a way of changing the rules, and that twisted changeability makes nonlinearity hard to calculate, but also creates rich kinds of behaviour that never occur in linear systems.

Oehmen et al (2015) note that nonlinear systems in the project environment are not just technical systems, they are socio-technical systems where people and technology are intertwined and have become dependent on one another, and are governed and driven by technical and organizational complexity so that project managers have to manage people, their interfaces and relationships to one another, as well as components and interfaces of the technical elements of the system. They also involve social intricacy of human behaviour that is often driven by subconscious thought processes, and exhibit uncertainty of long lifecycles, and all these increase the uncertainty to which human activities are exposed. According to Meadows (2008), social systems are the external manifestations of cultural thinking patterns and of profound human needs, emotions, strengths and weaknesses. Self-organizing, nonlinear, feedback systems are inherently unpredictable, are not controllable, and are understandable only in the most general way. The idea of making a complex system do just what one want it to do can be achieved only temporarily, at best. She further states that though the present thinking is obsessed with numbers and has given the idea that what can be measured is more important than what cannot be measured, pretending that something doesn't exist if it's hard to quantify leads to faulty models. This is particularly relevant for infrastructure projects in the electricity industry, where often, planning appears to focus more on quantifiable hardware elements. The qualitative human issues normally left out need to be taken seriously as they are also important for the success of the projects. As the infrastructure projects in the electricity industry increase in size and complexity, it will not be wise to continue analyzing them as if they were linear systems, and methods need to be developed to help the practitioners simulate and analyze these complex projects as nonlinear systems. Castellano et al (2015) report that the power sector in Sub Saharan Africa offers a unique combination of transformative potential and attractive investment opportunity, partly due to the inadequacy of electricity supply which is a fact of life in nearly every Sub Saharan Africa country.

Lane, A. & Silvasanker, S. (2014) are of a similar view and state that reducing the current power infrastructure shortcomings in Africa will be crucial in supporting the next chapter of Africa's growth model; one that pursues economic diversification and industrial development. Governments in the region are becoming more sophisticated and increasingly opening up to private sector and foreign investment in the energy sector. KPMG (2014) reports that there are currently various country-specific initiatives underway to improve the power sectors' infrastructure and to increase the number of power generation plants as well as transmission and distribution lines. They note that wherever the plans were poorly executed in the region, the economic growth slowed down, and this points to the importance of coming up with sound policies to drive sustainable growth in the region through efficient delivery of energy sector projects.

2.6.2 The endogenous point of view

Sterman (2000) states that system dynamics seeks endogenous explanations for phenomena. The word "endogenous" means "arising from within." An endogenous theory generates the dynamics of a system through the interaction of the variables and agents represented in the model. He however adds that the focus on endogenous explanations in system dynamics does not imply that one should never include any exogenous variables in models, but rather that the number of exogenous inputs should be small, and each candidate for an exogenous input must be carefully scrutinized to consider whether there are in fact any important feedbacks from the endogenous elements to the candidate.

In support of this view, Richardson (2011) states that the foundation of systems thinking and system dynamics is the “endogenous point of view”, and notes that while the most salient aspects of the system dynamics approach are undoubtedly stocks and flows and feedback loops, he states that it is worth noting that feedback loops are really a consequence of the endogenous point of view. Ghaffarzadegan et al (2011) note that a characteristic of public policy problems is the tendency that decision makers have to attribute undesirable events to exogenous rather than endogenous sources. In the judgment and decision making literature, such a tendency is usually referred to as “self-serving bias”.

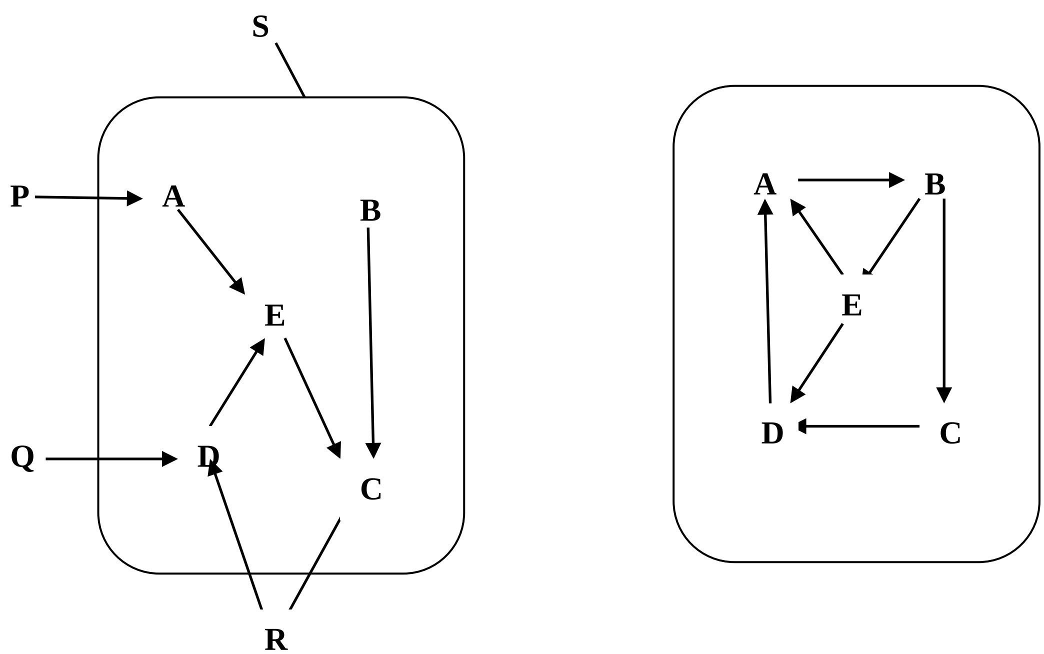

Fig. 2.9. Left: exogenous view of system structure; Right: endogenous view (Richardson, 2011)

An endogenous perspective is necessary for individual and organizational learning. Individuals who attribute adverse events to exogenous factors, and believe "the enemy is out there" lack the ability to learn from the environment and improve their behavior (Senge, 2006). Feedback loops, which stand out in the system dynamics approach, are a consequence of the endogenous point of view and this is illustrated in figure 2.9. On the left is a diagram of some simple causal system, with causal elements tracing ultimately outside the system boundary. The dynamics of variables A–E are generated partly by interactions among them inside the system boundary but really stem mainly from variables P, Q, R, and S outside the boundary. The dynamics of this system are generated exogenously by forces outside the system boundary. On the right of figure 2.9 is an endogenous view, in which the dynamics of variables A–E are generated solely from interactions among those variables themselves, within the system boundary. The figures illustrate that taking an endogenous point of view forces causal influences to form loops. Without loops, all causal influences would trace to dynamic forces outside the system boundary (Richardson, 2011).

Systems thinking and System Dynamics center on endogenous phenomena (Richardson, 2011). Endogenous refers to an action or object coming from within a system and is the opposite of exogenous, something generated from outside the system. The endogenous point of view is a crucial foundation of the field of System Dynamics. Systems thinking is the mental effort to uncover endogenous sources of system behavior, while System Dynamics is the use of informal maps and formal models with computer simulation to uncover and understand endogenous sources of system behavior. System Dynamics practitioners use systems thinking, management insights, and computer simulation to hypothesize, test, and refine endogenous explanations of system change, and use those explanations to guide policy and decision making. Complex systems have the ability to learn, diversify, become complex and evolve. It is the ability of a single fertilized ovum to generate, out of itself, the incredible complexity of a mature chicken or person. This capacity of a system to make its own structure more complex is called self-organization. (Meadows, 2008).

According to Radzicki and Taylor (1997), decision makers need not spend enormous amounts of time and money trying to develop models to precisely predict the future state of a system. This is because it is impossible, in principle, to precisely predict the future state of a nonlinear feedback system, except in the very short term. they state that a decision maker's resources are better spent trying to predict the behavior mode of a system in response to a proposed policy change, and in trying to redesign the stock-flow-feedback structure of a system so that it behaves well, regardless of what happens in the future. Any real system is continuously shocked or buffeted by external forces. From a system dynamics point of view, the decision maker's resources would be better spent trying to redesign the stock-flow-feedback structure of the system so that it responds well to shocks, regardless of when they arrive, how large their magnitude, or in what direction they push the system. The system dynamics perspective is an inward or endogenous point of view.

2.6.3 Causal loop diagrams

According to Haraldsson et al (2006), the Causal Loop Diagram is a tool for systematically identifying, analysing and communicating feedback loop structures. It is a systematic thinking and enables communication of complex information into simplified circular loop feedback structure. CLD's is a tool that promotes 'continuous' thinking, i.e. a story of a problem is read through the diagram and its development projected on a 'time scale graph' in order to understand the interaction of the feedback loop structure in the diagram.

Sterman (2000) notes that system dynamics is useful for identifying feedback processes with causal loop diagrams, and that these loop diagrams consist of variables that are connected by arrows that denote the causal influences between variables. Each causal link is assigned a polarity, either positive (+) or negative (-), to indicate how the dependent variable is impacted when the independent variable changes. Table 2.5 summarizes the definitions of link polarity. Siddiqi (2011) states that causal loop diagrams help in eliciting and capturing mental models and describing the hypothesis about the causes of the dynamics. According to Sterman (2000), the dynamics of all systems arise from the interaction of two types of feedback loops: positive, which is reinforcing, and negative, which is balancing.

Table 2.5: Link Polarity (Sterman 2000)

Symbol	Interpretation	Equations
	All else equal, if x increases (decreases), then y increases	$\frac{\partial y}{\partial x} > 0$

x $\xrightarrow{+}$ y	(decreases) above what it would have been. In the case of accumulations, x adds to y.	In the case of accumulations, $y = \int_{t0}^{t}(x + \cdots)\,ds + y_{t0}$ (2.1)
x $\xrightarrow{-}$ y	All else equal, if x increases (decreases), then y decreases (increases) below what it would have been. In the case of accumulations, x subtracts from y.	$\frac{\partial y}{\partial x} < 0$ In the case of accumulations, $y = \int_{t0}^{t}(-x + \cdots)\,ds + y_{t0}$ (2.2)

Fig. 2.10 gives an example of a causal loop diagram as well as the diagram notations commonly used with causal loop diagrams. “Polarities” indicate how the independent variable affects the dependent variable while “Loop identifiers” indicate direction of circulation and type (balancing or reinforcing).

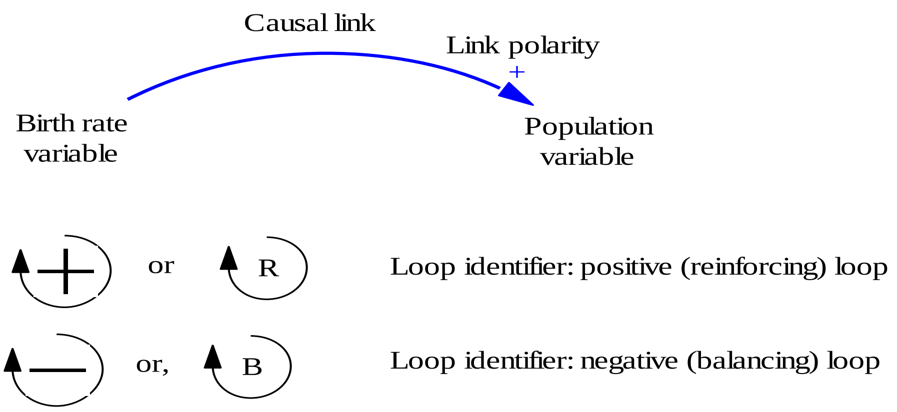

Fig. 2.10: Diagram notation. Siddiqi (2011)

Pruyt (2013) states that a simple way to determine the polarity of a loop is to count the negative signs. If the number of “–” signs in the feedback loop is uneven, then the feedback loop is negative, and if the number of “–” signs in the feedback loop is even, then the feedback loop is positive or reinforcing (+ and R). The net effect could thus be determined by multiplying the signs of all connections in the loop. A better way to determine the polarity is to start at one point in the loop and “read the loop” replacing A →+ B by “if A increases/decreases and everything else remains the same, then B increases/decreases beyond the value it would have taken without the increase/decrease in A" and replacing A→ - B by "if A increases/decreases and everything else remains the same, then B decreases/increases beyond the value it would have taken without the increase/decrease in A".

Fig. 2.11 presents a generic causal loop diagram. In the figure, the arrows that link each variable indicate places where a cause and effect relationship exists, while the plus or minus sign at the head of each arrow indicates the direction of causality between the variables when all the other variables remain constant. More specifically, the variable at the tail of each arrow in Fig. 2.11 causes a change in the variable at the head of each arrow, ceteris paribus, in the same direction, in the case of a plus sign, or in the opposite direction, in the case of a minus sign. (Radzicki and Taylor, 1997)

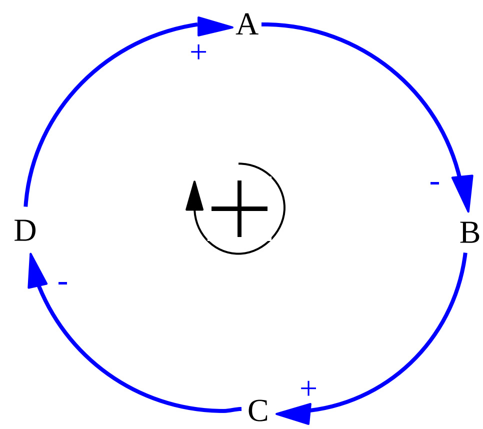

Figure 2.11: Generic causal loop diagram (Radzicki and Taylor, 1997)

The overall polarity of a feedback loop, that is whether the loop itself is positive or negative in a causal loop diagram, is indicated by a symbol in its center. A large plus sign indicates a positive loop; a large minus sign indicates a negative loop. In Figure 2.10 the loop is positive and defines a self-reinforcing process. This can be seen by tracing through the effect of an imaginary external shock as it propagates around the loop. For example, if a shock were to suddenly raise variable A in Figure 2.10, variable B would fall (i.e., move in the opposite direction as variable A), variable C would fall (i.e., move in the same direction as variable B), variable D would rise (i.e., move in the opposite direction as variable C), and variable A would rise even further (i.e., move in the same direction as Variable D) (Radzicki and Taylor, 1997).

By contrast, Fig. 2.12 presents a generic causal loop diagram of a negative feedback loop structure. If an external shock were to make variable A fall, variable B would rise (i.e., move in the opposite direction as variable A), variable C would fall (i.e., move in the opposite direction as variable B), variable D would rise (i.e., move in the opposite direction as variable C), and variable A would rise (i.e., move in the same direction as variable D). The rise in variable A after the shock propagates around the loop, acts to stabilize the system -- i.e., move it back towards its state prior to the shock. The shock is thus counteracted by the system's response.

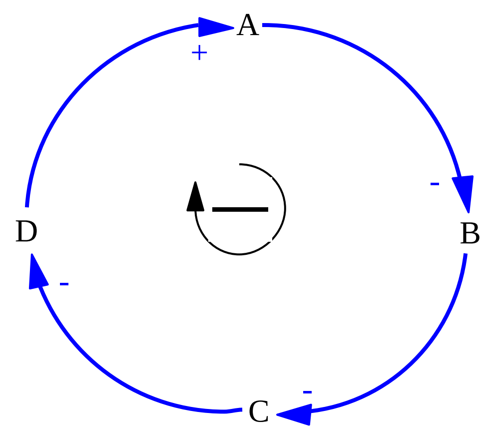

Fig. 2.12: Generic causal loop diagram of a negative feedback loop structure. (Radzicki and Taylor, 1997)

Causal loop diagrams help in capturing mental models and showing interdependencies and feedback processes. However, causal loop diagrams cannot capture accumulations or stocks and flows. They also cannot help in determining detailed dynamics (Siddiqi, 2011). This therefore leads to the concepts of stocks, flows and feedback structures in the next section.

2.6.4 Stocks and Flows

Pruyt (2013) notes that a stock variable, also called a level or a state variable, accumulates by integrating flows over time. Metaphorically, a stock variable could be seen as a "bathtub" or "reservoir". During simulation, a stock variable can only be changed by ingoing and outgoing flow variables, also called rates. A stock can be increased by increasing its inflow rate as well as by decreasing its outflow rate. Haraldsson (2006) states that the engineering analytical process always begins with a conceptual model where thinking is translated from an idea onto paper. This has traditionally been portrayed through the "stock and flow" diagram (SFD) concept. Stock and flow diagrams have been used for understanding processes as aiding tools for deriving differential equations. They are used to understand the flow and fluxes of quantities but lack the ability to illustrate the information associated to the flow and fluxes. The combination of the causal loop diagrams and stock and flow diagrams allows us to create differential equations structure that can be checked against the conceptual models.

One of the most important limitations of causal diagrams is their inability to capture the stock and flow structure of systems. Stocks and flows, along with feedback, are the two central concepts of dynamic systems theory. Stocks are accumulations. They characterize the state of the system and generate the information upon which decisions and actions are based. Stocks give systems inertia and provide them with memory. Stocks create delays by accumulating the difference between the inflow to a process and its outflow. By decoupling rates of flow, stocks are the source of disequilibrium dynamics in systems (Sterman, 2000). Meadows (2008) states that stocks are the elements of the system that at any given time one can see, feel, count, or measure. A system stock is a store, a quantity, an accumulation of material or information that has built up over time. She also notes that many of the interconnections in systems operate through the flow of information. Information holds systems together and plays a great role in determining how they operate. Stocks change over time through the actions of flows, and are shown as boxes while flows are shown as arrow-headed pipes leading into or out of the stocks as illustrated in Fig. 2.13.

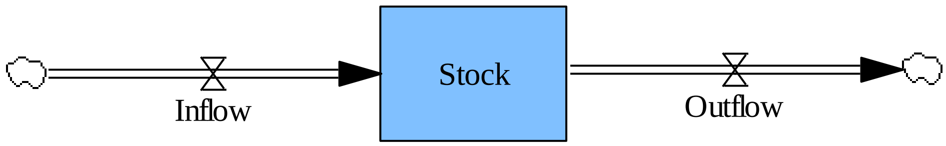

Fig. 2.13: Stock and flow diagram (Meadows, 2008)

As an example, water in a reservoir behind a dam is a stock, into which flow rain and river water, and out of which flows evaporation from the reservoir's surface as well as the water discharged through the dam. This is illustrated in Fig. 2.14. As long as the sum of all inflows exceeds the sum of all outflows, the level of the stock will rise. As long as the sum of all outflows exceeds the sum of all inflows, the level of the stock will fall. If the sum of all outflows equals the sum of all inflows, the stock level will not change; it will be held in dynamic equilibrium at whatever level it happened to be when the two sets of flows became equal (Meadows, 2008)

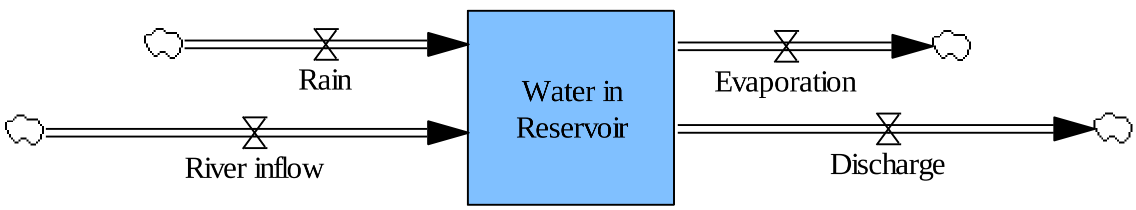

Fig. 2.14: Reservoir (Meadows, 2008)

A stock can be increased by decreasing its outflow rate as well as by increasing its inflow rate. Stocks generally change slowly, even when the flows into or out of them change suddenly. Therefore, stocks act as delays, buffers or shock absorbers in systems.

2.6.5 Mathematical representation of Stock and Flows

Stocks are the differential equations that are typically represented in a pictorial format. The mathematical formulation of the structure is:

Integral Equation: $Stock\ (t) = Stock\ (to)\ \int_{t0}^{t} [Inflow\ (t) - \ Outflow\ (t)]\ dt$ (2.3)

Thus, the value of stock at time t is the sum of the value of stock at time t_0 and the integral of difference between inflow and outflow rates from t_0 to t. (Moyano, 2012).

Or put differently, rate of change of stock is equal to the difference between inflow and outflow at any instance.

Differential Equation: $\frac{d(stock)}{dt} = [Net\ change\ in\ stock] = [Outflow(t) - Inflow(t)]$ (2.3)

2.7 Systems Dynamics approach in Strategic Project Management

Rodriguez and Bowers (1996) note that while the project management traditional approach faces challenges due to the analytical techniques such as PERT scheduling, risk assessment and contract management, the new approach employing system dynamics assumes a holistic view of the project organization, focusing on the behaviour of projects and its relation with managerial strategies. Gary et al (2008) state that strategy scholars are becoming more and more interested in understanding the dynamic processes that give rise to performance differences among firms. In addition, strategy researchers are increasingly investigating managerial decision making as a source of dynamics. They note that one of the most vibrant areas of strategy research over the next decade or more will focus on the role that managerial decision making has in creating performance differences among firms over time. This trend which is very positive for the strategy field, presents a great opportunity to leverage and expand on the strengths of system dynamics research to make important and unique contributions in the field of strategy.

Krumbeck (2010) notes that system dynamic modeling offers a systematic process to capture and analyse systems. It is proposed that the application of system dynamic modeling may improve the understanding of inter-dependencies between projects in complex project portfolios, and therefore may be a useful tool to assist with project portfolio strategic decisions. Similarly, Toole (2005) reports that project manager researchers (Rodrigues and Bowers 1996, Williams 1999, Love et al 2002) have written that one reason project goals are often not met is that the project management concepts and tools used today are too linear and deterministic. The systems in which project management occurs are too complex and volatile and contain too much apparent randomness to be managed effectively by the linear, deterministic tools that focus on one portion of the system at a time. These researchers have suggested that system dynamics concepts and tools, such as causal loop diagrams and detailed models, should be integrated into project management practices to allow project managers to better understand the structure of the system in which project management occurs and consequently better plan and control projects.

Despite the need to integrate system dynamics principles and tools into project management as articulated by Rodrigues and Bowers (1996) and the popularity of systems thinking among corporate managers that has been spurred by The Fifth Discipline (Senge 1990), integration of system dynamics into project management has progressed slowly. Over the years, project risk management practice has evolved primarily around the assumption that risks are independent entities that do not affect each other. Numerous tools and techniques have been developed around this assumption. For some risks these tools and techniques work effectively, but in many cases they are trying to manage the wrong things. In reality the risk environment is in most case a series of consequences, a risk network.

The System Dynamics approach to project management is based on a holistic view of the project management process. In contrast with traditional project management methodology, the primary objective of a System Dynamics model is to capture the major feedback processes responsible for the project system behaviors, with less concern about the detailed project components. There is a strong focus on human factors and managerial policies as these are considered to dominate that feedback structures. Concerning project risk management, the main advantages of System Dynamics approach lie in risk identification, risk analysis and risk response planning as these processes involve many factors which are subjective and dynamic and cannot be effectively dealt with by traditional tools (Qifan et al, 2005).

Lyneis (2003) reports that System Dynamics modeling provides a means of understanding the structure of projects, and how that structure creates behavior. He further states that while projects have some uniqueness in them, they also have many similarities, and so it is possible to have learning across projects. He notes that the drivers of project dynamics include the rework cycle as well as feedback effects on productivity and work quality. System Dynamics models have found wide usage in strategic project management, especially in planning and risk assessment. Lyneis et al (2001) noted that the types of decisions made on projects are often categorized as being strategic, tactical, or operational. They state that the use of System Dynamics most naturally falls into the strategic / tactical end of the spectrum. They define strategic project management as decisions that are taken up front in designing the project. Specifically, strategic project management involves designing of the project, determining what indicators to measure, to monitor and to exert pressure on. It includes risk management as well as incorporating of learning from past projects.

Strategic project management narrows down and takes into account an individual project's strategy, and provides a basis for determining major targets. In contrast, operational project management is the management actions incorporated to meet a project's target by adjusting time, cost, and resources (Rodrigues and Bowers, 1996). In other words, strategic project management can be represented as the steps taken to achieve a defined project strategy. The important role of project management in modern life has highlighted some of the deficiencies of traditional techniques which can encourage a narrow, operational view of the project, concentrating on detailed planning. Studies such as that done by Davidson and Huot (1991) have identified the need for a more strategic approach.

Use of system dynamics appears to offer this strategic alternative, assuming a holistic view of the organization with an emphasis on the behavioral aspects of projects and their relation with managerial strategies. Nicholas (1990) noted that while uncontrollable external forces are often cited as a major cause of project failure, the real cause may well be internal, and failure could largely be due to a defective project management system with ineffective organization practices and procedures. Rodrigues and Bowers (1996) note that good project management should be able to cope with many of the adverse external influences and ensure a successful completion despite the environment. They state that project managers often use informal mental models, based on their own experience and vision of reality to support strategic decision making. Once the key strategic decisions have been taken, the traditional techniques are then deployed to support the detailed operational planning, but the crucial mistakes may already have been made. They conclude that poor, informal strategic judgment may be the root cause of many project failures.

Ogunlana et al (2003) noted that governments and firms in developing economies are concerned about ways to improve performance of local firms. In this respect, the challenge faced by many organizations is that implementation scenario of the selected options requires an experimentation period either by actually implementing the option as a policy or simulating the complete process in a model. The former option is costly while the latter requires dynamic modeling of engineering processes integrated with the local influencing factors on overall performance. Construction projects are extremely complex and involve nonlinear relationships, as well as hard (quantitative) and soft (qualitative) data. System dynamics is well suited to handle these situations more than any other modeling tool, state Ogunlana et al (2003). This view is shared by Rahmandad and Hu (2010) when they state that project performance in terms of schedule, cost, and quality, evolves through time and thus it is a dynamic concept that lends itself to the application of system dynamics modeling.

System Dynamics is a methodology and mathematical modeling technique for framing, understanding, and discussing complex issues and problems (Radzicki and Taylor, 1997). Originally developed in the 1950s to help corporate managers improve their understanding of industrial processes, system dynamics is currently being used throughout the public and private sector for policy analysis and design. As social and economic systems are considered to be complex systems, System Dynamics modeling was introduced in the hope that it would be a useful guide for a working understanding of the world around us (Forrester, 1987). While modern projects have increasingly become larger, Moti et al (2007) note that more complex and interdisciplinary systems engineering has come to play an ever increasing major role in projects as regards both engineering and management processes and aspects. They state that the main functions of systems engineering in technology-based projects include optimally integrating individual components into a whole system that meets specific systems-level requirements. This therefore calls for the use of the systems approach in the early planning phase of the project which would entail involving stakeholders during the front end phase to define deliverables and to view the entire system lifecycle.

Writing on a paper on the role of System Dynamics in project management, Rodrigues and Bowers (1996) state that traditional planning techniques such as Critical Path Method (CPM) or Program Evaluation and Review Technique (PERT) do not allow experimentation so as to establish appropriate policies and post mortem diagnosis. They further state that a system dynamics approach has better flexibility for establishing a model, conducting experiments, and analyzing policy options. They note that system dynamics can be used simultaneously with traditional techniques, serving as an analysis tool for strategic decision making by construction management executives, thus complementing the planning technique. While still on the subject of System Dynamics, Chritamara et al (2002) note that it is a good methodology for understanding certain kinds of complex problems that involve changes over time through multiple feedback loops.

Minami et al (2010) report that because of the complexity of the construction process and its inherent non-linear relationships between different phases, actors, and resources, the System Dynamics methodology serves as an excellent tool for helping to better understand this system. They point out that construction projects are essentially human enterprises and cannot be understood solely in terms of technical relationships among components. According to Abdel-Hamid (2011), System Dynamics modeling is useful for managing and simulation of processes with two major characteristics namely; those that involve changes over time and those that allow feedback. He states that System Dynamics modeling has recently been applied to construction research and the literature on its application to project management is sizeable, including Sterman (1992) who has shown that construction design and management processes can be studied using system dynamics modeling.

Radzicki and Taylor (1997) state that the success or failure of a particular policy initiative or strategic plan is largely dependent on whether the decision maker truly understands the interaction and complexity of the system he or she is trying to influence. Considering the size and complexity of systems that public and private sector decision makers must manage, they note that it is not surprising that the intuitive or common sense approach to policy design often falls short, or is counter-productive to desired outcomes. They further note that System Dynamics is a powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems that is currently being used throughout the public and private sector for policy analysis and design.

According to Rodrigues and Bowers (1997) the application of System Dynamics to project management has been motivated by various factors such as a holistic approach and the concern to consider the whole project rather than the sum of individual elements. They state that system dynamics is appropriate for examining major nonlinear aspects typically described by balancing or reinforcing feedback loops, and fills the gap created by the need for a flexible project model which offers a laboratory for experiments with management's options. Its use is also justified by the failures of traditional analytic tools to solve all project management problems and therefore the desire to experiment with something new.

System Dynamics models facilitate the strategic management of projects, including planning the project, determining measurement and reward systems, evaluating risks, and learning from past projects (Lyneis et al, 2001). The types of decisions made on projects are often categorized as being strategic, tactical, or operational. They state that the use of System Dynamics most naturally falls into the strategic or tactical end of the spectrum and covers decisions that are taken up front in designing the project. In table 2.6, they give a breakdown of how system dynamics modeling can be used in strategic project management.

Table 2.6: The use of System Dynamics Modeling in Strategic Project Management (Lyneis et al, 2001)

Risk Management	Determine in advance which risks pose the greatest threat to the project, what should be monitored to provide early warning of each risk, and the best responses to such potential changes
Incorporating learning from past projects	Based on benchmarking and other analyses of past projects, how can we better design and then manage this and future projects? This requires determining what really happened in terms of cost, schedule, and rework on prior

	projects; what risks actually occurred; and what management initiatives worked and what did not
Pre-project Bid or Plan analysis	The model is used to establish and/or test the feasibility of schedule and budget given scope and other strategic requirements
Mitigation Analysis	The model is used to determine changes in program schedules, interim milestones, resourcing, etc., which minimize the consequences of risks during the project
Change Management	The model is used to determine the likely full cost and schedule implications of specification and scope changes by comparing two simulations: the baseline simulation and a simulation in which the direct impacts of the changes are included

Chapman (1998) states that the traditional practice of breaking a project into its elements for planning and cost purposes has the tendency to ignore important intra-project forces, and the appeal of systems thinking arises from its focus on the inter-relationships of the component parts and their influence upon the effectiveness of the total process. He further states that System Dynamics is concerned with creating models or representations of real world systems of all kinds and studying their dynamics or behavior. In particular, it is concerned with improving problematic system behavior. The purpose in applying System Dynamics is to facilitate an understanding of the relationship between the behavior of a system over time and its underlying structure and decision rules.

This view is shared by Morris (2002) when he states that the "hard systems" approach is essentially an engineering one about how to perceive, design, evaluate and implement a system to meet a defined need, and further notes that by the mid-1960s, the hard systems approach had given rise to almost the entire vocabulary of modern project management. He states that this "hard" view of project management is increasingly being recognized as not being the full view, and not always even the appropriate view, of the discipline. At the front end of project definition for example, things are often quite messy, poorly structured situations he notes, where objectives are not clear, where different constituencies have conflicting aims, and where the way forward requires vision and leadership as well as hard analysis and design. He further states that while the hard, engineering driven approach to systems management previously advocated for project management is still generally appropriate, it needs to augment it with a subtler, more emergent view for these fuzzier aspects of projects and their management.

From the foregoing revelations, it can be concluded that System Dynamics is a powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems, similar to the problems facing the major projects in the electricity industry in Sub Saharan Africa. Specifically, System Dynamics can be used to determine in advance which risks pose the greatest threat to the project, what should be monitored to provide early warning of each risk, and the best responses to such potential changes. It comes out that the traditional practice of breaking a project into its elements for planning and cost purposes has the tendency to ignore important intra-project forces, and the appeal of systems thinking arises from its focus on the inter-relationships of the component parts and their influence upon the effectiveness of the total process. System Dynamics approach would therefore be quite suitable at the front end of project definition for example, where situations appear to be poorly structured and objectives are unclear.

2.8 Suitability of System Dynamics modeling for projects in the energy sector

In the recent past, differing opinions have emerged that explore new paradigms in project management. Williams (2005) distinguishes between "the planning approach" to projects, in which a well-defined path to predetermined goals is assumed and "the learning approach," which "sees the project as an ambiguous task with changing objectives as the project progresses. He however adds that project risk management lends itself to conventional structured planning as the project manager tries to avoid deviations from the predefined project plan. Shenhar (2001) advocates that the project management style used should be dependent on the type of project, so that projects with lower technological uncertainty are managed in a formal style, while those with higher technological uncertainty should employ a more flexible attitude and tolerance for change and tradeoff between project requirements.

Meyer et al (2002) state that the challenge in managing uncertainty to whatever degree, is to find the balance between planning and learning. Planning provides discipline and a concrete set of activities and contingencies that can be codified, communicated and monitored. The two require different management styles and project infrastructure. They conclude that projects in which foreseen uncertainty dominate allow more planning, whereas projects with high levels of unforeseen uncertainty and chaos require a greater emphasis on learning. Similarly, and while reporting on a paper on the changing paradigms of project management, Pollack (2006) states that in many complex projects, it is impossible to foresee the actions which will be needed in the future and therefore through consultation and facilitation, the project manager defines what needs to be done as the project progresses, adapting as the project unfolds.

EPC contracting is the industrial version of commercial design-build where the contractor bids and builds a full turnkey facility for the plant owner. The primary difference between commercial design-build and EPC is the addition of plant performance guarantees in EPC contracts. These guarantees can include guaranteed plant output capacity, annual energy production and availability. Therefore, upon completion of start-up and testing on EPC projects, the contractor is responsible to deliver a running process plant that meets all performance criteria by a specified date. EPC contracts have traditionally been used on large and complicated power, petrochemical and heavy industrial projects. Recently, the EPC structure is emerging as a standard contracting method for large solar projects as well (Canada, 2013).

Engineering, Procurement and Construction (“EPC”) Contracts are the most common form of contract used to undertake construction works by the private sector on large scale and complex infrastructure projects. Due to the flexibility, the value and the certainty derived to sponsors and lenders, EPC contracts are being used as the main form of construction contract by project sponsors bidding for projects under South Africa's Renewable Energy Independent Power Producer ("RE IPP") Procurement Programme (Kieran and McNair, 2012*)*. Projects in the energy sector, specifically in the electricity utility sector can be categorized as formal in the sense that they either use existing technologies or adopt new technologies to an existing infrastructure. However, the projects are increasingly being outsourced as Design-Build, or EPC-Turnkey projects, and many of the projects are large in magnitude and budget.

Complexities therefore often arise from the interactions between the client, contractors, various project risks, and the assembly of equipment from different sources which have to be connected to an existing network. According to Love et al (2002), methods used in a risk management approach, as given in (Smith and Merritt, 2001), can be applied in dynamic approach successfully. For example, risk identification techniques can be applied to identify unattended dynamics. Therefore, System Dynamics modeling is relevant for managing risks of projects in the energy sector in Kenya and Sub Saharan Africa at large.

2.9 Chapter summary and conclusion

In summary, this chapter emphasizes the importance of not only managing risks in infrastructure projects, but highlights the fact that different risks may interact with each other to cause complications previously not anticipated. The literature reveals that construction projects are quite complex and consist of multiple interdependent components, are highly dynamic, involve multiple feedback processes, involve nonlinear relationships and involve both hard quantitative and soft qualitative data. The literature reveals that risks in large scale construction projects include technical risks, acts of God, financial, economic and political risks. It also reveals capability of owners' project group, contractor's failure, consultant failure, statutory clearance risks and vendor failure as other risks that construction projects encounter.

At the institutional level, the literature reveals that opposition to the project, political conflicts, and expertise in facilitating projects may lack in many developing countries. However, there is a literature knowledge gap in the area of the interaction of project risks and the resultant effects in the electricity energy sector projects, as well as what forces create the problems that lead to project delays and quality challenges experienced in projects in the electricity sector through these interactions, and how these negative forces may be mitigated. This research intends to bridge this gap. We learn from the literature that System Dynamics uses informal maps and formal models with computer simulation to uncover and understand endogenous sources of system behavior, and has found wide usage in strategic project management in planning and risk management. System Dynamics modeling was therefore found to be appropriate and best suited for managing project risk interactions in the electricity energy sector in Sub Saharan Africa.

The following chapter introduces the theoretical framework as used in this research to develop a model that captures project dynamics in the electricity sector in Kenya.

CHAPTER 3: Theoretical Framework of the research on project dynamics in the electricity industry in Sub Saharan Africa

3.1 Introduction

In this chapter, the theoretical standing of project management is discussed. The chapter expounds on the three dominant approaches in the theory of project management over time, while giving the strengths and weaknesses of each approach. The chapter evolves and explores the approach employing modeling techniques while the epistemological perspective of project management is also addressed in the chapter. A brief on interaction of project risks is also covered to shed light onto why the conventional approach to managing risks may not always suffice. Finally, the modeling approach employing system dynamics modeling is introduced, with reasons as to why it is the chosen approach in this research.

The chapter explores the area of project failures, and argues for a positioning aimed at laying the foundations for a discourse that can improve on the shortcomings of previous models. The chapter thereafter discusses the theoretical approaches to project management, and from the three dominant approaches, delves into why a leaning towards the more recent focus toward a greater emphasis on the front end phase of projects in the public sector is preferred. A section on postmodern thinking then follows and discusses an ontology of movement, emergence and becoming in which the transient nature of what is “real” comprises emergent relational interactions and patterns, and why research using this method is framed as cooperative inquiry where the researchers and the researched cooperate in interpreting the lived experience to achieve the research aims. This research borrows from this experience by working together with the stakeholders in the electricity energy sector to gain knowledge from past projects in the sector by focusing on the ‘lived’ experience of the stakeholders.

Knowledge gained from this chapter is used in the exploratory study as described in section 4.5.4, so as to aid in answering the sub-research question in section 1.5 (b) namely; “How can the interaction of project risks in the electricity sector in Kenya be studied and analyzed in a dynamic setting?”, which is later used in chapter 4 in answering the first research question “What are the project dynamics in the electricity industry in Kenya?”.

3.2 Theory of Project Management

According to Turner (2010), project management and project portfolio management are relatively young disciplines, and the research approaches and standards are still in transition. They note that advances in project management and project portfolio management research have resulted in studies with increased methodological rigor, such as those that develop and test conceptual models through sophisticated statistical analysis, and others that employ qualitative multiple case studies involving in depth interviewing, observation, and analysis. Shepherd and Atkinson (2011) report that the discipline of project management continues to evolve as the nature of projects change. They recommend the need for the research community to engage with the membership associations of project management to identify the contribution academic research might make to the body of knowledge development, and conclude that while there is no single theory of project management emerging, this should not be seen as a weakness since other major professions operate under the same development.

To improve project outcomes such as performance, satisfaction, and success, a guide to the project management body of knowledge (PMBOK Guide) was developed by the Project Management Institute to identify general project management knowledge, processes, techniques, tools and skills (PMI, 2008). The guide contains the fundamental, baseline practices that drive business results for any organization, including those organizations in the construction industry. Morris (2004) points out that many of the factors that cause projects not to meet their schedule or cost targets are not covered by the PMBOK type model, such as client driven changed specifications, technology problems, poor design management, external price changes, environmentalist issues, community or political difficulties, and labor problems. He concludes that while much of the PMBOK material is helpful in managing projects, it is not always sufficient to manage them successfully. The newer PMBOK versions such as PMBOK (2013) 5th edition have addressed some of these concerns.

This is reinforced by Pinto and Mantel (1990) when they state that the causes for project failures are getting harder to pinpoint. Pardo and Scholl (2002) suggest grasping the complex issue of project failure by examining the interdependence of technical, social, and behavioral factors, and report that an approach to examine this context of failure has recently emerged consisting of an epistemological reflection on the project management field and its particular features. The aim is to deepen understanding of epistemological issues in project management (Bredillet, 2008; Cicmil, 2006; Koskela & Howell, 2002). The objective of this positioning is aimed at laying the foundations for a discourse that can improve on the shortcomings of previous models.

Chou and Yang (2013) note that as society develops, construction projects naturally grow in scale, involving vast numbers of professionals, long life cycles, and complex interfaces, and the types and quantities of construction related information have become large and complex, which has increased the complexity of construction operations processes. They observe that most companies determine which management techniques or tools are needed for a particular project based on personal experience or on legacies passed down by industry predecessors which is not scientific or objective, and conclude that construction projects now require highly specialized knowledge and experiential feedback that will facilitate project implementation and delivery. This view is reinforced by Morris (2004) when he states that knowledge is tacit as well as explicit, and defines tacit knowledge as personal knowledge embedded in individual experience which involves intangible factors such as personal belief, perspectives, and values, while explicit knowledge is 'readily available', knowledge which can be codified and structured in a way that makes the knowledge easily transmissible. He notes that much of what is really useful in project knowledge is embedded in the minds of people as personal experience and is therefore tacit, private knowledge, and is not scientifically testable. Scientific knowledge which is publicly refutable knowledge, is explicit knowledge. He concludes that much of what is valuable knowledge about project management is thus inherently not scientific, unless and until it becomes explicit and can be addressed according to scientific practice.

Sage et al (2010) report that project management is widely recognized as the core discipline of construction management knowledge, and construction management scholars, practitioners and governments have advocated many highly standardized, structured and prescriptive formal project management knowledge tools, techniques and frameworks to develop organizational value. Assumptions regarding the value of sharing standardized and structured project management knowledge, and knowledge management processes, to improve project performance can be found in various key performance indicators (Yeung et al, 2007) and critical success factors (Kulatunga et al, 2009). In contrast, critical project studies (Hodgson and Cicmil, 2007, 2008) and other interpretative studies of project management (Crawford et al, 2006; Morris et al 2006; Crawford and Pollack, 2007) have questioned the efficacy, relevance and consequences of standardizing project management knowledge and practices and instead encourage a more reflective, or transformative, view of project management knowledge production and circulation. Drawing upon interpretative and critical approaches to knowledge in management studies, a variety of more reflective, transformative, collaborative and informal tools, techniques and guidelines have been proposed to develop project management knowledge (such as Cicmil, 2006; Bellini and Canonico, 2008).

Morris (2004) states that in general, the nearer to the definition stage of the project, referred to as the ‘front end’, the broader the range of issues project managers will often deal with, and this includes issues of strategy, finance, organisation, technology, control, people and culture, commerce and contracts, community and environment, process and timing. He notes that of all the approaches that have consciously sought to bring the rigour of the scientific method to management, that of ‘systems thinking’ has probably been the widest, most influential and most suitable, and its impact on project management has been enormous, as it illustrates both the possibilities and the limitations of the scientific method. Pierre-Luc et al (2010) state that the science of project management differs from the natural and social sciences such as biology and sociology because project management is not only a scientific discipline, it is also a professional discipline, a practice. Like other scientific disciplines such as engineering, clinical psychology, the nursing sciences, education, and architecture, which are fueled by professional practice, the project management field attempts to develop a body of knowledge that is transferable to management skills, thereby advancing the practice. At the end of the day, the key is to build knowledge that is relevant for the practitioner and not just for the project management research community. In this regard and towards this end, this research study aims at contributing new knowledge that will be useful to project management practitioners in the electricity energy sector in Sub Saharan Africa through a model representative of the interacting project risks in the sector.

In the field of project management, there is an imposing volume of literature devoted to failed projects, and many studies make the particular point that project management, like other professional disciplines, is experiencing some kind of knowledge crisis. Moreover, it seems that the causes for these failures are getting harder to pinpoint. Pinto and Mantel (1990) and Pardo and Scholl (2002), suggest grasping the complex issue of project failure by examining the interdependence of technical, social, and behavioral factors. An approach to examine this context of failure has recently emerged, and it emphasizes a reflection on the project management field and its particular features. The aim is to deepen understanding of epistemological issues in project management (Bredillet, 2008; Cicmil, 2006; Koskela & Howell, 2002). The objective of this positioning is aimed at laying the foundations for a discourse that can improve on the shortcomings of previous models.

Other authors underscore the relationships between project failure and human factors, such as conflicts between actors, political issues, power relations, and communication problems (Olander & Landin, 2005; Pinto, 2000). A number of studies have argued that the adoption of risk assessment and management practices are closely aligned with overall project performance (Nguyen et al 2004; Nguyen et al 2007), and a review of literature suggests that project failures seem to occur in all manner of projects such as in ambitious engineering projects (Miller and Lessard, 2001), construction projects (Dlakwa & Culpin, 1990; Mansfield, 1994), as well as the public sector (Arditi, Akan, & Gurdamar, 1985; Dlakwa & Culpin, 1990; Gauld, 2007). Research by Assaf et al (2015) and based on the overall assessment and ranking of causes of contractors' failure revealed that lack of contractor experience in industrial projects; war and acts of war; poor project management; poor cash management and lack of capital are risks to the project that could result in the contractors' failure. They noted that cost estimating practices are critical to the contractors' success because submitting high bids especially in competitive projects would result in the contractor not getting any contracts, while on the other hand, submitting low bids will result in losses to the contractor.

Similarly, Gilge (2013) reports that other causes of project failure include inadequate scoping by owners such that project scope does not fully address organizational business requirements, Inexperienced or unqualified project team so that the project team lacks appropriate skills and expertise to manage the project, lack of proactive risk management, unrealistic schedules, and project tools and infrastructure that are not set up to effectively plan, deliver, track, and report performance. He notes that contractors may also rely on flawed assumptions regarding regulatory issues, labor and material price escalation, and may underestimate impact of resource shortages. He adds that failure may occur where the project lacks support from senior management to address project issues and challenges in a timely manner. Beckers et al (2013) noted that the infrastructure sector significantly undermanages risks and lacks professional risk management, and further add that while under management of risk happens across the whole value chain, poor risk management during early conceptual planning and design phases, mostly under the responsibility of public project sponsors, has a particularly negative impact on governments' and private developers' ability to achieve the hoped for improvement of infrastructure services.

3.2.1 The three dominant theoretical approaches in Project Management

Winter et al (2006) note that there are various theoretical approaches to project management, many of which overlap. For the discipline as a whole, three dominant approaches stand out. Arguably the most dominant strand of project management thinking is the rational, universal, deterministic model, what has been termed the 'hard' systems model, emphasizing the planning and control dimensions of project management, (Yeo 1993, Winch 2004). This is chronologically the first of the strands arriving with critical path scheduling. Most popular project management textbooks and methodologies are based on this approach. It has however been criticized for failing to deal adequately with the emergent nature of front-end work, for tending to treat all projects as if they were the same, and for not accounting sufficiently for human issues, which are often the most significant, (Cicmil and Marshall, 2005).

A second strand of thinking is more theoretically based and emerged in the late 1960s and 1970s from the literature on organizational design, which focused on organizational structure as a means of achieving integration and task accomplishment (Winter et al, 2006). This second thinking promoted projects as ad-hoc organizational forms, which led to the so-called Scandinavian school (Lundin and Soderholm 1995, DeFillippi and Arthur 1998) looking at projects as temporary organizations, showing how projects are embedded within the firm and wider networks.

A more recent third group, stemming from the late 1980s, but still producing important contributions, has looked at major projects, with examples in specific sectors (Bauer et al 1992, Midler 1993, Davies and Hobday 2005, as cited by Winter 2006). Williams and Samset (2010), in reference to the period when the project exists only conceptually, report of a move toward a greater emphasis on the front end phase of projects in the public sector. they note that "front-end" management and project governance are increasingly popular research agendas in the field of project management, and this will likely help managers deal with complexity, particularly the systemicity and interrelatedness within project decisions. They state that identification of strategy, alignment of the project, and scenario planning are all rooted within the same set of organizational issues and need to be viewed as an integrative whole. They conclude that while there has been much research into each of these steps individually, there is a need for further research into how different organizational forms and cultures with different project complexities and domains operate in all of these stages and the correlations between them. This research contributes in this area by modeling project risks and investigating their interactions in an African context and environment.

Morris (2011) reports that from its earliest days, project management was holistic, covering the overall project life-cycle, from the initial development phases into hand-over and operation. He adds that in the 70s and 80s, this changed and the discipline came to be seen predominantly as an execution function, focusing on delivering the project 'on time, in budget, and to scope', and he adds that this emphasis misses the fact that most of the causes of projects failing are to be found in issues arising in the front-end stage of the project. He concludes that part of the reason for failure to focus adequately at the front-end is that in the early stages of a project, things are typically complex, intangible and uncertain.

Edkins et al (2013) supports this view when they state that many of the issues bearing on projects in their front-end are often addressed by specialists who are not part of the project team, and usually comprise strategists, policy-makers, financiers, regulators, planners, and sociologists, all experts whose views critically shape what may become 'the project'. They note that despite its importance, "front-end" management issues, responsibilities, roles and actions are too often ignored by official project management guidance which typically instead tends to dwell on the many "downstream" project management challenges and issues. They further state that the job of the project manager at the front-end is to provide professional support to the sponsor, advising on potential technical solutions, schedules, risks, estimates, contingencies, procurement, people or staffing issues. This research investigates the interaction of project risks at the front end of projects with the aim of arriving at new policy insights that would be beneficial to the overall management of projects in the electricity sector in Africa.

Faniran (1999) notes that the project environment in many developing countries presents special challenges for project managers could result into extensive cost and time overruns even before a project commences. He notes that these challenges arise mainly from inherent risks such as political instability, excessively bureaucratic contract procedures, and lack of adequate infrastructure such as transportation networks, electricity supply, and telecommunications systems, and adds that in recognition of these unique problems, there is a need to develop 'appropriate' management tools and techniques specifically tailored to the project environment of developing countries. This is further reinforced by Faniran et al (2000) when they state that good project management at the early stages of a project, or the 'front-end', has been found to provide potentially significant opportunities for eliminating, or reducing, several problems that prevent the achievement of project success. They add that 'front-end' project management is particularly relevant in developing countries where the achievement of project success often poses a special challenge to project managers due to inherent factors of uncertainty and unpredictability in the operating environment of projects. These studies emphasize a broader view of projects, recognizing the importance of the front-end, and of managing exogenous factors as well as the endogenous ones.

Samset and Volden (2015) note that there are many challenges facing public investment projects that must be overcome so as to achieve project success, and these include lack of competence among planners, underestimation of costs and overestimation of benefits, unrealistic and inconsistent assumptions, and how to secure essential planning data and adequate contract regimes. They further state that many of these problems can be interpreted in terms of deficiencies in the analytical or political processes preceding the final decision to go ahead, and hence the importance of the front-end decision making phase needed to strengthen project governance. They state that project governance refers to the processes, systems, and regulations that the financing party must have in place to ensure that projects are successful, and would typically include a regulatory framework to ensure adequate quality at entry, compliance with agreed objectives, management and resolution of issues that may arise during the project, and standards for quality review of key appraisal documents. From this latter strand has emerged the broader 'management of projects' framework (Morris 1994, Morris and Pinto 2004, as cited by Winter, 2006). This research study is anchored on this third type of thinking, with emphasis on endogenous factors at play in projects.

3.2.2 Complexity as an aspect of Project Management Research

The mainstream research into projects and project management has previously been criticized for its heavy reliance on the functionalist and instrumental view of projects and organizations (Kreiner 1995, Packendorff 1995, Hodgson 2002), where the function of project management is taken to be the accomplishment of some finite piece of work in a specified period of time, within a certain budget, and to agreed specification. Project actuality research as expounded by Cicmil et al (2006) attempts to respond to some of this critique. Project actuality encompasses the understanding of the "lived" experience of organizational members with work and life in their local project environments. Their actions, decisions and behaviors are understood as being embedded in and continuously re-shaped by local patterns of power relations and communicative inter-subjective interaction in real time. The underlying assumption that reflects practitioners' accounts is that projects are complex social settings characterized by tensions between unpredictability, control and collaborative interaction among diverse participants on any project (Cicmil et al 2006).

In line with the conceptual and methodological foundations of actuality research, Cicmil and Marshall (2005) have drawn on theory of complexity (Stacey 2000, 2001, 2003 as cited by Cicmil et al 2006) and a becoming ontology (Chia 1995) to propose a critical framework for the conceptualization of the complex nature of construction projects, and to identify alternative types of knowledge and skills relevant to practitioners involved in this kind of projects. According to Chia (1995), a modernist thought style relies on a strong ontology (the study of the nature and essence of things) of "being" which privileges thinking in terms of discrete phenomenal "states" and static "attributes". Postmodern thinking, on the other hand, privileges a weak ontology of "becoming" which emphasizes a transient, and emergent reality which is deemed to be continuously in flux and transformation and hence not representable in any static sense. Cooper and Law (1995) as cited by Chia (1995) maintain that the basic criticism of modern studies of organizations is that they tend to deal with results or organized states rather than with the complex social processes that lead to these outcomes, and the state of rest is viewed as normal whilst change is considered accidental, which they refer to as a sociology of 'being'.

Postmodern thinking on the other hand, privileges an ontology of movement, emergence and becoming in which the transient nature of what is 'real' is accentuated. What is real for postmodern thinkers are not so much social states or entities, but emergent relational interactions and patterns that are recursively intimated in the fluxing and transforming of our life-worlds (Chia, 1995). This method is framed as cooperative inquiry where the researchers and the researched cooperate in interpreting the lived experience to achieve the research aims. This research borrows from this experience by working together with the stakeholders in the electricity energy sector to gain knowledge from past projects in the sector by focusing on the 'lived' experience of the stakeholders.

The understanding of how complex projects behave has developed in recent years using management science modeling techniques, particularly through the work of two teams: Cooper and others at PA Consulting (Cooper 1993, Graham 2000, Cooper and Lyneis 2002), and the Strathclyde team (Ackermann et al 1997, Eden et al 2000, Eden et al 2005), the latter having been involved for some years in post-mortem analysis of a range of projects as part of claims preparation. The main results from this stream of work provide explanations for project behavior deriving from systemic inter-related sets of causal factors rather than tracing effects to single causes. The work shows how the systemicity involved produces a totality of effect beyond the sum of the results that would be expected from individual causes. The results from this research will therefore lead into new contributions and additional understanding in to the interactions prevalent in project risks in the electricity sector, thereby adding to the body of knowledge of project management.

The systemic models mentioned in the earlier paragraph show behavior arising from the complex interactions of the various parts of the project, and demonstrate how behavior arises that would not be predicted from an analysis of the individual parts of the project. The systemic models therefore show how the traditional decomposition models in some circumstances can be inadequate. The project behavior shown in this body of work is complex and non-intuitive. This brings into focus the relevance and importance of system dynamics approach that can bridge some of these shortcomings. This research uses the system dynamics approach to understand the dynamics that lead to the behavior of projects in the electricity energy sector.

3.3 An epistemological perspective for project management

According to Bredillet (2008), the field of project management includes both quantitative aspects dependent upon the positivist paradigm, where people have few degrees of freedom as exemplified by operational research, statistical methods, bodies of knowledge, application of standards, best practices on the one side and the qualitative aspects dependent upon the constructivist paradigm where people have many degrees of freedom such as learning, knowledge management, change management, and systemic approaches. However, some of these aspects are linked together, and this integrative epistemological approach for project management calls for better understanding of organizations by treating explicit, tacit, individual, and team/organizational knowledge as being distinct forms, inseparable and mutually enabling.

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Projects in the energy sector, specifically in the electricity utility sector can be categorized as formal in the sense that they either use existing technologies or adopt new technologies to an existing infrastructure. However, the projects are increasingly being outsourced as Design-Build, or EPC-Turnkey projects, and many of the projects are large in magnitude and budget (Herscowitz, 2015, International Energy Agency, 2014). Complexities therefore arise from the interactions between the client, contractors, various project risks, and the assembly of equipment from different sources which have to be connected to an existing network. According to Love et al (2002), methods used in a risk management approach, as given in Smith and Merritt (2001), can be successfully applied in dynamic approaches. As an example, risk identification techniques can be applied to identify unattended dynamics (Dulac et al, 2007). Therefore, system dynamics modeling is relevant for managing risks of projects in the energy sector in Africa.

3.4 Interaction of Risks in Mega projects

Alessandria et al (2004) state that varying levels of risk and uncertainty can affect a decision makers' choice of models, techniques, and processes used for making the investment decision, and managers usually employ different analytical tools for different levels of uncertainty. They define risk as representing the probability distribution of the consequences of each alternative, implying an ability to quantify the consequences of an alternative, while on the other hand, define uncertainty as "when the consequences of each alternative belong to some subset of all possible consequences, but that the decision maker cannot assign definite probabilities to the occurrence of particular outcomes", with a rider that these two constructs are interrelated and do overlap. As uncertainty increases, they propose more qualitative tools be used, especially because large complex capital budgeting projects can be difficult to assess and evaluate, with decisions and alternatives often being many and complex, as well as difficult to quantify for valuation purposes. Fang and Marle (2012) note that within the same project, the existence of interrelated risks implies that the occurrence of one risk may trigger one or more other risks with potential propagation phenomena like reaction chains, amplification chains or loops, so that a consequence of a risk may then trigger the occurrence of another risk. They note that the consequence of this complexity is a lack of capacity to anticipate and control the behavior of the project that often happens in many projects.

Schlindwein and Ison (2004) note that the 'real-world' of human affairs seems to be different than the world simplified by science, and is experienced as 'complex', and further state that for a long time, complexity has been ignored by classical science, in which scientists described an objective world following deterministic laws. They state that instead of considering complexity as a temporary shortcoming arising from limited or partial understanding of reality, or as something that has to be eliminated in order for scientific progress to proceed, complexity needs to recognized as an emergence in the world in which we live. They conclude that systems thinking in its many traditions, has evolved to an approach for making sense of and managing complexity. Birdseye and Dalton (1992) state that until recently, there has been insufficient analysis of, and learning from past experience with the problem of complex projects because managers lacked tools powerful enough to effectively analyse and control such projects.

Jackson (2003), while emphasizing the importance of the systems thinking and the systems approach, notes that even if all parts in an organisation are optimized, the performance of the whole organisation can be disastrous if the parts do not interact together well. He further states that the study of a system as a whole should be put before that of the parts, so that at an organizational level the parts are related properly, and serve the purposes of the whole. He notes that simple solutions often fail because they are not holistic or creative enough, and they often concentrate on the parts of the organization rather than on the whole, and yet in doing so, they miss the crucial interactions between the parts because they fail to recognize that optimizing the performance of one part may have consequences elsewhere that are damaging for the whole.

Risks in mega construction projects are usually complex and uncertain. Though risk management standards have been recommended for the best practice, there is still lack of systematic approaches to describing the interaction among social, technical, economic, environmental and political risks (STEEP) with regard to all complex and dynamic conditions of megaproject construction for better understanding and effective management (Boateng et al, 2012). This is a gap which has been identified in this research in relation to projects in the electricity sector in Africa.

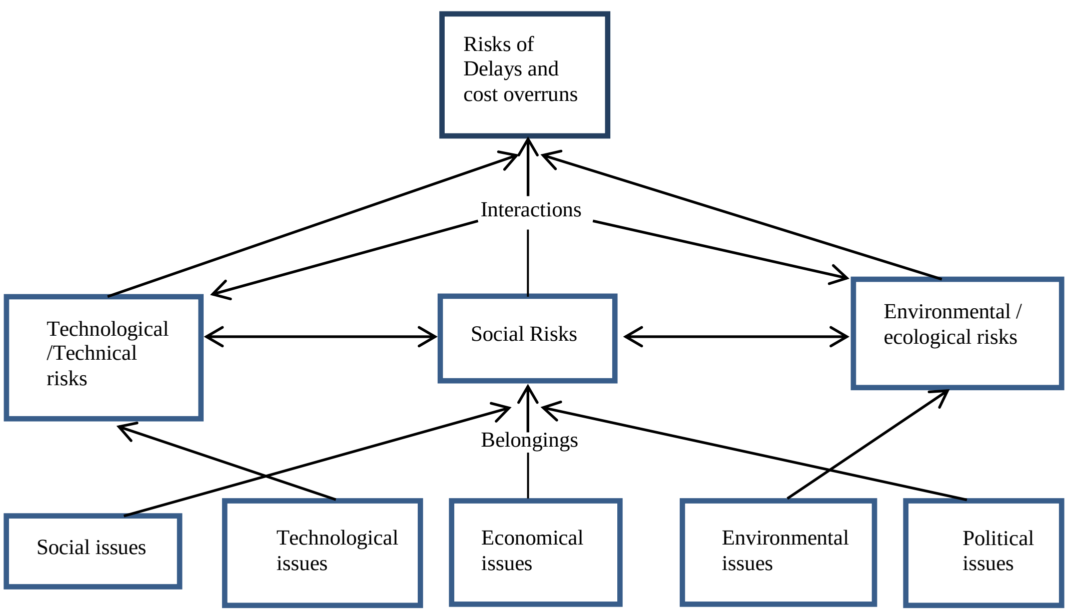

Fig. 3.1: The effects of Interactions and belongingness of STEEP factors in megaproject development (Adapted from Boateng et al, 2012)

Fig. 3.1 depicts how these risks may interact with one another to influence relationships and generate risk landscapes of unprecedented complexities. Li (2006) employed the systems approach to analyse risks in an international residential property development project in South Africa, and notes that there are many ways to deal with project risks such as risk avoidance, risk prevention, risk decentralization, risk retention, risk transfer, risk control and risk utilization, and emphasizes the importance of identifying risks early in the project, and taking possible preventative measures, thus enabling project re-engineering. She pointed out that engineering risk management should be regarded as a 'system', and that the achievement of an optimal level of risk for a particular participant cannot be realized without making use of the methods of systems engineering. This research uses this approach to explore the dynamics at play in project risks in the electricity sector in Sub Saharan Africa.

3.5 Modeling Project Dynamics using System Dynamics

Project modeling has been one mainstay of System Dynamics practice for many years. Modeling has been used in projects ranging from military and commercial shipbuilding projects to aerospace and weapons systems, power plants, civil works and software projects. As an illustration, System Dynamics has been used by Silva and Ferao (2009) to model a communication tool that would allow the project team to illustrate potential project results to customers, and to better understand their expectations, while Cooper and Lee (2009) have also used System Dynamics approach in modeling in designing, building, testing, and implementing a model-based system to aid project management at Fluor Corporation. Ling and Yan (2014) also built a System Dynamics model to identify causes of schedule risk of Wuzhun railway in China. To successfully evaluate investments related to integrated information management in the construction industry, causal loop diagramming was used by Tatari et al (2008) to depict the qualitative system dynamics model for the study of the dynamics of construction enterprise resource planning systems and with the aid of system dynamics principles, to identify the major variables that influence the successful evaluation of construction enterprise resource planning in the construction industry.

System Dynamics has been used in the defense industry to build models in naval engineering services (Lisse, 2013) and for policy modeling in the defense sector (Onori, 2013). It was also used by Sterman (1992) to develop a System Dynamics model for project management in large scale ship building projects, and has subsequently been used to understand factors behind the Chernobyl accident (Salge and Milling, 2006) and in specific areas concerning operational issues with safety case production at civil nuclear generation sites in the UK (Carhart, 2009). Teufel et al (2013) used System Dynamics modeling to model electricity markets focusing on deregulated electricity market models, while Chung et al (2008) used a System Dynamics modeling approach in civil engineering works for a water supply system. However, a model of the project risk dynamics specific to the electricity sector in Africa has up to now not been developed, and this research uses the system dynamics approach to build a model that is used to explore the interaction of risks prevalent in the electricity energy sector in Sub Saharan Africa.

The real leverage lies in using these models so overruns and delays are avoided (Sterman 2000). System dynamics has a strong and established history of modeling development projects and has been successfully applied to a variety of project management issues, including failures in fast track implementation (Ford and Sterman 1998) and the impacts of changes on project performance (Rodrigues and Williams 1997; Cooper 1980, 1993b). Forrester (1991) noted that in many organizations, new corporate policies are tested experimentally on the organization as a whole without dynamic modeling of the long-term effects and without first running small-scale pilot experiments.

Models are simplifications of reality and usually help people to clarify their thinking and improve their understanding of the world (Sterman, 2000). A computer model, for instance, can compress time and space and allow many system changes to be tested in a fraction of the time it would take to test them in the real world. Sterman (2002) states that System Dynamics is designed to help identify high-leverage policies for sustained improvement, and further notes that understanding complex systems requires mastery of concepts such as feedback, stocks and flows, time delays, and nonlinearity. He states that becoming an effective systems thinker requires the rigorous and disciplined use of scientific inquiry skills so that one can uncover hidden assumptions and biases. Radzicki and Taylor (1997) note that testing changes on a model, rather than on an actual system, is a good way to avoid implementing a faulty policy. That is, if a change does not perform well in a model of a system, it is questionable as to whether it will perform well in the actual system itself. In addition, experimenting on a model can avoid causing harm to an actual system, even when the change being tested is successful. System dynamics was therefore the method of choice for modeling in this research because it allows changes to be made on the model to facilitate learning using the model, and it also allows for testing of different scenarios which can be shared with stakeholders in the electricity sector in the region, including Ministry of Energy officials who sponsor most projects in the electricity energy sector.

3.5.1 The Rework cycle structure

The majority of system dynamics studies that focus on project dynamics include a simulation model of project evolution and the core feature of these models is the rework cycle (Cooper, 1993). While most of the original work is usually finished early in the project, delays are usually caused by the need to rework that original work. The rework cycle is illustrated in Fig. 3.2. It was first developed by Pugh-Roberts Associates (Cooper, 1980) and refined over many subsequent applications. By considering defects, quality and testing through rework cycle, many path-dependent reinforcing loops are generated that critically impact the fate of projects. Almost all dynamic project models have a rework cycle in some form (Lyneis, 1999). Thus the rework cycle is central to understanding project delays and disruptions (Lyneis and Ford, 2007).

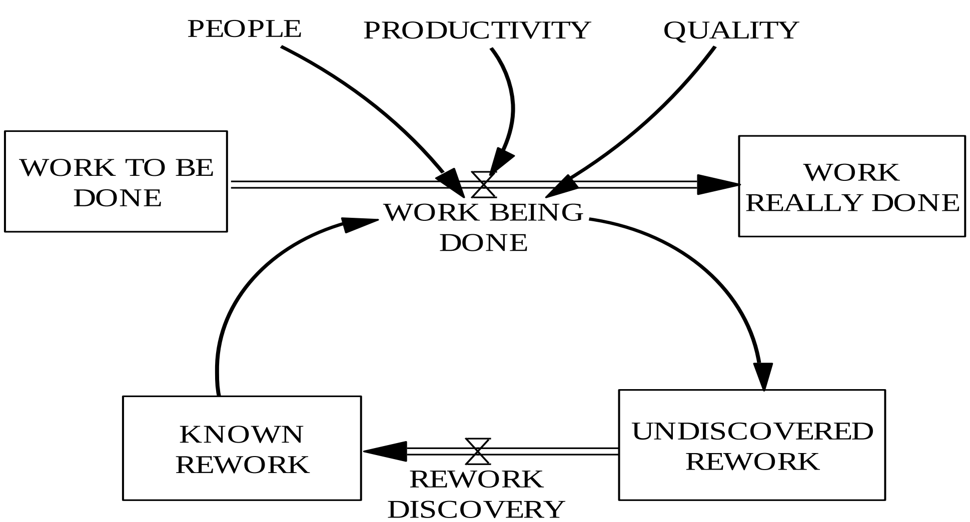

Fig. 3.2: The work accomplishment or rework cycle structure. Adapted from Cooper, 1993

As shown in Figure 16, the rework cycle represents four pools of work. At the start of a project or project stage, all work resides in the pool "WorkTo Be Done". As the project progresses, changing levels of staff working at varying rates of "Productivity" determine the pace of "Work Being Done". "Work Being Done" depletes the pool of "Work to be Done". This work is executed at varying, but usually less than perfect, "Quality". "Quality" represents the fraction of the work being done at any point in time that will enter the pool "Work Really Done" and which will never need re-doing. The rest will subsequently need some rework, but remains in a pool of "Undiscovered Rework", which is work that contains as yet undetected errors (Lyneis, 1999). The model developed in this research uses the rework cycle, essentially because many projects in the power industry in Sub Saharan Africa suffer from rework that results into project delays.

3.5.2 Modeling project dynamics - Richardson

Project planning is a successful System Dynamics application field (Pruyt, 2013). The model in Fig. 3.3 is a system dynamics model by Richardson (2013) that depicts the project dynamics that are linked endogenously.

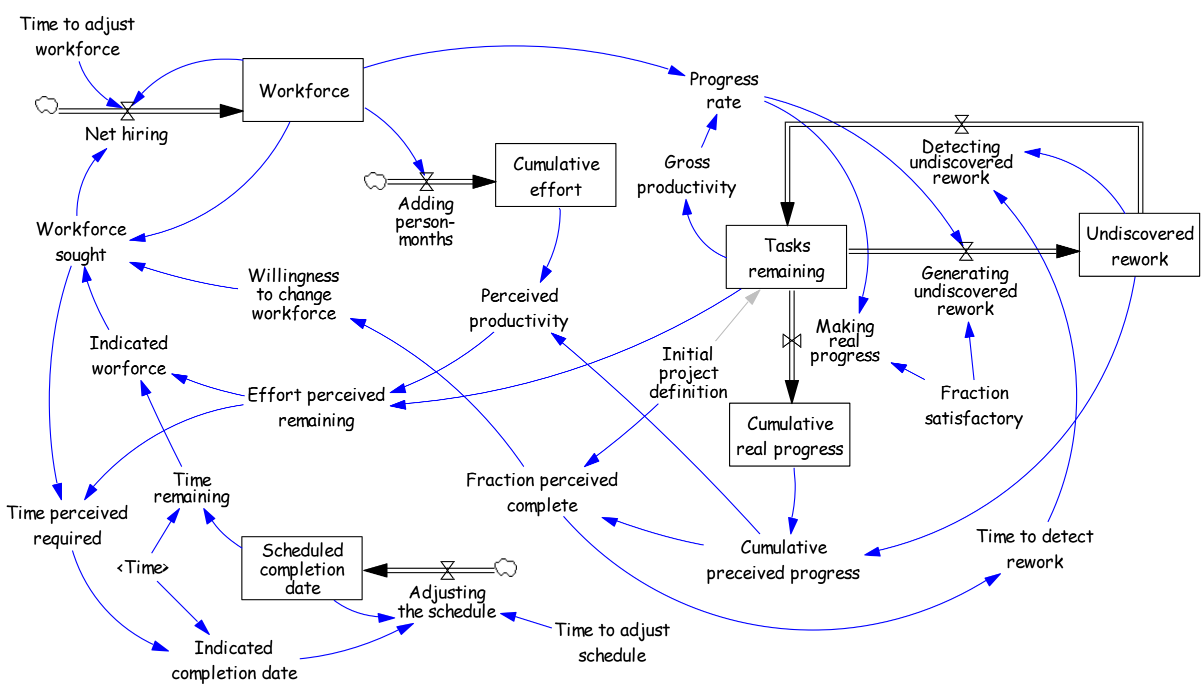

Fig. 3.3: ***A typical system dynamics model of project dynamics (Richardson, 2013)***

The model incorporates the rework cycle at its core, showing how rework is generated and dealt with in projects, the workforce component, showing how the project dynamics at play would result into variations on the size of workforce needed at a particular time. It also shows how the workforce size affects the cumulative effort on the project, and how the cumulative effort in turn affects and influences the perceived productivity.

The model developed in this research extends the model by Richardson (2013) as the foundation for the new model that presents the project dynamics in the electricity industry in Kenya. The new model developed in this research includes new focus areas having new project variables namely political risk, multitasking, unforeseen technical difficulties and project management competence as presented in section 5.3 and as given in Fig 6.2, and investigates the effect of changes in each of these variables individually as well as collectively on the overall performance of the model. The focus is on how these changes affect the overall project completion time and the quality of completed project tasks. This is later used to compare and contrast different policy scenarios so as to generate suitable policy alternatives as indicated in chapter 6.

3.6 Choice of System Dynamics as a suitable research Method

According to Crawford et al (2003), difficulties can arise when attempting to apply “standard” project management practices in complex, multi-stakeholder project environments. They note that systems thinking in general was found to offer a rich source of theoretical and model-based contributions to inform development of project management practice in these contexts. On a similar note, Kapsali (2011) states that simulation methodologies have systematically applied systems thinking constructs to projects. She further states that System Dynamics is an excellent tool for applying the systems thinking construct of holism, in providing a whole picture of a specific system and most importantly, in abstracting its main attributes to show the particular system's pattern of “organized complexity”.

This view is further reinforced by Rodrigues (1994), who states that planning is concerned with the specification of the actions that have to be performed to implement the project. He notes that in traditional project management, the assessment of the project status is based on the comparison of the current state of the work with the project plan. In contrast, the primary objective of a System Dynamics model is to capture the major feedback processes responsible for the project system behavior, with less concern about the detailed project components. Table 3.1 emphasizes the ability of System Dynamics models to consider a wide range of subjective factors that are difficult to incorporate in operational models, and are usually addressed in the traditional approach by simplistic assumptions.

Table 3.1: Comparison of some important characteristics of the traditional and System Dynamics approach. Rodriques, (1994)

	Traditional Approach	System Dynamics Approach
Factors explicitly considered	-Logic of the work structure -Cost of resources -Indirect cots -Constraints on resources availability -Work resources requirements	-Quality of work performance -Staff productivity -Staff experience level, learning and training -Schedule pressure on the staff -Rework generation and discovery time -Mismatch of perceptions and reality -Staff motivation -Client and project team relationship
Managerial decisions	-Cost-time trade-offs, crashing activities -Changes in the schedule of activities -Scheduling resources among activities -Changes in the logic of the project work structure	-Hiring staff vs. delaying the project completion date -Introduction of new technologies -Effort on quality assurance -Effort on rework discovery time - Cost-time trade-offs, hiring staff -Multi project scheduling -Multi project staff allocation -Managerial turn-over/ succession -Estimation of schedule and cost
Uncertain events	-Delays in completion of activities -Constraints in the schedule of activities -Resource constraints -Uncertainty in the duration of activities (simulation)	-Changes in the project work-scope -Changes in quality and productivity levels -Customer/vendor delays in delivering information -Constraints in the staff levels
Major estimations	-Project duration -Project cost	-Project duration -Project cost

	-Resource allocation	-Staff allocation -Demand on staff

Ocak (2012) further notes that project management is a suitable field for approaches using system dynamics because multiple factors can be analyzed at the same time, simulations can be run under any conditions, and experimentation with extreme factors or constraints is possible while extreme assumptions can be analyzed. Thus a simulation with a System Dynamics model is capable of revealing the underlying conditions and causes of an existing or a potential problem, and clarifying this characteristic in projects. Similarly, Wang et al (2005) note that in contrast with traditional project management methodology, the primary objective of a system dynamics model is to capture the major feedback processes responsible for the project system behaviors, with less concern about the detailed project components. They note that in System Dynamics modeling, there is a strong focus on human factors and managerial policies as these are considered to dominate the feedback structures. Concerning project risk management, they state that the main advantages of System Dynamics approach lie in risk identification, risk analysis and risk response planning as these processes involve many factors which are subjective and dynamic and cannot be effectively dealt with by traditional tools.

Rodriquez (2001) notes that risks are dynamic events, and overruns, slippage and other problems can rarely be traced back to the occurrence of a single discrete event in time. In projects, risks take place within a complex web of numerous interconnected causes and effects, which generate closed chains of feedback. He notes that system dynamics modeling is a complete technique and tool that covers a wide range of project management needs by addressing the systemic issues that influence the project outcome, while Its' feedback and endogenous perspective of problems is very powerful, widening the range for devising effective management solutions.

The choice of the research method should allow answering the research problem in the best possible way, within the given constraints of time, budget and skills (Ghauri and Gronhaug 2002). Specifically, System Dynamics was chosen as the modeling and simulation tool in this research largely due to insights from the literature review. The nature of projects in the electricity industry can be framed as complex dynamic systems (Sterman 1992, Rodrigues and Bowers

1996) because these projects are formed by multiple interdependent and dynamic components, and include multiple feedback processes and non-linear relationships. Engineering projects also generally involve both “hard” and “soft” data (Sterman 1992). System Dynamics method would therefore be suitable for analyzing risk interactions in the electricity industry environment.

3.7 Chapter Summary

In this chapter, project management comes out as not only a scientific discipline, but also a professional one. As in other professional areas, the knowledge area appears to be in crisis as evidenced by the volume of literature dedicated to failed projects, while the theoretical base of project management is seen as growing and expanding. The chapter traces the three dominant approaches to project management starting with the rational, deterministic model emphasizing the planning and control dimensions of project management, to the model popularized in the 1960s and 1970s of projects as temporary organizations embedded within the firm and wider networks. From the 1980s, the dominant approach has been to focus on the front-end of the project while managing exogenous and endogenous factors associated with the project in a systemic format.

The chapter explores the “project actuality” that emphasizes the understanding of the “lived” experience of organizational members of the project, with the underlying assumptions of projects as complex social settings characterized by tensions and unpredictability. The chapter touches on recent research methods focused on systemic, interrelated sets of causal factors in project failures rather than on single causes, and introduces modeling of project dynamics using system dynamics modeling approach which has a strong history of success when employed to project management. The next chapter outlines the research framework, giving the design and method used in this research.

PART 2: THE EMPIRICAL RESEARCH

CHAPTER 4: The Research Framework, Design, Method and Data Collection

4.1 Introduction and outline of the chapter

Glazunov (2012) describes research as scientific or critical investigation aimed at discovering and interpreting facts, while Kuhn (1962) describes scientific method as a body of techniques for investigating phenomena, acquiring new knowledge, and consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses. Eisenhardt & Graebner (2007) state that there are two ways that empirical research can make theoretical contributions; one way is to test theory, and this can be done by using theory to formulate hypotheses before testing those hypotheses with observations, while the other way is by building theory, and this can be done by using empirical evidence from one or more cases to create theoretical constructs and propositions. According to Colquitt and Phelan (2007), theory testing and theory building represent key components of theoretical contribution that can coexist within a given empirical research, and both have impacts on the accumulation and sharing of knowledge.

This research is designed as a theory testing and theory building research. The purpose of this chapter is to describe the scientific procedure which has been used in this research. This chapter is organized as follows: first, it describes the research strategy and the research paradigm used in this study. Then it describes the research design used in this research. After, it discusses the processes that were undertaken so as to collect data and to ensure the credibility of the research findings, the interview process, data analysis method for the exploratory study, and the choice of research method. An overview of the system dynamics method is also presented, including the model testing process and method used in this research.

Knowledge gained from this chapter is used as described in section 4.5.4 in answering the first research question namely “What are the project dynamics in the electricity industry in Kenya?” as well as in answering the sub-research question in section 1.5 (c) namely; “What research strategy and paradigm can be employed in studying project risks in the electricity sector?”, which is later used in chapter 5 in answering the second research question "How do the prevalent risks and other elements interact with each other in a dynamic project set up?".

4.2 Research Strategy

In a paper on "understanding project management practice through interpretative and critical research perspectives", Cicmil (2006) notes the possibilities that a qualitative research approach grounded in critical interpretative perspectives of phronetic social science can offer an alternative way of understanding and talking about the practice of project management. Such an approach implies a combination of practical philosophical considerations and concrete empirical analysis of "lived" experiences and social processes in concrete project settings. She further stresses the importance, and need to understand the implications for research implied by Fig. 4.1; notably the need to understand research as a holistic intellectual activity, spanning all three elements in Fig. 4.1, and the intrinsic link between research methodology and the nature of the knowledge created in the process.

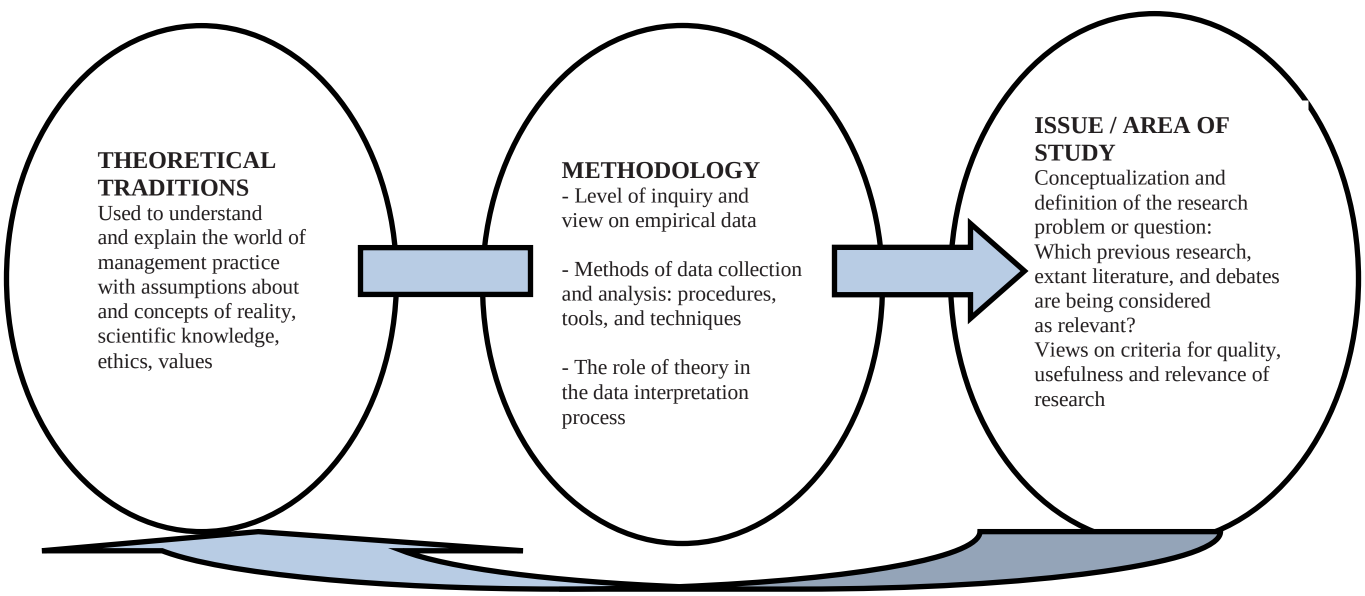

Fig. 4.1: A representation of the research activity as a knowledge creation process and the interconnectedness between its key elements. (Cicmil, 2006)

The research strategy sets a logic or procedure that will help to answer the research questions. The research strategy should define the ontological, epistemological and methodological position of the research. Ontology is the nature of reality (Hudson and Ozanne, 1988) and epistemology can be defined as the relationship between the researcher and the reality (Carson et al., 2001) or how this reality is captured or known. Methodology is the way to solving the research problem. (Industrial Research Institute, 2010). Simply put, one's view of reality and being is called ontology and the view of how one acquires knowledge is termed epistemology.

Ontology is also defined as what constitutes the “reality” that a researcher investigates, how “things really are” and how “things really work”. Epistemology is what constitutes valid knowledge, the different forms of knowledge of that reality, while methodology encompasses the techniques used by the researcher to investigate that reality, the tools used to know that reality (Denzin and Lincoln, 1998). Understanding the philosophical positioning of a research study at the onset is useful to help the researcher clarify alternative designs and methods for conducting the research, and identify which ones are more likely to work in practice. Fig. 4.2 depicts how the three interact in a research study.

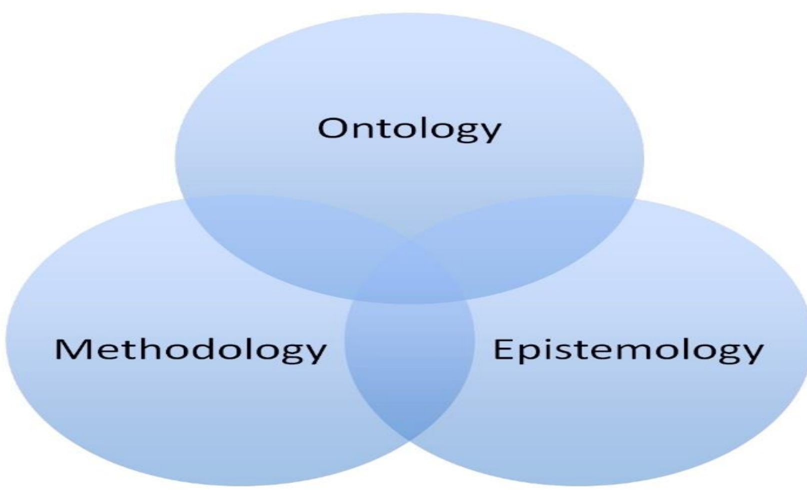

Fig. 4.2: Representation of the interaction of ontology, epistemology and methodology in research, (Grix, 2002).

Figure 4.2 sets out clearly the interrelationship between what a researcher thinks can be researched (their ontological position), linking it to what we can know about it (their epistemological position) and how to go about acquiring it (their methodological approach), as given by Grix (2002).

The choice of which method to use should be guided by research questions (Grix 2002). Research questions investigated in this thesis are given in section 1.5 and by their expression and nature, lend themselves to the choice of qualitative research of the constructivist / interpretivism paradigm as detailed in section 4.3. To investigate the first research question – “What are the project dynamics in the electricity industry in Kenya?” – an explorative study was undertaken. The findings were subsequently analyzed and interpreted through pattern matching and explanation building as explained in section 4.5.6. The results of the exploratory study were used to build the conceptual model. This model then provided a basis to investigate the second research question; “How do the prevalent risks and other elements interact with each other in a dynamic project set up?” – done with the help of computer-based simulation, and the results are given in section 5.3.6. The basic model was tested and validated, after which the resultant model was used to investigate the third research question – “What policy scenarios derived from the resulting model are available that can help stakeholders in the sector to better manage such projects so as to deliver value?” - done through what-if scenario analysis, leading to policy scenario generation as given under section 6.6.

4.3 Research Paradigm

In research paradigms, positivism is quantitative, and is about discovery of the laws that govern behavior, while constructivist / interpretivism is qualitative, focusing on understandings from an insider perspective (Collins, 2010). Table 4.1 compares and contrasts the two types of paradigms. Guided by the research questions, this research is of the interpretivism type, able to investigate the dynamics of risks in complex project environments through in depth interviews conducted to elicit views of key stakeholders in the industry as given in section 4.5.

Table 4.1: The Positivism vs. Interpretivism paradigm. (Collins, 2010)

Assumptions	**Positivism**	**Interpretivism**
Nature of reality	Objective, tangible, single	Socially constructed, multiple
Goal of research	Explanation, strong prediction	Understanding, weak

		prediction
Methodology & Methods	Multiple cases, survey	Small number of in-depth cases, interviews / surveys
Focus of interest	What is general, average and representative	What is specific, unique, and deviant
Knowledge generated	Laws Absolute (time, context, and value free)	Meanings Relative (time, context, culture, value bound)
Subject/Researcher relationship	Rigid separation	Interactive, cooperative, participative
Desired information	How many people think and do a specific thing, or have a specific problem	What some people think and do, what kind of problems they are confronted with, and how they deal with them

Creswell (2003) notes that constructivism involves understanding of multiple participant meanings and theory generation. The research in this thesis is set up as a qualitative research of the constructivist / interpretivism paradigm, which is a quest for subjective knowledge, a theory building approach. Interpretivism enables the researcher to be alive to changes that occur, and allows for complexity and contextual factors. Qualitative approaches have two things in common; first, they focus on phenomena that occur in natural settings, in the "real world". Second, they involve studying those phenomena in all their complexity (Leedy and Ormrod, 2009). The research study will seek to understand stakeholders' perceptions and perspectives of the critical issues at play in projects in the energy sector in Kenya through interviews with selected sample of participants.

4.4 Research description and classification

Phelps and Horman, (2010) note that existing construction methods may not be adequate to enable understanding of the complex interactions that lead to many of the industry's pervasive social and technical problems. One means of addressing these limitations is for the construction research community to complement prevalent quantitative and case study methodologies with qualitative theory-building methodologies, based on detailed and long-term observation of project environments (Phelps and Horman, 2010). A good theory should be coherent logical and internally consistent, and able to explain a good range of known findings and predict future observations (Higgins, 2004).

According to Gay and Weaver (2011), qualitative research's contribution to theory is important, particularly when exploring topics that are difficult to quantify, or when trying to make sense of complex social situations and when attempting to explain how stakeholders make sense of their situation, and the resulting theory is grounded in social reality. To build and test theories Hong et al (2010) note that attention needs to be given to the importance of the local particulars such as cultural and historical background foundational to each of the events. Through better understanding and more widespread use of theory-building methods, the construction research community can provide a needed complement to the current prevailing methods and greatly aid the maturation of the field. The type of research undertaken in this project is a theory testing and theory building research using the System Dynamics modeling approach. Empirical research is a way of gaining knowledge by means of direct and indirect observation or experience. This research study relies on the experience over time of the key practitioners in the electricity energy sector in Kenya, as well as archival data from past projects in the sector.

4.5 Grounded Theory Research

In referring to strategies associated with the qualitative approach, Creswell (2003) notes that the researcher attempts to derive a general, abstract theory of a process in grounded theory, which involves action or interaction grounded in the views of participants in a study. Grounded theory is a research methodology that facilitates the discovery of theory from data (Glaser and Strauss 1967, as cited by Valvi et al, 2013) with the aim of conceptualizing the main concern of participants and how they resolve or process that concern. Specifically, it is a systematic yet flexible methodology for the concurrent collection and analysis of all types of data, including qualitative data, to construct theories that are grounded in data themselves. Charmaz (2006) as cited by Valvi et al (2013), has presented a constructivist version of grounded theory which can be seen as an approach between positivism and postmodernism. Constructivism assumes that there are multiple simultaneous social realities, rather than one real reality. In constructivist grounded theory, data are constructed through an ongoing interaction between researcher and participant, where the actual meaning and reality are created during individuals' reflexive interactions in real settings (Valvi et al, 2013).

Grounded theory has been a success story and has been taken up and used by social researchers across a wide range of disciplines, from 'pure' ones like sociology and social psychology to 'applied' ones such as education, health studies and management studies (Strauss and Corbin, 1998). This research uses the grounded theory method in the preliminary stages of the study through the interaction of the researcher and the participants who are active in projects undertaken by Kenya Power and Lighting Company Limited, the dominant electricity distribution and retail utility company in Kenya.

4.5.1 The Research Design

According to UN-Energy (2014), sustainable energy is a key enabler of sustainable development for all countries and all people, and energy is vital for alleviating poverty, improving human welfare and raising living standards while the adequate provision of energy services has become especially important for economic development since the industrial revolution. Kendagor and Prevost (2013) state that the overall national development objectives of the government of Kenya are economic growth; increasing productivity of all sectors; equitable distribution of national income; poverty alleviation through improved access to basic needs; enhanced agricultural production; industrialization; accelerated employment creation; and improved rural-urban balance. They further state that the realization of these objectives is only feasible if quality energy services are availed in a sustainable, cost effective, and affordable manner to all sectors of the economy, and they note that public and private recognition of the value of energy generation and distribution in Kenya is widespread. This view is shared by Onuonga et al (2011) when they state that the manufacturing sector in Kenya, which mainly uses electricity and oil as sources of energy in its production processes, distribution, and transport services, accounts for approximately 10 percent of Kenya's gross domestic product (GDP).

Energy has therefore been singled out as one of the key enablers of economic development in Kenya, and various projects are presently underway by parastatals under the ministry of energy and petroleum in Kenya aimed at expanding the reach of the electricity infrastructure across the country. This research focuses on projects undertaken by Kenya Power which owns and operates most of the electricity transmission and distribution system in the country, with a key mandate of building and maintaining the power distribution and transmission network and retailing of electricity in the country. The Government has a controlling stake at 50.1% of shareholding with private investors at 49.9%. Kenya Power is listed on the Nairobi Securities Exchange.

Crotty (1998) suggests that three questions are central to the design of research: What knowledge claims are being made by the researcher, including a theoretical perspective? What strategies of inquiry will inform the procedures? What methods of data collection and analysis will be used? This research study is anchored on the holistic view of project management, focusing on the period when the project exists only conceptually, with greater emphasis on endogenous factors at play in the front end phase of projects in the public sector. The System Dynamics modeling process is used in this research, while qualitative data was gathered through direct interactive in-depth interviews with project stakeholders in the sector namely project engineers and project managers as well as Ministry of Energy officials. Document review was also used as sources of data in this research, especially data from past projects in the sector.

4.5.2 Data Collection

Forrester (1980) proposes use of three types of data needed to develop the structure and decision rules in models; numerical, written, and mental data. Numerical data are the familiar time series and cross-sectional records in various databases. Written data include records such as operating procedures, organizational charts, media reports, emails, and any other archival materials. Mental data cannot be accessed directly but must be elicited through interviews, observation, and other methods. The numerical data contain only a small fraction of the information in the written database, which in turn is even smaller compared to the information available only in people's mental models. Most of what we know about the world is descriptive, impressionistic, and has never been recorded. Such information is crucial for understanding and modeling complex systems (Forrester, 1980). Sterman (2000) notes that ultimately, people will take action only to the extent their mental models have changed and in turn, peoples' mental models are unlikely to change unless they have confidence in the integrity and appropriateness of the formal model.

Luna-Reyes and Andersen (2003) reinforce the views expressed by Sterman (2000) when they note that the perception about mental data is shared among mainstream authors in the field of System Dynamics (Randers, 1980, Richardson and Pugh, 1981, Roberts et al, 1983, Wolsteinholme, 1990, Sterman, 2000, Forrester, 2009, Capelo and Diaz, 2009, Groessera and Schaffernicht, 2012, 2014). They also state that although System Dynamics models are mathematical representations of problems and policy alternatives, most of the information available to the modeler is not numerical in nature, but qualitative. Sterman (2000) suggests that in the earliest phase of modeling, it is often worthwhile to use experiential data and estimate parameters judgmentally so as to get the initial model running as soon as possible and later, sensitivity analysis of the initial model can then identify those parameters and relationships to which the behavior and policy recommendations are sensitive. All three types of data were used in this research. Qualitative data was gathered through direct interactive in-depth interviews with project stakeholders in the sector namely project engineers and project managers as well as Ministry of Energy officials. Document review was also used as sources of data in this research, especially data from past projects in the sector.

4.5.3 Field work for model development – Exploratory research Phase

The first phase of data collection aimed at understanding the nature and type of project risks prevalent in the electricity power projects in Kenya. This was an exploratory study that was done to get qualitative data from key stakeholders in the sector, namely ministry of energy personnel, project managers at the power utility companies and project managers at key contractor firms active in the sector in Kenya. The field work for data collection for this exploratory study took one year, from January 2013 to December 2013. The target group was a general, multidisciplinary group comprising project engineers as well as project managers in the sector, and policy makers at the parent Ministry of Energy as given in table 4.3 comprising 60 numbers of participants. None of them had significant prior experience with simulation modeling of the type of system dynamics, therefore the model had to be valid from the perspective of an inexperienced but interested and critical audience. The knowledge gained from this phase of the study was instrumental in the development of the conceptual model in chapter 5.

Table 2.1, 2.2 and 2.3 provide lists of risks in large scale construction projects obtained from literature and considered relevant to large scale construction projects in the electricity industry. These form the basis of the exploratory study done in the first phase to determine the risks that are prevalent in the electricity sector in Kenya. The mode of data collection was face to face interviews covering stakeholders in the industry, and a sample of the opening questions asked of the participants can be found in 'appendix A'. In total, 60 stakeholders were interviewed as indicated in table 4.3. Archival documents from previous projects in the electricity power sector were also used, especially with regard to risks that arose during project implementation and subsequently resulted into project delays. A total of 23 archival documents were examined, and the results of the enquiry included in table 4.2 as questions discussed with stakeholders.

4.5.4 Data Collection Methods and instruments – Exploratory study

The data was collected through face-to-face interviews and from archival data of past projects. To guide the discussions during data collection, a table was constructed with various risk items common in construction projects sourced from literature review in chapter 2. This was aimed at creating a link between the knowledge gained from the literature review so as to help engage the interviewees during the face to face interviews, as well as during analysis of archival records on past projects. This phase of research was aimed at addressing the first research question namely; "what are the project dynamics in the electricity industry in Kenya?" The factors and dimensions critical to risks in construction projects are listed in table 4.2. The properties of each dimension were expounded and the questions relevant to these properties were then generated and listed on the third column, and these were then used as a guide during the interviews. Examples of opening questions used are given as appendix A.

Table 4.2: Operationalizing Project risks: From literature and archival documents to the electricity industry sector projects in Kenya

Dimension of risk	**Definition Of the dimension**	**Relevant Issues**	**Data collection process**	**Example refs & dates**
Technical Risks	Scope change, technology selection, implementation methodology selection, equipment risk, materials risk and engineering and design change	- What is your experience with scope changes? -Does selection of technology affect project delivery? How? -what equipment and material risks have you witnessed? - Have you ever experienced	Face to face interviews, analysis of archival documents of past projects	Prasanta, 2002 Baydoun, 2010

		engineering & design changes?		
Acts of God	Normal natural calamities and abnormal natural calamities	- What unavoidable incidences have you experience during project execution? - How did these impact the project? - How did you handle such situations when they occurred?	Face to face interviews, analysis of archival documents of past projects	Prasanta, 2002
Financial, Economic and Political Risk	Inflation risk; fund risk; changes of local law; changes in government policy and improper estimation Discontinuity in business environment -Change the "rules of game"	- How has the inflation changed during the course of the project? - Have there been any changes in government policy that impacted the project? - How do you normally calculate project duration? What happens when duration as given proves inaccurate? - How does change of government affect projects in the sector? - Have projects been affected by strike action, terrorism?	Face to face interviews, analysis of archival documents of past projects	Prasanta, 2002 Bael and Qian, 2011 Jacobsen (2010) Marrewijk et al (2008) Bonacek et al (2014) Heldeweg et al (2015) Deng et al, 2014 Robock & Simmonds, 1983. Kapila & Hendrickson, 2001 Barbalho (2015)
Organizational Risk	Capability risk of owner's project group; contractor's failure; vendor's failure and consultant's failure	- How would you rate the procuring utility's capability in packaging projects in the sector? - How would you rate the contractor's capability in packaging projects in the sector? - How would you rate the consultant's capability in packaging projects in the sector?	Face to face interviews, analysis of archival documents of past projects	Prasanta, 2002 Marrewijk et al (2008) Barbalho (2015) Heldeweg et al (2015)
Inspection and testing	Performing inspection and testing to verify conformance to specifications including identification of whether a finished task is conforming or non-conforming	- Do contractors perform quality inspections and tests on completion of construction works? - Do utility project supervisors witness quality inspections and tests on completion of construction works?	Face to face interviews, analysis of archival documents of past projects	Marrewijk et al (2008)

Statutory Clearance Risk	Environmental clearance; land acquisition; and other clearance from government authorities	- Do you always get environmental clearance on time? - Is the site handed over and ready when the project commences? - Are there other clearance needed from government bodies before or during the course of the project?	Face to face interviews, analysis of archival documents of past projects	Prasanta, 2002 Barbalho (2015) Marrewijk et al (2008) Heldeweg et al (2015)
Finance	Securing finance, Maintaining finance, Interest rate and tax amendments, Tax rulings Price escalation in capital components	- How easy is it to secure financing locally? - Comments about interest rates at the local banks? Are there fluctuations? - Are taxes payable known and determinable for period of project? - Are there any price escalations in regard to capital components?	Face to face interviews, analysis of archival documents of past projects	Hodge, 2004 Baydoun, 2010 Heldeweg et al (2015) Barbalho (2015)
Design and Development	Design suitability, Development problems, Testing problems, Design and development variations, Delivery of design	- Whose responsibility is it to design the project? - Comments on the designs? - Do variations arise? Why?	Face to face interviews, analysis of archival documents of past projects	Hodge, 2004
Construction	Fixed time and cost to complete Delivery schedule, Planning approvals, Disruption to existing services, Industrial disputes	- Is project time fixed and part of contract? - Are planning approvals needed, are approvals received in good time? - Are there cases of disruption to existing services? How do you make good? - Are there cases of strikes or other forms of industrial disputes?	Face to face interviews, analysis of archival documents of past projects	Hodge, 2004 Hilmarsson (2012) Denys et al, 2015 Barbalho (2015)

Operation	Asset/service performance Asset/service availability Repairs and maintenance cost, Security, Staff training, Cost of keeping existing assets operational, Latent defects in existing assets, Changes in demand	- How would you rate asset availability and performance on project completion? - How would you rate the repair and maintenance costs of the completed projects? - Is security thought of and taken care of during project design and delivery? - Are there cases where latent defects occur during the project delivery? - Are there cases where demand changes on completion of project, necessitating need for an upgrade?	Face to face interviews, analysis of archival documents of past projects	Hodge, 2004 Baydoun, 2010 Denys et al, 2015 Prasanta, 2009
Quality of onsite supervision	Adequacy of supervision	- Does the utility deploy adequate and competent technical staff for supervision of contractors? - Do contractors have adequate and competent supervision?	Face to face interviews, analysis of archival documents of past projects	Prasanta, 2002 Marrewijk et al (2008)
Ownership	Uninsurable loss or damage to the assets, Technology change or obsolescence, Public/third-party liabilities	- Are there cases of uninsurable loss or damage to assets? Who bears responsibility? - Are there cases where the design ha components affected by obsolescence? - How do you deal with public or third party liabilities?	Face to face interviews, analysis of archival documents of past projects	Hodge, 2004 Barbalho (2015) Marrewijk et al (2008) Heldeweg et al (2015)
Armed conflicts	These are related to risks that might emerge from armed conflicts	- Are there incidences of armed conflicts such as civil wars during the course of the project? - How does this affect the project?	Face to face interviews, analysis of archival documents of past projects	Baydoun, 2010

Delay of incentives	This applies when and where projects are dependent on special incentives like tax or customs exemptions. Delays in the implementation of these incentives pose risk to project management.	- Are there instances where projects are dependent on incentives such as tax or custom exemptions? Are there any challenges or delays in approvals? How does this affect the project?	Face to face interviews, analysis of archival documents of past projects	Baydoun, 2010 Heldeweg et al (2015) Barbalho (2015)
Legal risks	These are related to impracticality of some existing local laws and regulations in the country of the project	- Are there cases where local laws in Kenya have proved difficult for the project environment?	Face to face interviews, analysis of archival documents of past projects	Baydoun, 2010 Hilmarsson (2012) Barbalho (2015)
Conflicts	Conflicts between different authorities or within individual authorities can undermine development and implementation of projects	- Have you experienced cases of conflict between authorities responsible for governance of the project environment? Explain what happened.	Face to face interviews, analysis of archival documents of past projects	Baydoun, 2010
Lack of approvals facilitation	Risk arises from absence of mechanism in the public sector that would facilitate project approvals, particularly when authorities that do not benefit from the project might not have interest in facilitating procedures for project approval	- Are there cases when projects have delayed due to difficulties in gaining the necessary approvals from government bodies?	Face to face interviews, analysis of archival documents of past projects	Prasanra, 2002 Hilmarsson (2012) Barbalho (2015)
Any other risks not previously documented	Open to interviewee	- Have you experienced any other risks not previously mentioned during the discussion?	Face to face interviews, analysis of archival documents of past projects	

The data was collected over a one year period from January 2013 to December 2013 as part of the exploratory research targeting project managers, project engineers as well as contractors working for the Kenya Power and Lighting Company Limited.

Table 4.3: A breakdown of the type and number of stakeholders interviewed.

Stakeholder	**Target number to be interviewed**	**Number of people interviewed**	**Purpose, linked to research objectives stated in section 1.4**
Ministry of Energy (MOE)	6 interviewees	4 interviewees	Determine risks in projects in the energy power sector from MOE perspective
Electricity utility (Kenya Power & Lighting Company Ltd.)	28 interviewees	20 interviewees	Determine risks in projects in the energy power sector and how they affect the utilities
Contractors	47 interviewees	36 interviewees	Determine risks in projects in the energy power sector in Kenya

From the data collected, a System Dynamics conceptual model of interacting project risks, which was one of the objectives of the research as given in section 1.4, was thereafter developed as indicated in chapter 5.

4.5.5 Interview process

The potential interviewees were first contacted by email, and then by telephone calls to confirm the meetings. The authorization document along with a short description of the research project was sent electronically to each interviewee in advance. The interviews were one-on-one. The data collection and the process of model development were inter-related. The data from the interviews informed the representation of specific feedback loops as part of the System Dynamics models to be developed. These feedback loops then informed new questions in subsequent interviews which enabled the validation of the loops and uncovered other loops. The interviews were therefore semi-structured to allow the interviewee to highlight issues relevant to the subject. Answers were written down as they were given in most cases, and on a few occasions the interviews were recorded as audio files, and subsequently transcribed. The interviewees spoke in English but often English was their second language, which occasioned some incomplete and grammatically incorrect sentences. The interviews lasted between 40 minutes and one hour, and 60 numbers of interviews were successfully conducted. Sample data from the interview process is given in Appendix B.

4.5.6 Data Analysis, Coding and results - Exploratory research study

The data was analyzed using the following two techniques as proposed by Yin (2009).

Pattern Matching

The pattern matching approach deals with identifying patterns in the evidence (data) collected through the study of a phenomenon, organization or other. Yin (2009) is of the opinion that simple patterns can also be uncovered and applied.

Explanation Building

This form of analysis deals with creating causal links among the various forms of evidence and by that explaining what happened and why.

Data Coding

Saldana (2009) describes a code in qualitative inquiry as a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data. The data can consist of interview transcripts, participant observation field notes, journals, documents, literature, or video. He adds that the majority of qualitative researchers will code their data both during and after collection as an analytic tactic. The research in this thesis, guided by research questions in section 1.4 and interviews done on the basis of literature review as indicated in table 4.2, used data transcribed from and based on written texts from field notes. In the preliminary data analysis, the goal was to analytically reduce data by producing summaries and coding as given in table 4.4. The goal was to search for commonalities in the data gathered which lead to categories known as codes or themes.

Table 4.4: Data Coding of the preliminary interviews with stakeholders in the Energy sector in Kenya

Idea from interview guide	Coded phenomena	Categories	Emerging Themes
Project completion time	Keeping to time schedules	Contractors handling many sites Contractors managing	Multitasking

		project time well	project time remaining
Competence of project personnel	Supervision	Competent supervision Meeting set standards	Project Management competence Fraction properly completed Gross productivity of project personnel Progress Perceived cumulative progress Quality of completed project tasks
Identification of defects	Quality of testing	Competent testing engineers /technicians Adequate testing engineers /technicians	Productivity of testing Unforeseen technical difficulties detecting undiscovered rework Testing personnel Rework
Experience of project personnel	Skills possessed by project personnel	Knowledge of project team in similar work	Time to adapt workforce
Country stability	Contractors views on political risk insurance on projects in the sector	Violence during elections Threat of terrorism that may interfere with project	Political risk

The data from the interview notes was analyzed by searching for threads cutting across the data as indicated in table 4.4, from which a summary was made of key risks identified by the stakeholders interviewed. The results of the data analysis give the risks and other variables at play in projects in the electricity sector in Kenya as given in table 4.5.

Table 4.5: Risks and other variables critical to projects in the electricity sector in Kenya

Critical Risks identified by stakeholders
Project management competence
Adequate workforce
Productivity of project personnel
Time needed to train new locally hired workers
Testing personnel (commissioning engineers)
Productivity of testing personnel
Multitasking amongst key project engineers
Unforeseen technical difficulties
Political risk
Rework and its effects on schedule

The data and results from this exploratory study were used to build the conceptual system dynamics model in chapter 5.

4.6 The System Dynamics Research Method

The system dynamics approach to project management is based on a holistic view of the project management process and focuses on the feedback processes that take place within the project system. It offers a rigorous method for the description, exploration and analysis of complex project systems comprised of organizational elements, the project work packages and the environmental influences (Rodriquez and Bowers, 1996, Nasirzadeh et al (2008), Bendoly, (2014), Chritamara et al (2002), Cooper & Lee (2009), De Marco and Rafele (2009).

4.6.1 The System Dynamics Modeling Process – Sterman (2000)

Fig. 4.3 gives the system dynamics modeling process as described by Sterman (2000). Problem articulation deals with finding what problem there is and the key variables. The dynamic hypothesis lists the current theories of the problematic behavior with causal maps created, while in formulation, a simulation model is created specifying structure and decision rules. In testing, the model is checked if it reproduces the problematic behavior while in policy formulation and evaluation, future conditions that may arise are articulated, and the effects of a policy or strategy are analyzed.

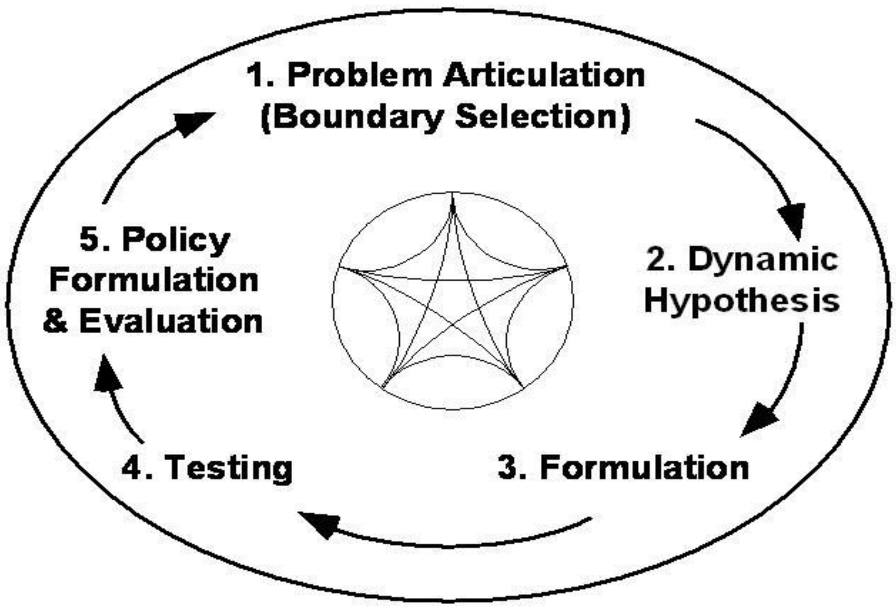

Fig. 4.3: The modeling process (Sterman, 2000)

Project performance is typically measured in terms of schedule, cost, quality, and scope (Atkinson 1999). The modeling process by Sterman (2000) as given in Fig. 4.3 was found suitable and is therefore used for this research. As such the System Dynamics model developed and used in this research underpins the basic research objective to expand the understanding of the causes and effects of risks affecting projects in the electricity power industry in Sub Saharan Africa and especially how they can be dynamically linked. This is explained in chapter 5.

Wolsteholme (2003) states that System Dynamicists and system thinkers promote a holistic and systemic view of issues under study, and successful systems thinking is about being able to see the whole picture or context of a situation and its interconnections to its environment. System dynamics models are mainly used for; what-if scenarios (Morecroft, 1988), policy testing (Forrester, 1958) and policy optimization (Kleijnen, 1995). Lyneis (2007) states that System Dynamics focuses on modeling features found in actual systems and in projects, these include development processes, resources, managerial mental models, and decision making, while Yeager et al (2014) noted that System Dynamics modeling and the tools that support it offer unique advantages for building simulation models of large and complex systems that include, use of graphical descriptions, useful variable names and documentation fields, separation of model structure from data and output unlike spreadsheets, productive debugging from visibility of full model state and causal tracing, as well as good testing habits and automated testing tools, such as in Vensim's “Reality Check”.

Warhoe (2014) further notes that System Dynamics has been used in identifying the cause and effect dynamics that result in productivity loss when scope changes are introduced on construction projects. Jiang et al (2015) state that the unsafe behaviors of construction workers are often the immediate causes of construction accidents, but the underlying causation of such behaviors are not well understood. By setting up the management of construction safety as a system, they used System Dynamics to demonstrate how the system influences construction workers in terms of unsafe behaviors. Meanwhile, the allocation of construction risks between owners and their contractors has a significant impact on the total construction costs. Nasirzadeh et al (2014) developed and used an integrated fuzzy System Dynamics approach for quantitative risk allocation.

Increasingly adopted by both public and private organizations, design-build (DB) has become a favored construction project delivery system, outperforming other systems in terms of cost, schedule, and quality (Molenaar et al, 1999, Gransberg and Windel, 2008, Cho et al 2010, Ling and Chong, 2005). However, DB has been especially criticized by the public sector for practicing subjective evaluation, for requiring excessive resources, and for providing only limited accessibility to small and medium-sized contractors. In order to address these challenging issues, Moonsea et al (2009) developed a qualitative System Dynamics model and used it to propose and test hypothetical DB policy alternatives which are expected to enhance DB performance. Construction projects are known to involve complex, inter-dependent, uncertain and labor intensive processes. Based on extensive literature review and industry focus group investigations, Wan et al (2013) developed a System Dynamics model to address production process inefficiencies in this subsector. The simulation model provides relevant insights to project managers who may apply this knowledge when designing or targeting better performance.

4.6.2 The System Dynamics Modeling Process – Warren (2014)

In the agile method of System Dynamics modeling, Warren (2014) explains that each step is taken directly with the problem owners or concerned stakeholders. The initial diagnosis may be carried out with the team who own the problem, rather than engaging all who may have some knowledge of the wider system. The others may become involved as the build out of the model runs into issues on which they have knowledge. At each stage, however, the simple, logical and data-supported steps of the agile process take less time than the open-ended consultation needed to develop causal loop diagrams. In essence, qualitative causal loop or influence diagrams do not feature at any stage in this process (Warren, 2014). The logical progression of these principles informs the agile process for system dynamics modeling as presented in figure 4.4. This method complements the process as given by Sterman (2000).

The agile model development process also recommends use of standard structures to complement the other processes. This involves re-using known, rigorous structures such as project management, supply-chain, or fisheries structures as the backbone for a new model. This research therefore uses the agile method to complement the process by Sterman (2000), which is something new in this research. This is done by moving from time charts of the problem into stock and flow conceptual model diagrams and during the model formulation stage, re-using Richardson's standard System Dynamic model of project dynamics, which is customized to the Kenyan energy sector construction projects scenario, which is the new part in this research. The conceptual model is extended to include variables that were identified from the exploratory study as given in section 4.5.6 under table 4.5. The resultant basic simulation model is thereafter tested by relying on the “lived” experience of project engineers and key stakeholders in the electricity sector in Kenya, and subsequently, policy analysis, formulation and evaluation is done.

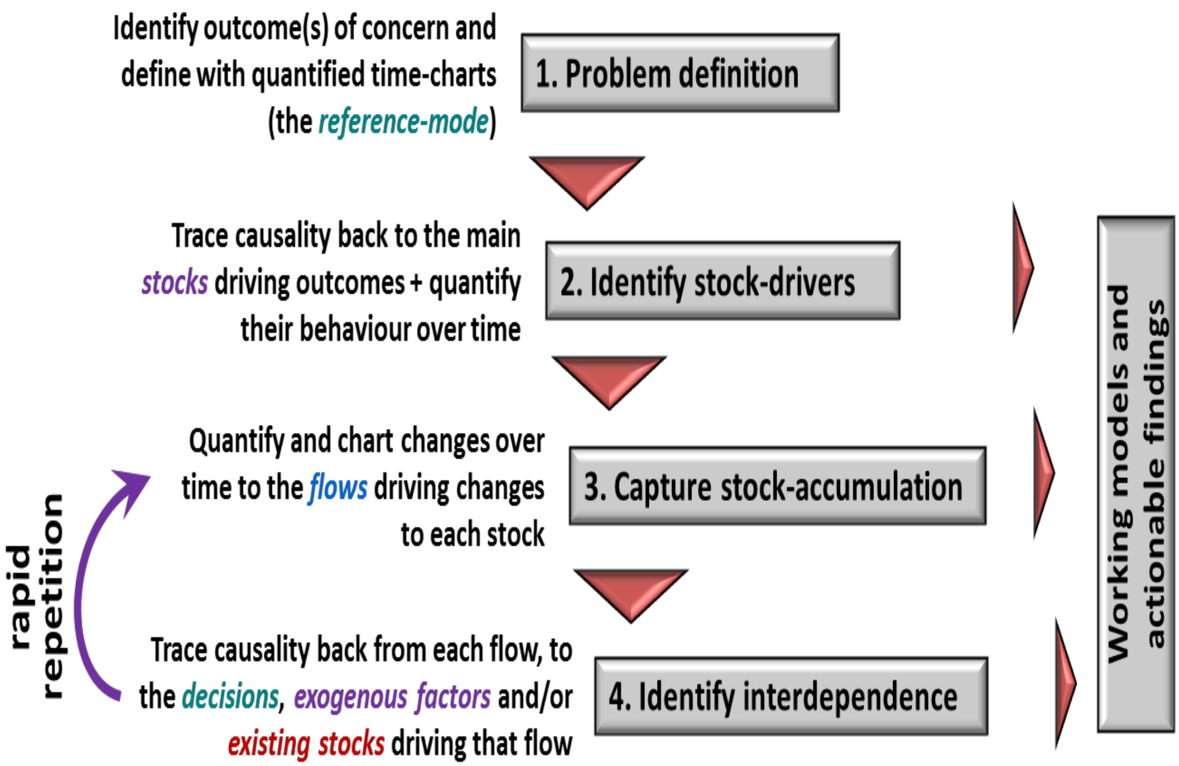

Figure 4.4: An agile model development process (Warren, 2014).

4.6.3 Arguments for using the System Dynamics Methodology

Large scale projects belong to the class of complex dynamic systems. Such systems are extremely complex, consisting of multiple interdependent components, are highly dynamic, involve multiple feedback processes, involve non-linear relationships, and involve both hard and soft data (Sterman, 1992, Thakurta 2013, Haejin et al 2015, Akkermans and Oorschot 2016). According to Crawford et al (2003), difficulties can arise when attempting to apply "standard" project management practices in complex, multi-stakeholder project environments. They note that systems thinking in general was found to offer a rich source of theoretical and model-based contributions to inform development of project management practice in these contexts. On a similar note, Kapsali (2011) states that simulation methodologies have systematically applied systems thinking constructs to projects. She further states that System Dynamics is an excellent tool for applying the systems thinking construct of holism, in providing a whole picture of a specific system and most importantly, in abstracting its main attributes to show the particular system's pattern of "organized complexity".

This view is further reinforced by Rodrigues (1994), who states that planning is concerned with the specification of the actions that have to be performed to implement the project. He notes that in traditional project management, the assessment of the project status is based on the comparison of the current state of the work with the project plan. In contrast, the primary objective of a System Dynamics model is to capture the major feedback processes responsible for the project system behavior, with less concern about the detailed project components. Table 4.6 emphasizes the ability of System Dynamics models to consider a wide range of subjective factors that are difficult to incorporate in operational models, and are usually addressed in the traditional approach by simplistic assumptions.

Table 4.6: Comparison of some important characteristics of the traditional and System Dynamics approach. Rodriques, (1994)

	Traditional Approach	System Dynamics Approach
Factors explicitly considered	-Logic of the work structure -Cost of resources -Indirect cots -Constraints on resources availability -Work resources requirements	-Quality of work performance -Staff productivity -Staff experience level, learning and training -Schedule pressure on the staff -Rework generation and discovery time -Mismatch of perceptions and reality -Staff motivation -Client and project team relationship
Managerial decisions	-Cost-time trade-offs, crashing activities -Changes in the schedule of activities -Scheduling resources among activities	-Hiring staff vs. delaying the project completion date -Introduction of new technologies -Effort on quality assurance -Effort on rework discovery time - Cost-time trade-offs, hiring staff

	-Changes in the logic of the project work structure	-Multi project scheduling -Multi project staff allocation -Managerial turn-over/ succession -Estimation of schedule and cost
Uncertain events	-Delays in completion of activities -Constraints in the schedule of activities -Resource constraints -Uncertainty in the duration of activities (simulation)	-Changes in the project work-scope -Changes in quality and productivity levels -Customer/vendor delays in delivering information -Constraints in the staff levels
Major estimations	-Project duration -Project cost -Resource allocation	-Project duration -Project cost -Staff allocation -Demand on staff

The choice of the research method should allow answering the research problem in the best possible way, within the given constraints of time, budget and skills (Ghauri and Gronhaug 2002). Specifically, System Dynamics was chosen as the modeling and simulation tool in this research largely due to insights from the literature review. The nature of projects in the electricity industry can be framed as complex dynamic systems (Sterman 1992, Rodrigues and Bowers 1996, Eriksson 2005, Elsobki et al 2009, Volk 2013) because these projects are formed by multiple interdependent and dynamic components, and include multiple feedback processes and non-linear relationships. Engineering projects also generally involve both "hard" and "soft" data (Sterman 1992). The System Dynamics method would therefore be best suited for analyzing risk interactions in the electricity industry environment.

In addition, System Dynamics has been used successfully in the study of energy sector projects in the past. Andra et al (2014) used a System Dynamics approach to explore the short, medium and long term impact of different national consumer oriented energy efficiency policies in the residential building sector. They validated the System Dynamics model through a case study using historical data from a subsidy scheme in Latvia, and obtained results from the tests that showed that the model generated behaviour that was consistent with available data. Similarly, Qudrat-Ullah and Seong (2010) state that System Dynamics based simulation models are becoming increasingly popular in the analysis of important energy policy issues including global warming, deregulation, conservation and efficiency. They note that the usefulness of these models is predicated on their ability to link observable patterns of behavior of a system to micro-level structures.

Hu et al (2015) note that contracting has a significant impact on the efficiency of acquisition processes, especially in the context of so-called public private partnership (PPP) projects. Hu et al (2015) developed a System Dynamics model which depicts the complex relationship between the different aspects of a PPP project, with the main objective being to give a better understanding of opportunistic behaviour in PPP projects. Domenge (2012) reports that there are increasing environmental concerns in México regarding the CO2 emissions tendency due to the intensive use of fossil fuel based electric generation. He developed a System Dynamics model which he used to evaluate three scenarios so as to assess the non-fossil generation capacity investment and timing requirements needed in order to achieve both ecological and safety strategic objectives, and to satisfying the electric energy demand in Mexico as well. Based on experiences given in this paragraph, System Dynamics modeling was chosen as a suitable method of analyzing risk dynamics in projects in the electricity sector in Kenya. The following section expounds on the System Dynamics paradigm.

4.7 The System Dynamics paradigm

4.7.1 Definition of a system

A system is an interconnected set of elements that is coherently organized in a way that achieves something (Meadows, 2008). The system, to a large extent, causes its own behavior and consists of three kinds of things: elements, interconnections, and a function or purpose. Hommes et al (2010) define a system as a combination of interacting elements organized to achieve one or more stated purposes. It is an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products, processes, people, information, techniques, facilities, services, and other support element. These definitions are quite similar, and will be used as the definition of a system for the purposes of this research.

4.7.2 Modeling Project Dynamics using System Dynamics

Project modeling has been one mainstay of System Dynamics practice for many years. Modeling has been used in projects ranging from military and commercial shipbuilding projects to aerospace and weapons systems, power plants, civil works and software projects. Cooper and Lee (2009) designed, built, tested, and implemented a System Dynamics model-based system to aid project management at Fluor Corporation. Grogan et al (2015) report that frequent and significant cost and schedule overruns in large aerospace and defense projects are hypothesized to be attributed to limitations on designers' perception of complex systems. They extended an existing System Dynamics model of system project management to incorporate new methods for collaborative modeling and rapid sensitivity analysis using web and browser based technologies. System Dynamics modeling technique was found suitable for modeling project dynamics in the electricity energy sector in Kenya since it was possible to incorporate risks such as political risk, project management competence, as well as unforeseen technical difficulties and thereafter simulate the model to understand the effects and contributions made by these variables in a dynamic set up representative of project dynamics in Kenya.

Han et al (2013) noted that design errors leading to rework and/or design changes are considered to be the primary contributor to schedule delays and cost overruns in design and construction projects. They further state that while design errors are deemed prevalent, most design and construction firms do not measure the number of errors they create, thereby having limited knowledge regarding their mechanism to undermine project performance. To address this shortcoming, they developed a System Dynamics model to capture the dynamics of design errors and systematically assess their negative impacts. Park (2005) reports that excess resource idling can result in cost overruns, while low resource coverage or long lead-time in resource acquisition can delay the project schedule. He therefore notes that systematically managing this trade-off is critical to ensure project delivery in time and within budget, and in an effort to address these issues, he developed a System Dynamics model for construction resource management.

The real leverage lies in using these models so overruns and delays are avoided (Sterman 2000). System dynamics has a strong and established history of modeling development projects and has been successfully applied to a variety of project management issues, including failures in fast track implementation (Ford and Sterman 1998) and the impacts of changes on project performance (Rodrigues and Williams 1997; Cooper 1980,1993b). Forrester (1991) noted that in many organizations, new corporate policies are tested experimentally on the organization as a whole without dynamic modeling of the long-term effects and without first running small-scale pilot experiments. With the aid of a System Dynamics model that is developed in this research, it will be possible to test different policy scenarios using the model developed here so as to gauge their effects on key variables such as project completion time and quality of completed project tasks. The most suitable policy alternative would then be chosen and implemented.

Models are simplifications of reality and usually help people to clarify their thinking and improve their understanding of the world. A computer model, for instance, can compress time and space and allow many system changes to be tested in a fraction of the time it would take to test them in the real world. Testing changes on a model, rather than on an actual system, is a good way to avoid implementing a faulty policy. That is, if a change does not perform well in a model of a system, it is questionable as to whether it will perform well in the actual system itself. In addition, experimenting on a model can avoid causing harm to an actual system, even when the change being tested is successful (Radzicki and Taylor, 1997). System Dynamics will therefore be the method of choice for modeling in this research.

4.7.3 Dynamic Hypothesis

A dynamic hypothesis is a theory about what structure exists that generates the reference modes. A dynamics hypothesis can be stated verbally, as a causal loop diagram, or as a stock and flow diagram. Radzicki (1997) states that with a clearly defined problem statement in hand, the first model building step is to develop a theory of why the system is behaving the way that it is. Tools such as causal loop diagrams and stock and flow networks can be used to map out a set of assumptions about what is causing the "reference modes" of the system to behave in a particular way. This is an important stage to collect information about the problem through brainstorming with groups, data, literature, and personal experience (Sterman, 2000). The dynamic hypotheses generated can be used to determine what will be kept in the model, and what will be excluded. Like all hypotheses, dynamic hypotheses are not always right and refinements and revisions are an important part of developing good models (Albin, 1997).

The continuous growth of project backlogs over time can be attributed to many different dynamic factors. Over the years, dynamic causes identified through System Dynamics include a lack of knowledge transfer between projects (Cooper et al.2002), rework (Cooper 1993a, 1993b) and concealing rework (Ford and Sterman 2003), schedule pressure (Cooper 1994, Ford and Sterman 2003). Dynamic hypothesis of development project failure would also include unrealistic performance targets as well as negative feedback loops that describe responses to schedule, budget, and other pressures that can trigger fatal reinforcing loops through productivity losses, overstaffing, inadequate training, and other project behaviors (Taylor and Ford, 2006). Other changes that slow progress, degrade performance, and can lead to failure such as increased regulation, scope changes, and temporary work stoppage, would provide the bases for additional hypotheses. The dynamic structure would also include the amplification of impacts due to delays in discovering rework that allow problems to be passed among development phases.

In this research project, the dynamic hypothesis used to explain the persistent project delays, cost overruns and quality challenges was that the problem is likely caused by engaging contractors handling multiple projects, thereby resulting into multitasking. It was also hypothesized that risks in the sector tend to interact and result into effects not seen at the planning stage of projects. The low competence in project management in the industry and region, especially in contract administration was also given as a contributing factor. These insights were collated from 60 experts and stakeholders in the industry, including project engineers, project managers at the utilities and with the contracting firms, and from interviews with officials at the ministry of Energy. This was done as per the breakdown of those interviewed which is given in table 4.3.

4.8 The modeling process

According to the engineers and Statistics handbook (2004), the basic steps used for model-building are the same across all modeling methods. The details vary somewhat from method to method, but an understanding of the common steps, combined with the typical underlying assumptions needed for the analysis, provides a framework in which the results from almost any method can be interpreted and understood.

The development of the System Dynamics model is an iterative process (Sterman, 2000) as depicted in fig. 4.3 where problem articulation, formulation of model hypothesis, testing are all given as iterative processes. The process used in this thesis is also iterative, and has followed the process thus; problem articulation, followed by dynamic hypothesis. In model formulation, the agile method as given in section 4.6.2 is used in the initial conceptual model formulation by using the standard projects model by Richardson (2013). This was informed by the findings of the exploratory research study, where some of the risks and variables identified by the stakeholders were similar to the variables previously identified in Richardson (2013), as given in table 4.4. However, significant differences between the conceptual model developed in this research as compared to the conceptual model by Richardson, as indicated in section 4.6.2, were also noted, and these were used to extend and vary the initial model by Richardson. The conceptual model developed in this research is presented in chapter 5. After developing the conceptual model, the model testing and validation followed, after which policy analysis, formulation and evaluation were undertaken as per the modeling steps by Sterman (2000) in Fig. 4.3.

4.9 Workshop for model validation

After the development of the conceptual model, the model was shared with experts who were active in the project management field in the electricity industry in Kenya. This was done through a presentation at a workshop attended by 22 experts in the power industry comprising project managers and project engineers involved in projects with Kenya Power and Lighting Company Limited, representatives of contractors active in the sector in Kenya, and Ministry of Energy engineers dealing with projects in the electricity sector. This was a different group from the 60 number earlier used in the preliminary study to identify the risks. The aim was to elicit reactions from the experts, and to receive comments on the model structure at conceptual stage. The findings from the reactions informed adjustments and improvements on the conceptual model.

The second presentation at a workshop in Nairobi was after the model had been developed, equations generated and simulation results were available, which were shared with a second group of 32 experts in the power industry comprising project managers and project engineers involved in projects with Kenya Power and Lighting company, representatives of contractors active in the sector in Kenya, and ministry of energy engineers dealing with projects in the electricity sector. During this process, the project experts were taken through the improved conceptual model and simulation results as part of the process of working together with the client to validate the model. The results of the model were compared and contrasted with a real project as given in Appendix K, and the findings at this stage informed some modifications and improvement to the basic model, the details of which are given in chapter 6, section 6.2.1. The workshop was conducted as per the schedule in Appendix E, while sample questions used to guide the workshop discussions is shown in Appendix F. Table 4.7 gives a summary of, and schedule of the fieldwork during this stage of the research.

Table 4.7: Model validation workshops and schedule

Time period	Purpose	Data type	No. of participants
March 2014	Initial conceptual model validation	Presentation / Reactions & comments from participants	22
November 2014	Revised model validation, simulation results validation	Presentation / Reactions & comments from participants	32

4.10 Model Credibility –Verification and validity Testing

Models are an estimation of reality and therefore no models are valid or verifiable in the sense of establishing their truth. According to Sterman (2000), the question facing modelers is never whether a model is true but whether it is useful. Model testing is iterative and multidimensional and begins at the start of the project, and testing is an integral part of the iterative process of modeling such that by continuously testing assumptions and the sensitivity of results as the model is developed, one uncovers important errors early and establishes confidence in the model.

Instead of viewing validation as a testing step after a model is completed, theory building and theory testing are intimately intertwined in an iterative loop (Sterman, 2000).

This viewpoint is shared by Barlas (2014) who states that validity is built-in as the model is developed, rather than inspected at the end. Barlas (1996) notes that no model can claim absolute objectivity, for every model carries in it the modeler's worldview. He observes that models are not true or false, but lie on a continuum of usefulness. The general logical order of validation is, first to test the validity of the structure, and then start testing the behavior accuracy only after the structure of the model is perceived adequate.

4.10.1 Credibility testing process

Conceptually, the credibility testing process is a learning process in which understanding is enhanced through the interaction of a formal model with a mental model (Morecroft, 2007). As this process evolves, both the formal model and the mental model of the modelers change, leading to a successive approximation of the formal model to reality.

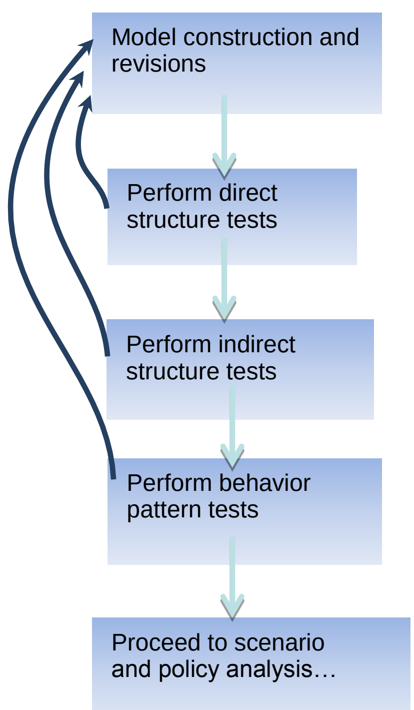

Fig. 4.5: Logical sequence of formal steps of model credibility testing (Barlas, 2014)

As models are used, they are adapted as a function of feedback from the real world (Sterman, 2000), and as they are tested, modelers fit them to the properties of the real world. The process by Barlas (2014) as given in figure 4.5 was used for testing in this research. Model construction and revisions as indicated in Fig. 4.5 in this research used the process by Sterman (2000) as given in 4.6.1 during problem articulation and setting the dynamic hypothesis, after which the process by Warren (2014) was used in model formulation as described in 4.6.2.

4.10.1.1 Direct structure tests

Direct structure tests assess the validity of the model structure, by direct comparison with knowledge about real system structure (Sterman, 2000). This involves taking each relationship (mathematical equation or any form of logical relationship) individually and comparing it with available knowledge about the real system. There is no simulation involved. Direct structure tests can be classified as empirical or theoretical. Empirical structure tests involve comparing the model structure with information (quantitative or qualitative) obtained directly from the real system being modeled. Theoretical structure tests involve comparing the model structure with generalized knowledge about the system that exists in the literature (Barlas, 1996).

4.10.1.2 Indirect structure tests (Structure-oriented behavior tests)

The second general category of structural tests, structure-oriented behavior tests, assess the validity of the structure indirectly, by applying certain behavior tests on model-generated behavior patterns (Sterman, 2000). These tests involve simulation, and can be applied to the entire model, as well as to isolated sub-models of it. These are "strong" behavior tests that can help the modeler uncover potential structural flaws. Such tests include extreme-condition (indirect) test which involves assigning extreme values to selected parameters and comparing the model-generated behavior to the observed (or anticipated) behavior of the real system under the same extreme condition. Behavior sensitivity test consists of determining those parameters to which the model is highly sensitive, and asking if the real system would exhibit similar high sensitivity to the corresponding parameters (Barlas, 2014).

Structure oriented behavior tests were carried out on the model developed in this thesis.

4.10.1.3 Behavior pattern tests

Sterman (2000) notes that the two categories of tests discussed above are designed to evaluate the validity of the model structure. As a result of these tests, once enough confidence has been built in the validity of the model structure, one can start applying certain tests designed to measure how accurately the model can reproduce the major behavior patterns exhibited by the real system. Once the model has been through all the structural tests, the pattern prediction ability of the model can be assessed by applying a series of behavior tests. On reaching the final step of behavior pattern testing, the emphasis is on the accuracy of pattern predictions, and is essentially done for communication of results and implementation purposes. Behavior pattern tests will be carried out on the model developed in this thesis (Barlas, 1996, 2014).

4.11 Chapter Summary

This chapter makes it clear that a qualitative research approach was used in this study, designed as a guided participative cooperative enquiry based on active interviewing as well as use of archival data from previous projects. The research paradigm is of the constructivist / interpretivism, of a qualitative grounded theory building type whereby data was sourced through participants active in the projects in the electricity sector in Kenya. The data was used to formulate a dynamic model representative of the project dynamics in the electricity sector in Kenya using the System Dynamics approach.

The chapter also brings out the fact that System Dynamics models are especially useful for analyzing what-if scenarios, policy testing and policy optimization. In this research study, the agile modeling process as developed by Warren (2013) was used to complement the main process as developed by Sterman (2000). The chapter also brings out the fact that system dynamics modeling approach was found suitable for this study because projects in the electricity sub-sector can be framed as complex dynamic systems, and project management has previously been a successful research area for use of this type of modeling approach. Model validity, the property a model has of adequately reflecting the system being modeled, is a primary measure of model utility and effectiveness. In this research, the initial data is gathered in an exploratory study that is then used to develop a conceptual system dynamics model, which is then developed into a system dynamics simulation model (Barlas, 1996).

The next chapter describes and presents the System Dynamics model as developed in this study, together with the analysis and "what – if" scenarios from the new model.

CHAPTER 5: Model Development, Modeling and Simulation

5.1 Introduction

This chapter presents the conceptual model which was built upon the empirical findings of the exploratory study as guided by the questions to the interviewees (Appendix A) and findings (Appendix B), based on the fieldwork undertaken in Kenya. The questions in Appendix A were derived from the literature, but also included research sub-questions from section 1.5. The purpose of a System Dynamics model is to address a problem and not just model a system (Richardson and Pugh 1981). This view is supported by Albin (1997) when she states that the purpose of a model is usually to clarify knowledge and understanding of the system and to discover policies that will improve system behavior. A System Dynamics model is built to understand a system of forces that have created a "problem" and continue to sustain it. Likewise, this research develops a model of the electricity infrastructure project dynamics in Kenya, tests and validates the model, and through policy analysis, identifies suitable model scenarios that would lead to "on time" project delivery. Policy analysis also aims at identifying policy options that lead to better average quality in the electricity sector projects in Kenya and by extension, Sub Saharan Africa region. This is to generally link research objectives to research questions as posed in section 1.4 and 1.5.

The chapter starts by marking out the boundary of the conceptual model, then proceeds to identify the key risks from focus group discussions with stakeholders in the sector. A conceptual System Dynamics model is then developed based on the interaction and feedback structure from discussions with stakeholders. The conceptual model is then used to develop a basic system dynamics model which is simulated to understand the underlying dynamics which have informed the development of the model. The knowledge gained is used in answering the sub-research question 1.5 (d) namely "What forces create the problems that lead to project delays and quality challenges experienced in projects in the electricity sector in Kenya?" This is also used in answering the second research question as given in section 1.5 "How do the prevalent risks and other elements interact with each other in a dynamic project set up?" This makes a new contribution to the body of knowledge by availing a model of interacting project risks that will be useful in helping stakeholders in Kenya and the wider Sub Saharan Africa region, including donors supporting projects in the energy sector in the region, to better understand and mitigate risks that often cause delays and quality challenges in many projects in the energy sector in the region.

5.2 Conceptual model of feedback structure for interacting project risks in the Power sector in Africa

5.2.1 Background /Literature used in Conceptual Model Development

The system dynamics process starts from a problem to be solved, a situation that needs to be better understood, or an undesirable behavior that is to be corrected or avoided. The first step is to tap the wealth of information that people possess in their heads. The mental data base is a rich source of information about the parts of a system, about the information available at different points in a system, and about the policies being followed in decision making. The management and social sciences have in the past unduly restricted themselves to measured data and have neglected the far richer and more informative body of information that exists in the knowledge and experience of those in the active, working world (Forrester1991, Doyle and Ford 1998, Forrester 2009, Luna and Deborah 2002, Alasad et al 2013, Houghton et al 2014). This research relied on data gathered from experienced project practitioners in the electricity industry in Kenya as project managers in the power utilities, contracting firms and project coordinators at the parent ministry of energy as indicated in section 4.5.4.

From a paper on best practices in system dynamics modeling, Moyano and Richardson (2013) report on the need to approach system conceptualization from different perspectives, to elicit clients' mental models so as to help develop the building blocks of the dynamic hypothesis, to identify important accumulations (stocks) early in conceptualization, identify key variables representing problematic behavior, to strive for an endogenous dynamic hypothesis and to make sure the boundary of the dynamic hypothesis is large enough to enable the endogenous point of view. Sterman (2001) noted that policy resistance arises because mental models are usually limited, internally inconsistent, and unreliable and to understand the sources of policy resistance, one needs to understand both the complexity of systems and the mental models used to make decisions.

Pruyt (2013) states that project planning is a successful System Dynamics application field, and system dynamicists model the perceived underlying material, informational, social structure of largely closed real world systems. People are trained to see the world as a series of events, to view situations as the result of forces from outside, forces largely unpredictable and uncontrollable. In most peoples' perception, there are no side effects, only effects comprised of those effects thought of in advance which most people take credit for, and those not anticipated that are termed side effects (Sterman, 2002, Maddux and Yuki 2006). With these thoughts in mind and as part of the research method followed in this research, discussions during the interviews with the practitioners and project managers were deliberately broad and prodding was used so as to get a wide and deep understanding of the causes of the system behavior (see Appendix A and Appendix B).

5.2.2 Time charts (Reference Mode) of project Dynamics in the electricity Energy sector in Kenya

To improve understanding for the reasons that create problems, the problems need to be articulated and characterized according to the available modes of understanding. Problem articulation refers to the initial understanding for the reasons for deviation in terms of time horizon, stakeholders' perceptions of the problem, observable symptoms, perceived causes of the problem and factors affecting it (Khan et al, 2004). This is usually done through discussions with the client team, archival research and interviews (Saeed, 2002, Sterman, 2000). Reference mode refers to a set of graphs and other descriptive data showing the development of the problem over time (Khan et al 2004). Saeed (2002) notes that though historical data may be the starting point for developing a reference mode, it is an abstract concept subsuming past as well as inferred future behavior, and can best be visualized as a fabric collecting several patterns as well as the phase relationships existing between them.

The reference mode captures mental models and historical data on paper, gives clues to appropriate model structure, and can check plausibility once the model is built. Reference modes are not infallible, and can change throughout the modeling process as a modeler understands the system better and updates their mental model. In drawing reference modes, a modeler needs to think clearly about which factors influence each other and graphs their behavior over time. One should draw reference modes on the same graph if possible, though multiple graphs may become necessary due to crowding (Albin, 1997). Reference modes, so called because one refers back to them throughout the modeling process, help the modeler, the client and the participants in the research break out of the short term event-oriented worldview so many people have (Albin 1997, Zlatanovic 2012). Reference modes use historical data, and comparing model output to the reference mode is particularly useful in later stages of model construction so that if the model does not produce behavior similar to historical observations, it is an indication that the model might need re-work (Albin, 1997). The developer of the reference mode presents dynamic hypothesis of the causality of the problem based on empirical data and local knowledge (Khan,2004).

In this research study, reference mode graphs were developed by using historical data from past projects in Kenya Power and Lighting Company, through reference to records of previous projects completed in the company, and local knowledge possessed by staff working in the company. The time charts (The reference mode graphs) for typical projects in the electricity sector in Kenya are given in Appendix D, which were derived by considering records on 12 number of past projects.

5.2.2.1Time Horizon

The time horizon should extend far enough back in history to show how the problem emerged and describe its symptoms. It should extend far enough into the future to capture the delayed and indirect effects of potential policies. A principal deficiency in mental models is the tendency to think of cause and effect as local and immediate. In dynamically complex systems, cause and effect are distant in time and space (Sterman, 1994, Dunham, 1998, Sterman, 2000, Sterman, 2002, Sterman, 2012, Neuwirth, 2015). Working with organizations which include utility companies in the sector in Kenya as well as the Ministry of Energy and Petroleum, the time horizon for the model in this research was chosen to be 200 months. The average time projects in the sector take is 36 months. Delays of between 6 months and 12 months are common.

5.2.3 Logic used in developing the conceptual model

In the causal loop diagram in figure 5.1, political risk has been modeled as a stock influenced by positive or negative political events. Political risk refers to the complications businesses and governments may face as a result of what are commonly referred to as political decisions or any political change that alters the expected outcome and value of a given economic action by changing the probability of achieving business objectives (Koc and Ciftci 2014). The exploratory study results obtained as part of the current research project show that political risk is a key risk that affects projects in the sector (Appendix B). Political risk often results into schedule slippage, and so affects the planned schedule for projects, leading to delays, as indicated in Appendix B.

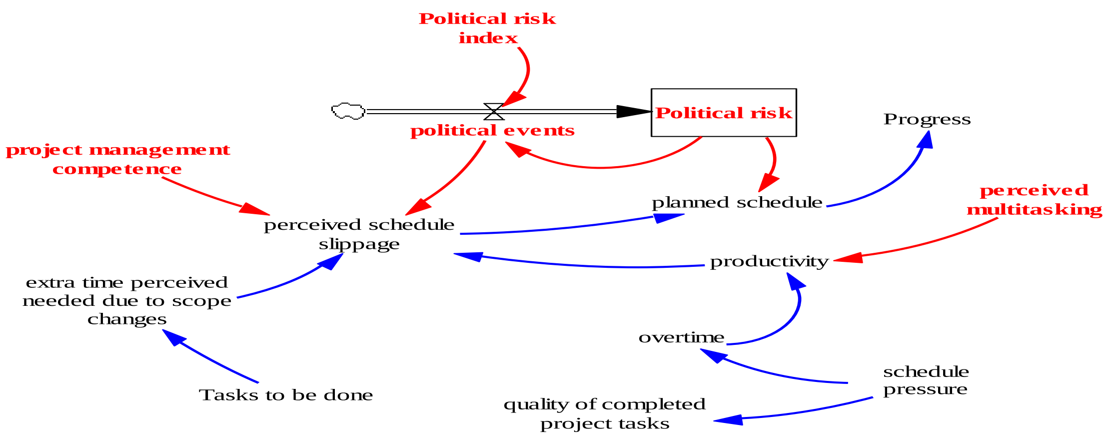

Fig. 5.1: Conceptual model, portion incorporating political risk, perceived multitasking and project management competence

The other risks which were mentioned highly in the exploratory study interviews with the stakeholders in the power sector were project management competence, perceived to be low amongst utility companies as well as within the contracting firms operating in the region, and multitasking that is common amongst the key staff of contracting firms operating in the sector (refer to study results in Appendix B). Project management competence is key in contract management and administration, and the exploratory study revealed that low project management competence often leads to schedule slippage, which then leads to adjustment of the planned schedule for project completion. During the discussions, it came out that contracting firms operating in the region often win and manage many projects concurrently, leading to multitasking amongst the key personnel such as those carrying out testing and commissioning parts of projects. All the portions and variables in Fig. 5.1 marked in red colour are new and are additions to previous models based on the results from the exploratory research in this thesis.

Similarly, an increase in multitasking impacts productivity negatively as the few highly skilled staff move from one project to another, meaning that subsequent tasks often have to wait for completion of key tasks performed by these skilled staff, resulting into instances of idle resource, and hence leading to schedule slippage and low productivity of project personnel. During the exploratory study conducted as part of the current research, and partly as a result of the risks previously mentioned such as political risk, low project management competence, and multitasking, rework was mentioned as a common occurrence in many projects in the power sector in Kenya and the region. The rework cycle is captured separately in figure 5.2, as adapted from an earlier conceptual model by Cooper (2003), with the addition of "unforeseen technical difficulties" which extends the previous rework model by Cooper (2003). In figure 5.1, "tasks to be done", "progress" and "quality of completed project tasks", link to the conceptual model portion in figure 5.2.

As indicated in figure 5.2, poorly completed project tasks lead to undiscovered rework, which is later discovered through testing and the tasks that have to be re-done which re-enter the 'tasks to be done' stock. The exploratory study referred to previously revealed that work progress is influenced by the productivity of project personnel as indicated in Appendix B, Interview # 7; "Contractors working in the sector bid for many projects, and end up employing project staff with limited technical skills, hence low productivity, which affects progress of the entire project" and Interview # 53; "Shortage of local workforce with necessary technical skills, especially in testing and commissioning new substations, results in key functions being performed by semi-skilled personnel, leading to rework and negatively affecting progress". On the same note, undiscovered rework directly and negatively influences quality of completed project tasks. During the exploratory study, "Unforeseen technical difficulties", which refers to technical problems that are only discovered late into the project, was mentioned as a common problem in projects in the energy sector in Kenya. Unforeseen technical difficulties often influenced the poor completion of project tasks, while also affecting quality of completed project tasks as some technical difficulties cannot be fully addressed in the course of the project.

In figure 5.2, progress is often influenced by the productivity of the project personnel, and either leads to proper completion of project tasks, which forms the stock of satisfactorily completed project tasks, or may lead to poor completion of project tasks, which feeds into the stock of undiscovered rework that later leads to detection of rework, feeding into the stock of tasks to be done. Completed project tasks done well would lead to high quality of completed project tasks, while undiscovered need for rework is a major source of poor quality of completed tasks. The variable "unforeseen technical difficulties" in Fig. 5.2 marked in red colour is new and an addition in the research in this thesis, based on the results from the exploratory research, extracts from which are given in Appendix B.

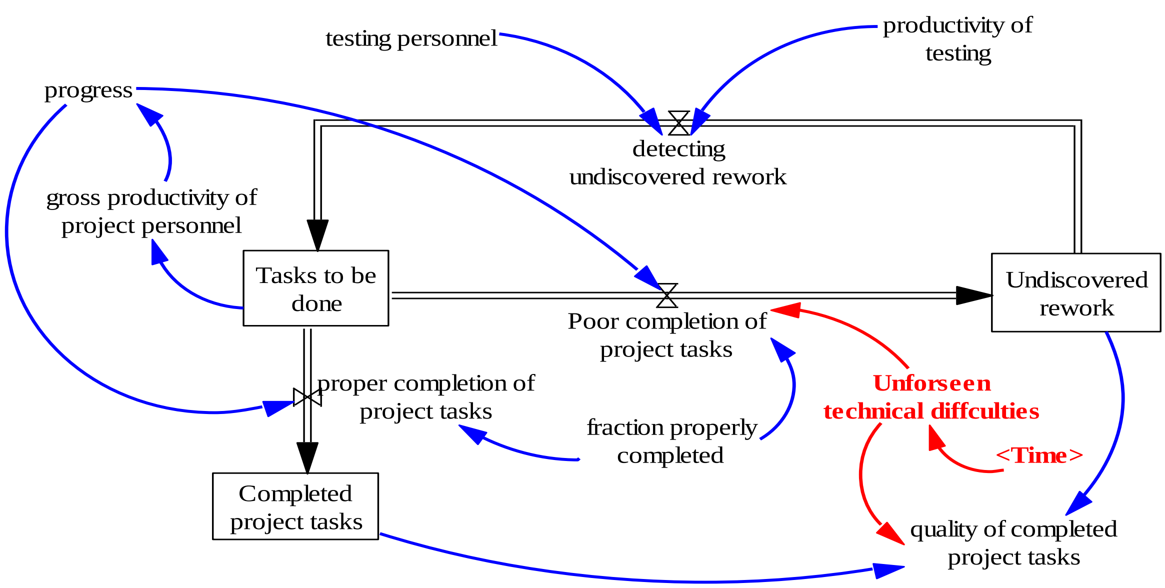

Fig. 5.2: Conceptual model, portion incorporating the rework cycle (Adapted from Cooper, 1993)

5.2.4 The conceptual model

Figure 5.3 presents the resultant new conceptual model achieved by unifying figure 5.1 and figure 5.2. The productivity of testing personnel, especially commissioning engineers usually determines the speed at which rework is detected in energy sector projects in Kenya. Similarly, productivity and competence of project personnel impact the fraction of properly completed project tasks.

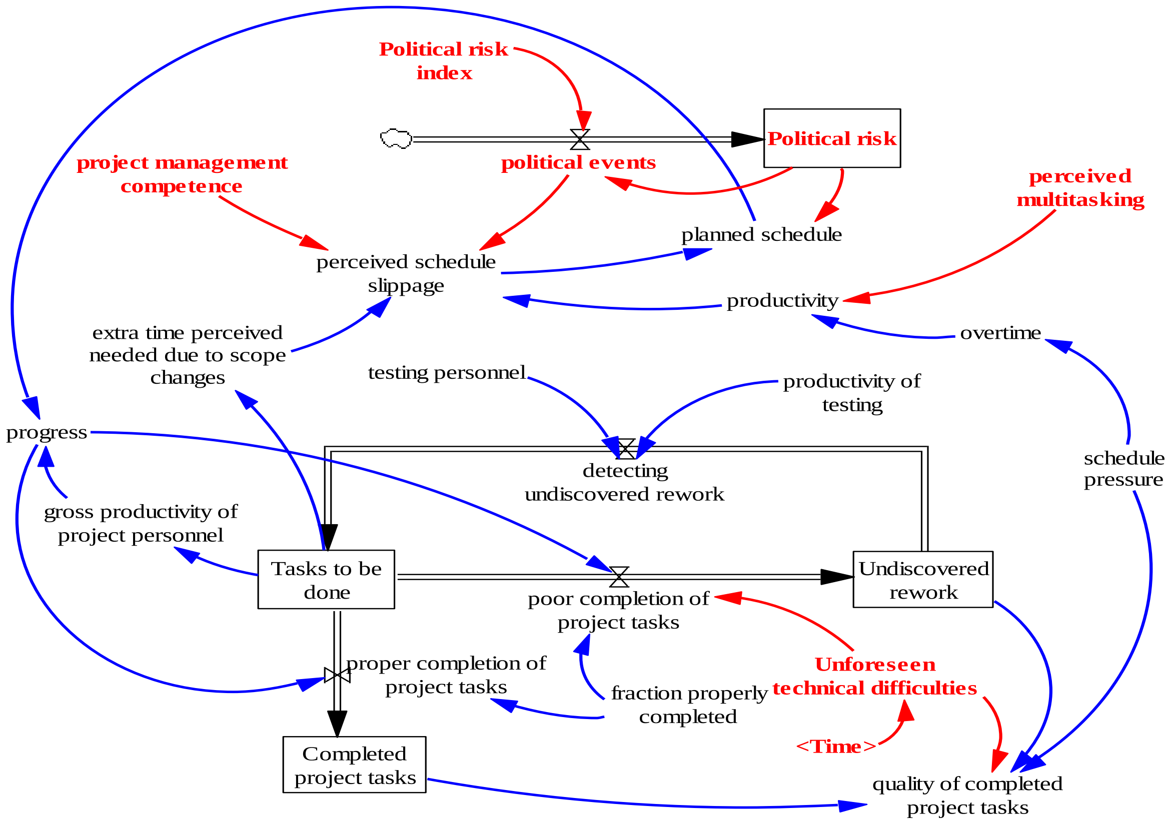

Fig. 5.3: Conceptual model of the interacting project risks in the power sector in Kenya

The variables marked in red in figure 5.3 are all new based on feedback obtained from participants during the exploratory study in this research.

5.3 Modelling Electricity Project Dynamics in Kenya

The conceptual model as developed in figure 5.3 bears similarities to the project model by Richardson (2013) in figure 3.3, except for political risk, project management competence, and multitasking which are additions, as presented in Appendix C. In developing the basic model therefore, the model developed in this research will be based on a modified and extended version of the project model by Richardson (2013), leading to a new contribution to knowledge.

The rework cycle is the most important single feature of System Dynamics project models in which rework generates more rework that further generates even more rework (Lyneis and Ford, 2007). It is the source of many project management challenges, and was first developed by Pugh

Roberts Associates. The majority of System Dynamics studies that focus on project dynamics include a simulation model of project evolution and the core feature of these models is the rework cycle (Cooper 1993, Lyneis 2012, Richardson 2013, Rahmandad and Hu 2010, Owens et al 2011). While most of the original work in projects is usually finished early in the project, delays are usually caused by the need to rework that original work. By considering defects, quality and testing through the rework cycle, many path-dependent reinforcing loops are generated that critically impact the fate of projects. Almost all dynamic project models have a rework cycle in some form (Lyneis and Reichelt, 1999, Richardson 2013, Rahmandad and Hu 2011). The basic model developed in this research uses the rework cycle, essentially because many projects in the power industry in Kenya and by extension Sub Saharan Africa suffer from rework as supported by evidence from interviews in the exploratory study, as indicated in Appendix B.

5.3.1 Model Boundary

In delimiting system and model boundaries, all potentially important elements which influence other parts of the system and are also significantly influenced by elements of the system are modeled as endogenous variables, while all elements that could seriously impact the system but that are not sufficiently influenced by the system become exogenous variables, and all other elements are omitted (Pruyt, 2013). When creating a system dynamics model of a feedback system, a modeler must clearly define the model boundary, and separate the initial components list into two important groups; endogenous components, which are dynamic variables involved in the feedback loops of the system and exogenous components whose values are not directly affected by the system (Albin, 1997).

Table 5.1 gives the endogenous, exogenous, and the excluded elements in the development of the basic model presented in Fig. 5.6 for the current research. The following considerations were made in developing this model;

a) Projects in the electricity energy sector in Kenya and the East African region generally take about 36 months to complete. The country and regional political risk index of 67%

used in the model is a yearly figure, and therefore political risk index is changed to a constant in the model in Fig. 5.6 for the current research.

b) According to results of the exploratory study as given in Appendix B and further analyzed in Appendix C, the model variables identified through the exploratory study in this research were fairly similar to those earlier identified by Richardson (2013), with the exception of Multitasking, Political risk, Project Management Competence, and Unforeseen technical difficulties which were additions. The original basic conceptual project model as given in Fig. 3.3 by Richardson (2013) was therefore adapted and extended in developing the model in Fig. 5.6 by including the variables; "Multitasking", "Political risk", "Project Management Competence", and "Unforeseen technical difficulties".

Table 5.1: Model-boundary Chart of the project risks in the electricity energy sector in Kenya as identified during the basic model development stage

Endogenous	**Exogenous**	**Excluded**
workforce	Initial project time remaining	Weather
Cumulative effort	Project risk index	Inflation
Remaining project tasks	Maximum productivity of testing	Acts of God
Properly completed project tasks		Financial risks
Undiscovered rework		Organizational Risk
Net hiring of personnel		Statutory Clearance Risk
Additional cumulative effort		Ownership risk
Detecting undiscovered rework		Market risks
Proper completion of project tasks		Management risks
progress		
Unforeseen technical difficulties		

5.3.2 Model of the Project rework dynamics in electricity sector in Kenya

The models in Fig. 5.1, Fig. 5.2 and Fig. 5.3 were presented to a group of 22 project experts, as indicated in section 4.9 and table 4.7, as part of the conceptual model validation process, results of which are included in Appendix M. The discussions from the workshop were used to structure and develop the basic System Dynamics models as presented in section 5.3.2, 5.3.3 and 5.3.4. Fig. 5.4 shows the portion of the basic model developed illustrating the rework dynamics prevalent in the electricity sector in Kenya. "Fraction undiscovered rework" which is a function of "undiscovered rework" and "perceived cumulative progress" has been added as a variable that influences "productivity of testing". "Average quality of completed project tasks", a function of "properly completed project tasks"; "undiscovered rework" and "unforeseen technical difficulties", has also been included arising from the exploratory study results as given in Appendix B. In addition to the variables in previous models as exemplified in the model by Richardson (2013), as well as from results of the exploratory study as given in Appendix B, four additional variables came out as prevalent risk factors in the sector.

These are multitasking, political risk, project management competence and unforeseen technical difficulties as given in Appendix B and Appendix C. These risks were therefore added to the previous project model by Richardson (2013) to generate the new model as developed in the research in this thesis.

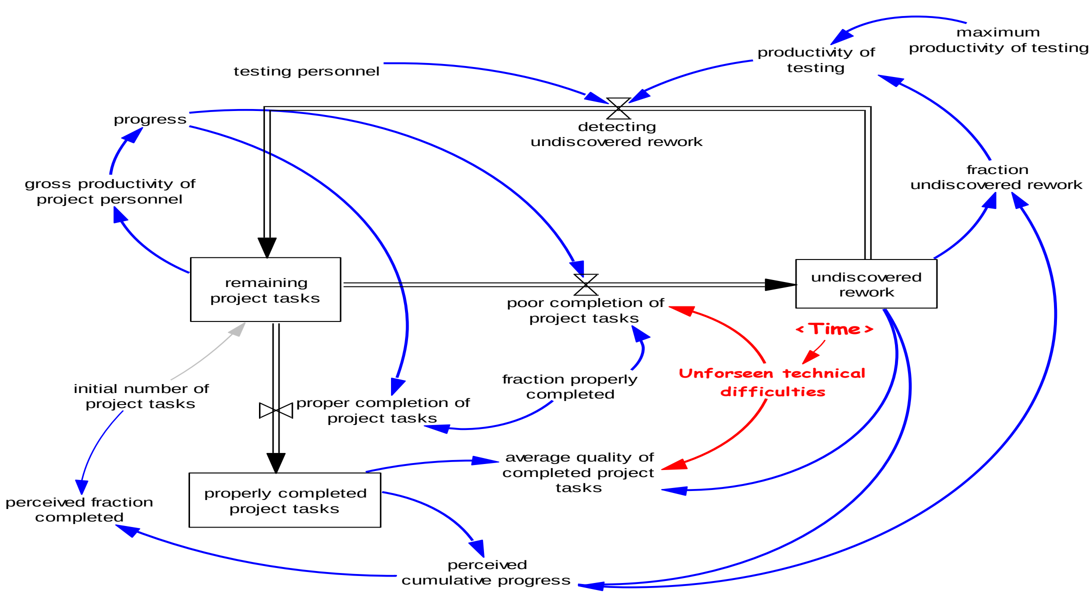

Fig. 5.4: Model of the Project rework dynamics in electricity sector in Sub Saharan Africa (Adapted from Richardson, 2013)

5.3.3 Model of workforce Project dynamics in electricity sector in Kenya

Fig. 5.5 shows the conceptual model of the workforce dynamics in electricity energy projects, incorporating political risk, Multitasking and Project Management competence into the model adapted from Richardson (2013). The new contributions, different from the original model by Richardson (2013), shows that political risk influences project progress in projects in the electricity sector in Kenya, while multitasking, modeled as a function of project time remaining, influences both the additional cumulative effort as well as project progress. In addition, the variable, "project management competence" is shown in the model in figure 5.5 as influencing the gross productivity of project personnel as well as the additional cumulative effort. The model in figure 5.5 therefore expands and extends the model by Richardson through the inclusion of new variables which were mentioned as significant in the projects in the electricity sector in Kenya as per the results in Appendix F.

In comparison to the model in Fig. 5.1, the model in Fig. 5.5 treats political risk as a constant as explained in section 5.3.1 "(a)", includes and models "perceived time remaining" as a function of "Time" and "initial project time remaining" so as to inform "desired workforce" requirements, and models "additional cumulative effort" as a function of "workforce", "project management competence" and "Multitasking". In Fig. 5.5, "perceived productivity" is modeled as a function of "cumulative effort" and perceived cumulative progress". "perceived time remaining" is modeled so as to influence "fraction personnel for testing" such that as the project nears completion, fraction of personnel deployed for testing increases as the project enters the commissioning stage. "perceived time remaining" is also modeled so as to influence "Multitasking" such that as the project time remaining reduces, multitasking tends to increase as testing personnel move from one project to another doing commissioning tests. The variables marked in red in figure 5.5 are all new based on feedback obtained from participants during the exploratory study in this research.

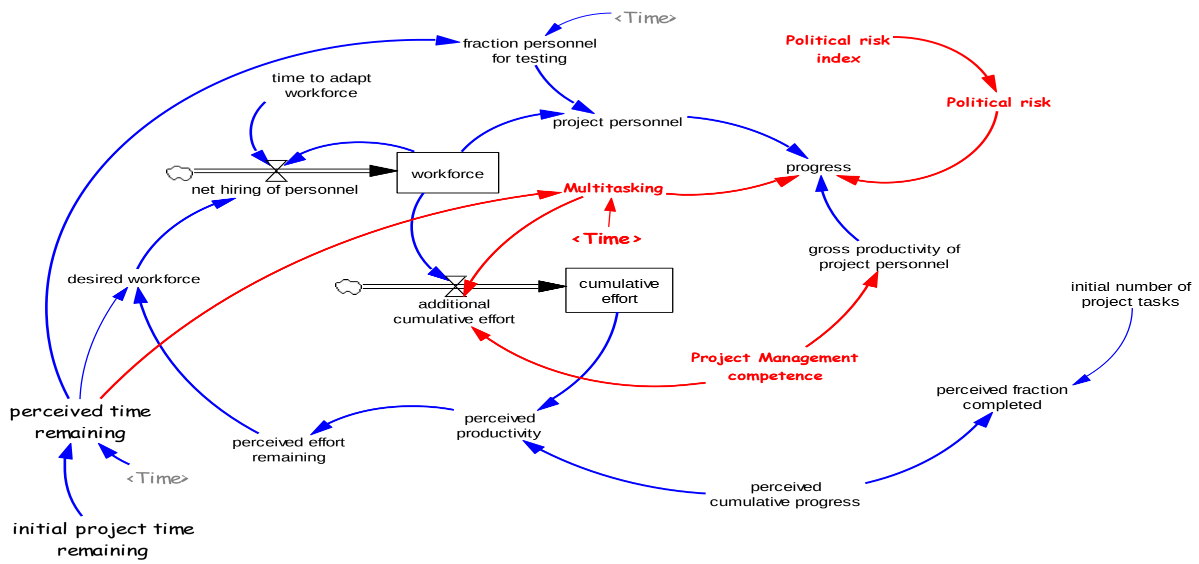

Fig. 5.5 Model of workforce Project dynamics in electricity sector in Sub Saharan Africa (Adapted from Richardson, 2013)

5.3.4 The Basic Model of interacting project risks in the electricity sector in Kenya

Fig. 5.6 combines the two conceptual models as given in Fig. 5.4 and Fig. 5.5 to come up with a model possibly representative of the dynamics at play in projects in the electricity energy sector in Kenya. The variables marked in red in figure 5.6 are all new based on feedback obtained from participants during the exploratory study in this research.

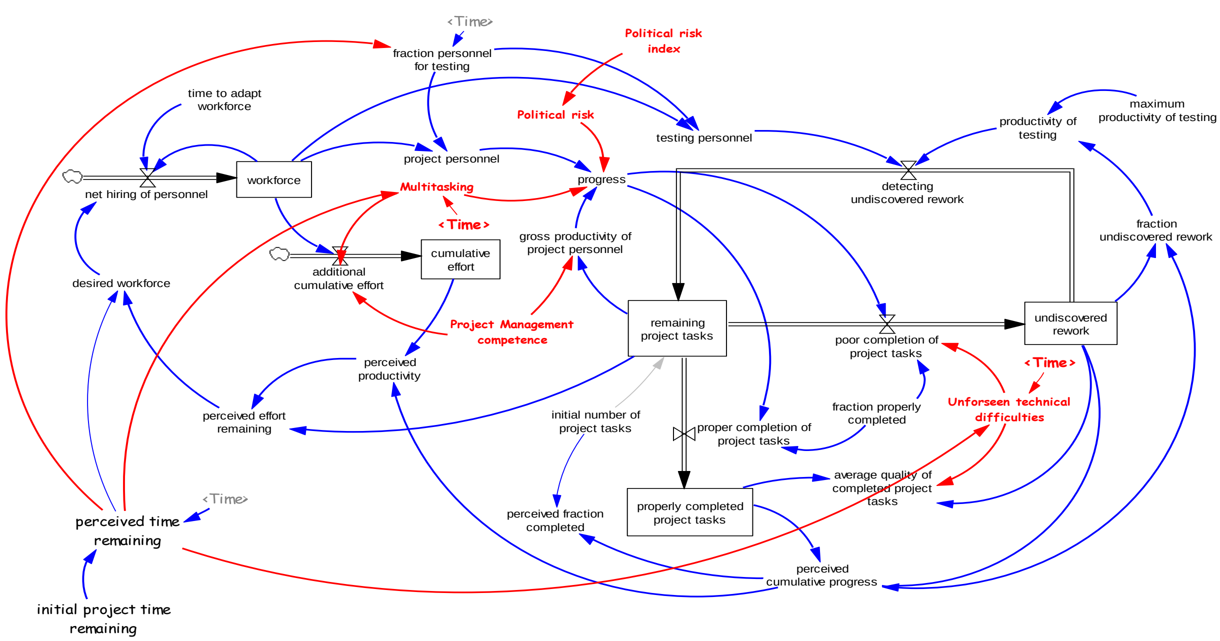

Fig. 5.6: Model of the interacting project risks in the electricity sector in Kenya

5.3.5 Model Equations generation

The equations used to develop the system dynamics model in Fig. 5.6 are discussed in this section. Where appropriate, motivation for relationships as well as model data determined from focus group discussions and other project data sources is discussed alongside the equation development.

From the exploratory study results (Appendix B), political risk was perceived to affect progress of projects in the energy sector by slowing progress. Data over the past five years of the Political Risk Index (Political Risk Services, 2014) gives an average index of 67% for Kenya over the four-year period from 2011 to 2014 (Appendix H, rank 65), with the lowest risk ranking at 100%. The average time frame for mega projects in the electricity industry in Kenya at bidding is 36 months. Political risk index changes minimally during this period, and therefore the political risk index is modeled as a constant of 0.67.

Political risk index = 0.67 (units: dimensionless) (5.1)

Projects in the energy sector in Kenya witness multitasking by the contractors due to shortage of skilled staff (see Appendix B), and this is prevalent as the project nears the projected completion time. To capture the interviewees sentiments in the model, multitasking is modeled as a non-linear function of time, as a Lookup function;

Multitasking = WITH LOOKUP (Time,
([(0,0)-
(52,10)],(0,1),(4,1),(8,1),(12,0.85),(16,0.75),(20,0.7),(24,0.7),(28,0.65),(32,0.65),(36,0.75),
(40,0.8),(44,1),(48,1),(52,1),(200,1)) (Units: dimensionless) (5.2)

Project Management competence is modeled as a constant at 60% (0.6). This result came from the exploratory study with stakeholders, as well as in analysis of data on previous projects in the energy sector in Kenya (Appendix B).

Project Management competence = 0.6 (units: dimensionless) (5.3)

In the energy sector projects in Kenya, results of the exploratory study with stakeholders (Appendix B) indicate that unforeseen technical difficulties are prevalent, and problems related to this effect become pronounced as the projects near completion. "Unforeseen technical difficulties" is therefore modeled as a non-linear function of time;

Unforeseen technical difficulties = WITH LOOKUP (Time, ([(0,0)-(60,10)],(0,1),(2,0.99),(6,0.98),(10,0.97),(14,0.96),(16,0.95),(20,0.9),(24,0.8),(26,0.8), (28,0.92), (30,0.95),(36,0.97),(38,0.98),(40,1),(44,1),(48,1),(52,1),(54,1),(60,1),(200,1))(Units: dimensionless) (5.4)

A typical project in the energy sector in Kenya initially consists of about 600 project tasks to be completed (see results of the exploratory study with stakeholders in Appendix B). A typical project model thus starts with a stock of 600 remaining project tasks. During the project, tasks that are properly completed become part of the properly completed project tasks. At the start of a project, the number of properly completed project tasks is 0.

initial number of project tasks = 600 (units: dimensionless) (5.5)

*Proper completion of project tasks = progress * fraction properly completed (units: tasks/month)* (5.6)

Remaining project tasks = INTEG(detecting undiscovered rework-poor completion of project tasks-proper completion of project tasks) (units: Tasks) (5.7)

Properly completed project tasks = INTEG (proper completion of project tasks) (units: Tasks) (5.8)

Progress made during the project is modeled as being equal to the gross productivity of project personnel times the size of the workforce assigned to the project. In the model, this is also affected by political risk and Multitasking, which tend to slow down the progress. Progress is therefore modeled as follows;

*Progress = gross productivity of project personnel*project personnel*Political risk*Multitasking (units: Tasks/month)* (5.9)

During the course of developing model equations, focus group meetings were held with experts comprising project engineers who were involved in projects in Kenya Power and Lighting Company Limited with an experience of about 8 years (between 2005 to 2013). In the discussions, gross productivity of project personnel was noted to be a function of "remaining project tasks", related so that with a project comprising 600 tasks, the gross productivity of project personnel is maximum at 100% from 600 remaining tasks until there are about 100 remaining tasks, after which the gross productivity of project personnel decreases to 95% at 75 remaining tasks, 85% at 50 remaining tasks, to 20% at 0 remaining tasks. The gross productivity of project personnel is however also impacted by "project management competence", such that when project management competence is low, the gross productivity of project personnel is depressed and vice versa. It is therefore modeled as follows;

*gross productivity of project personnel= WITH LOOKUP (remaining project tasks*Project Management competence,*
([(0,0)-(600,1)],(0,0.2),(50,0.85),(75,0.95),(100,1),(200,1),(600,1)) (units: Tasks/person/month)
(5.10)

From the focus group meetings held with experts comprising project engineers who were involved in projects in Kenya Power and Lighting Company Limited, the workforce assigned to a particular project increases and decreases through net hiring of personnel, equal to the difference between the desired workforce and the workforce, divided by the time to adapt the workforce;

net hiring of personnel = (desired workforce – workforce)/time to adapt workforce
(units: person/month) (5.11)

Workforce = INTEG (net hiring of personnel) (units: person) (5.12)

From the focus group meetings held with experts comprising project engineers who were involved in projects in Kenya Power and Lighting Company Limited, the time to adapt the workforce is relatively constant and ordinarily, the time to adapt the workforce would be about 0.5 Month, which is used for this case;

time to adapt the workforce = 0.5 (units: Month) (5.13)

The desired workforce is modeled as the perceived effort remaining divided by the perceived time remaining.

desired workforce = perceived effort remaining / perceived time remaining (units: person) (5.14)

The perceived time remaining is modeled as initial project time remaining minus "Time" with the delay time needed to adjust the project schedule. In the model, the perceived time remaining is at least a month: experience from discussions with experts comprising project engineers in Kenya Power and Lighting Company Limited shows that such projects always have a time overrun of at least a month;

perceived time remaining = MAX(1, initial project time remaining - Time)
(units: month) (5.15)

From the focus group meetings held with experts comprising project engineers in the electricity sector, projects in the sector typically average 36 months from start to completion. the remaining project time of projects in the electricity sector is therefore modeled as 36 months, and the perceived effort remaining is modeled as equal to the remaining project tasks divided by the perceived productivity, and in the model, the "MAX" function is used so as to avoid dividing by zero;

perceived effort remaining = remaining project tasks/MAX(perceived productivity,1)
*(units: person*Month)* (5.16)

The perceived productivity corresponds to the perceived cumulative progress over the cumulative effort delivered.

perceived productivity = perceived cumulative progress/cumulative effort (5.17)
(units: tasks/person/Month)

From the focus group meetings held with experts the perceived cumulative progress in the model is equal to the amount of properly completed project tasks plus undiscovered rework;

Perceived cumulative progress = properly completed project tasks + undiscovered rework
(units: tasks) (5.18)

From the focus group meetings held with experts comprising project engineers, the cumulative effort delivered increases by means of the additional effort delivered by the workforce, but is slowed down both by "Multitasking" of skilled staff such as the commissioning engineers and the poor levels of "Project Management competence". The additional cumulative effort is therefore modeled as being equal to the workforce times Multitasking times the level of Project Management competence prevailing;

*additional cumulative effort = workforce*Multitasking*Project Management competence*
(units: person) (5.19)

*Cumulative effort = INTEG (additional cumulative effort) (units: person*Month)* (5.20)

The perceived fraction completed is modeled as the perceived cumulative progress divided by the initial number of project tasks;

perceived fraction completed = perceived cumulative progress/initial number of project tasks
(units: fraction) (5.21)

From the rework cycle, focus group meetings held with experts comprising project engineers revealed that the "detection of undiscovered rework" depends on the number of testing personnel times the average productivity of testing;

*detecting undiscovered rework = productivity of testing*testing personnel*
(units: tasks/Month) (5.22)

Poor completion of project tasks goes hand in hand with progress and is modeled as proportional to (1- fraction properly completed), while it is also a function of unforeseen technical difficulties, and generates undiscovered rework. This is as a result of the discussions in focus group meetings with experts at Kenya Power and Lighting Company. The fraction properly completed is assumed as about 50% for this model, based on results from the exploratory study in Appendix B.

poor completion of project tasks = progress(1 - fraction properly completed)*Unforeseen technical difficulties (units: tasks/Month)* (5.23)

fraction properly completed = 0.5 (units: dimensionless) (5.24)

undiscovered rework = INTEG (poor completion of project tasks – detecting undiscovered rework) (units: tasks) (5.25)

The productivity of testing is modeled as equal to the fraction of undiscovered rework times the maximum productivity of testing. From the focus group meetings held with experts comprising project engineers in Kenya Power and Lighting Company Limited, the maximum productivity of testing in projects in the electricity sector in Kenya is at about 2 tasks per person per month. Therefore "Maximum productivity of testing" is modeled as equal to 2 tasks per person per month;

*productivity of testing = maximum productivity of testing*fraction undiscovered rework*
*(units: tasks/ (person*Month)* (5.26)

Maximum productivity of testing = 2 (units: tasks/person/month) (5.27)

Average quality of completed project tasks is impacted by unforeseen technical difficulties such that the higher the rate of unforeseen technical difficulties, the lower the average quality of completed tasks. Therefore, average quality of completed project tasks is modeled as "properly completed project tasks" times "unforeseen technical difficulties" divided by "properly completed project tasks" plus "undiscovered rework", with the MAX function applied to the denominator so that it may not equal zero.

*Average quality of completed project tasks = (properly completed project tasks*unforeseen technical difficulties)/MAX ((properly completed project tasks + undiscovered rework), 1) (units: dimensionless)* (5.28)

The "fraction undiscovered rework" is modeled as equal to "undiscovered rework" divided by "perceived cumulative progress", and the "perceived cumulative progress" is modeled with a 'MAX' function so that the denominator cannot be equal to zero;

fraction undiscovered rework = undiscovered rework/MAX (perceived cumulative progress, 0.01) (units: dimensionless) (5.29)

From the focus group meetings held with experts comprising project engineers in Kenya Power and Lighting Company Limited, the amount of the testing personnel is equal to the fraction of personnel for testing multiplied by the total workforce assigned to the project.

*testing personnel = fraction personnel for testing*workforce (units: person)* (5.30)

From the focus group meetings held with experts, the testing personnel in projects in the electricity sector vary, with the lowest numbers being at the start of the project when civil works are in progress, with the numbers rising during equipment installations, and peaking during the commissioning period. The "fraction of personnel for testing" is therefore modeled as an endogenous function of “Time” and “perceived time remaining”, going through the following possible sequence; (0,0.1), (0.1,0.09), (0.2,0.1), (0.3,0.14), (0.4,0.16), (0.49,0.2), (0.59,0.24), (0.68,0.26),(0.76,0.27), (0.87,0.28), (0.99,0.3), (200, 0.3) derived from discussions with the experts;

fraction personnel for testing = WITH LOOKUP (reported fraction detection undiscovered rework,
([(0,0)-(1,1)],(0,0.1), (0.1,0.09), (0.2,0.1), (0.3,0.14), (0.4,0.16), (0.49,0.2), (0.59,0.24), (0.68,0.26),(0.76,0.27), (0.87,0.28), (0.99,0.3), (200, 0.3).*)* *(units: dimensionless)* (5.31)

From the focus group meetings held with experts, the projects in the electricity sector are generally programmed to take an average of 36 months to completion. The “initial project time remaining” is therefore modeled as a constant of 36 months;
initial project time remaining= 36 *(units: Month)* (5.32)

Workforce is comprised of project personnel + fraction of personnel for testing, and therefore project personnel is modeled as;

*project personnel= (1-fraction personnel for testing)*workforce* *(units: person)* *(5.33)*

Political risk is derived directly from the Political risk index in equation (5.1), and therefore Political risk is modeled as;
Political risk = Political risk index (units: dimensionless) *(5.34)*

5.3.6 Some Preliminary Simulation results

According to Yeager et al (2014), System Dynamics modeling and the tools that support it, such as Vensim, offer unique advantages for building simulation models of large and complex systems which include, use of graphical descriptions to promote inspection and peer interaction, useful variable names and documentation fields, separation of model structure from data and output (unlike spreadsheets), debugging from visibility of full model state and causal tracing, good testing habits and easy syntax and unit checking. Vensim is an interactive software environment for the development, simulation, and exploration of System Dynamics models and in Vensim, models are created either by a text editor or by a sketch editor (Ventana Systems, 2002). The text editor allows the specification of the model's underlying variables and equations, while the sketch editor provides a graphical user interface to the modeling elements. No matter in which way a model is created, Vensim as System Dynamics software always stores the model data in a single file (Bauer and Bondendorf, 2006). Vensim was therefore chosen as the simulation software in the research in this thesis. All the Vensim System Dynamics simulation results shown in this section for the model portrayed in Fig. 5.6 were obtained using numerical integration with the fourth order Runge Kutta method.

In the trends shown in Fig. 5.7, multitasking is represented in blue colour, perceived cumulative progress is represented by the red colour, properly completed project tasks in green, while remaining project tasks appears in grey colour. The simulation trends in Fig. 5.7 show that multitasking tends to increase at between 30 and 45 months of project time, usually when the project is at the commissioning stage and nearing the planned completion time of 36 months. This trend invariably leads to project delays as the few commissioning engineers move from one project to another, and this delay is captured by the trends for the perceived cumulative progress, properly completed project tasks and remaining project tasks.

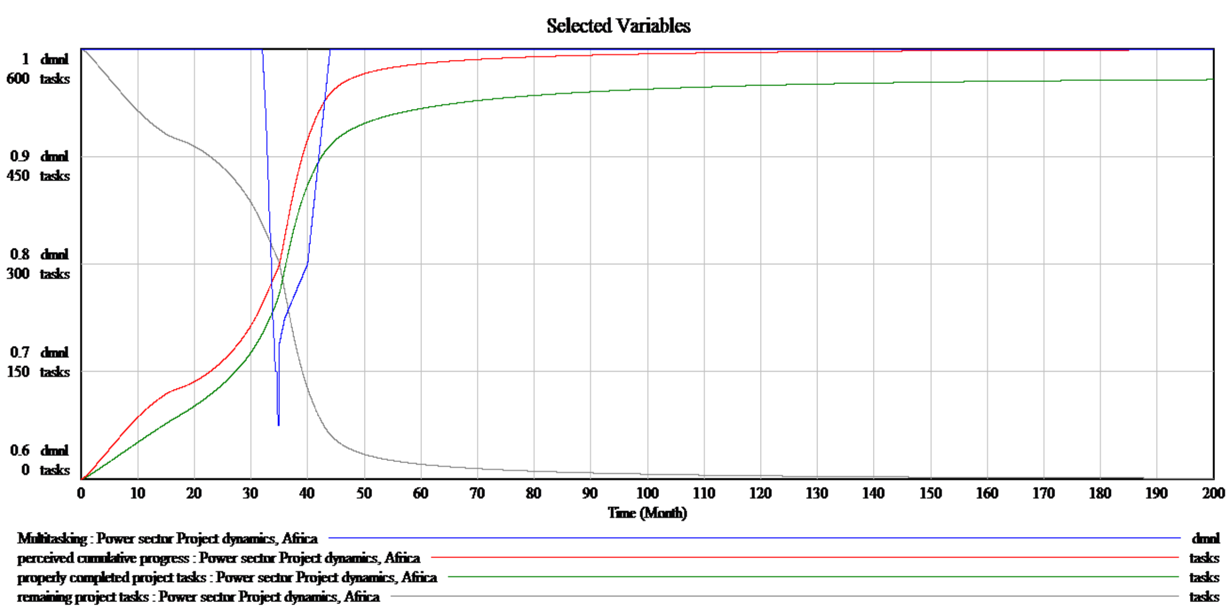

Fig. 5.7: Comparison of trends of multitasking, perceived cumulative progress, properly completed project tasks and remaining project tasks.

In the trends shown in Fig. 5.8, unforeseen technical difficulties appear in red colour, average quality of completed project tasks in blue colour, while undiscovered rework is in green colour. The simulation trends in Fig. 5.8 show that as the unforeseen technical difficulties become prominent between month 30 and month 40, the average quality of completed project tasks also dips as rework sets in to address some technical difficulties. The average quality of completed tasks recovers later as the technical difficulties are addressed. The recovery happens as the technical difficulties are attended to by the project team, as based on discussions shared with experts in focus group meetings.

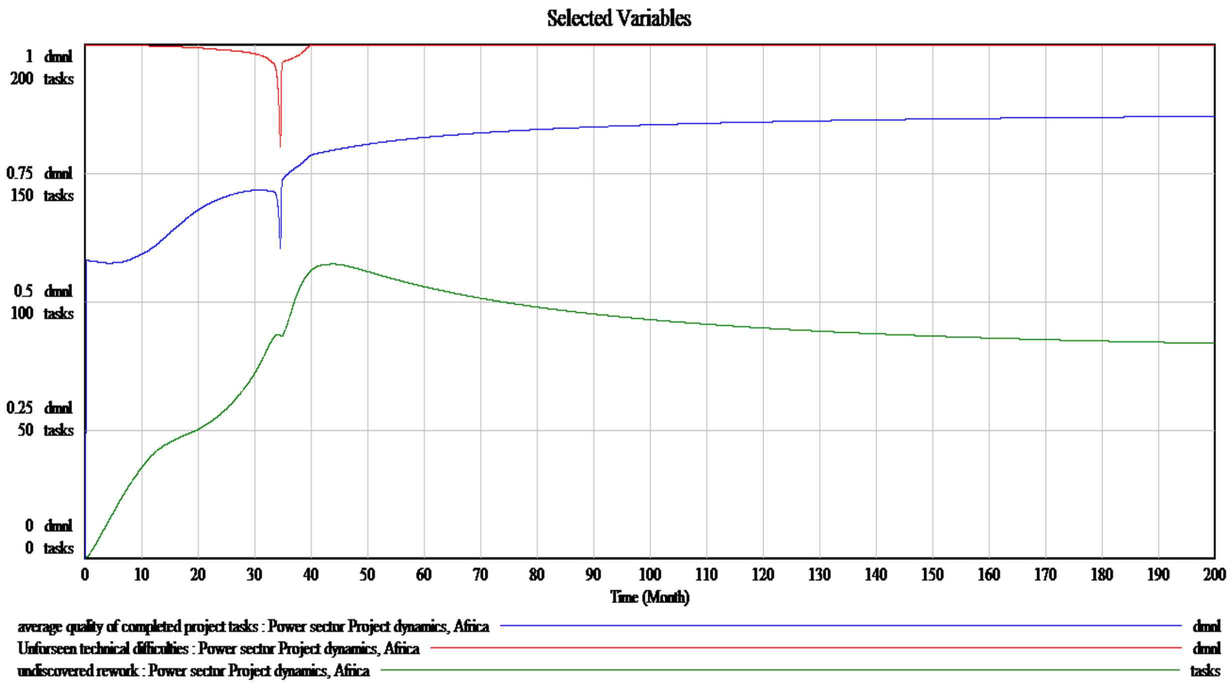

Fig. 5.8: Comparison of trends of average quality of completed project tasks, unforeseen technical difficulties and undiscovered rework

This period in Fig. 5.8 between month 30 and month 50 in the life cycle of the project also sees the undiscovered rework peaking at approximately 115 tasks, and as the rework is detected and attended to by the project team, the average quality rises further.

In the trends shown in Fig. 5.9, poor completion of project tasks is shown in blue colour, proper completion of project tasks in red, project management competence in green, while properly completed project tasks in grey colour. The simulation trends in Fig. 5.9 show that with the level of project management competence at 0.6 (60%), poor completion of project tasks trend is close to the proper completion of project tasks. This leads to rework, which slows down the project, leading to proper completion of project tasks approaching 550 tasks out of the 600 tasks at month 60.

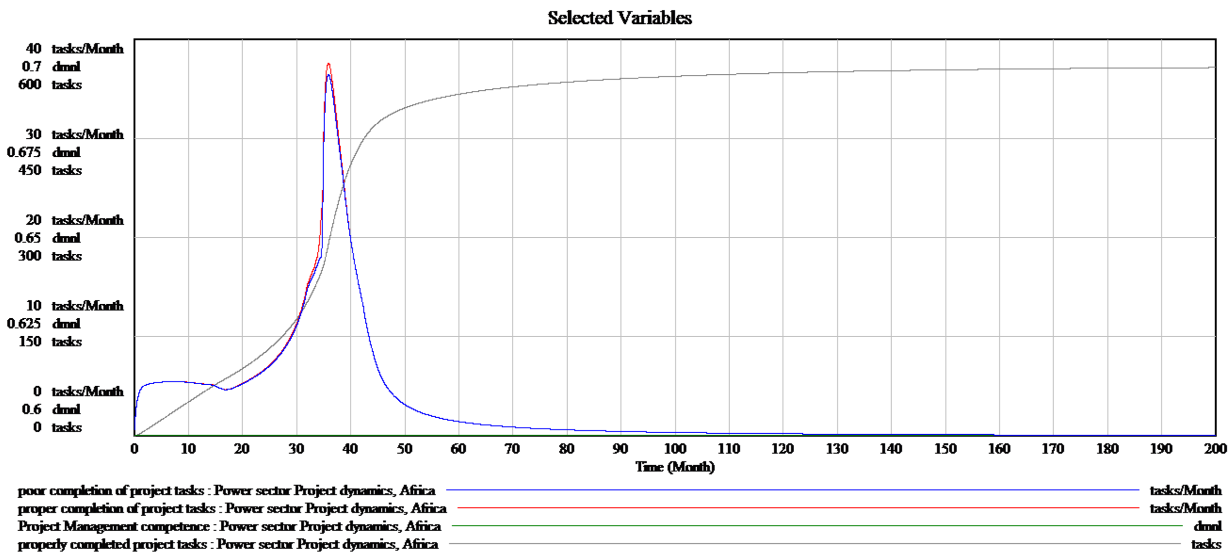

Fig. 5.9: Comparison of trends of poor completion of project tasks, proper completion of project tasks, project management competence and properly completed project tasks

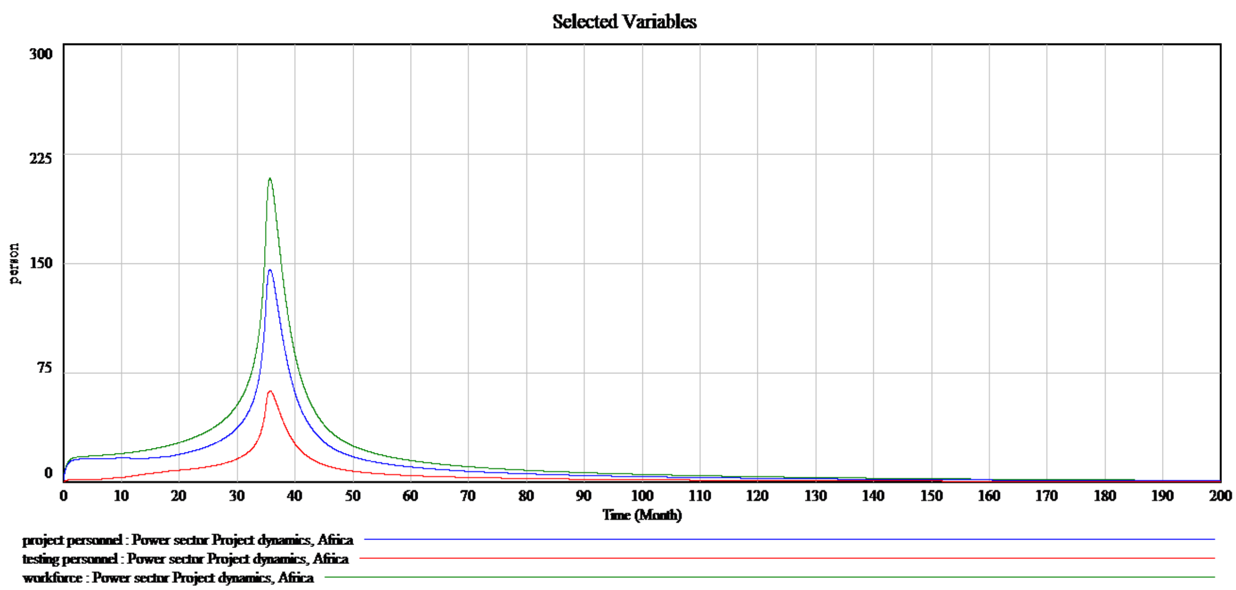

Fig. 5.10: Comparison of trends of project personnel, testing personnel, and workforce

In the trends shown in Fig. 5.10, workforce is shown in green colour, project personnel in blue, while testing personnel is shown in red colour. The simulation trends in Fig. 5.10 show that the workforce, project personnel and testing personnel all rise to a maximum at approximately 34 months to 38 months of project time. This is the time when the project should be nearing completion, yet this is when undiscovered rework also becomes significant, leading to repeat jobs. The workforce is the sum of project personnel and the testing personnel.

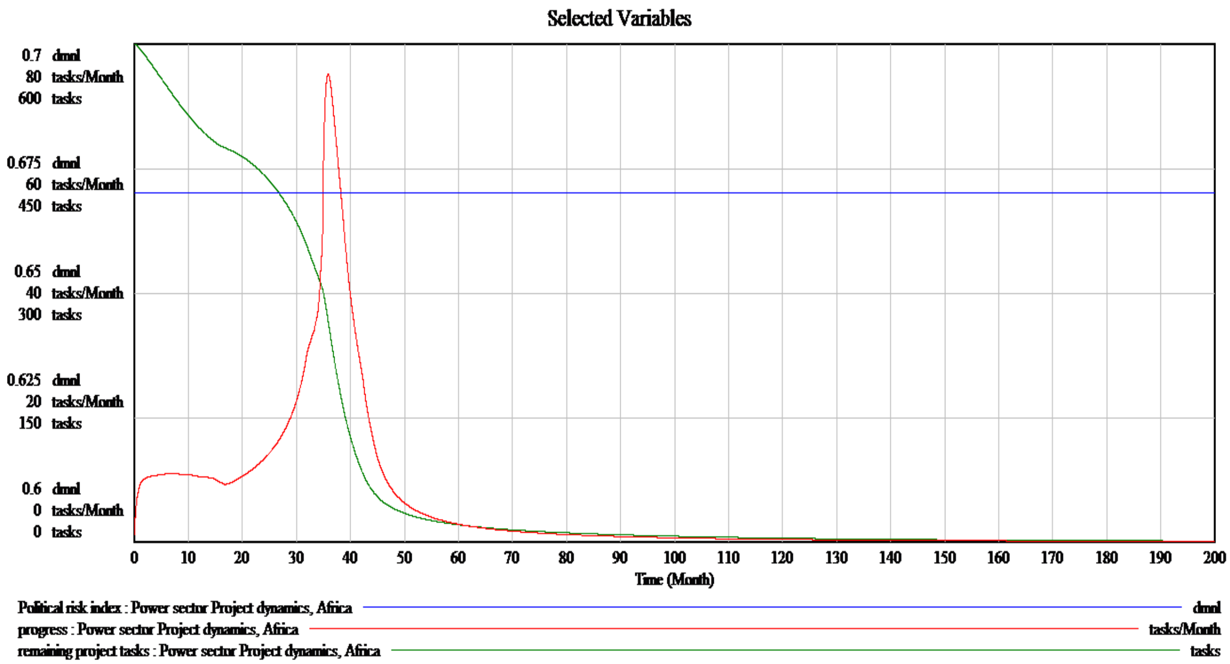

Fig. 5.11: Comparison of trends of political risk, progress, and remaining project tasks

In the trends shown in Fig. 5.11, political risk is shown in blue colour, progress in red, while remaining project tasks is shown in green colour. From the literature in section 2.2.4, political risks may include "ownership and/or personnel restrictions" which may limit the number of competent project staff allowed by the government into the host country. The simulation trends in Fig. 5.11 show that with the political risk at 0.67 (2014) in Kenya, progress in the project starts on a slow note, and only tends to peak between month 30 and month 40, which has a negative effect on the reduction of remaining project tasks, which move from 600 tasks to about 20 tasks in 60 months rather than the anticipated 36 months.

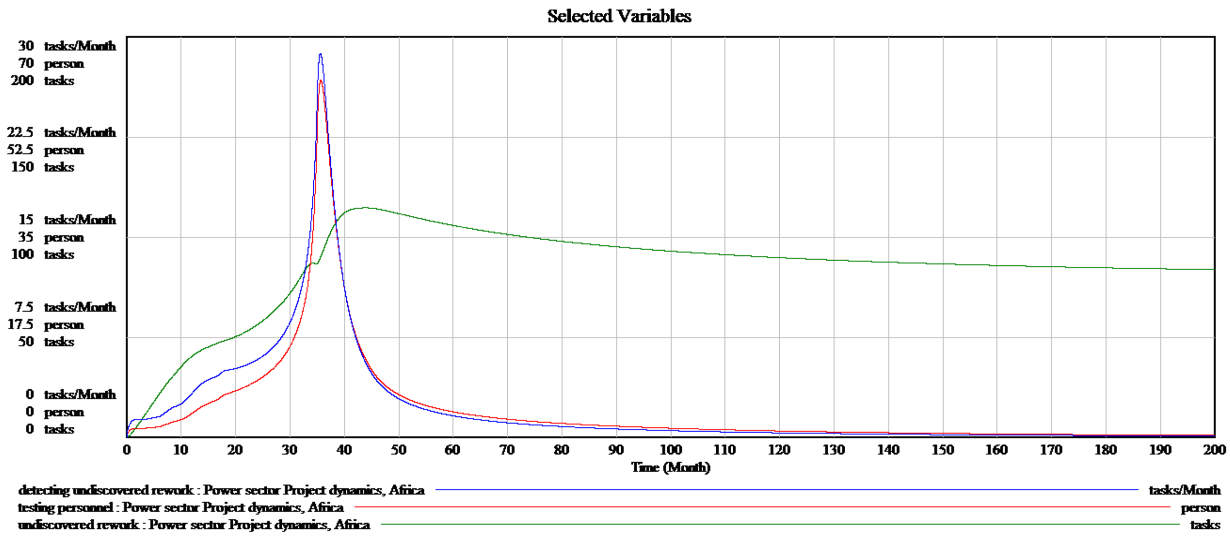

Fig. 5.12: Comparison of trends of detecting undiscovered rework, testing personnel, and undiscovered rework

In Fig. 5.12, detecting undiscovered rework is shown in blue colour, testing personnel in red, while undiscovered rework is shown in green colour. The simulation trends in Fig. 5.12 show that detecting of undiscovered rework rises as the number of testing personnel rises towards the initial project completion time of 36 months, to peak at approximately 35 months of project time. This causes delays in completion of project tasks, as the detection of undiscovered rework creates additional tasks to be done.

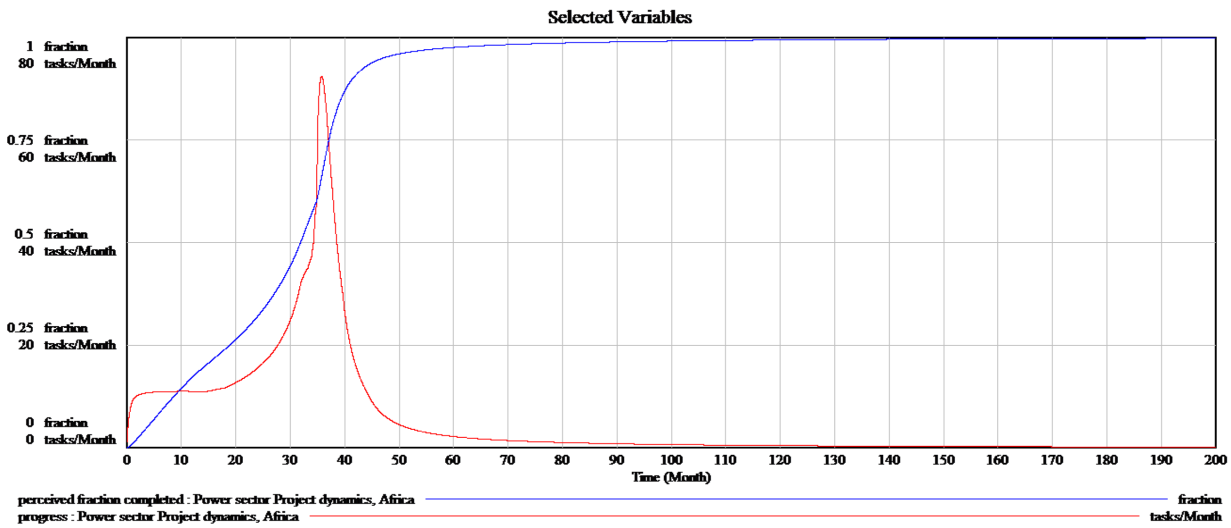

Fig. 5.13: Comparison of trends of perceived fraction completed and progress

In Fig. 5.13, perceived fraction completed is shown in blue colour, while progress is shown in red. The simulation trends in Fig. 5.13 show that progress is slow at the beginning of the projects, but rises sharply to a high at between 30 months and 40 months of project time before slowing down again. Similarly, perceived fraction completed also rises, achieving 0.98 fraction completed by 60 months.

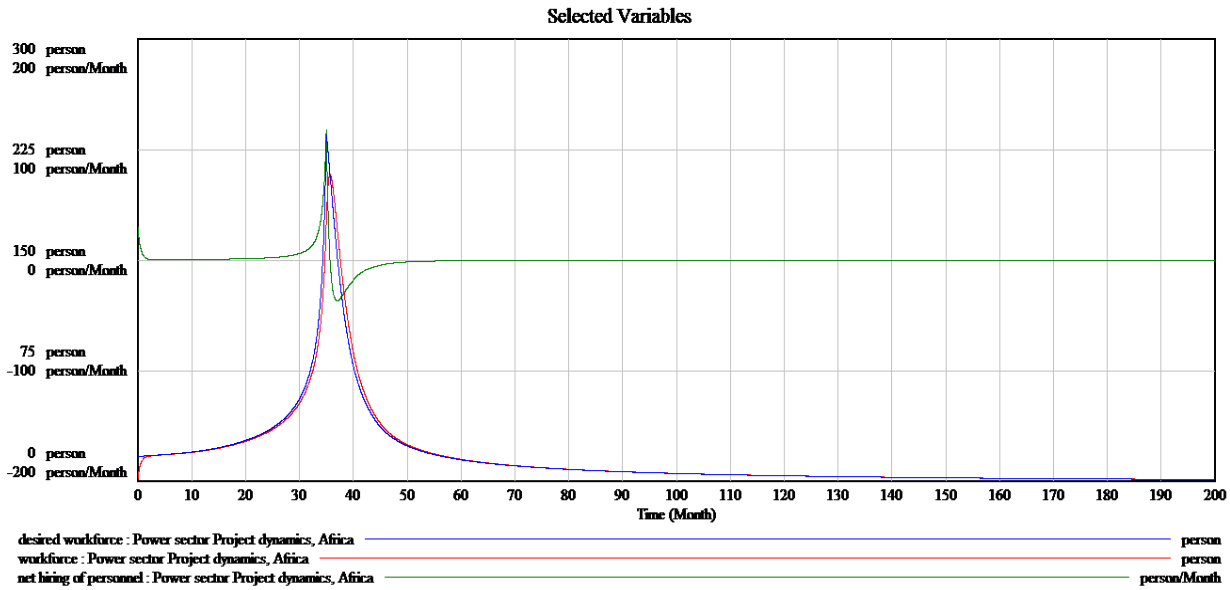

Fig. 5.14: Comparison of trends of desired workforce, workforce and net hiring of personnel

In Fig. 5.14, desired workforce is shown in blue colour, workforce in red, while net hiring of personnel is shown in green. The simulation trends in Fig. 5.14 show that the desired workforce rises and falls with the workforce, and is slightly more than the workforce before the peak, but falls to slightly below the workforce levels after the peak, resulting in a positive trend in net hiring of personnel between 24 months and 34 months of project time and a negative trend in hiring of personnel at between 35 months and 50 months of project time.

All the preliminary simulation results as reported in section 5.3.6 bear a close similarity in trends to the historical reference mode results earlier obtained from historical records of past projects in the electricity sector in Kenya, and are given in Appendix D. This is an indication that the model as developed and presented in Fig. 5.6 has to a great extent captured the dynamics of projects in the electricity sector in Kenya.

5.4 Chapter Summary

For projects in the electricity energy sector in Kenya, common risks that afflict the projects include multitasking, which eats into project lead time and is caused by a shortage of skilled staff in the region, worker fatigue, political risk, and low competence of project teams which affect contract management and administration. The other risks that are prominent are substandard quality of work leading to rework, and frequent scope changes that interferes with the project schedule. Rework causes delays and disruptions in projects, and was mainly caused by shortage of skilled manpower for project delivery, as well as by lack of project management skills within the project team.

The most significant risks at play in the electricity industry project sector in Kenya include political risk that can slow down projects or make them costly, multitasking that occurs as a result of contractors handling too many projects at the same time and in the process, being forced to share key technical personnel from one project to another. Inadequate competence of project staff is also noticeable, as it leads to poor contract management and administration. The results presented in this chapter are the initial simulation results, before model testing and validation.

The main contribution of this research is the development of a System Dynamics model that will be useful for the management of electricity power projects in Kenya and by extension Sub Saharan Africa by enabling stakeholders understand the dynamics at play during the implementation of projects in the sector, and how the risks involved may interact to generate undesirable trends leading to project delays and quality challenges. The behavior of the model provided some insights into the structure of the factors that contribute to the dynamics that lead to project delays in projects in the energy sector in Kenya.

In the following chapter, the basic model is tested and validated, sensitivity analysis is carried out on the model and policy scenarios are presented and evaluated. During the validation of the model, “political risk” and “project management competence” are made endogenous, while two variable equations are corrected based on the results of the tests. The validation process in chapter 6 therefore contributes significantly to the enhancement and improvement of the basic model as given in Fig. 5.6.

CHAPTER 6: Model Testing, Analysis and Policy Design

6.1 Introduction

In this chapter, the basic model of interacting project risks in the electricity sector in Kenya as given in Fig. 5.6, which is an extension of the model by Richardson (2013), is tested as described in the research strategy in section 4.2, as a way of evaluating the effects of interaction of risks under extreme conditions as mentioned under section 3.4. In the energy sector projects in Kenya, this may take the form of interaction among risks due to choice of technical solutions prevalent in fully financed turnkey projects where the financier dictates source of equipment (usually sourced from home country), risks associated with natural calamities such as flooding that renders work sites inaccessible, land acquisition risks due to unpredictable pricing, risks associated to disruption of existing services such as water pipes and fiber optic cables, security to staff and equipment, environmental issues related to right of way and compensation to local communities affected, and political risks such as change of government and the risk of violence during and after elections.

The testing as detailed in this chapter is also part of the process of validating the model, and contributing to the "theory testing" process in the research study. Thereafter, policy scenarios derived from the resulting model are investigated, with the aim of helping stakeholders in the electricity energy sector in Kenya to better manage projects in the energy sector in future, contributing to the "theory building" process of the research. This chapter starts by comparing the basic model structure with the reality as represented by the reference mode graphs in Appendix D which represent insight gained from historical data on past projects in the sector in Kenya as well as mental models arising from interviews with key stakeholders in the sector comprising project engineers and Ministry of Energy personnel. Thereafter, indirect structure tests comprising extreme condition test, boundary adequacy test, numerical sensitivity test and behavior sensitivity test are done.

Behavior pattern tests are then carried out on the basic model involving comparison of the simulated behavior of the basic model to check that it reproduces the behavior as observed in the real system, while also checking for any surprise or anomalous behavior. Sensitivity analysis, which is the study of how uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model input (Khasawneh et al, 2010) then followed, with the objectives of testing the effects of uncertainties in parameter values on the model outcome, and to generate insights about the structure–behavior relation and the real world. Policy scenarios were then explored and analyzed with the aim of generating new strategies and policies that would be useful in reducing delays and quality challenges in projects in the energy sector in Kenya. In this chapter, two sub-set questions as indicated in 1.5(e) and 1.5(f) are answered namely "What policy scenarios derived from the project dynamics in the electricity sector in Kenya can be used to improve project delivery time?" and "What policy scenarios derived from the project dynamics in the electricity sector in Kenya can be used to improve the quality of the delivered projects?" Subsequently, this is used in answering the third research question as indicated in section 1.5 namely "What policy scenarios derived from the resulting model are available that can help stakeholders in the sector to better manage such projects so as to deliver value?"

6.1.1 Model verification and model validation

Several authors have written on the subject of System Dynamics model testing and evaluation, and this research has made reference to Sterman (2000) who published 12 tests for assessment of dynamic models from which this research has borrowed, and Barlas (1996, 2014) who linked the tests as given by Sterman 2000, Ullah 2005, Martis 2006) to the model purpose. The model was tested as per the plan in section 4.8, which is summarized in Fig. 6.1. Model testing consists of model verification and model validation. Model verification refers to testing whether the model is correctly coded or simulated correctly, that is, whether model equations, and the whole model is correctly coded, whether the units are consistent or inconsistent (dimensional analysis), or whether there are numerical errors due to the use of an inappropriate combination of numeric integration method and step size (Pruyt, 2013). On the other hand, model validation refers to the entire range of tests to check whether a model meets the objectives of the modeling study; therefore, validation is really about building confidence in its fitness for purpose, that is, confidence of the modeler or analyst as well as of the client/audience (Pruyt, 2013).

6.2 Direct Structure tests

This test involves comparison of model structure with the reality as represented in the reference mode. It is crucial, yet highly qualitative and informal, and is distributed through the entire modeling methodology (Barlas, 2014). During this research, structure confirmation, dimensional consistency and parameter confirmation tests were done as presented in section 6.2.1 to 6.2.3.

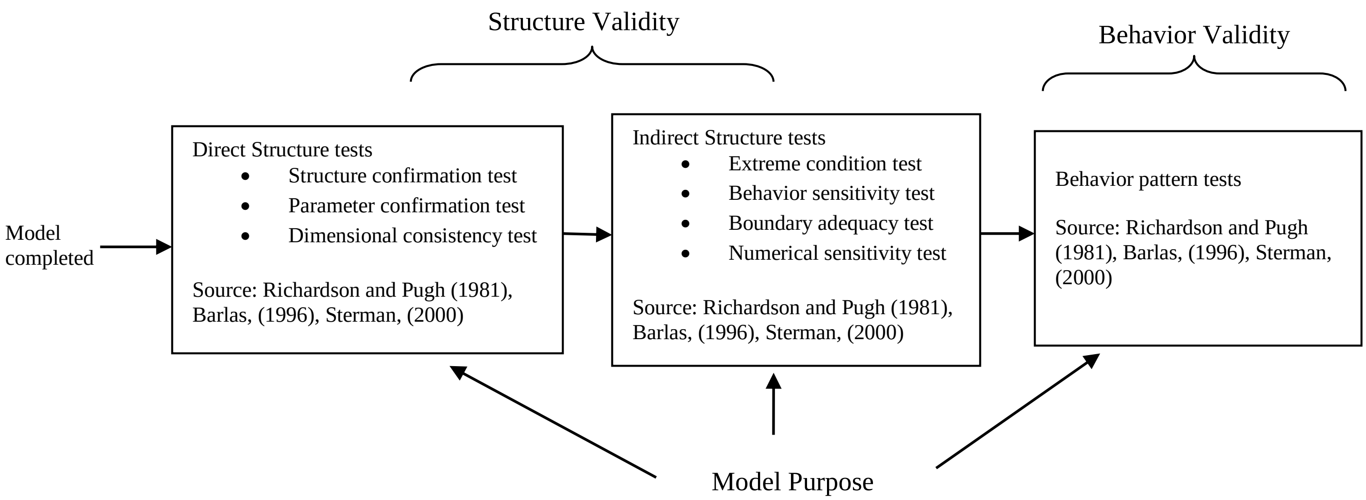

Figure 6.1: Formal Model testing (Evaluation), Barlas (2014).

6.2.1 Structure Confirmation test

Verifying structure means comparing structure of a model directly with structure of the real system that the model represents. To pass the structure verification test, the model structure must not contradict knowledge about the structure of the real system (Forrester and Senge, 1980). This may be done through review of model assumptions by persons highly knowledgeable about corresponding parts of the real system. It may also involve comparing model assumptions to descriptions of decision making and organizational relationships found in relevant literature.

During this research, the basic model was presented at a stakeholder workshop comprising project managers from utility companies in Kenya, project managers from construction companies working in the electricity industry in Kenya, as well as ministry of energy personnel. The model simulation results were compared with a project in the electricity energy sector in

Kenya as described in Appendix K. During the discussions, it was clear that the simulation results from the basic model in figure 6.2, as shown in figures 6.81 to figure 6.90 which show that projects often delay and may be completed in 60 months instead of the planned 36 months, while undiscovered rework remains at a high of about 150 tasks at the end of the project, mirrors the project status report as presented in Appendix K. the results that show that only about 450 tasks out of the original 600 tasks end up as "properly completed project tasks" bears close similarity to the results of the projects under the contract as described in Appendix K which lead to some projects being taken over for completion by the employer as the contractor lacked the capacity to fully complete all the tasks in some of the projects.

The schedule for the workshop is shown in Appendix E, and the questions posed to participants to guide the discussions during the workshop are shown in Appendix F. The structure was explained to all the participants in an open discussion forum, and compared with policy structure diagrams from the electricity utilities in Kenya, contracting firms and ministry of energy. The general agreement was that the model structure as presented adequately represented the reality of projects in the sector.

6.2.2 Dimensional Consistency test

During this test, each equation of the System Dynamics model was checked for dimensional consistency, and care was taken to ensure that equations do not use parameters having no real world meaning. A revealing test, the dimensional consistency test entails dimensional analysis of a model's rate equations.

All equations in the model were checked one at a time and confirmed to have passed the dimensional consistency test. The basic model equations were shown in chapter 5 and summarized in the model representations in Appendix I.

6.2.3 Parameter Confirmation test

Model parameters (constants) can be verified against observations of real life. Parameter verification means comparing model parameters to knowledge of the real system to determine if parameters correspond conceptually and numerically to real life (Forrester and Senge 1980, Oliva 2003, Ullah 2005). Conceptual correspondence means that parameters match elements of system structure, while numerical verification involves determining if the value given the parameter falls within the plausible range of the parameter in real life. Failure to pass the dimensional consistency test often reveals faulty model structure. Sterman (2000) proposes use of judgmental methods based on interviews, expert opinion, focus groups, archival materials, direct experience, etc. to judge and estimate parameter values.

In this research, the model was shared and presented to project managers in the energy sector as well as in a workshop organized for key stakeholders in the industry. The schedule for the workshop is shown in Appendix E, and the questions posed to participants to guide the discussions during the workshop are shown in Appendix F. The discussions and feedback from the stakeholders revealed that the model was conceptually and numerically sound, as the results presented matched the results from the real project environment conceptually and numerically. Further suggestions from the workshop participants were incorporated in the model during the boundary adequacy test, as shown in section 6.3.1.

6.3 Indirect Structure tests

This test includes extreme condition tests and other tests done based on simulated outcomes of the basic model (Barlas, 2014). During this research, Extreme condition, Boundary adequacy, Numerical sensitivity and Behavior sensitivity tests were done as presented in section 6.3.1 to 6.3.4.

6.3.1 Boundary Adequacy test

During this test, the important concepts for addressing the problem were confirmed to be endogenous to the model, the behavior of the model was checked when boundary assumptions of the model were relaxed to see if the behavior would change, and the policy (as defined in section 6.6) recommendations were checked to confirm that they do not change when the model boundary is extended.

According to Forrester and Senge (1980), boundary adequacy can be used as a test in the context of structure, behavior and policy. The boundary adequacy (structure) test considers structural relationships necessary to satisfy a model's purpose. The boundary adequacy asks if the model includes all relevant structure. It involves developing a convincing hypothesis relating the proposed model structure to a particular issue addressed by the model. The evaluator must distinguish questions of boundary adequacy relative to a particular purpose from questions of model purpose so that the model is not extended indefinitely as one incorporates further aspects of real system structure which, even if accurate, are not necessary for the particular purpose. The purpose of this research was to identify the risks present in electricity sector projects in Kenya and the wider Sub Saharan Africa, to reconstruct the dynamics at play using feedback loops and employs system dynamics modeling to study and analyse the project dynamics in the electricity sector projects in the region, with the aim of deriving suitable policies that would benefit such projects in future.

The boundary adequacy (behavior) test considers whether or not a model includes the structure necessary to address the issues for which it is designed. The test involves conceptualizing additional structure that might influence behavior of the model. It would include analyzing behavior with and without the additional structure (Forrester and Senge,1980). During this test, the model was modified to include plausible additional structure, whereby two key constants were made endogenous. "Project management competence" which was originally a constant, was made to vary with the "average quality of completed project tasks". This insight was gained from discussions with stakeholders during the workshop for stakeholders in the electricity sector in Kenya. The schedule for the workshop is shown in Appendix E, and the questions posed to participants to guide the discussions during the workshop are shown in Appendix F. The participants at the workshop suggested that from experience, project management competence tended to increase as the project progresses, and at a rate proportional to the quality of completed project tasks.

The equation for project management competence therefore changed from a constant of 0.6 in the basic model to;

*project management competence =0.75*MAX (average quality of completed project tasks*, 0.1) (6.1)

Similarly, and during the workshop discussions, a suggestion was made by stakeholders to introduce an "insurance index" as a factor of "perceived cumulative progress" and "Political risk index" to allow for "Political risk adjustment" with the following equations;

Insurance index = Political risk index(perceived cumulative progress/MAX (undiscovered rework, 0.01))* (6.2)

Political risk adjustment = Political risk index + insurance index (6.3)

This is intended to encourage progress on the project by introducing an insurance premium pegged on "perceived cumulative progress" so that projects are completed on time, and the contractor can pay less insurance premium by using progress to mitigate the effects of political risk.

The workshop with the stakeholders also indicated that the fraction of *properly completed project tasks* at 0.5 in the basic model was rather low for the projects in the electricity sector in Kenya, and proposed that this fraction would most probably be at approximately 0.7 (70%). The equation for "fraction properly completed" was therefore changed from 0.5 to the following;

Fraction properly completed = 0.7 (6.4)

The resultant new and adapted model is as given in Fig. 6.2. Dimensional consistency test was carried out on the three new equations which passed the test. All subsequent tests that follow in this chapter were done using the model in Fig. 6.2 as the basic model, and the effect of these additions as given in equations 6.1, 6.2, and 6.3 can be seen in section 6.5; "Simulation Results after Model verification and validation", and are captured in Fig. 6.89 and Fig. 6.90.

The sections marked in blue represent portions of the model that were inherited from the basic model by Richardson (2013) as explained in section 5.3, while all the sections marked in red represent the new parts of the model developed in this research based on the views of participants active in the electricity energy sector in Kenya. The model in figure 6.2 therefore is an expansion and extension of the previous model by Richardson by including variables such as political risk, unforeseen technical difficulties, and project management competence that present significant dynamics to projects in the electricity sector in Kenya and by extension, to the wider Sub Saharan Africa region.

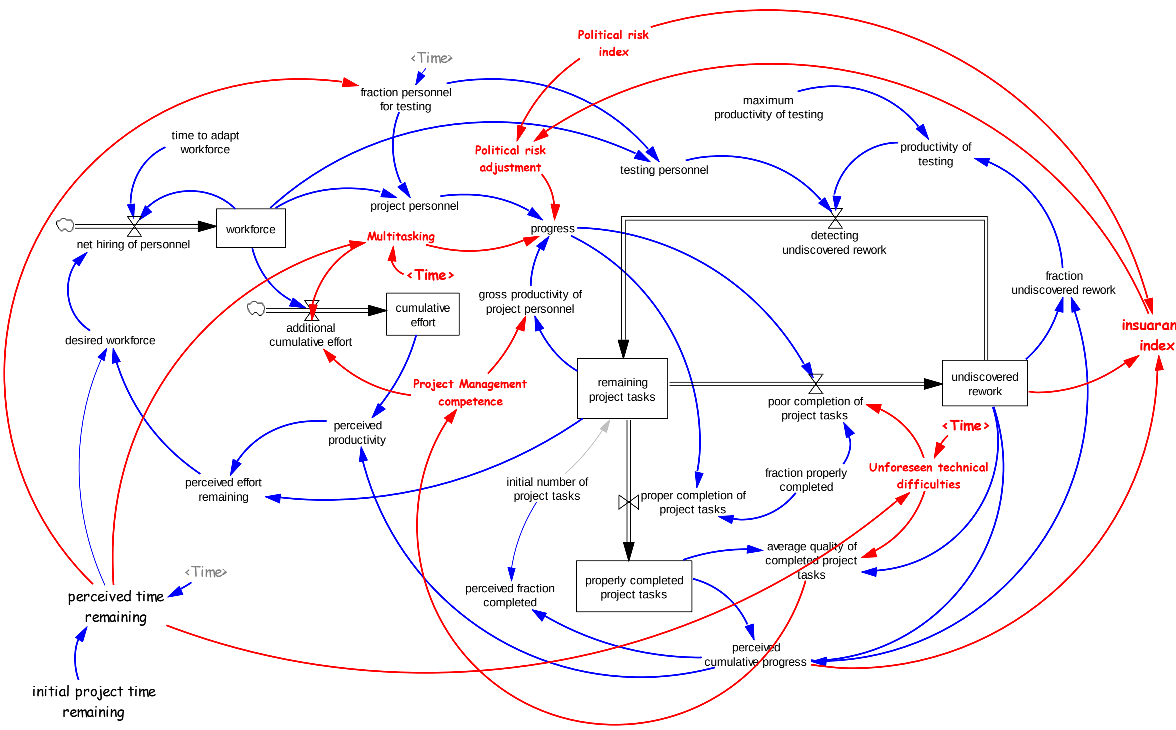

Fig. 6.2: Basic model with Political risk & Project Management competence made endogenous

6.3.2 Extreme Condition test

During this test, inputs to each equation were given extreme values such as 0, 1, 100%, 1,000,000 and the basic model simulated to check that the equations still made sense. Further, the model was subjected to extreme policies, shocks and parameters and the model response in each case checked to ascertain that results were reasonable and made sense. When extreme values are assigned to each equation, the whole model is run in each instance to give the results as indicated in Fig. 6.3 to Fig. 6.66.

According to Forrester and Senge (1980), much knowledge about real systems relates to consequences of extreme conditions and a model should be questioned if the extreme conditions test is not met. These views are shared by Ullah (2005) and Martis (2006). During the test, each rate equation (policy) in a model was examined, traced back through any auxiliary equations to the levels (state variables) on which the rate depends, implications of imaginary maximum and minimum (very small values, zero, very large values) considered of each state variable and combinations of variables to determine plausibility of the resulting rate equation. The extreme conditions test is powerful for discovering flaws in model structure, and it can also reveal omitted variables. The second reason for using extreme condition tests is to enhance usefulness of a model for analyzing policies that may force a model to operate outside historical regions of behavior. By examining model structure for extreme conditions, one develops confidence in a model's ability to behave plausibly for a wide range of conditions and therefore enhances the models usefulness to explore policies that move the system outside of historical ranges of behavior (Sterman 2000, Ullah 2005, Martis 2006). The basic model in Fig. 6.2 was used during these tests.

Model parameters and variables are interlinked with each other and in setting model variables to extreme values such as 0 or 1 therefore essentially means converting the model variable to a constant. As an example, "Unforeseen technical difficulties" is modeled as a non-linear function of time as given in equation 6.4. In setting "Unforeseen technical difficulties" to zero in the Vensim model in figure 6.2, the equation function for "Unforeseen technical difficulties" is opened, the "check units" is changed from "With Lookup" to "Normal", and the resultant equation is set to "0". The model is then simulated. The same procedure is followed when setting "Unforeseen technical difficulties" to a constant of "1".

Results – Extreme condition tests

In this research, "*Unforeseen technical difficulties*" is modeled as a non-linear function of time. The simulation trend for *Unforeseen technical difficulties* as presented in equation 6.4 was developed based on archival data from past projects in the electricity sector in Kenya, and was shared with participants at a workshop during model validation.

Unforeseen technical difficulties = WITH LOOKUP (Time, ([(0,0)-(60,10)],(0,1),(2,0.99),(6,0.98),(10,0.97),(14,0.96),(16,0.95),(20,0.9),(24,0.8),(26,0.8),(28,0.92), (30,0.95),(36,0.97),(36,0.97),(38,0.98),(40,1),(44,1),(48,1),(52,1),(54,1),(60,1),(200,1)) (Units: dimensionless) (6.5)

"Unforeseen technical difficulties" as used in the model refers to technical problems that arise late in projects in the electricity sector in Kenya and Sub Saharan Africa, which are made worse by the shortage of technical expertise in the form of project commissioning engineers or testing engineers critical in unearthing technical hitches early enough in the project so that they are addressed as the project progresses. In modeling this variable, the equation is formulated so that the ideal case is achieved when *"Unforeseen technical difficulties"* is at 1, meaning all technical difficulties would be seen and dealt with so that "*poor completion of project tasks"* would reduce to a minimum. The worst case scenario is when "*Unforeseen technical difficulties" is at "0"*, meaning all technical difficulties would pass unseen, and "*poor completion of project tasks"* would be high.

When "*Unforeseen technical difficulties"* is set to zero and the basic model is simulated, "*poor completion of project tasks"* stays at zero as shown in figure 6.3 in blue colour. This does not make sense, since "*Unforeseen technical difficulties"* being zero would mean technical difficulties are not seen at all, and the "*poor completion of project tasks*" should be high, as well as "*undiscovered rework*".

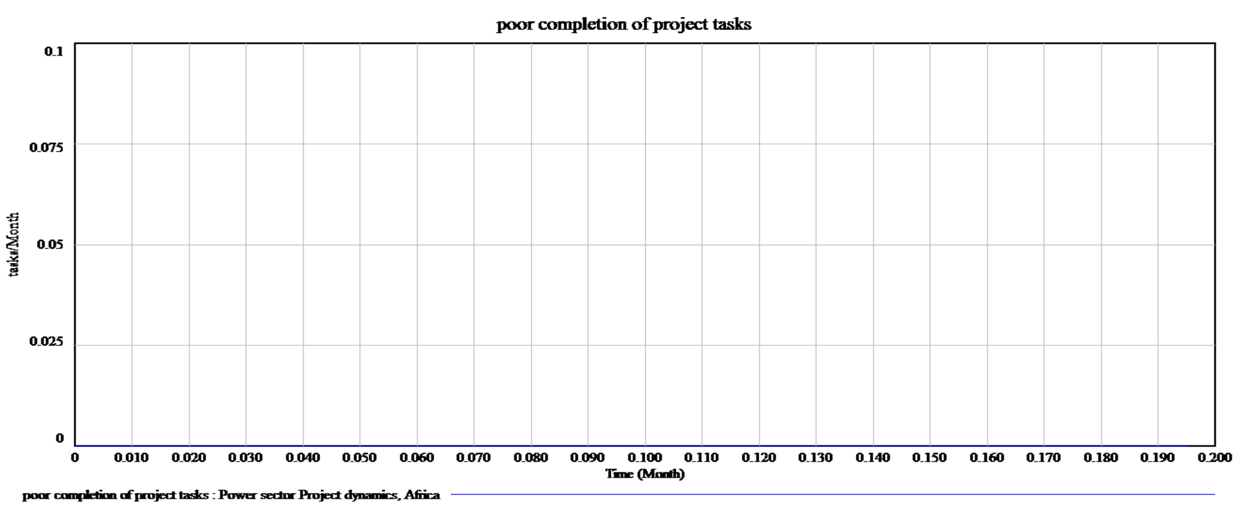

Figure 6.3: Simulation results when unforeseen technical difficulties is set to 0.

The equation:

Poor completion of project tasks = progress(1 - fraction properly completed)*Unforeseen technical difficulties* (6.6)

Is therefore not correct, and is hereby corrected to read:

Poor completion of project tasks = progress(1 - fraction properly completed)/Unforeseen technical difficulties* (6.7)

The equation is corrected in the model in Fig. 6.2, and now, when "*Unforeseen technical difficulties"* is set to 0.000000001and the basic model is simulated, the results are as shown in figure 6.4 where "*poor completion of project tas*ks" (in red colour) starts at a high of 270 million tasks/month, while "*undiscovered rework"* (in green colour) rises to 1 million tasks in 0.007 months. This is a reasonable expectation. Simulation results when "*Unforeseen technical difficulties"* is set to 0.05 are given in Appendix P that clearly shows the nonlinear relationship in the results.

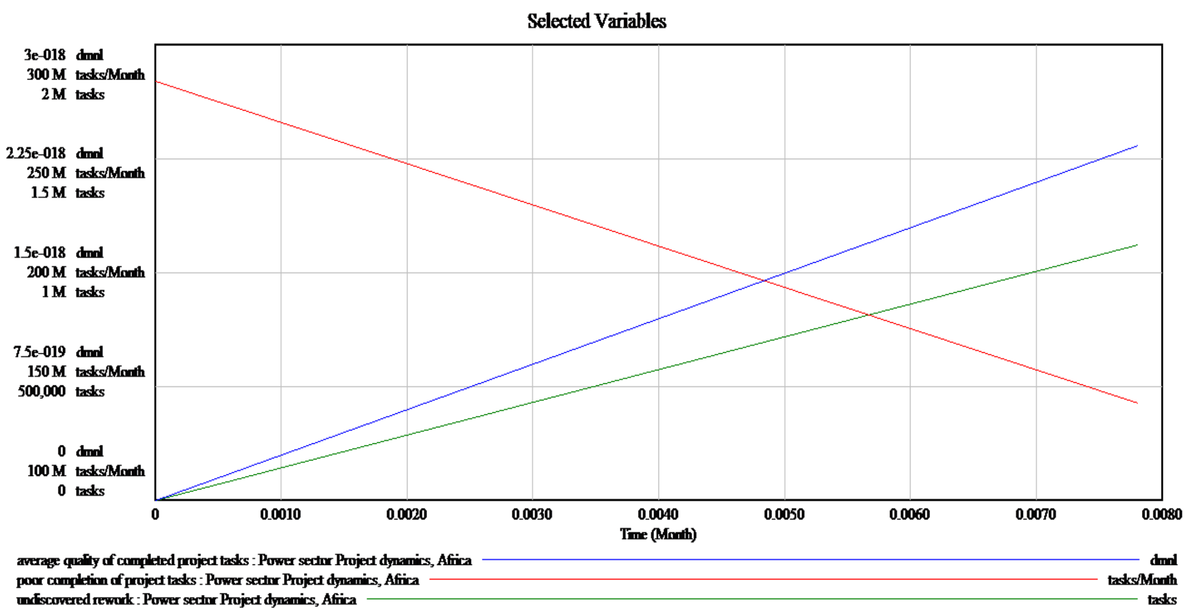

Figure 6.4: Simulation results when unforeseen technical difficulties is set to 0.000000001.

When "*Unforeseen technical difficulties"* is set to 1 and the basic model is simulated, the results are as shown in figure 6.5 where "*poor completion of project tas*ks" (in red colour) rises to a high of 18 tasks/month at about project time 36 months, while *undiscovered rework* (in green colour) rises to about145 tasks at project time 58 months. This mirrors the results from projects in the energy sector in Kenya, and the projects under Appendix K bear similarities to these results. All subsequent simulations that follow are done using the basic model in Fig. 6.2 after incorporation of the correction on the equation for "*Poor completion of project tasks"* as given in this section.

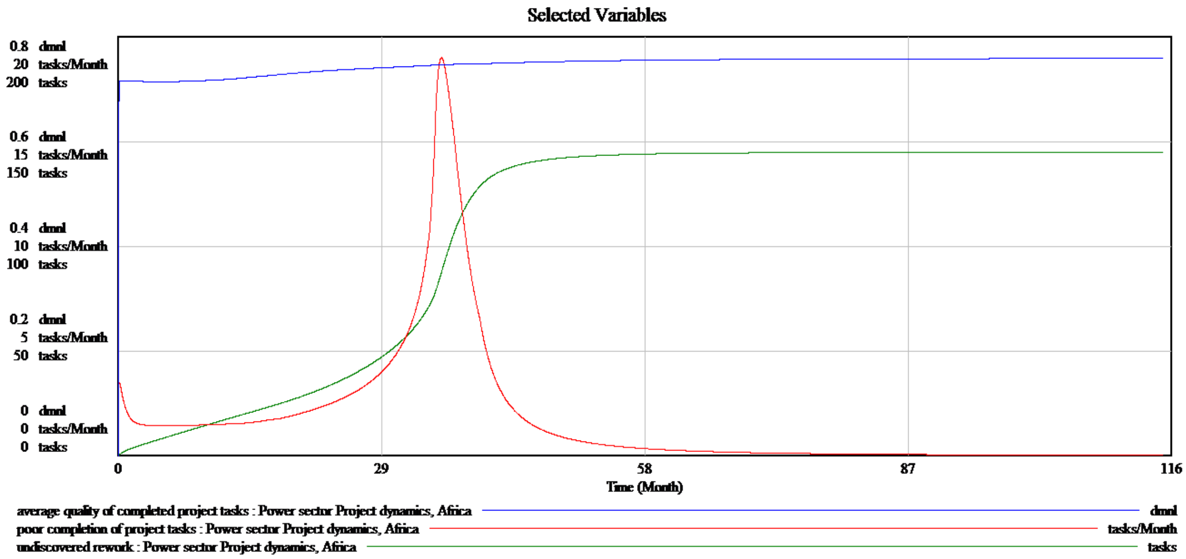

Figure 6.5: Simulation results when unforeseen technical difficulties is set to 1.

The perceived productivity corresponds to the perceived cumulative progress over the cumulative effort delivered, and is modeled as; *perceived productivity = perceived cumulative progress/cumulative effort (units: tasks/person/Month)*

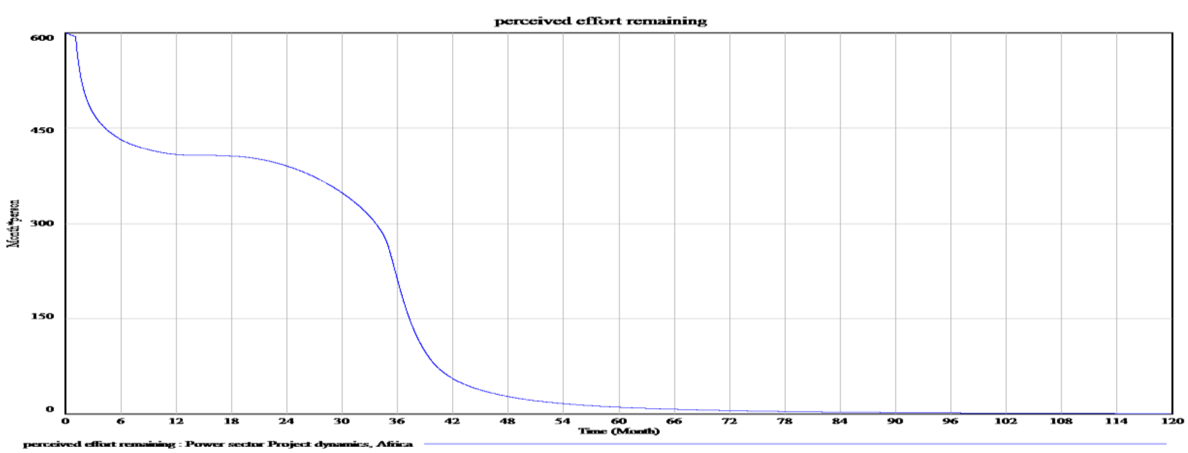

Figure 6.6: Simulation result for perceived effort remaining in the basic model

From the basic model, the simulation result for the "perceived effort remaining" is as shown in figure 6.6 in blue colour, and the logic used in developing this equation is given in the narrative for equation 5.16, and represents the perceived effort required to the completion of the project. When *"perceived productivity"* is fixed at 0 tasks/person/Month and the basic model is simulated, the "*perceived effort remaining"* curve shown in figure 6.7 in blue colour is fairly similar to the curve in figure 6.6, and does not show noticeable changes.

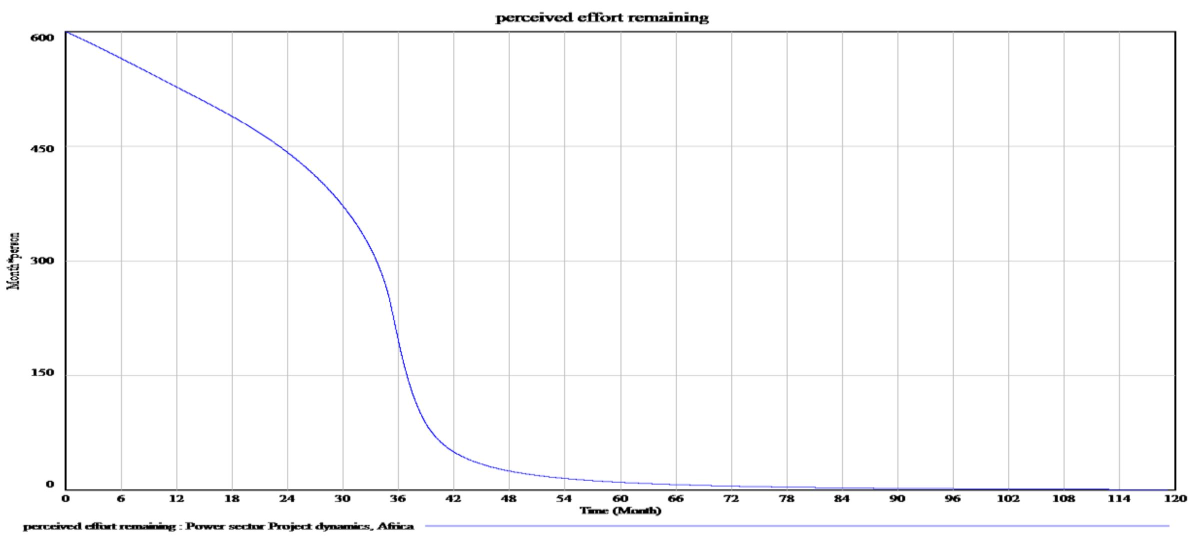

Figure 6.7: Simulation result for perceived effort remaining when perceived productivity is set at 0 in the basic model

This is because in the equation; *perceived effort remaining = Remaining project tasks /MAX(perceived productivity, 1)* (6.8)

"perceived productivity" is between 0.9 and 1.3 tasks/person/month in the basic model, and the 'MAX' function rounds the "*perceived productivity"* to 1 in the model whenever it is between 0.9 and 1 task/person/month, which is 80% of the time.

The equation is therefore adapted, refined and changed to the following:
perceived effort remaining = Remaining project tasks /MAX(perceived productivity, 0.05) (6.9)

And now when *"perceived productivity"* is fixed at 0 tasks/person/Month and the basic model is simulated, the results as shown in figure 6.8 indicate that "*desired workforce"* (in blue colour) initially rises to 43 persons, *"workforce"* (in red colour) then rises to a peak of 35 persons, *"net hiring of personnel"* (in green colour) rises initially to about 80 persons/month, and *"progress"* (in grey colour) rises to a peak of 95 tasks/month before dropping off. This is a reasonable expectation.

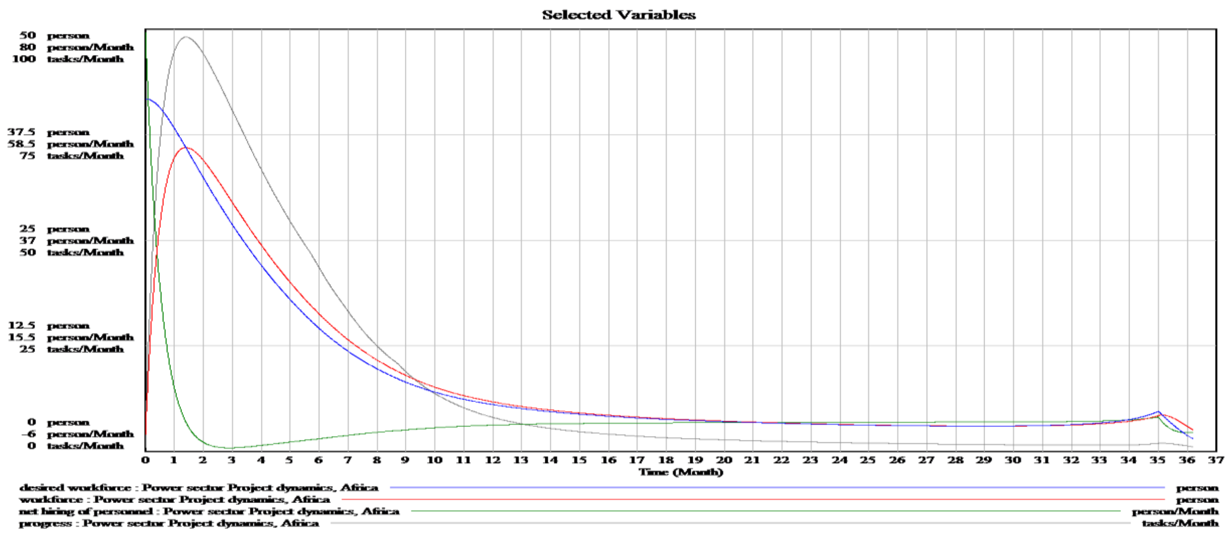

Figure 6.8: Simulation results when perceived productivity is set at 0 tasks/person/month

When *"perceived productivity"* is fixed at 1,000,000 tasks/person/Month and the basic model is simulated, the results as shown in figure 6.9 indicate that the "perceived effort remaining" (in blue colour) drops sharply to zero, while the "workforce" (in red colour) also drops from the initial 2 persons to zero. This is a reasonable expectation when "*perceived productivity"* is so high.

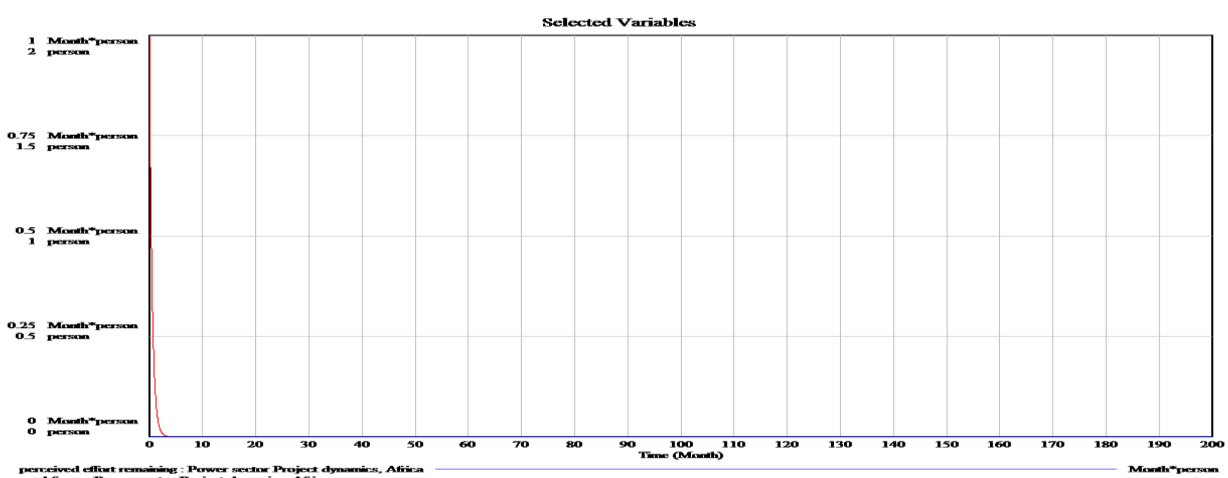

Figure 6.9: Simulation results when perceived productivity is set at 1,000,000 tasks/person/month

All subsequent simulations that follow are done using the basic model in Fig. 6.2 after incorporation of the correction on the equation for "*Perceived effort remaining*" as given in this section.

From the exploratory study results (Appendix B), political risk was perceived to affect progress of projects in the energy sector by slowing progress. Data over the past five years of the Political Risk Index (Political Risk Services, 2014) gives an average index of 67% for Kenya over the four year period from 2011 to 2014 (Appendix H, rank 65). In the definition of political risk index, the lowest risk is 100% (theoretically, this represents countries with no political risk) while the highest risk is at 0 (theoretically, this represents countries with the highest political risk). The average time frame for mega projects in the electricity industry in Kenya at bidding is 36 months. Political risk index changes minimally during this period as shown in Appendix H where the average for the political risk index for Kenya for the years 2011 (0.66), 2012 (0.67) and 2013 (0.67) comes to 0.667, and therefore the political risk index is modeled as a constant of 0.67.

Political risk index = 0.67 (units: dimensionless) (6.10)

When *"Political risk index"* is set to zero and the basic model is simulated, the results as shown in figure 6.10 reveal that "*poor completion of project tasks*" (blue colour), *"progress"* (red colour), *"proper completion of project tasks"* (green colour) all remain constant at zero, while *remaining project tasks* (grey colour) stays constant at 600 tasks. This is a reasonable expectation in real life, since a political risk index of zero represents a chaotic situation in which no project can progress.

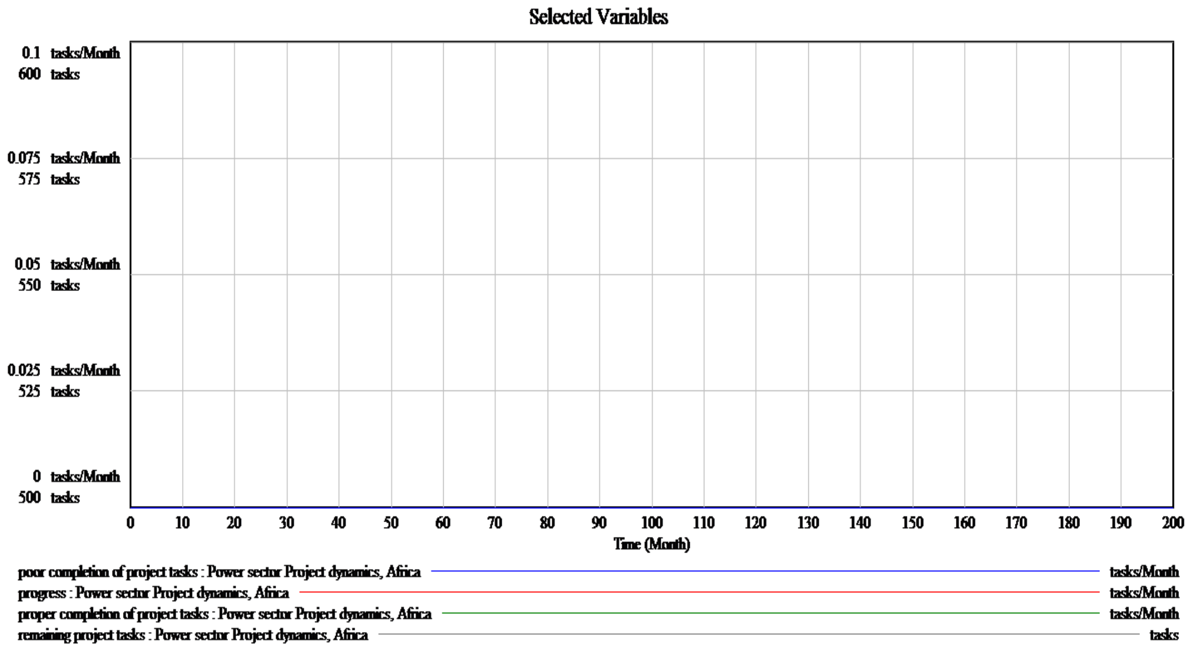

Figure 6.10: Simulation results when Political risk index is zero.

When "*Political risk index"* is set to 1 and the basic model is simulated, the results as shown in figure 6.11 reveal that "*poor completion of project tasks"* (blue colour) peaks at about 18 tasks/month during month 36 of the project, *"proper completion of project tasks"* (red colour) peaks at about 44tasks/month during month 36 of the project, "*remaining project tasks"* (grey colour) reduces from 600 tasks at project time zero to about zero tasks at project time 55 months, while "*properly completed project tasks"* (green colour) rises to about 440 tasks at project time 55 months. This is a reasonable expectation in real life projects in the sector, since a political risk index of '1' represents a perfect situation in which there is no political risk at all.

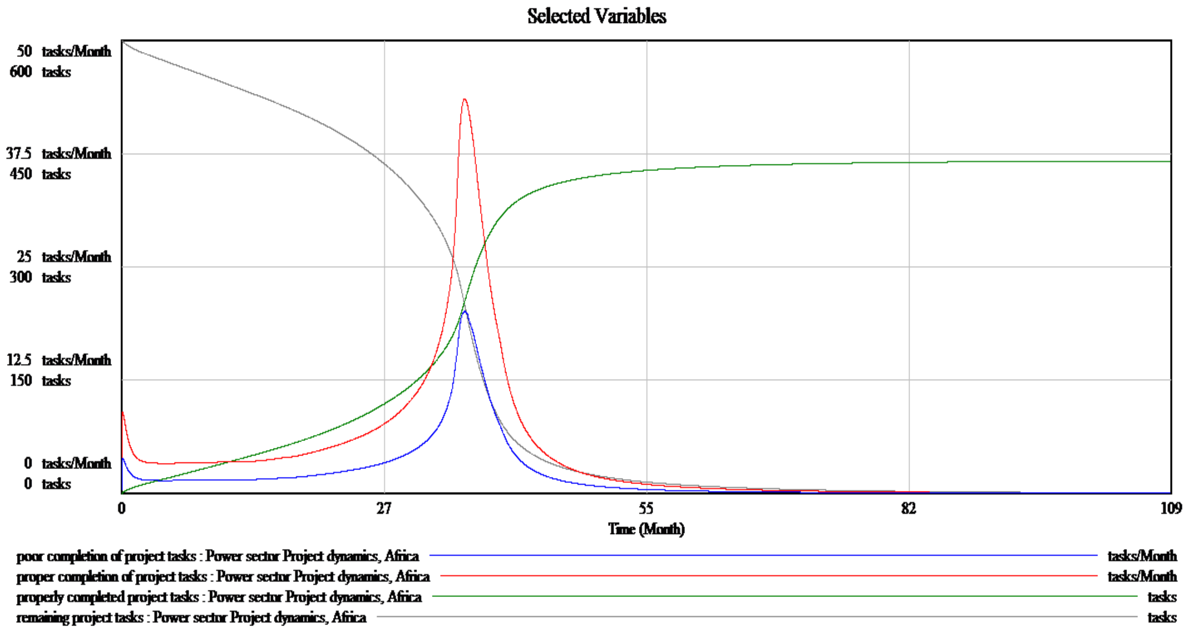

Figure 6.11: Simulation results when Political risk index is 1 (100%).

Projects in the energy sector in Kenya witness multitasking by the contractors due to shortage of skilled staff (see Appendix B), and this is prevalent as the project nears the projected completion time, when the need for commissioning and testing engineers is critical. However due to the shortage of qualified commissioning engineers, the few available engineers are shared between projects, and this often causes delays. To capture the interviewees' sentiments in the model which suggested that multitasking in electricity sector projects in Kenya is often prevalent and significant between the 34th month and the 36th month of project time, multitasking in this research is modeled as a non-linear function of time, as a Lookup function, varying between 0 (maximum multitasking) and 1(no multitasking);

Multitasking = WITH LOOKUP (Time,

([(0,0)-

(52,10)],(0,1),(4,1),(8,1),(12,0.85),(16,0.75),(20,0.7),(24,0.7),(28,0.65),(32,0.65),(36,0.75),

(40,0.8),(44,1),(48,1),(52,1),(200,1)) (Units: dimensionless) (6.11)

When *"Multitasking"* is set at 0.0001 and the basic model is simulated, this represents the highest level of multitasking which ordinarily would slow down the project considerably. The "*progress*" (green colour) is slow as indicated in figure 6.12, and the "*remaining project tasks*" (grey colour) stays fairly constant for the initial 36 months before reducing slowly, while the *"perceived effort remaining"* (red colour) also stays constant for the initial 36 months before falling at a slow pace. This is a reasonable expectation in real life projects.

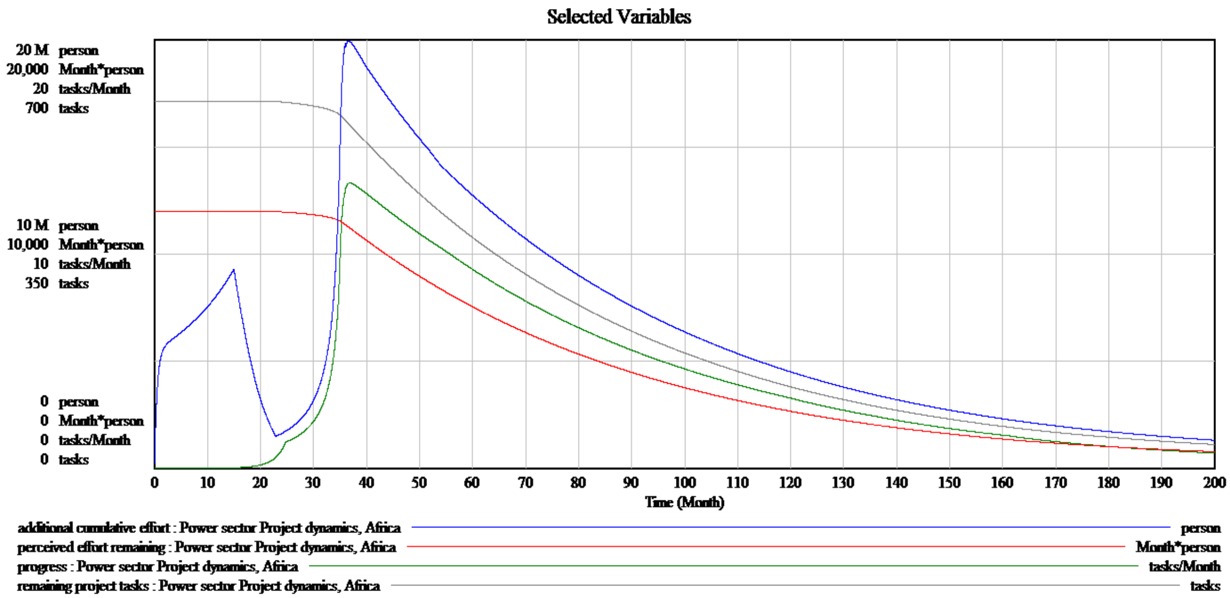

Figure 6.12: Simulation results when Multitasking is 0.0001.

When *"Multitasking"* is set at 1 and the basic model is simulated, this represents the lowest level of multitasking. The project progresses as shown in figure 6.13, and the "*remaining project tasks"* (green colour) reduces from 600 tasks to about zero in 60 months when the project ends. This is a reasonable expectation in real life projects in the sector.

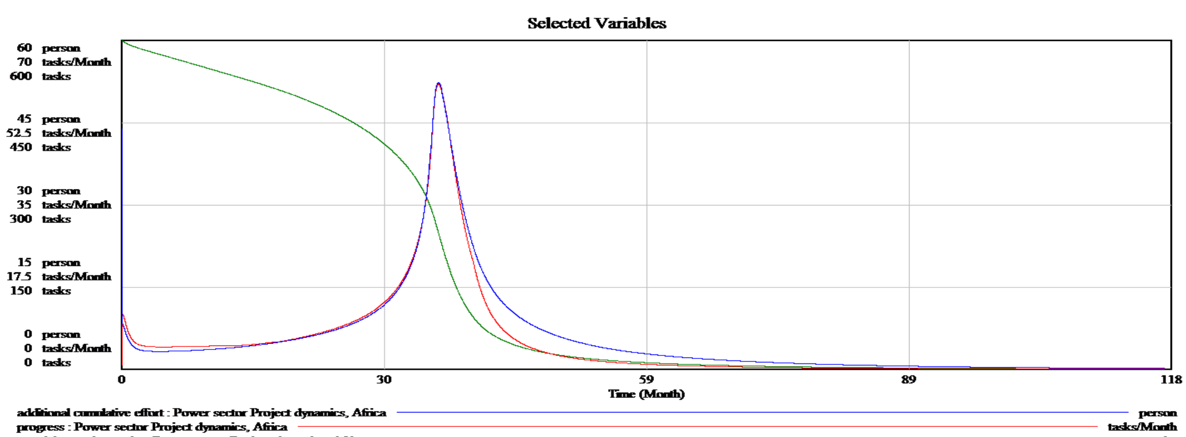

Figure 6.13: Simulation results when Multitasking is set to 1.

Project Management competence is modeled as a function of average quality of completed project tasks;

*Project Management competence = 0.75*MAX (average quality of completed project tasks, 0.1) (units: dimensionless)* (6.12)

When "*Project Management competence*" is set at 0.00000001 and the basic model is simulated, the "*gross productivity of project personnel*" will be very low as shown in figure 6.14 in red colour, while the "*perceived productivity*" (green colour) stays at zero tasks/person/Month. This is a reasonable expectation in real life projects in the sector.

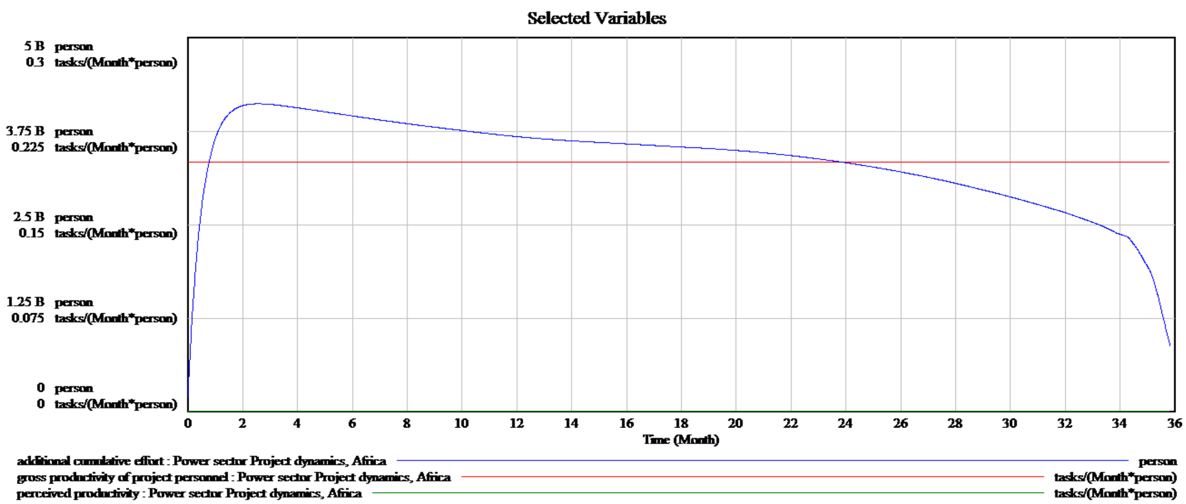

Figure 6.14: Simulation results when project management competence is set to 0.00000001.

When "*Project Management competence*" is set at 1 and the basic model is simulated, the "*gross productivity of project personnel*" (red colour) rises to about 1 task/person/month as shown in figure 6.15, while the "*perceived productivity*" (green colour) rises to about 2.5 tasks/person/month. This is a reasonable expectation in real life projects in the sector.

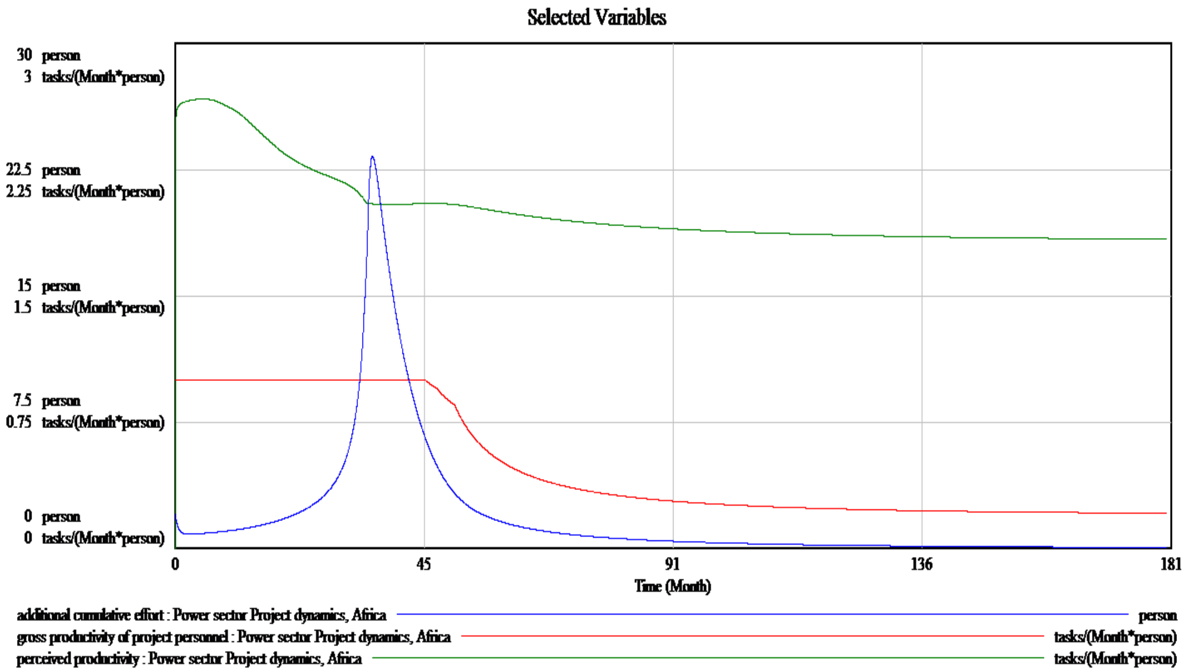

Figure 6.15: Simulation results when project management competence is set to 1.

The initial number of project tasks is modeled as a constant of 600 tasks in this research. This is because projects in the electricity energy sector in Kenya have approximately 600 tasks to be accomplished from start to end of the project.

initial number of project tasks = *600 (units: dimensionless).* (6.13)

When *"initial number of project tasks"* is set to a minimum of 1 task and the basic model is simulated, the results are as shown in figure 6.16 where the "*workforce"* (green colour), starting at 2 persons quickly drops to 1 person in the first month of project time, while the "*perceived fraction completed"* (blue colour) rises to 1 (100%) at project time 38 months, and the "*remaining project tasks"* (red colour) drops from 1 task to zero at project time 38 months. This is a reasonable expectation in real life projects.

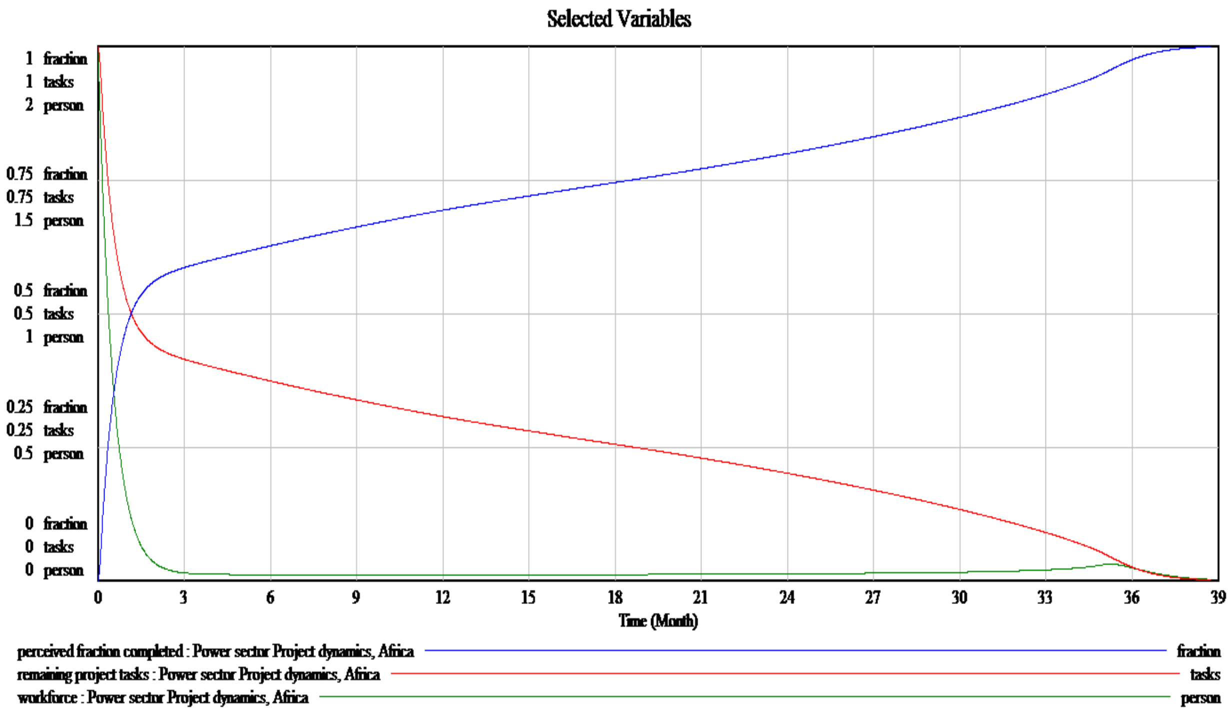

Figure 6.16: Simulation results when initial number of project tasks is set to '1' task.

When *"initial number of project tasks"* is set to 10,000 tasks and the basic model is simulated, the results are as shown in figure 6.17 where the "*properly completed project tasks"* (red colour) rises to about 7,500 project tasks at project time 55 months, while the "*perceived fraction completed"* (blue colour) rises to 1 (100%) at project time 55 months, and the "*remaining project tasks"* (green colour) drops from 10,000 tasks to zero at project time 55 months when project is completed. This is theoretically a reasonable expectation from projects in the sector where some tasks remain without being properly completed at project completion time, hence the difference between "*properly completed project tasks"* at time zero and "*remaining project tasks"* at time 55 months.

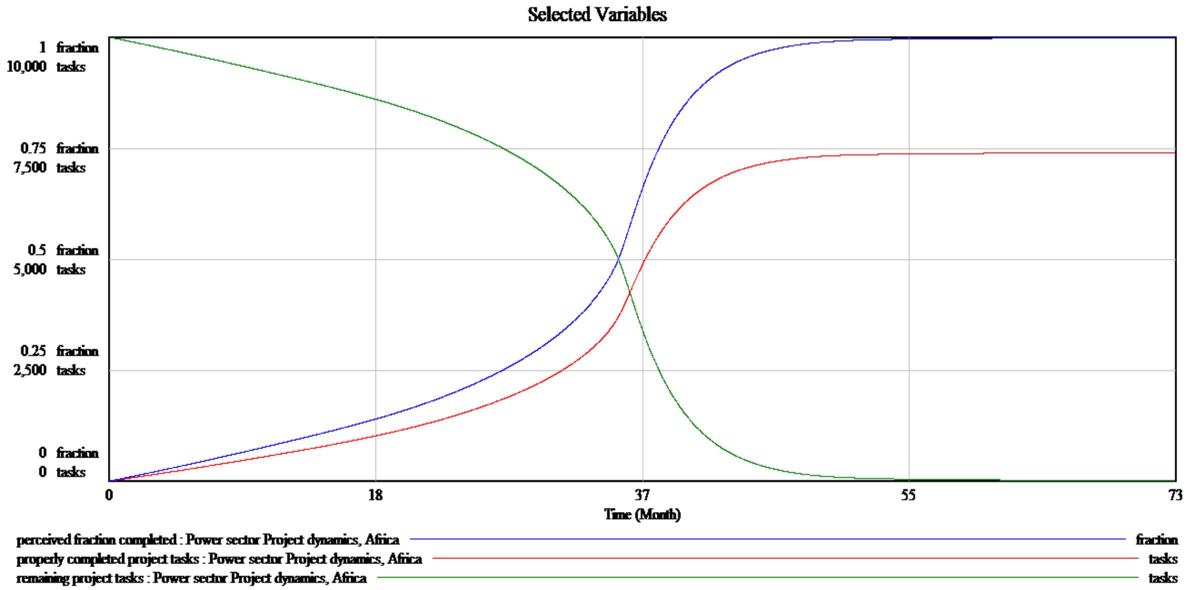

Figure 6.17: Simulation results when initial number of project tasks is set to 10,000 tasks.

"Proper completion of project tasks" is modeled as = *progress*fraction properly completed (units: tasks /month)*

When *"Proper completion of project tasks"* is set at 0.0833 tasks/month (equivalent to 1 task per year) and the basic model is simulated, the results as shown in figure 6.18 indicate that *"properly completed project tasks"* (blue colour) remains low and rises to only about 15 tasks at month 180 of project time. This is a reasonable expectation.

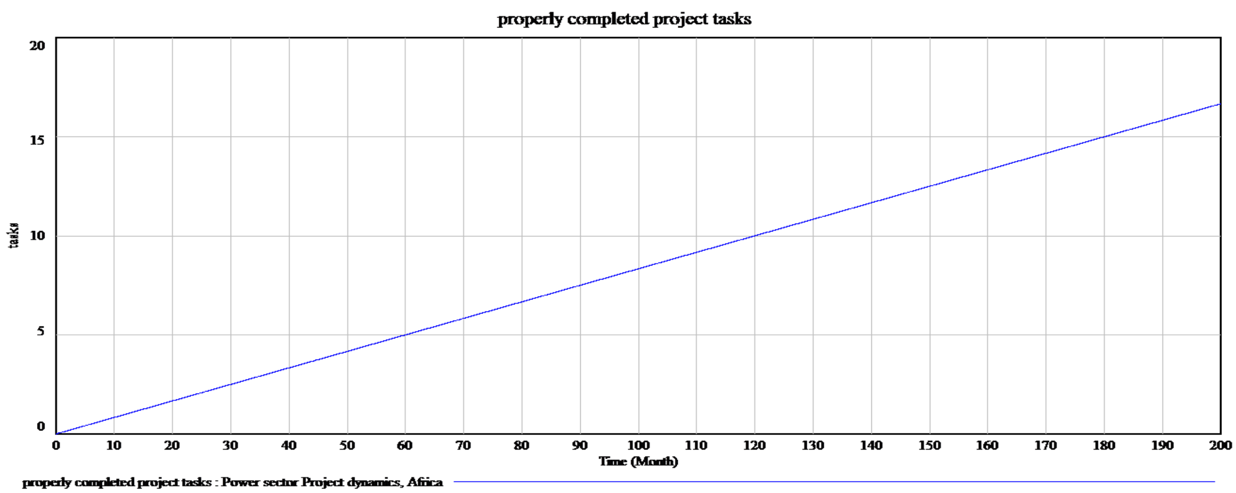

Figure 6.18: Simulation results when proper completion of project tasks is set to 0.08333 tasks/month (equivalent to 1 task/year).

When *"Proper completion of project tasks"* is set at 600 tasks/month and the basic model is simulated, the results as shown in figure 6.19 indicate that *"properly completed project tasks"* (red colour) rises from 0 to 600 tasks in 1 month of the project time. At the same time, the *"average quality of completed project tasks"* (blue colour) stays high at about 0.95 as shown in figure 6.14. This is a reasonable expectation.

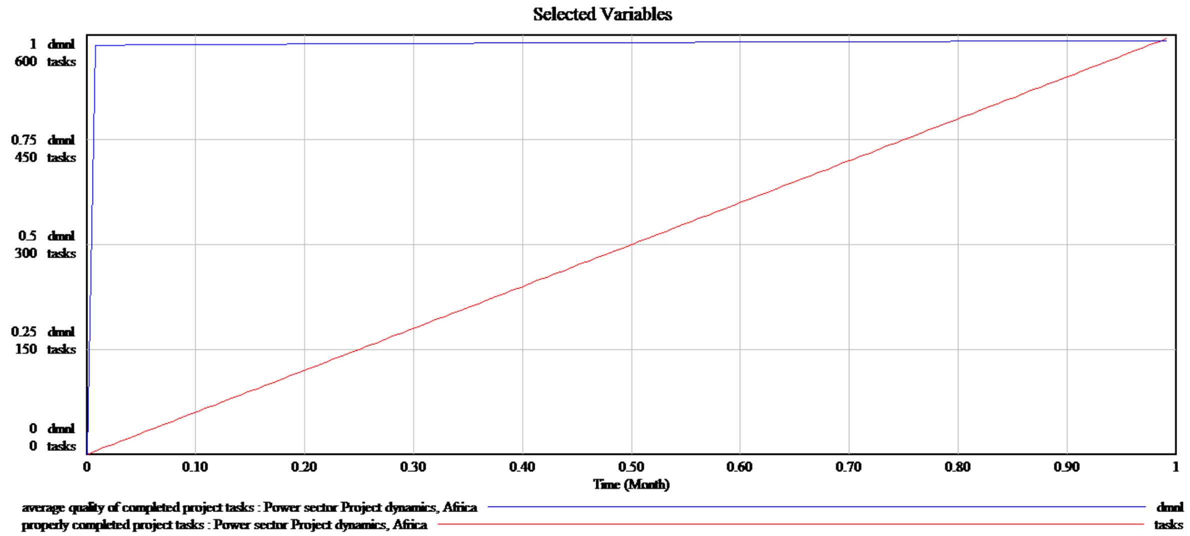

Figure 6.19: Simulation results when proper completion of project tasks is set to 600 tasks.

Remaining project tasks is modeled as;

Remaining project tasks = INTEG(detecting undiscovered rework-poor completion of project tasks-proper completion of project tasks) (units: Tasks) (6.14)

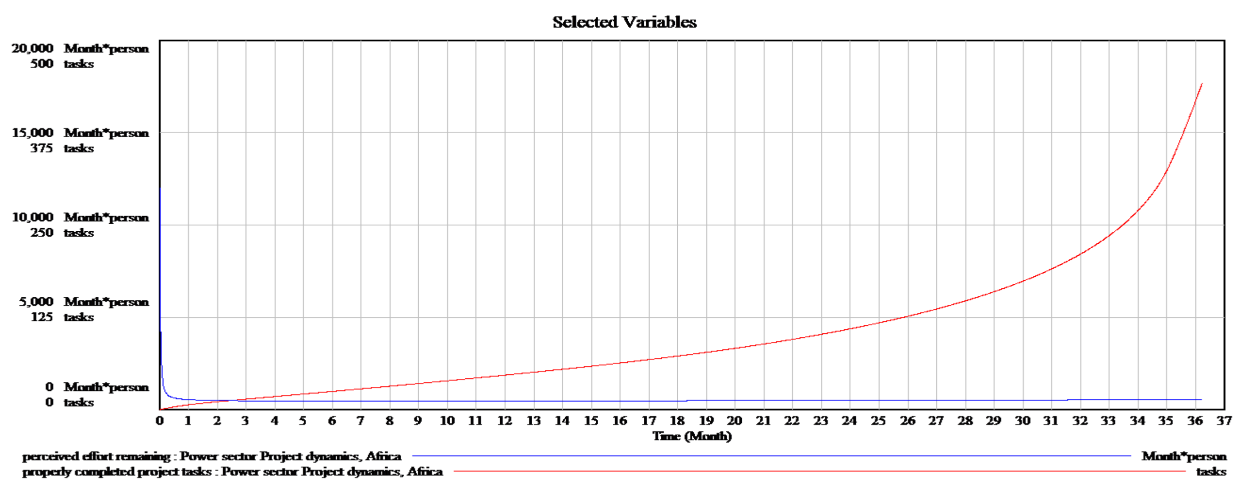

Figure 6.20: Simulation results when remaining project tasks is fixed at 0 tasks.

When *"Remaining project tasks"* is fixed at 0 by changing the equation in the model in Fig. 6.2 to;

Remaining project tasks = 0 *(6.15)*

and the basic model is simulated, the results are as shown in figure 6.20 where "*properly completed project tasks"* (red colour) rises to about 500 tasks by project time 37 months, while the "*perceived effort remaining"* (blue colour) falls to near zero. This is a reasonable expectation in an academic research.

When *"Remaining project tasks"* is fixed at 1,000,000 tasks and the basic model is simulated, the results are as shown in figure 6.21 where the rate of *"poor completion of project tasks"* (blue colour) quickly rises to about 525 tasks/month by project time 0.6 month, while *"undiscovered rework"* (red colour) quickly rises to about 170 tasks in project time 0.7 months. This is a reasonable expectation.

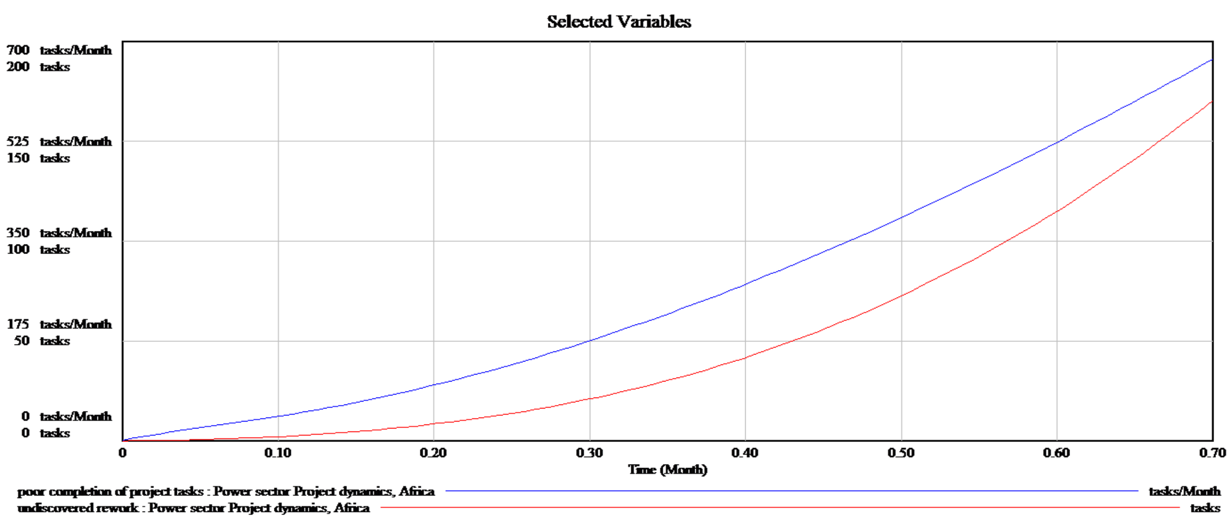

Figure 6.21: Simulation results when remaining project tasks is fixed at 1,000,000 tasks.

"Properly completed project tasks" is modeled as;

Properly completed project tasks = INTEG (proper completion of project tasks)

(units: Tasks) (6.16)

When *"Properly completed project tasks"* is fixed at 0 and the basic model is simulated, the results as shown in figure 6.22 indicate that the "*average quality of completed project tasks"* (blue colour) remains constant at zero. This is a reasonable expectation.

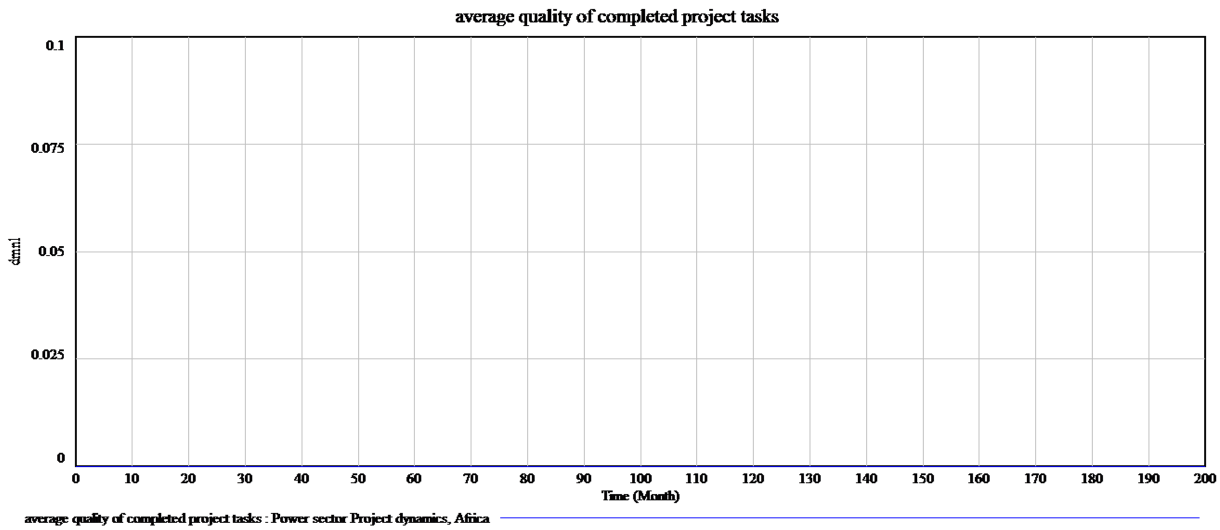

Figure 6.22: Simulation results when properly completed project tasks is fixed at 0 tasks.

When "*Properly completed project tasks*" is fixed at 10,000,000 and the basic model is simulated, the results as shown in figure 6.23 indicate that the "*average quality of completed project tasks"* (blue colour) quickly rises to 100% in about 0.0077months of project time. This is a reasonable expectation because 10,000,000 is a large figure.

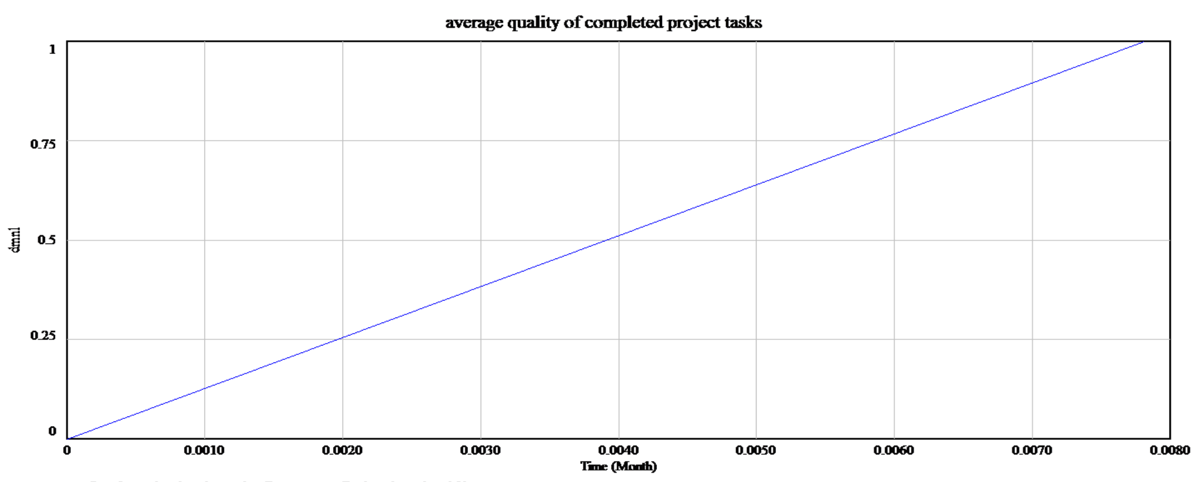

Figure 6.23: Simulation results when properly completed project tasks is fixed at 10,000,000 tasks.

Progress made during the project is modeled as;

*Progress = gross productivity of project personnel*project personnel*Political risk*Multitasking (units: Tasks/month)* (6.17)

When *"Progress"* is fixed at 0.0833 tasks/month (equivalent to 1 task/year) and the basic model is simulated, the results as shown in figure 6.24 indicate that *"properly completed project tasks"* (blue colour) stays at near zero, only rising slightly in month 200 of project time while "*remaining project tasks"* (red colour) stays fairly flat at 600 tasks, only dropping to about 598 tasks at month 200 of project time. This is a reasonable expectation because the completion rate is so low.

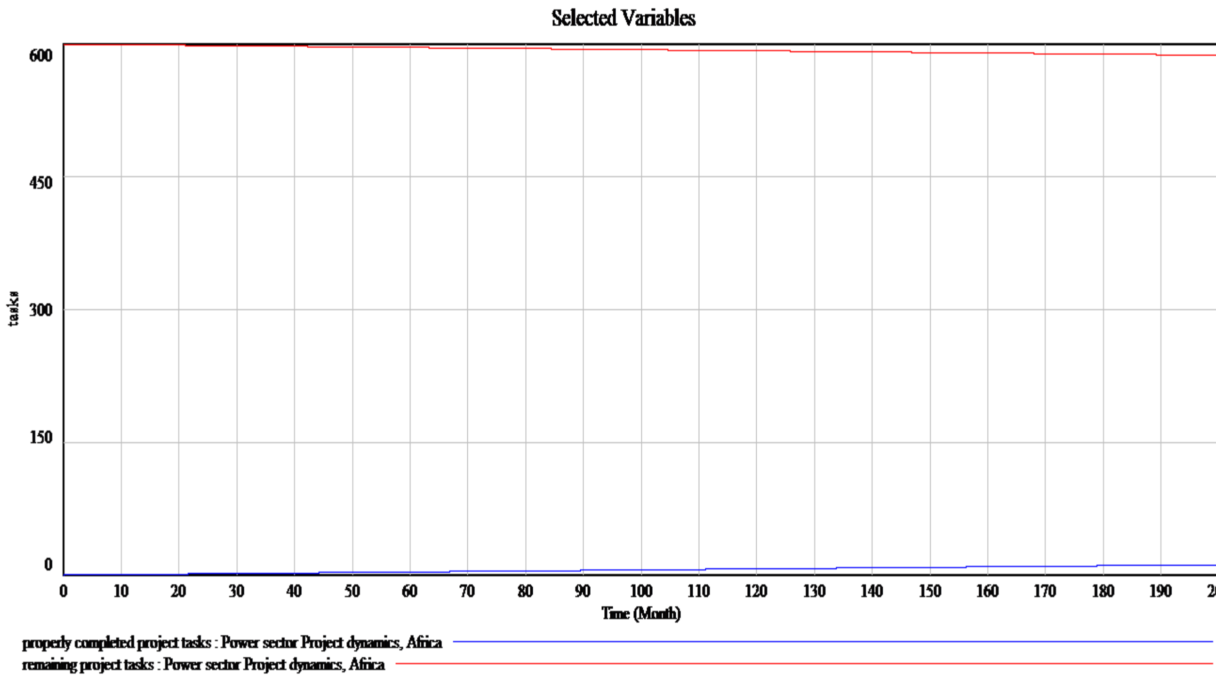

Figure 6.24: Simulation results when progress is fixed at 0.0833 tasks/month (equivalent to 1 task/year).

When *"Progress"* is fixed at 80 tasks/month and the basic model is simulated, the results as shown in figure 6.25 indicate that *"properly completed project tasks"* (blue colour) rises from 0 to about 440 tasks in 7.5 months, while *"remaining project tasks"* drops from 600 to 0 in 7.5 months. This is a reasonable expectation.

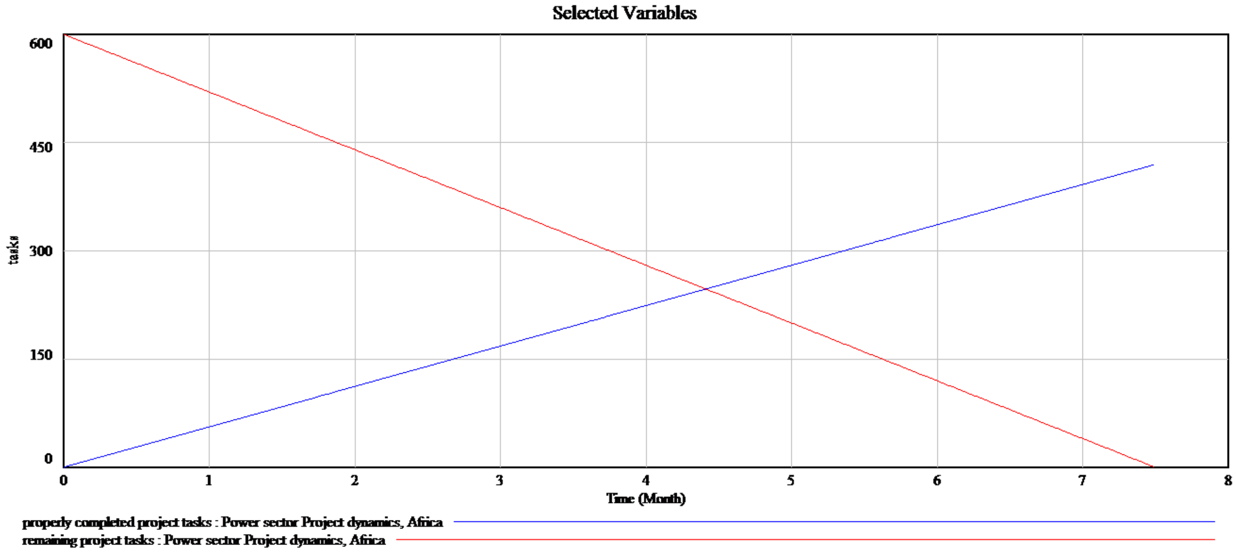

Figure 6.25: Simulation results when progress is fixed at 10,000,000 tasks/month.

The gross productivity of project personnel is modeled as;

*gross productivity of project personnel= WITH LOOKUP (remaining project tasks*Project Management competence, ([(0,0)-(600,1)],(0,0.2),(50,0.85),(75,0.95),(100,1),(200,1),(600,1)) (units: Tasks/person/month)* (6.18)

When *"gross productivity of project personnel"* is fixed at 0 tasks/person/month and the basic model is simulated, the results as shown in figure 6.26 indicate that "*progress"* (blue colour) remains constant at zero tasks/month, "*properly completed project tasks"* (red colour) also stays constant at zero tasks while "*remaining project tasks"* (green colour) stays constant at 600 tasks. This is a reasonable expectation.

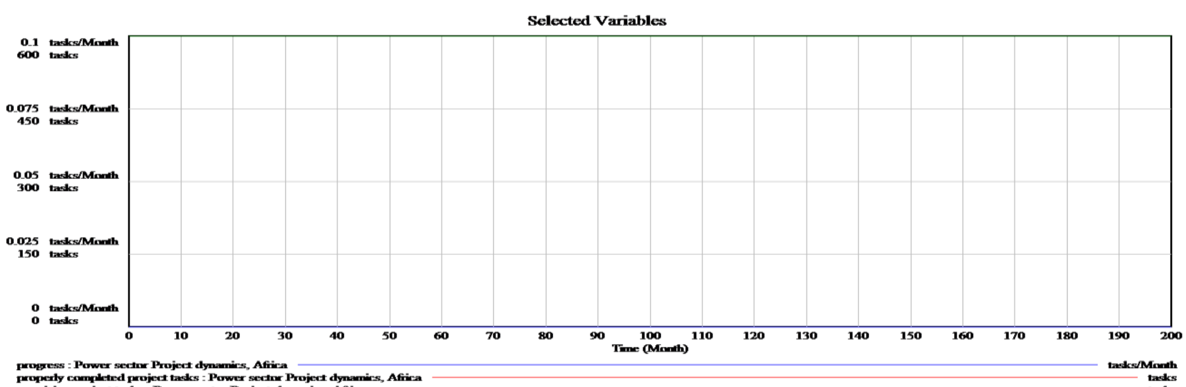

Figure 6.26: Simulation results when gross productivity of project personnel is fixed at 0 tasks/person/month.

When *"gross productivity of project personnel"* is fixed at 1,000,000 tasks/person/month and the basic model is simulated, the results as shown in figure 6.27 indicate that "*progress"* (red colour) rises to about 5.25 million tasks/month in about 0.008-month project time, "*poor completion of project tasks"* (blue colour) also rises to about 1.5 million tasks/month in 0.0075-month project time while "*undiscovered rework"* (green colour) rises to about 12500 tasks in 0.008-month project time. This is a reasonable expectation.

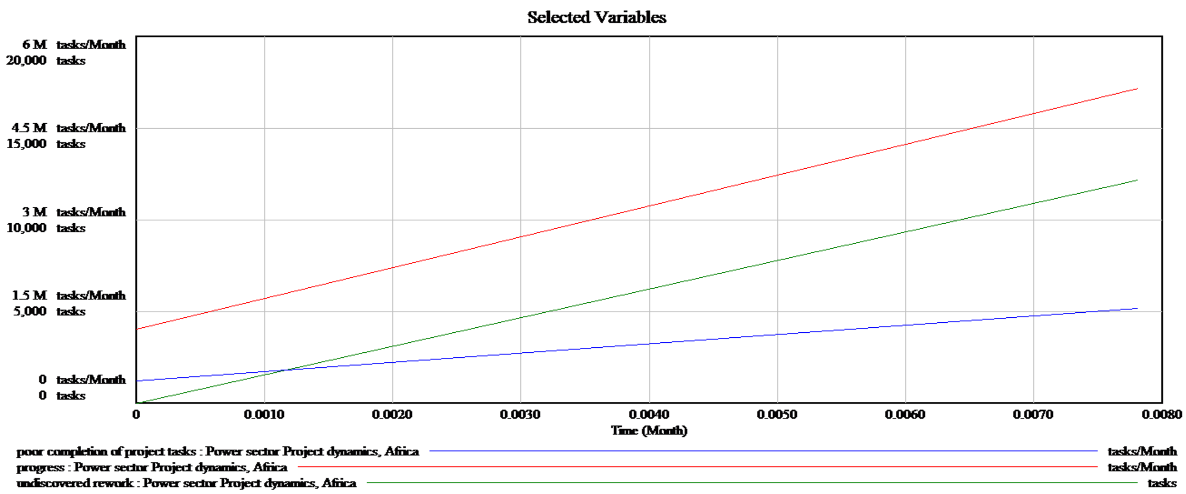

Figure 6.27: Simulation results when gross productivity of project personnel is fixed at 1,000,000 tasks/person/month.

Net hiring of personnel is modeled as;

net hiring of personnel = (desired workforce – workforce)/time to adapt workforce

(units: person/month) (6.19)

When *"net hiring of personnel"* is fixed at 0 person/month and the basic model is simulated, the results as shown in figure 6.28 indicate that "*workforce"* stays constant at the initial value of 2 persons, while the "*remaining project tasks"* changes from 600 tasks to 0 tasks in 170 months of project time, and "*properly completed project tasks"* also takes 170 months of project time to settle at 450 tasks. This is a reasonable expectation.

When *net hiring of personnel* is fixed at 10,000 person/month and the whole basic model is simulated, the results as shown in figure 6.29 indicate that *workforce* (green colour) quickly rises to about 2250 persons in 0.22 months of project time, while the *remaining project tasks* (red colour) changes from 600 tasks to 0 tasks in 0.23 months of project time, and *properly completed* *project tasks* (blue colour) rises to 450 tasks in 0.24 months of project time. This is a reasonable expectation.

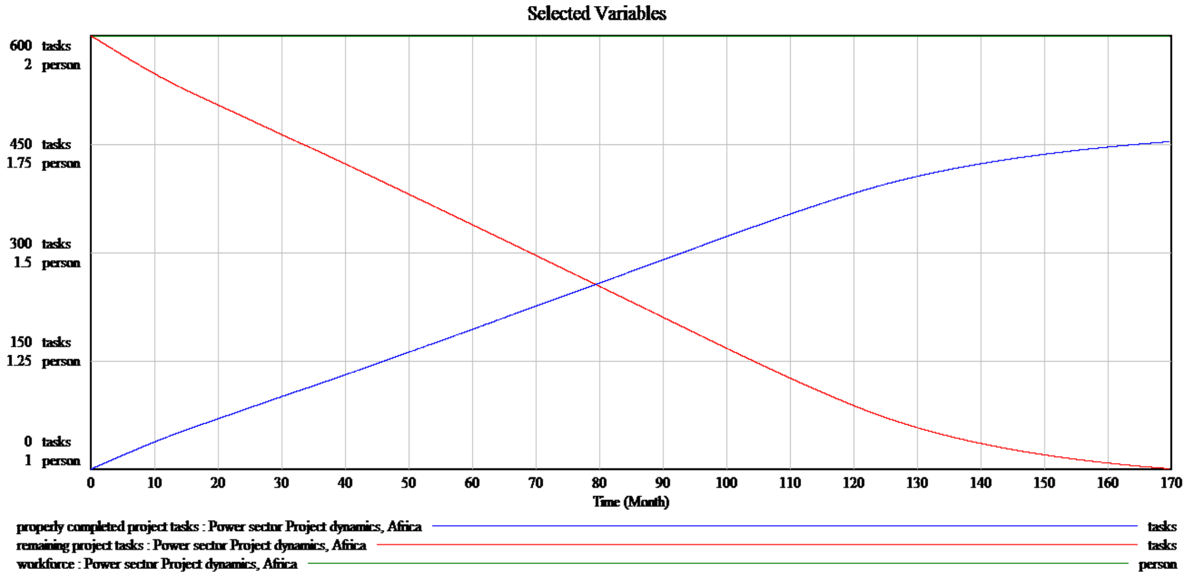

Figure 6.28: Simulation results when net hiring of project personnel is fixed at 0 person/month

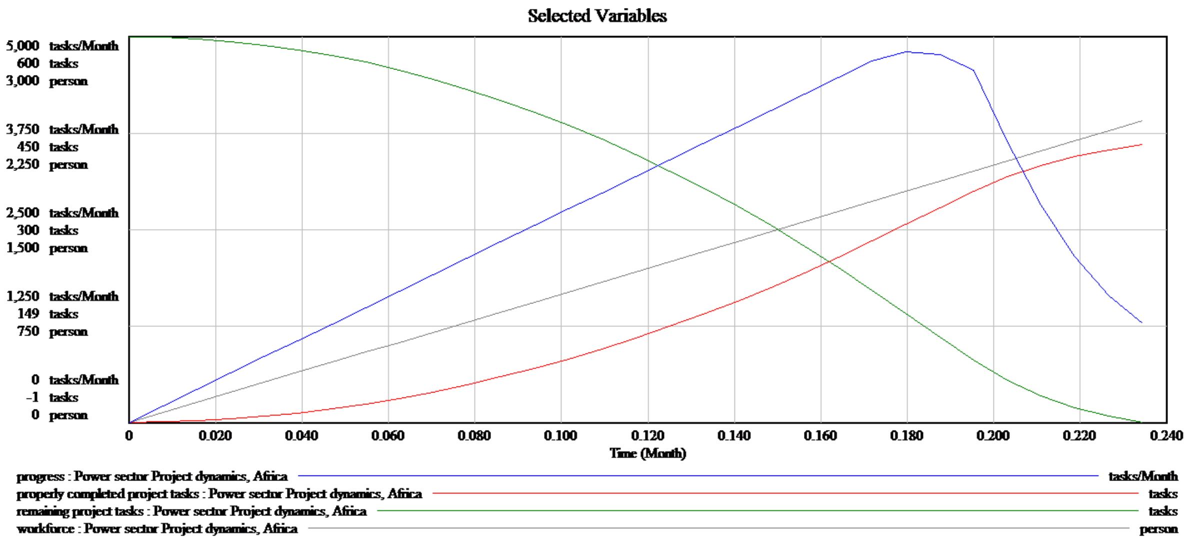

Figure 6.29: Simulation results when net hiring of project personnel is fixed at 10,000 person/month

Workforce is modeled as;

Workforce = INTEG (net hiring of personnel)   (units: person) (6.20)

When *"Workforce"* is fixed at 0 person and the basic model is simulated, the results as shown in figure 6.30 indicate that both "*project personnel"* (blue colour) and "*properly completed project tasks"* (red colour) stay constant at zero, while "*remaining project tasks"* (green colour) stays constant at 600 tasks. This is a reasonable expectation.

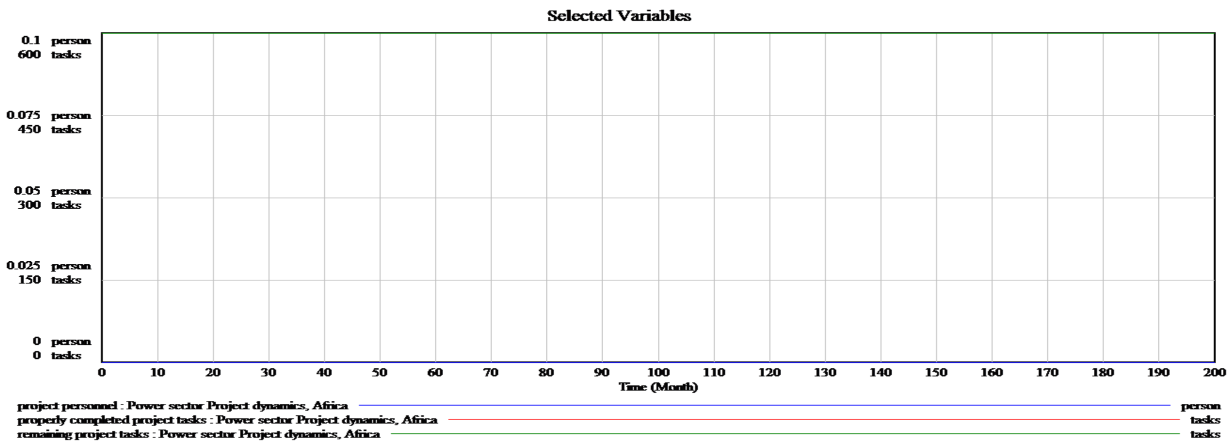

Figure 6.30: Simulation results when workforce is fixed at 0 person

When *"Workforce"* is fixed at 10,000 persons and the basic model is simulated, the results as shown in figure 6.31 indicate that "*multitasking"* (blue colour) stays constant at 1, meaning no multitasking takes place, "*progress"* (red colour) quickly peaks at 4,900 tasks/month, "*project personnel"* (green colour) rises to 2250 persons in 0.24 months and "*remaining project tasks"* (grey colour) changes from 600 tasks to zero tasks in 0.24 months. This is a reasonable expectation because the workforce is quite large, and most probably tasks that would ordinarily be accomplished by one person end up being shared and done by several people.

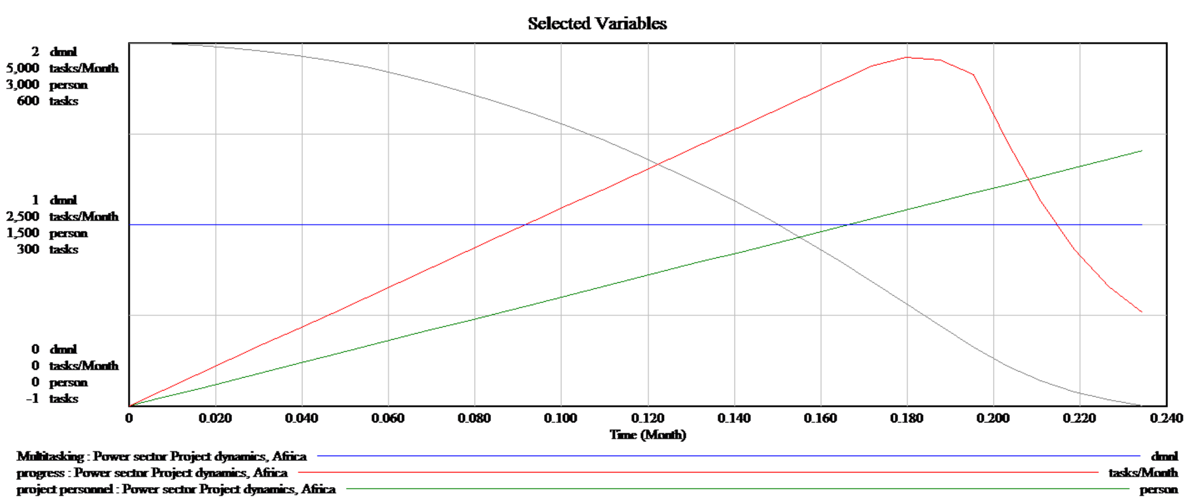

Figure 6.31: Simulation results when workforce is fixed at 10,000 persons

The time to adapt the workforce in electricity sector projects in Kenya is modeled as a constant equal to half a month, based on results from the exploratory study, as derived in Appendix L, also supported by extracts of feedbacks given in Appendix B;

time to adapt the workforce = 0.5 (units: Month) (6.21)

When *"time to adapt the workforce"* is fixed at 0.1 Month and the basic model is simulated, the results as shown in figure 6.32 indicate that both the "*desired workforce"* (blue colour) and "*workforce"* (red colour) quantities are very close to each other and peak at approximately 32 persons at 36 months of project time, with a very low "*net hiring of personnel"* (green colour). This is a reasonable expectation because a low "*time to adapt workforce"* essentially means the project is hiring highly experienced personnel.

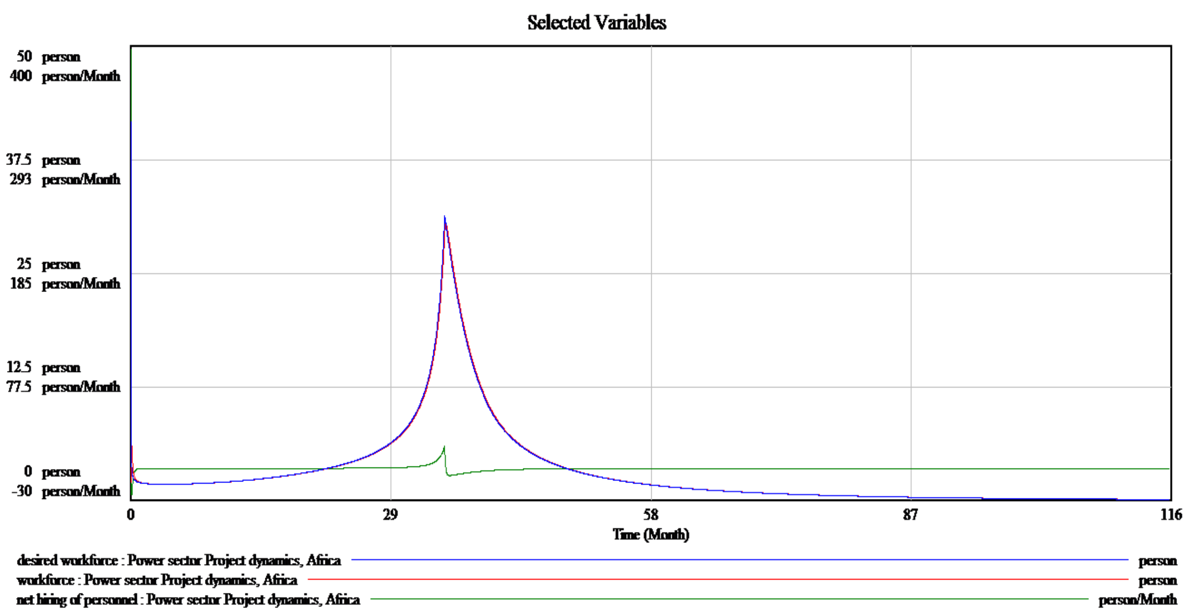

Figure 6.32: Simulation results when time to adapt workforce is fixed at 0.1 Month

When *"time to adapt the workforce"* is fixed at 1,000,000 Months and the basic model is simulated, the results as shown in figure 6.33 indicate that the "*desired workforce"* (blue colour) rises to about 48 persons, while "*workforce"* (red colour) quantities remain low at about 2 persons (the initial project personnel) despite the "*net hiring of personnel"* (green colour) rising to about 46 persons. The "*remaining project tasks"* (black colour) changes from 600 tasks to zero in 170 months. This is a reasonable expectation because a very high "*time to adapt workforce*" essentially means the project personnel hired take a very long time in training before joining the workforce.

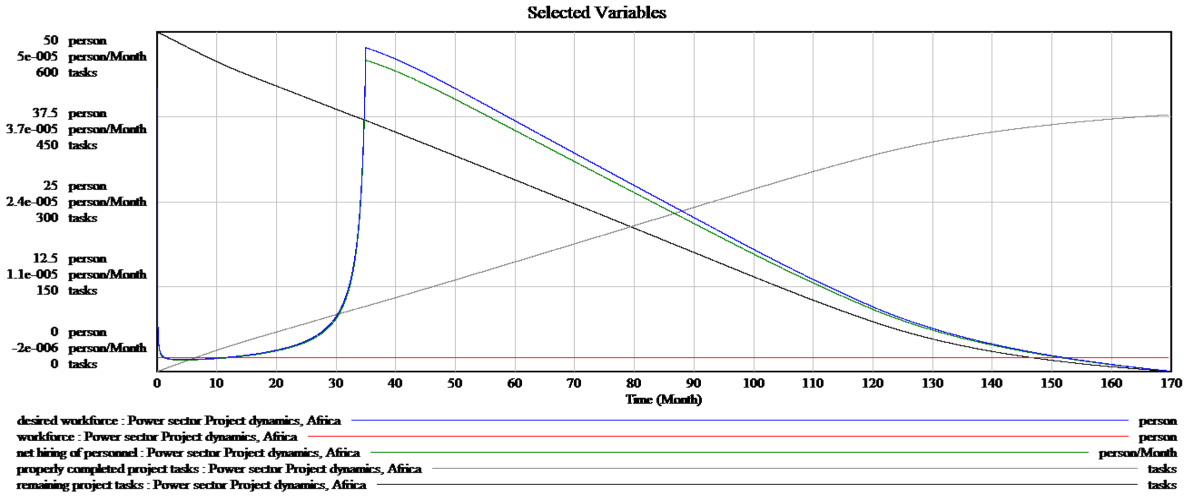

Figure 6.33: Simulation results when time to adapt workforce is fixed at 1,000,000 Months

The desired workforce is modeled as;

desired workforce = perceived effort remaining / perceived time remaining (units: person) (6.22)

When *"desired workforce"* is fixed at 0 person and the basic model is simulated, the results as shown in figure 6.34 indicate that "*remaining project tasks"* (blue colour) drops slightly to about 598 tasks in the initial 2 months of the project, and the "w*orkforce"* (red colour) also drops to zero in the same time. This is a reasonable expectation, as the initial workforce likely perform the 2 tasks in the initial 2 months before being released from the project.

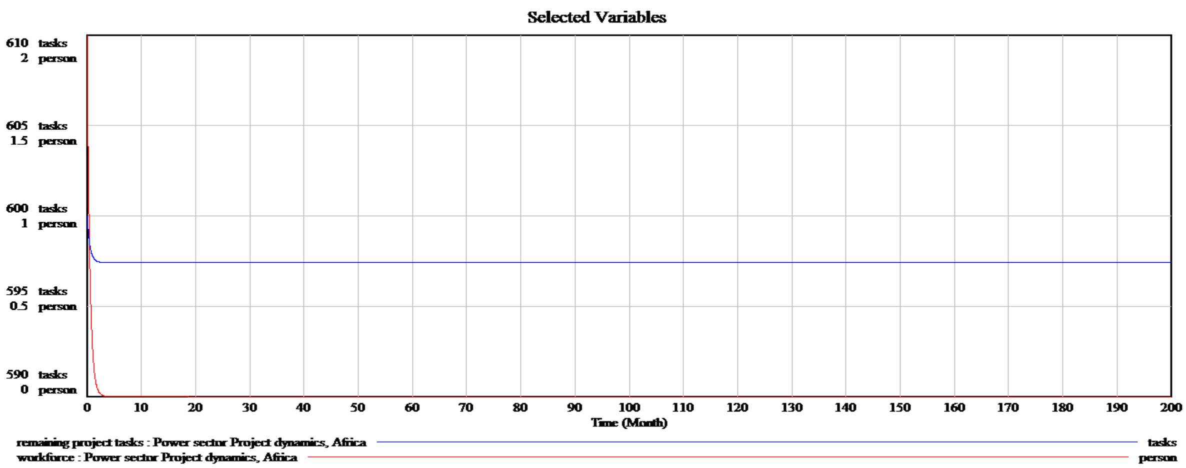

Figure 6.34: Simulation results when desired workforce is fixed at 0 person

When *"desired workforce"* is fixed at 1,000,000 persons (theoretically) by changing the equation to;

desired workforce = 1,000,000 *(6.23)*

and the basic model is simulated, the results as shown in figure 6.35 indicate that the "*net hiring of personnel"* (blue colour) starts at a high of 50,000 persons/month, while the "*workforce"* (grey colour) rises to about 37,500 persons in just 0.019 months. The "*remaining project tasks"* (green colour) changes from 600 tasks to zero tasks in 0.019 months, and the "*properly completed project tasks"* (red colour) reaches 450 tasks in 0.019 months. This is a reasonable expectation theoretically.

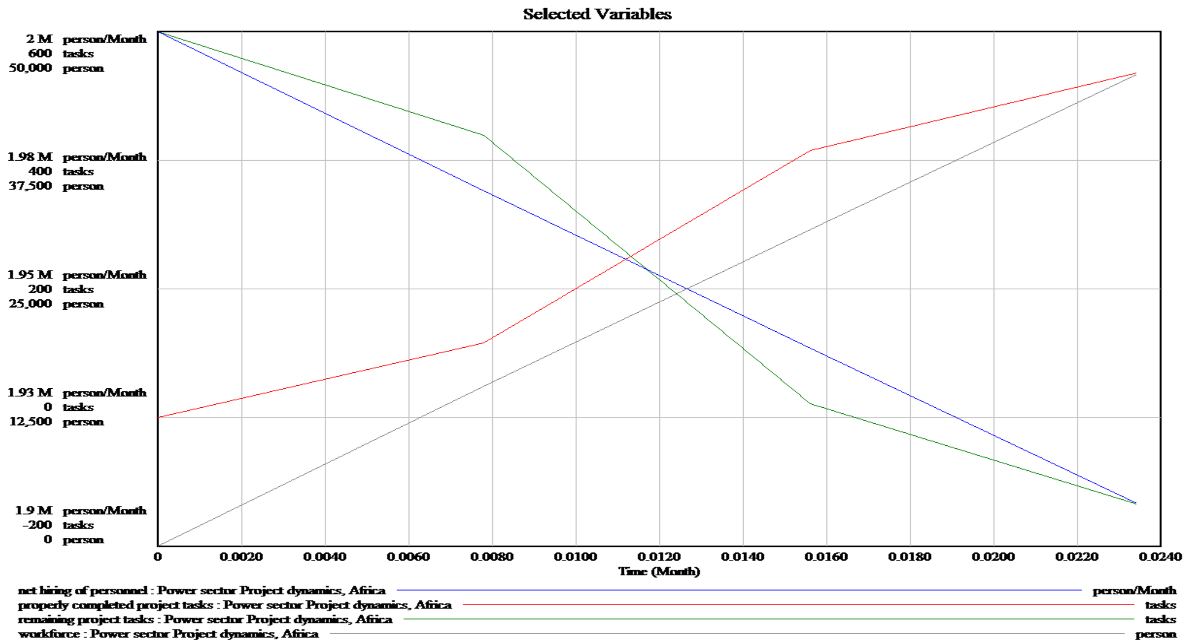

Figure 6.35: Simulation results when desired workforce is fixed at 1,000,000 Months

Perceived time remaining is modeled as;

perceived time remaining = MAX(1, initial project time remaining - Time) *(units: month)*

(6.24)

When *"perceived time remaining"* is fixed at 0.01 months and the basic model is simulated, the results as shown in figure 6.36 indicate that the "*workforce"* (green colour) rises to a high of about 1,700 persons, "*project personnel"* (blue colour) to a high of 1,200 persons, and "*testing personnel"* (red colour) to a high of 500 persons, all within 0.18 months.

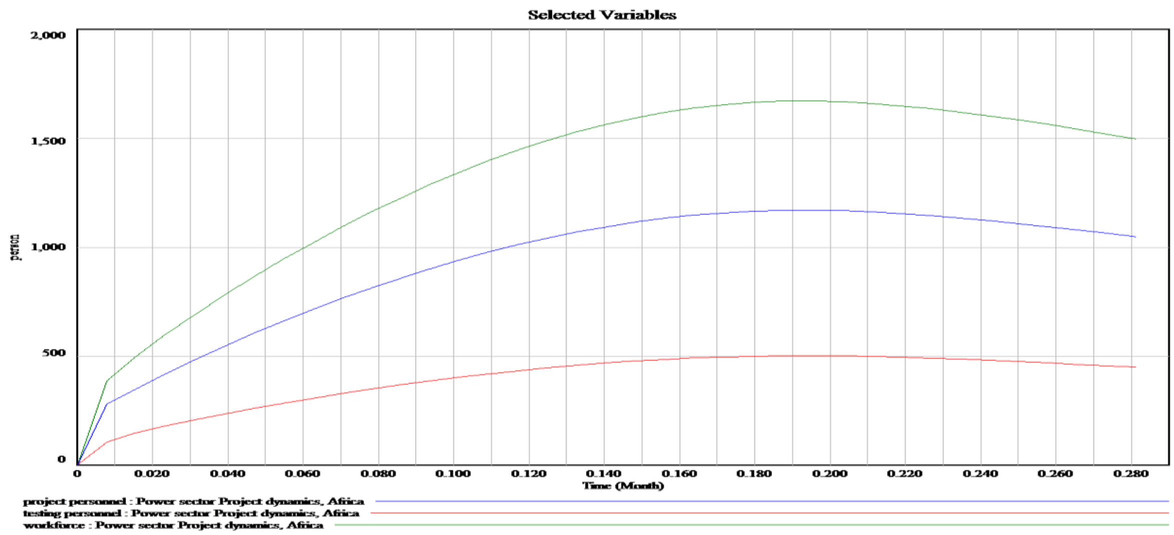

Figure 6.36: Simulation results when perceived time remaining is fixed at 0.01 Months (1)

Similarly and as shown in figure 6.37, the *"desired workforce"* (blue colour) changes from about 150,000 persons to about 10,000 persons in 0.005 months, while the *"remaining project tasks"* (green colour) changes from 600 tasks to zero in 0.28 months, and "*properly completed project tasks"* (red colour) rises to 450 tasks in 0.28 months. This is a reasonable expectation.

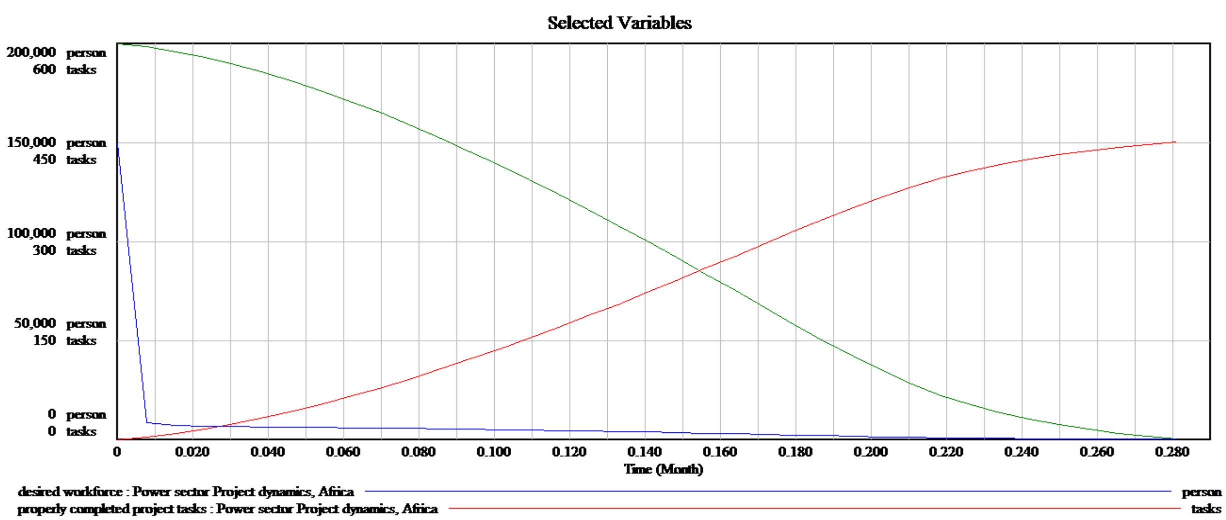

Figure 6.37: Simulation results when perceived time remaining is fixed at 0.01 Months (2)

When *"perceived time remaining"* is fixed at 1,000,000 months (theoretically for the extreme condition test) by changing the model equation to;

perceived time remaining = 1,000,000 *(6.25)* and the basic model is simulated, the results as shown in figure 6.38 indicate that the "*net hiring of personnel*" (red colour) stays constant at zero person/month while "*properly completed project tasks*" (grey colour) shows a change of about only 1.8 tasks within 200 months. This is a reasonable expectation as the project has so much time remaining, and "*progress*" is therefore low at near zero, and no multitasking takes place.

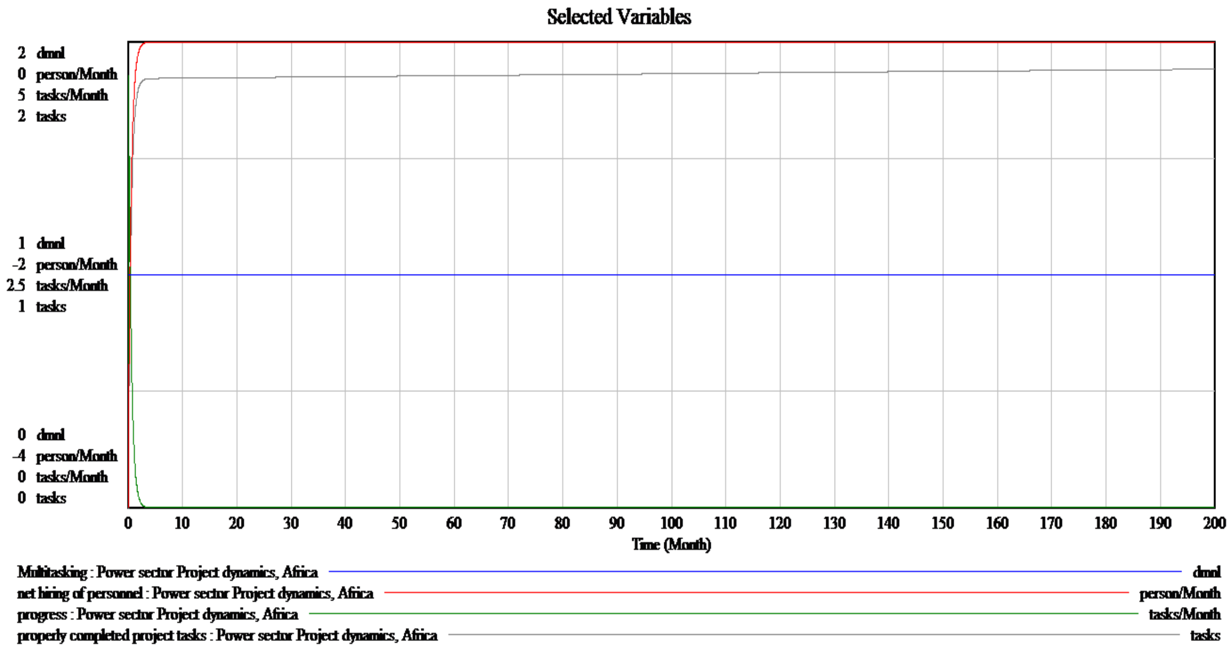

Figure 6.38: Simulation results when perceived time remaining is fixed at 1,000,000 Months

The perceived effort remaining is modeled as;

perceived effort remaining = remaining project tasks/MAX(perceived productivity,1) (6.26)

*(units: person*Month)*

When *"perceived effort remaining"* is fixed at 0 person/Month and the basic model is simulated, the results as shown in figure 6.39 indicate that the "*desired workforce*" (blue colour), "*workforce*" (red colour) and *"progress"* (green colour) all drop to zero within 3 months of the project time, and the "*remaining project tasks*" (grey colour) drops slightly from 600 tasks to about 598 tasks and stays constant within the 3 months. This is a reasonable expectation.

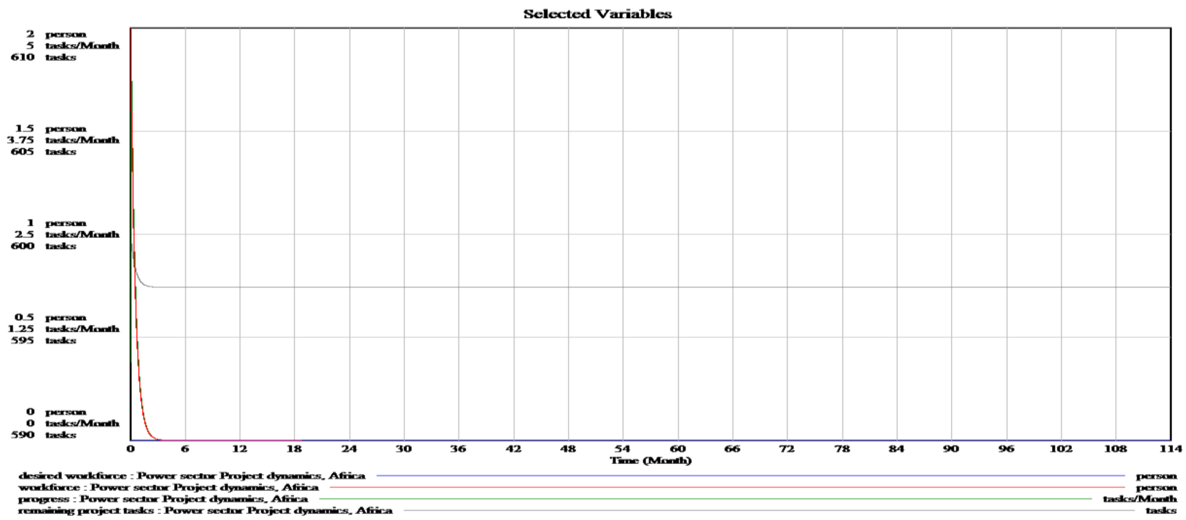

Figure 6.39: Simulation results when perceived effort remaining is fixed at 0 person*month

When *"perceived effort remaining"* is fixed at 100,000 person*Month and the basic model is simulated, the results as shown in figure 6.40 indicate that the "*desired workforce"* (blue colour) stays constant at a high of about 3,500 persons, while the "*workforce"* (grey colour) rises to about 1,600 persons in 0.3 months of project time. The "*project personnel"* (red colour) and "*testing personnel"* (green colour) also rise to 1,500 persons and 100 persons respectively in 0.3 months, while "*progress"* (black colour) peaks at about 3,500 tasks per month.

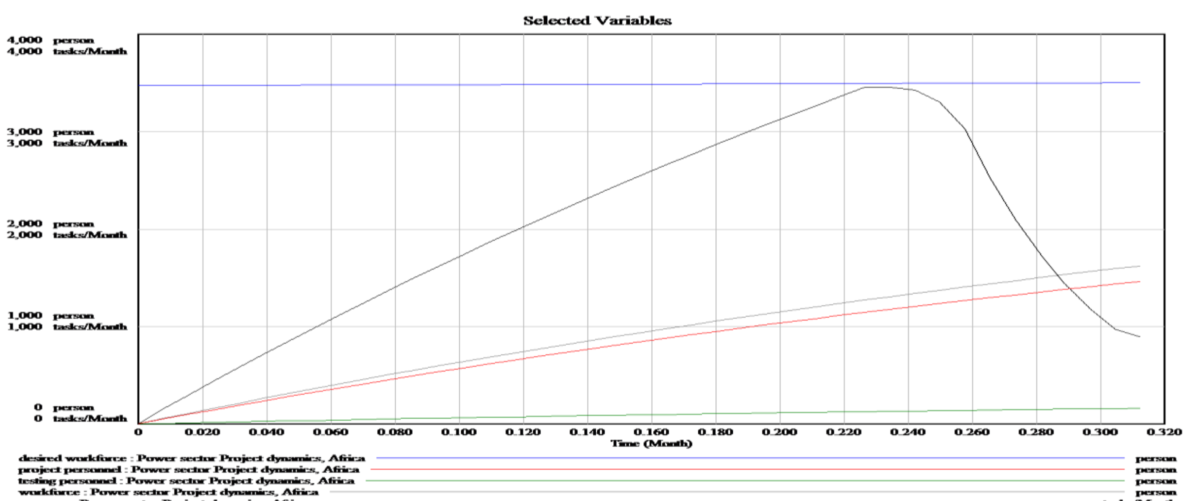

Figure 6.40: Simulation results when perceived effort remaining is fixed at 100,000 person*month (1)

At the same time, "*detecting undiscovered rework"* (blue colour) rises to about 88 tasks/month in 0.3 months while "*remaining project tasks"* (green colour) changes from 600 tasks to zero tasks in 0.32 months as shown in Fig. 6.41, and "*properly completed project tasks"* (red colour) rises to about 450 tasks in 0.32 months, the difference between the 600 tasks and 450 tasks being caused by "*undiscovered rework"* (grey colour) that rises to about 150 tasks in 0.32 months. This is a reasonable expectation.

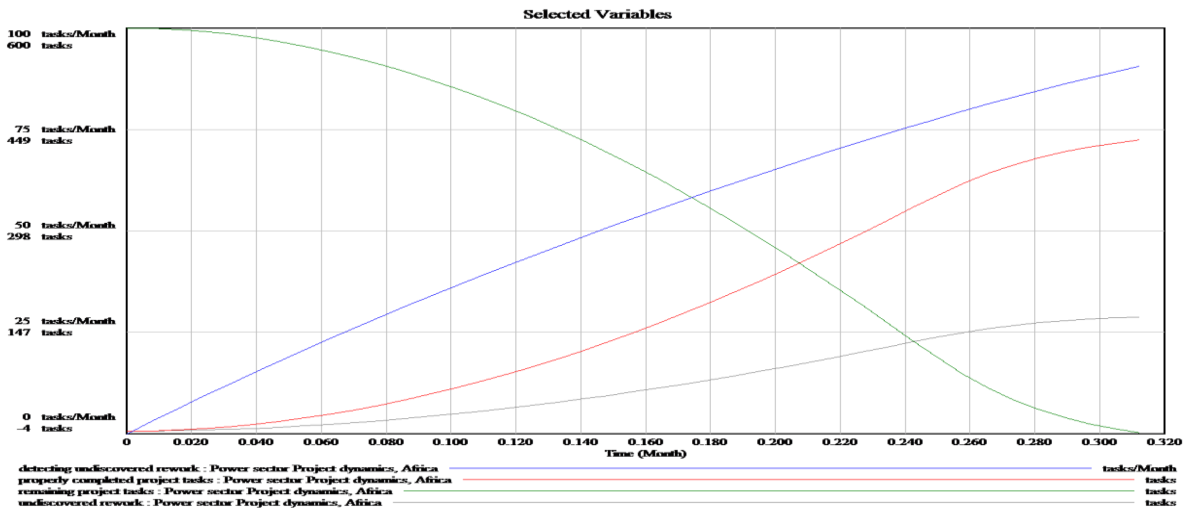

Figure 6.41: Simulation results when perceived effort remaining is fixed at 100,000 person/month (2)

The perceived cumulative progress is modeled as;

Perceived cumulative progress = properly completed project tasks + undiscovered rework

(units: tasks) (6.27)

When *"Perceived cumulative progress"* is fixed at 0 tasks and the basic model is simulated, the results as shown in figure 6.42 indicate that "*perceived fraction completed"* (blue colour) will stay constant at zero, while "*perceived productivity"* (red colour) also stays constant at zero tasks/person/month. This is a reasonable expectation

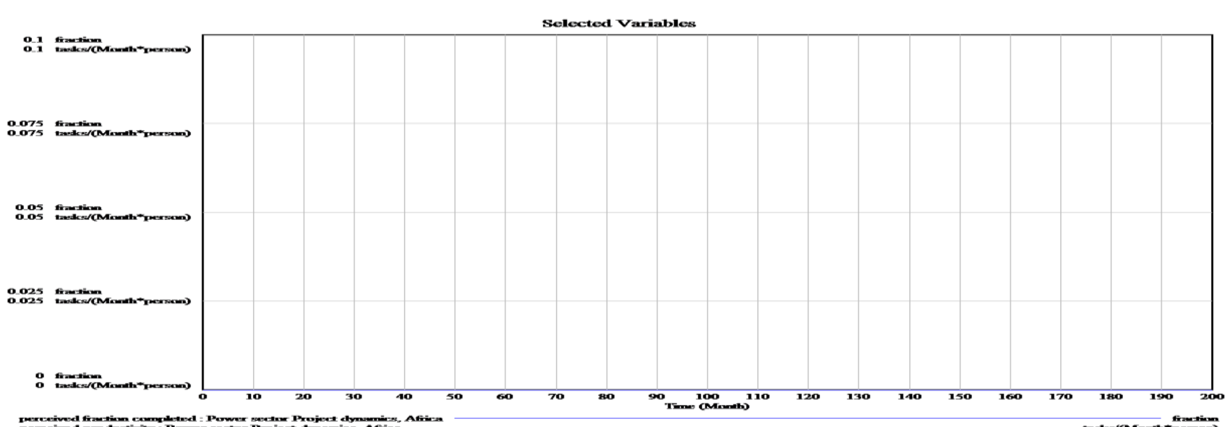

Figure 6.42: Simulation results when perceived cumulative progress is fixed at 0 tasks

When *"Perceived cumulative progress"* is fixed at 600 tasks and the basic model is simulated, the results as shown in figure 6.43 indicate that "*perceived fraction completed"* (blue colour) stays constant at 1 (100%), "*perceived productivity"* (red colour) starts at a high of 600,000 tasks/person/month before dropping off sharply. "*Progress"* (green colour) starts at a high of 55,000 tasks/month before reducing sharply. This is a reasonable expectation.

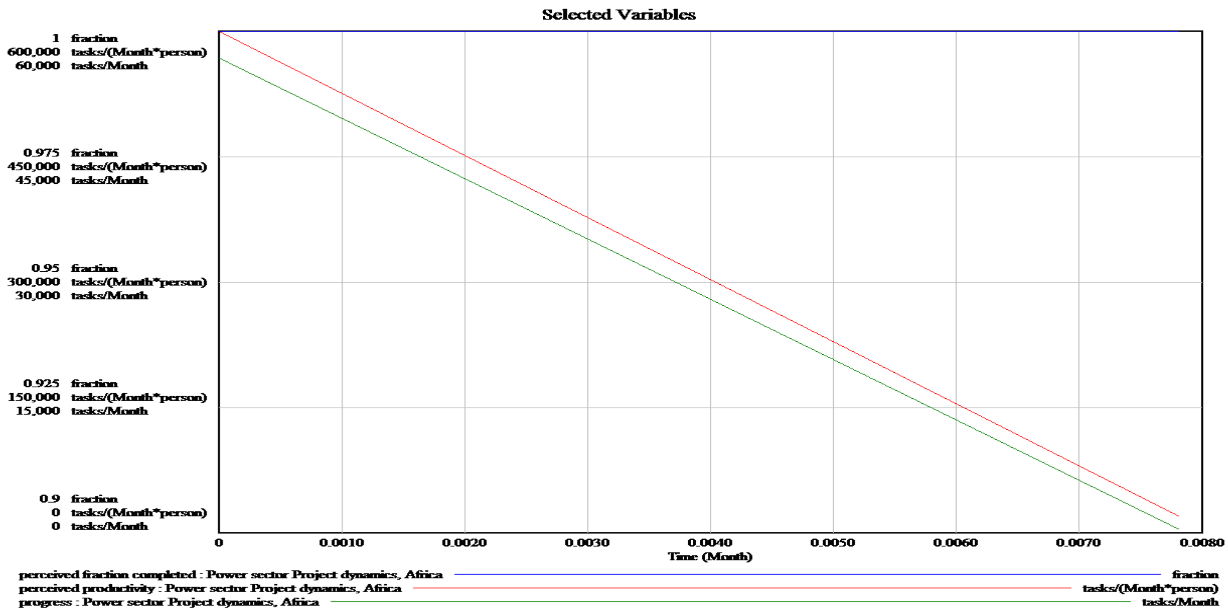

Figure 6.43: Simulation results when perceived cumulative progress is fixed at 600 tasks

The additional cumulative effort is modeled as;

*additional cumulative effort = workforce*Multitasking*Project Management competence (units: person*Month)* (6.28)

and;

When *"additional cumulative effort"* is fixed at 0 and the basic model is simulated, the results as shown in figure 6.44 indicate that "*perceived cumulative progress"* (blue colour), *"properly completed project tasks"* (red colour) and *"perceived fraction completed"* (green colour) will be extremely low even at 200 months of project time, while the "*workforce"* (grey colour) figure drops from the initial 2 persons to near zero (theoretically). This is a reasonable expectation.

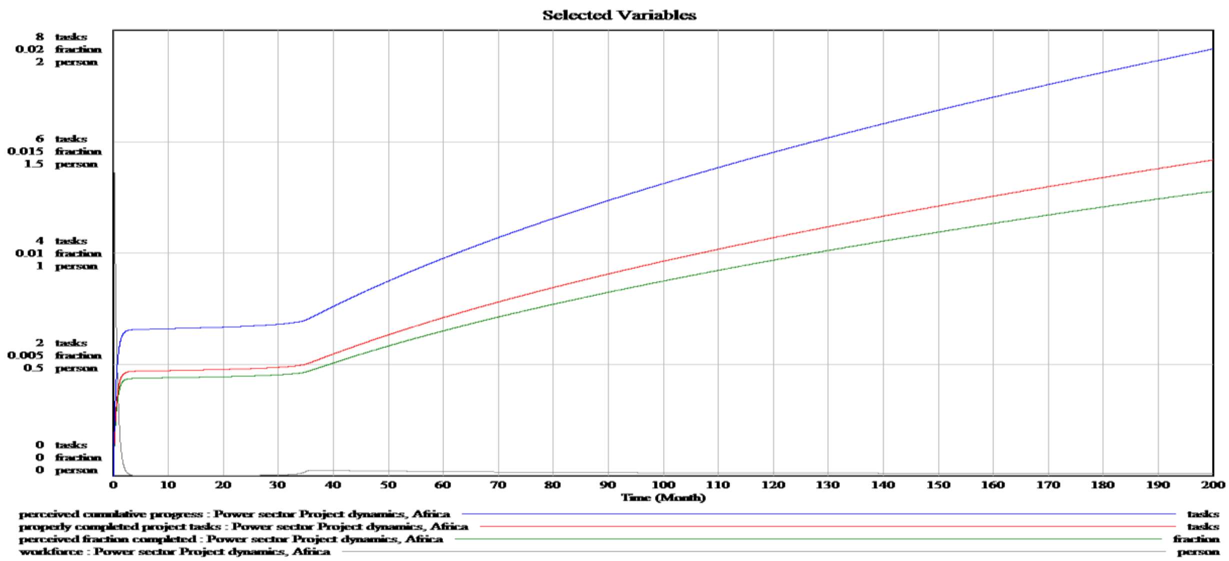

Figure 6.44: Simulation results when additional cumulative effort is fixed at 0

When *"additional cumulative effort"* is fixed at 1,000,000 and the basic model is simulated, the results are as shown in figure 6.45.

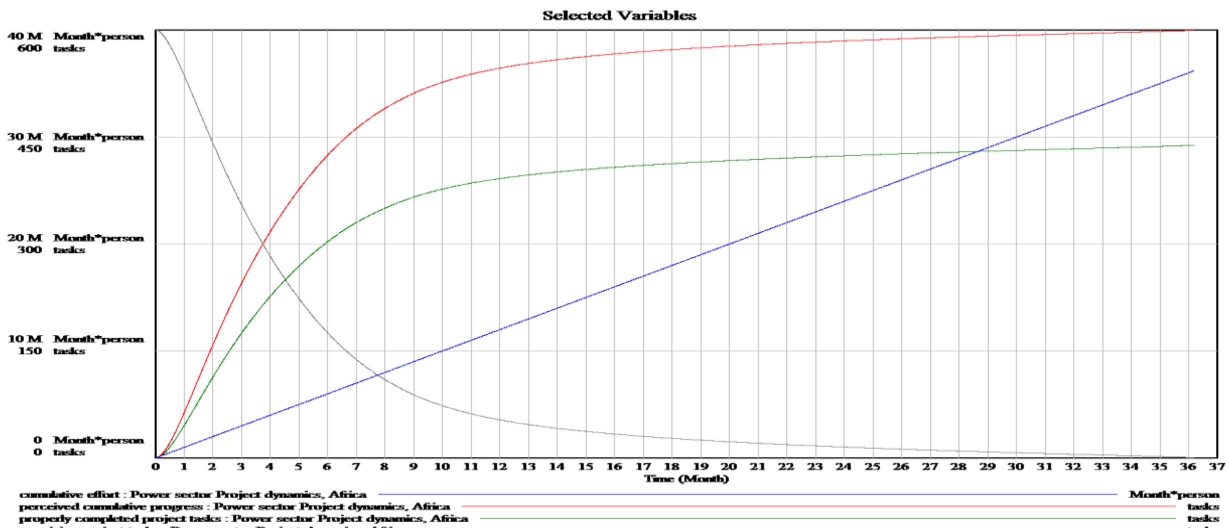

Figure 6.45: Simulation results when additional cumulative effort is fixed at 1,000,000

The results in figure 6.45 indicate that "*cumulative effort"* (blue colour), which is the integral of "*additional cumulative effort"*, grows as a straight line from point zero, "*perceived cumulative progress"* (red colour) rises smoothly to 600 tasks in 36 months of project time, *"properly completed project tasks"* (green colour) rises to about 450 tasks in about 36 months of project time, *"remaining project tasks"* (grey colour) changes from the initial 600 tasks to zero in about 36 months of project time. This is a reasonable expectation.

Cummulative effort is modeled as;

*Cumulative effort = INTEG (additional cumulative effort) (units: person*Month)* (6.29)

When *"Cumulative effort"* is fixed at 0 and the basic model is simulated, the results as shown in figure 6.46 indicate that "*perceived cumulative progress"* (blue colour), *"properly completed project tasks"* (red colour) and *"progress"* (grey colour) fall rapidly to take on zero or near zero values, while "*remaining project tasks"* (green colour) reduces by a very small margin from 600 tasks at the beginning to about 595 tasks in month 200 of project time. This is a reasonable expectation.

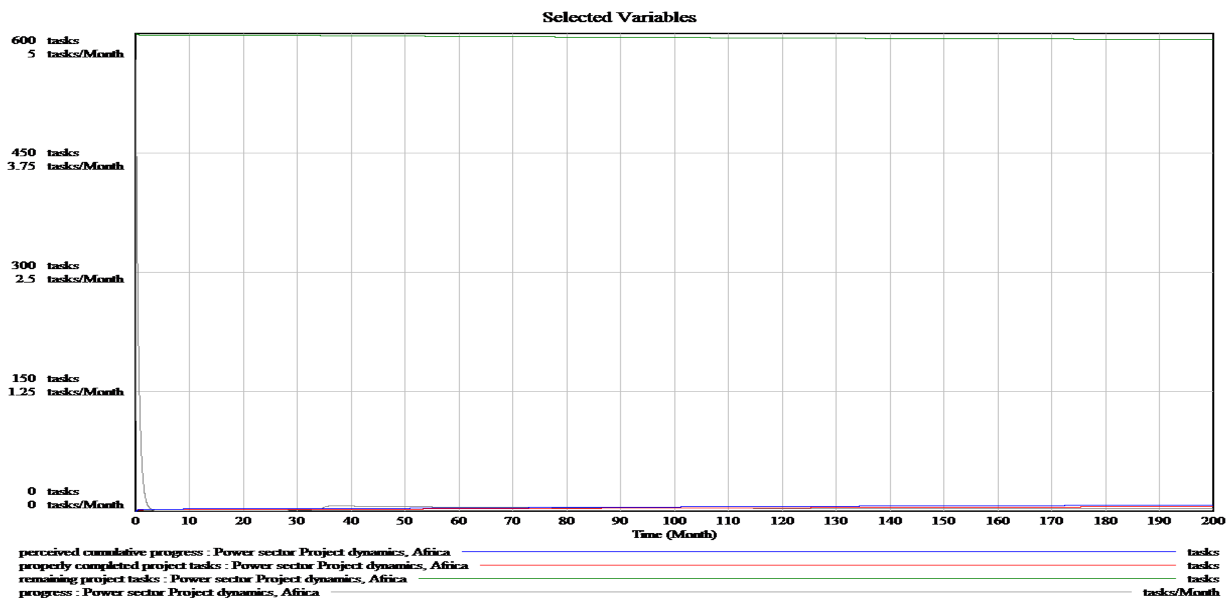

Figure 6.46: Simulation results when cumulative effort is fixed at 0

When *"Cumulative effort"* is fixed at 1,000,000 and the basic model is simulated, the results as shown in figure 6.47 indicate that "*desired workforce"* (blue colour), *"workforce"* (red colour), *"perceived effort remaining"* (green colour) and "*perceived productivity"* (grey colour) all rise sharply before easing off and reducing with time.

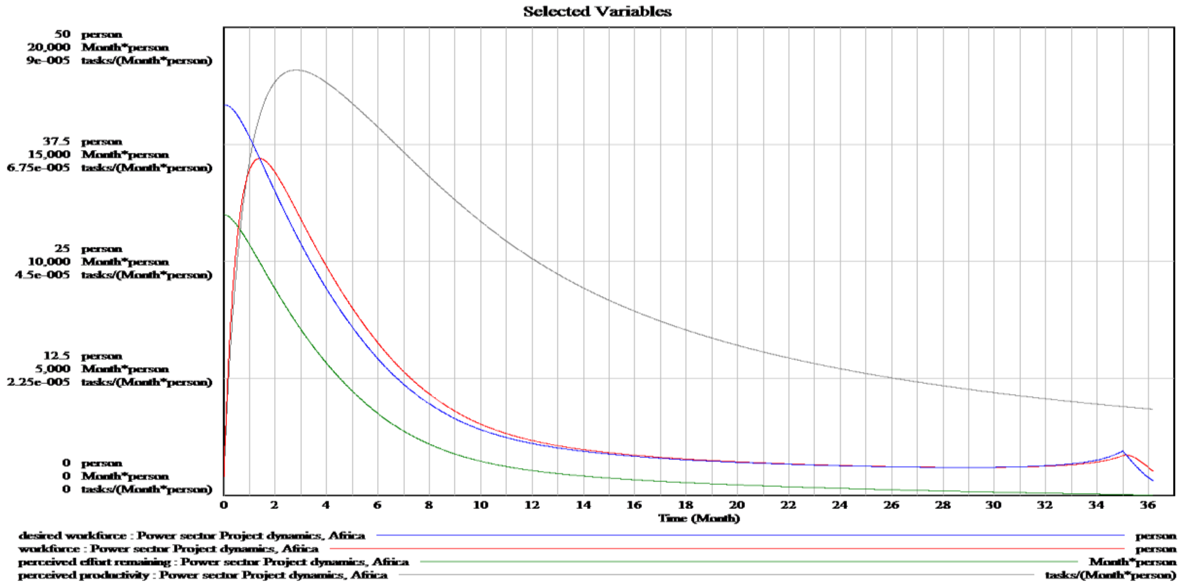

Figure 6.47: Simulation results when cumulative effort is fixed at 1,000,000

Similarly, as shown in figure 6.48, the project runs to completion within projected time of 36 months. This is a reasonable expectation.

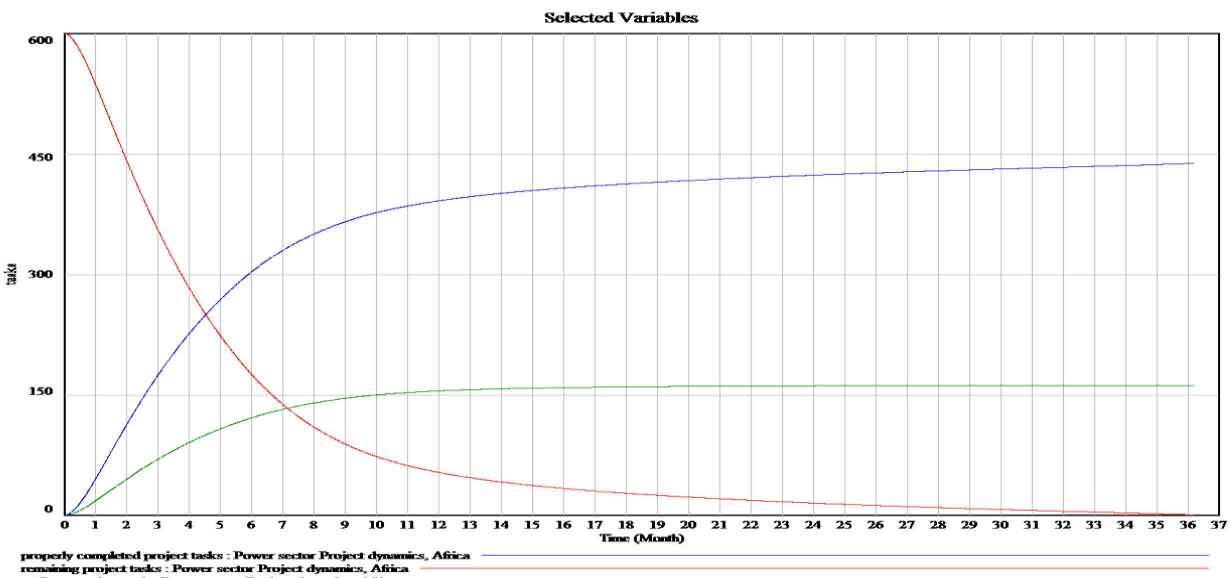

Figure 6.48: Additional Simulation results when cumulative effort is fixed at 1,000,000

From the rework cycle, the detection of undiscovered rework is modeled as;

*detecting undiscovered rework = productivity of testing*testing personnel (units: tasks/Month)*

(6.30)

When *"Detecting undiscovered rework"* is fixed at 0 tasks/Month and the basic model is simulated, the results as shown in figure 6.49 indicate that "*undiscovered rework"* (green colour) rises to a high of about 180 tasks and stays at 180 tasks for the rest of the project, while "*properly completed project tasks"* (blue colour) rises to about 420 tasks. "*Remaining project tasks"* (red colour) changes from 600 tasks at the beginning of the project to about zero in 72 months when the project is likely completed. This is a reasonable expectation.

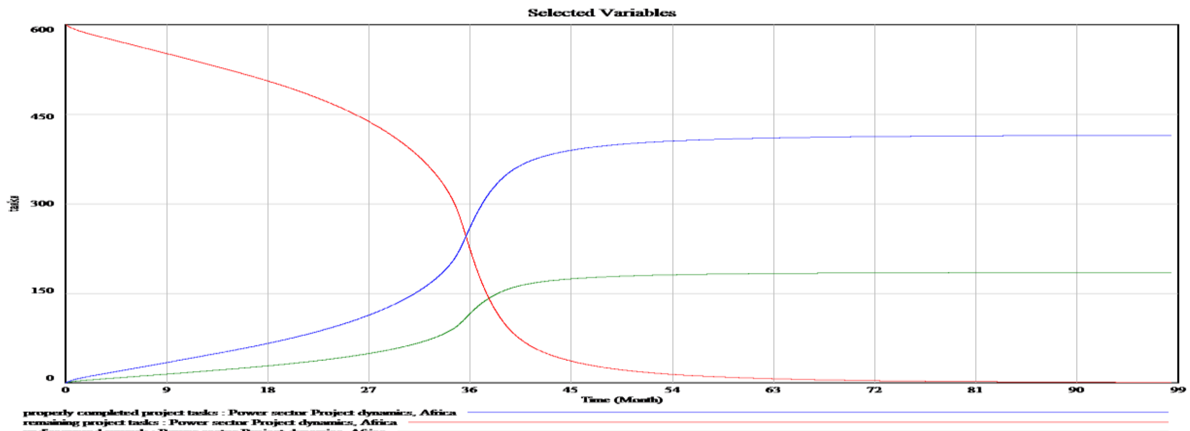

Figure 6.49: Simulation results when detecting undiscovered rework is fixed at 0

When *"Detecting undiscovered rework"* is fixed at 1.2 tasks/Month and the basic model is simulated, the results as shown in figure 6.50 indicate that "*undiscovered rework"* (green colour) rises to about 140 tasks before dropping off towards zero, while "*properly completed project tasks"* (blue colour) rises to about 570 tasks at month 200 of the project. This is a reasonable expectation.

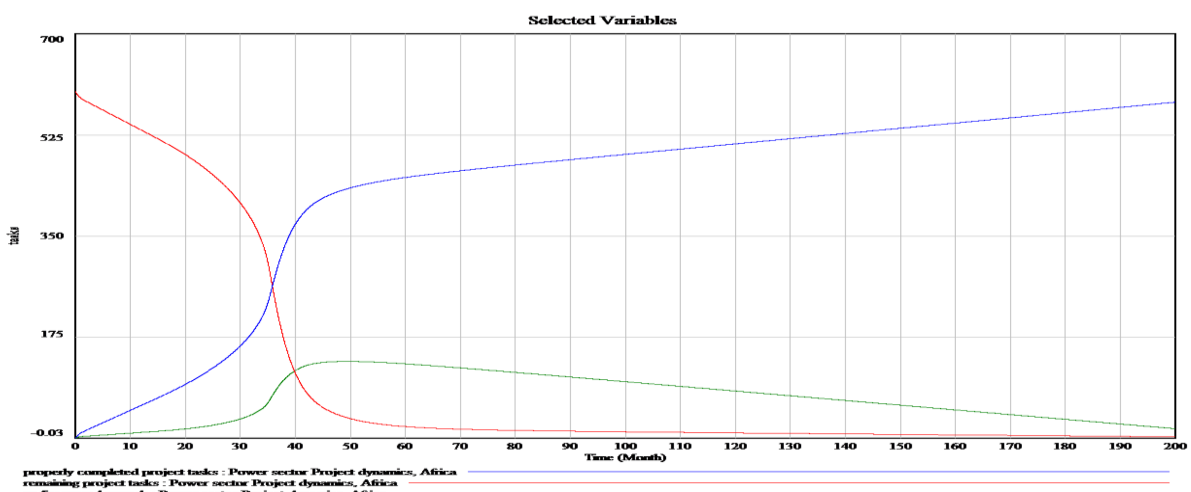

Figure 6.50: Simulation results when detecting undiscovered rework is fixed at 1.2 tasks/month

Poor completion of project tasks goes hand in hand with progress and is modeled as;

poor completion of project tasks = progress(1 - fraction properly completed)*Unforeseen technical difficulties (units: tasks/Month)* (6.31)

When *"poor completion of project tasks"* is fixed at 0 tasks/Month and the basic model is simulated, the results as shown in figure 6.51 indicate that "*fraction properly completed"* (blue colour) stays constant at 1 (100%), "*properly completed project tasks"* (red colour) rises to 600 tasks in about 0.07 months, "*remaining project tasks"* (green colour) changes and drops from 600 tasks to zero in about 0.07 months while "*undiscovered rework"* (grey colour) stays constant at zero. This is a reasonable expectation.

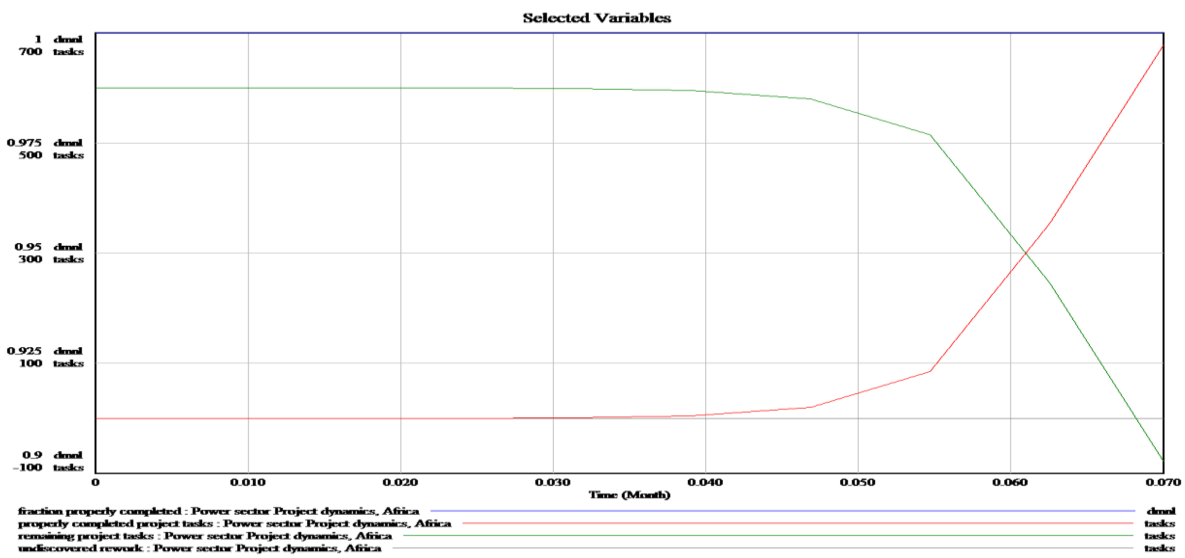

Figure 6.51: Simulation results when poor completion of project tasks is fixed at 0 tasks/month

When *"poor completion of project tasks"* is fixed at 600 tasks/Month and the basic model is simulated, the results as shown in figure 6.52 indicate that "*average quality of completed project tasks"* (blue colour) takes a low value and drops from about 0.002 to 0.00075 within 1 month of project time and "*workforce"* (red colour) reduces from 2 persons to 1 person by 0.35 months of project time. This is a reasonable expectation.

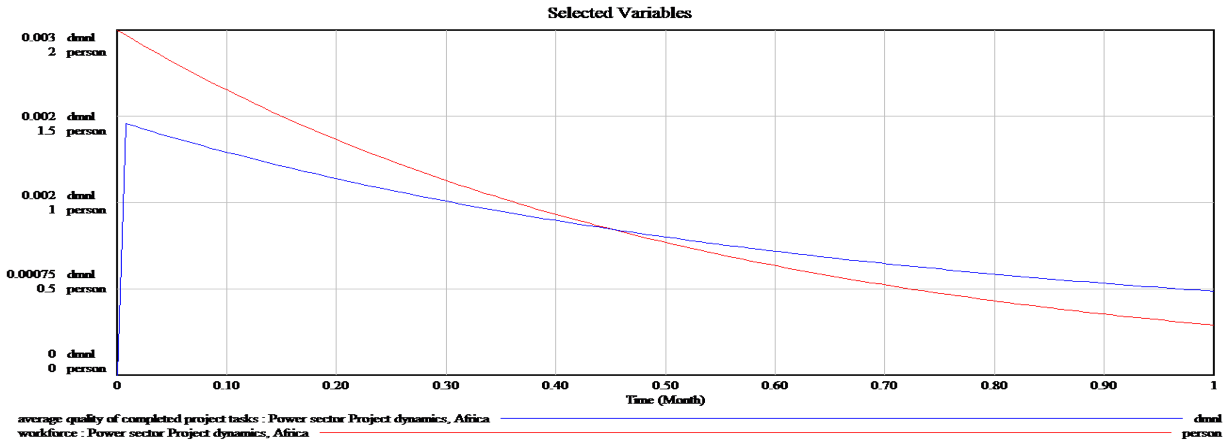

Figure 6.52: Simulation results when poor completion of project tasks is fixed at 600 tasks/month

Fraction properly completed is modeled as a constant;

fraction properly completed = 0.7 (units: dimensionless) (6.32)

When *"fraction properly completed"* is fixed at 0.0001 and the basic model is simulated, the results as shown in figure 6.53 indicate that "*remaining project tasks"* (green) drops to approximately 450 tasks in 80 months, and later reduces by small margins with time, while the perceived cumulative progress (blue) rises to at a slow pace to about 150 tasks in 80 months, while "*properly completed project tasks"* (red colour) remains fairly constant at zero. This is a reasonable expectation.

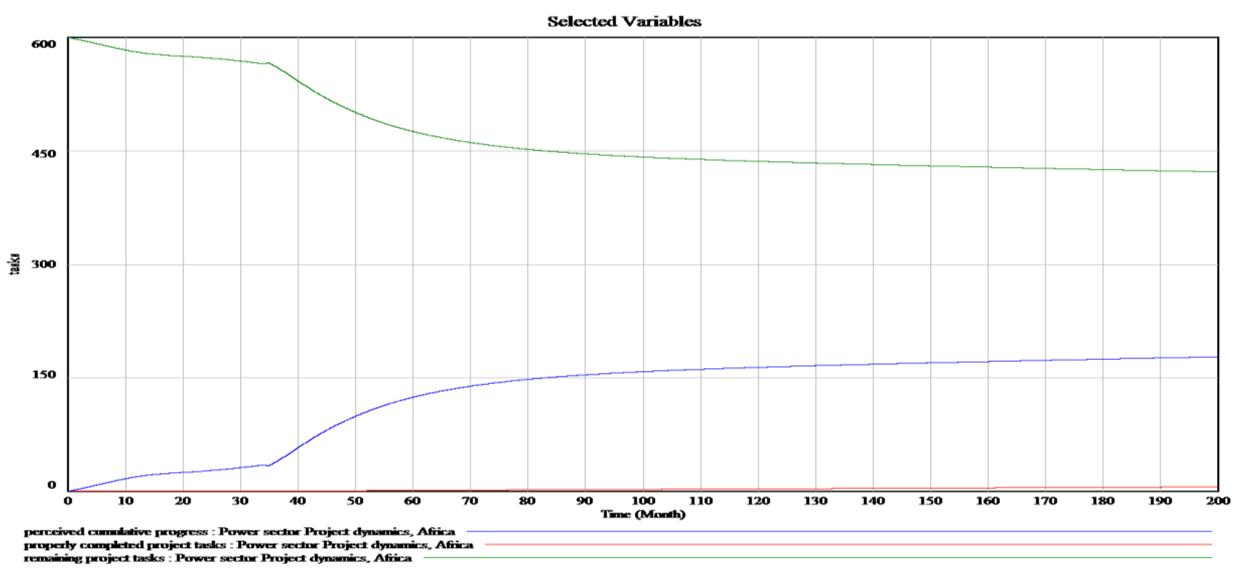

Figure 6.53: Simulation results when fraction properly completed is fixed at 0.001

When *"fraction properly completed"* is fixed at 0.99 and the basic model is simulated, the results as shown in figure 6.54 indicate that "*average quality of completed project tasks"* (blue colour) remains high at approximately 0.99 save at period between 24 months and 50 months when it dips due to effects of "*multitasking"* and "*unforeseen technical difficulties"*, while "*properly completed project tasks"* (red colour) rises to about 595 tasks. "*Undiscovered rewo*rk" (grey colour) stays at near zero throughout the project life time. This is a reasonable expectation.

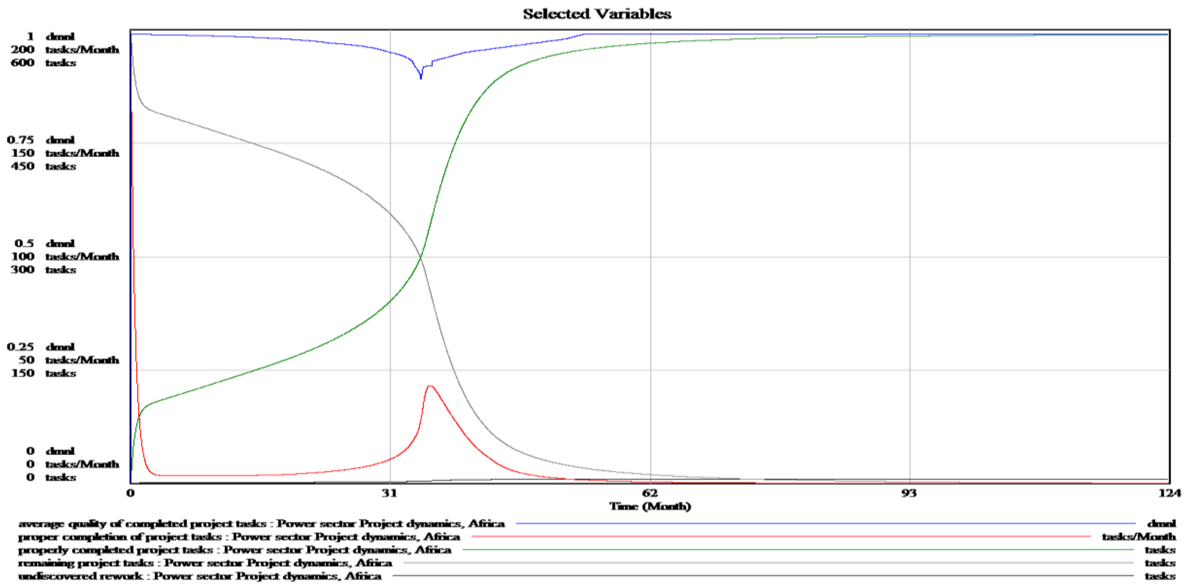

Figure 6.54: Simulation results when fraction properly completed is fixed at 0.99

Undiscovered rework is modeled as;

undiscovered rework = INTEG (poor completion of project tasks – detecting undiscovered rework) (units: tasks) (6.33)

When *"undiscovered rework"* is fixed at 0.5 tasks and the basic model is simulated, the results as shown in figure 6.55 indicate that "*detecting undiscovered rework"* (blue colour) and "*testing personnel"* (green colour) fall and stay constant at near zero throughout the project life time, while "*fraction undiscovered rework"* (red colour) rises slightly but remains low at about 0.075 by month 70 of the project time. This is a reasonable expectation.

When "*undiscovered rework"* is fixed at 600 tasks and the basic model is simulated, the results as shown in figure 6.56 indicate that "*average quality of completed project tasks"* (blue colour) stays at zero during the project life, while "*fraction undiscovered rework"* (red colour) stays at 1 (100%).

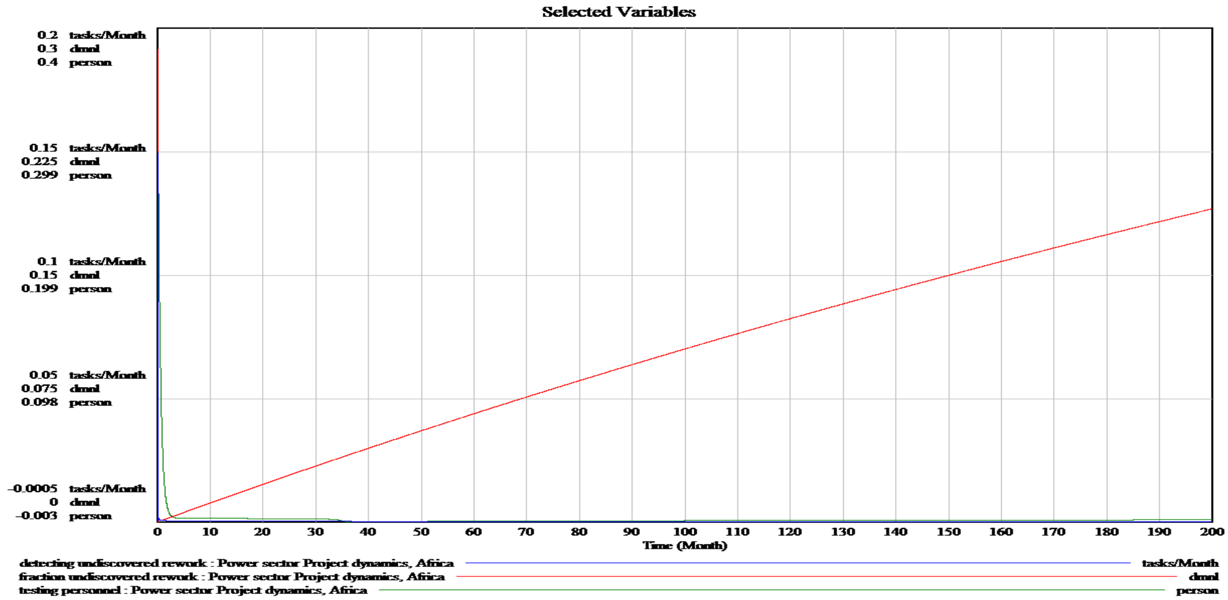

Figure 6.55: Simulation results when undiscovered rework is fixed at 0.5 tasks

Further, figure 6.56 also indicates that *"progress"* (green colour) drops from about 1.75 tasks/month to about 0.3 tasks/month within 1 month of the project time. This is a reasonable expectation.

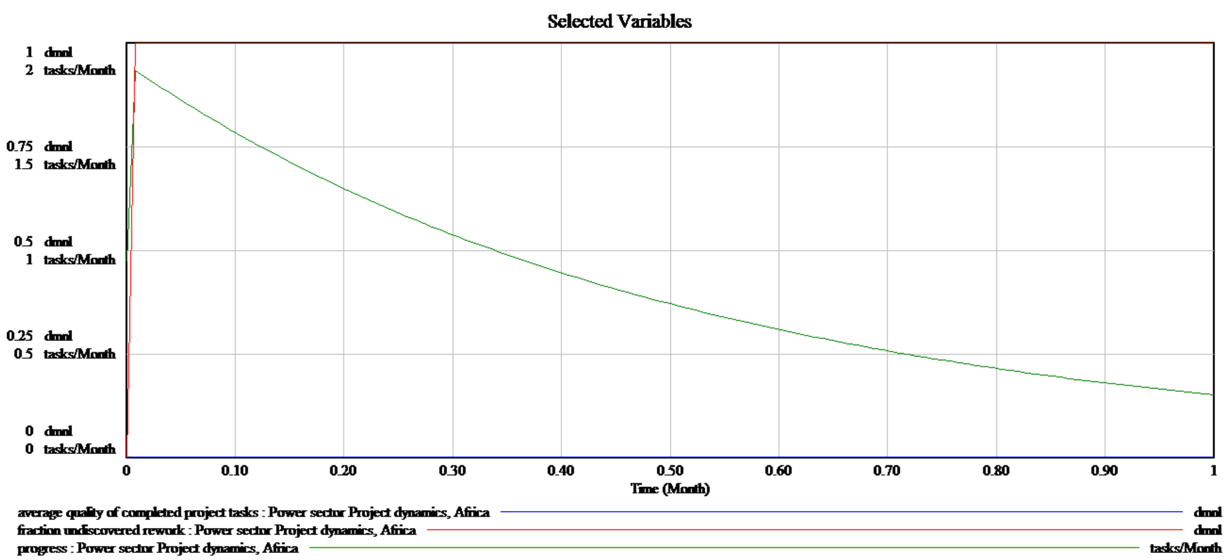

Figure 6.56: Simulation results when undiscovered rework is fixed at 600 tasks

The “*productivity of testing”* is modeled as;

*productivity of testing = maximum productivity of testing*fraction undiscovered rework* (6.34)

*(units: tasks/ (person*Month)*

When *“productivity of testing”* is fixed at 0 tasks/ person/Month and the basic model is simulated, the results as shown in figure 6.57 indicate that “*detecting undiscovered rework”* (blue colour) stays at zero for the project duration, “*properly completed project tasks”* (red colour) rise to a maximum of about 420 tasks, while “*undiscovered rework”* (grey colour) rises and stays constant at about 180 tasks for the rest of the project lifetime. This is a reasonable expectation.

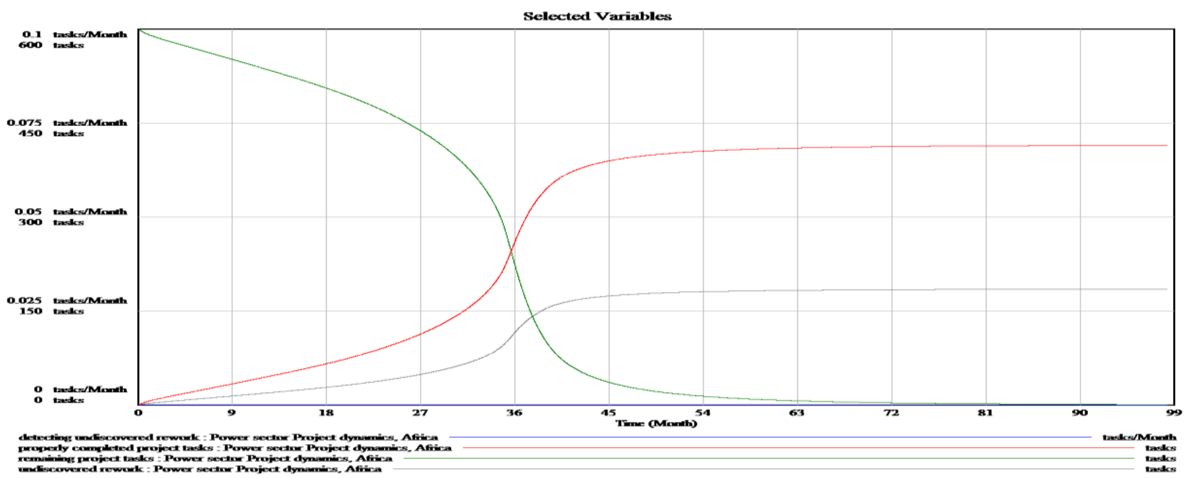

Figure 6.57: Simulation results when productivity of testing is fixed at 0 tasks/person/month

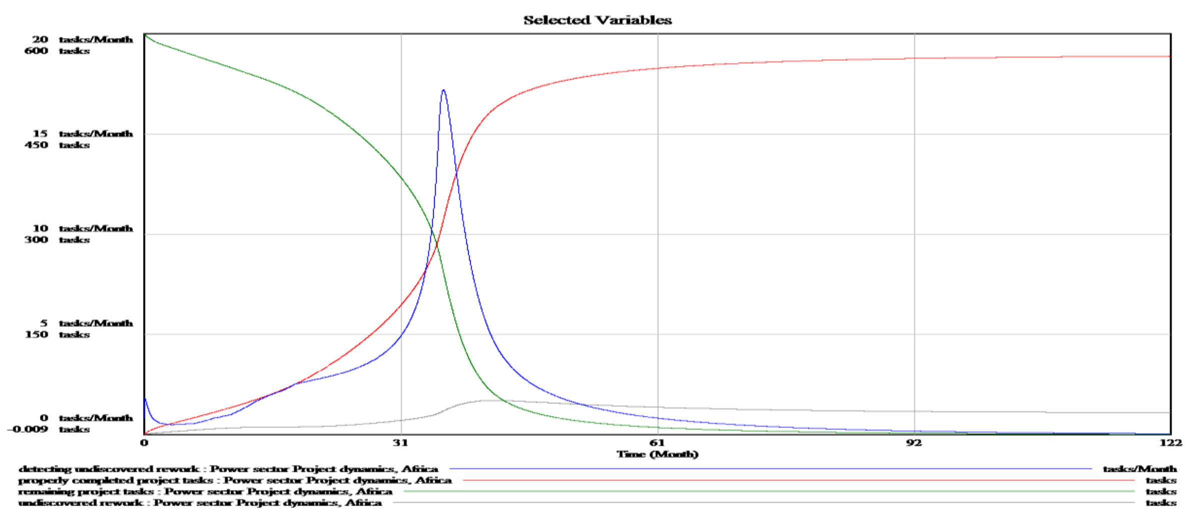

Figure 6.58: Simulation results when productivity of testing is fixed at 4 tasks/person/month

When *"productivity of testing"* is raised and fixed at 4 tasks/ person/Month and the basic model is simulated, results as shown in figure 6.58 indicate that "*detecting undiscovered rework"* (blue colour) rises and peaks at about 17 tasks/month, while "*properly completed project tasks"* (red colour) rises to about 550 tasks. "*Undiscovered rework"* (grey colour) rises to about 50 tasks, then drops progressively to about 30 tasks. This is a reasonable expectation.

Maximum productivity of testing is modeled as a constant; *Maximum productivity of testing = 2 (units: dimensionless)* (6.35)

When *"Maximum productivity of testing"* is fixed at 0 and the basic model is simulated, the results as shown in figure 6.59 indicate that "*detecting undiscovered rework"* (blue colour) as well as "*productivity of testing"* (red colour) both stay constant at zero, while "*undiscovered rework"* (grey colour) rises to about 180 tasks and "*properly completed project tasks"* (green colour) rises to about 420 tasks. This is a reasonable expectation.

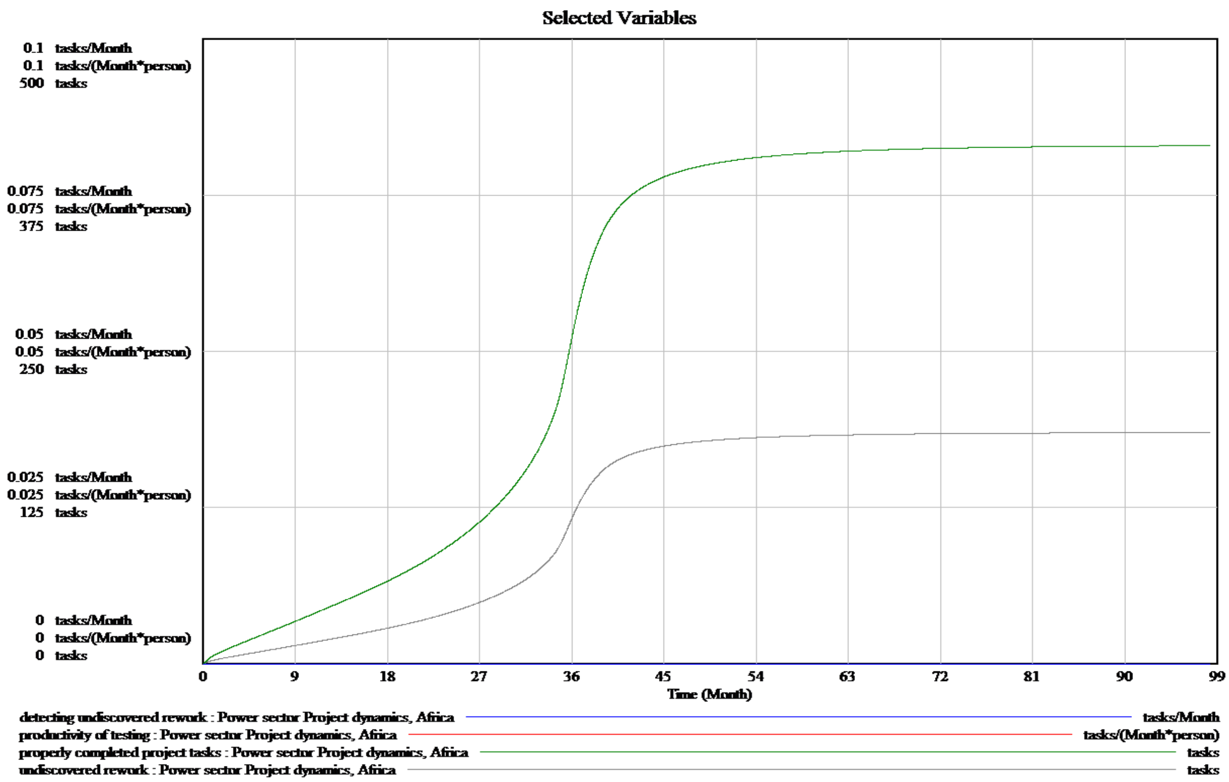

Figure 6.59: Simulation results when maximum productivity of testing is fixed at 0 tasks/person/month.

When "*Maximum productivity of testing*" is fixed at 1000 tasks/person/month and the basic model is simulated, the results as shown in figure 6.60 indicate that "*detecting undiscovered rework*" (blue colour) rises to a peak of about 22 tasks/month at about 36 months, "*productivity of testing*" (red colour) rises to about 60 tasks/person/month at 4 months project time before dropping off to about 30 tasks/person/month at 18 month project time and later to 17 tasks/person/month at about 60 month project time. "*Properly completed project tasks*" (green colour) rises to about 598 tasks at 88 months project time, while "*undiscovered rework*" (black colour) stays at a low of near zero. This is a reasonable expectation.

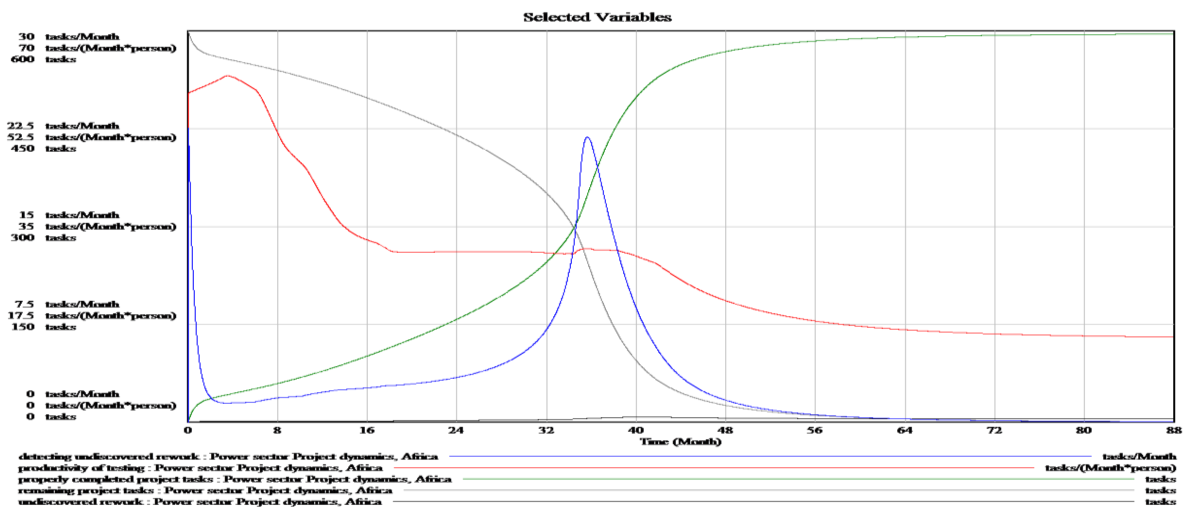

Figure 6.60: Simulation results when maximum productivity of testing is fixed at 1000 tasks/person/month

The "*fraction undiscovered rework*" is modeled as equal to undiscovered rework divided by "*perceived cumulative progress*", and the "*perceived cumulative progress*" is modeled with a 'MAX' function so that the denominator cannot be equal to zero.

fraction undiscovered rework = undiscovered rework/MAX (perceived cumulative progress, 0.01)(units: dimensionless) (6.36)

When *"fraction undiscovered rework"* is fixed at 0 and the basic model is simulated, the results as shown in figure 6.61 indicate that "*detecting undiscovered rework*" (blue colour) and *"productivity of testing"* (red colour) both stay constant at zero during the project duration, while "*remaining project tasks"* (green colour) reduce from 600 tasks to zero in about 72 months. This is a reasonable expectation.

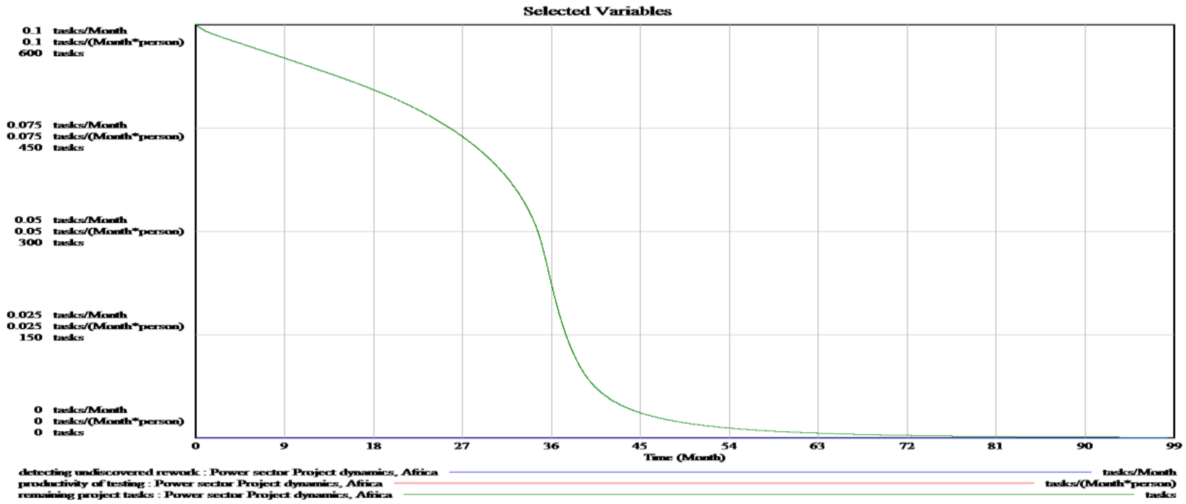

Figure 6.61: Simulation results when fraction undiscovered rework is fixed at 0

When *"fraction undiscovered rework"* is fixed at 1 and the basic model is simulated, the results as shown in figure 6.62 indicate that "*detecting undiscovered rework"* (blue colour) rises to peak at about 13 tasks/month, while "*productivity of testing"* (red colour) stays at 2 tasks/person/month. "*Properly completed project tasks"* (green colour) rise to about 525 tasks, and "*undiscovered rework"* (black colour) rises to about 80 tasks then reduces slowly to about 75 tasks. This is a reasonable expectation.

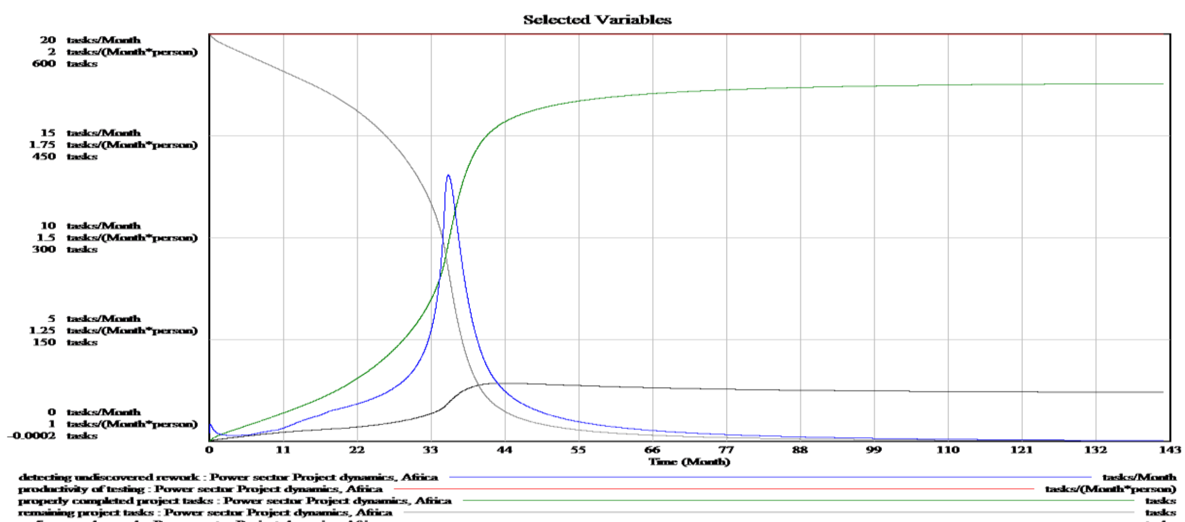

Figure 6.62: Simulation results when fraction undiscovered rework is fixed at 1

The quantity of the "*testing personnel*" is equal to the "*fraction of personnel for testing*" multiplied by the total "*workforce*" assigned to the project.

*testing personnel = fraction personnel for testing*workforce (units: person)* (6.37)

When *"testing personnel"* is fixed at 0 person and the basic model is simulated, the results as shown in figure 6.63 indicate that "*detecting undiscovered rework*" (blue) remains at a constant of zero for the duration of the project, while "*properly completed project tasks*" (red) rise to about 420 tasks. "*Remaining project tasks*" (green) change and reduce from 600 tasks to zero at project time 72 months, while "*undiscovered rework*" (grey) rises to about 180 tasks. This is a reasonable expectation.

When *"testing personnel"* is fixed at 400 persons and the basic model is simulated, the results as shown in figure 6.64 indicate that "*average quality of project tasks*" (blue colour) rises to about 0.99 except between project time 24 months and 48 months when it dips due to effects of "*multitasking*" and "*unforeseen technical difficulties*".

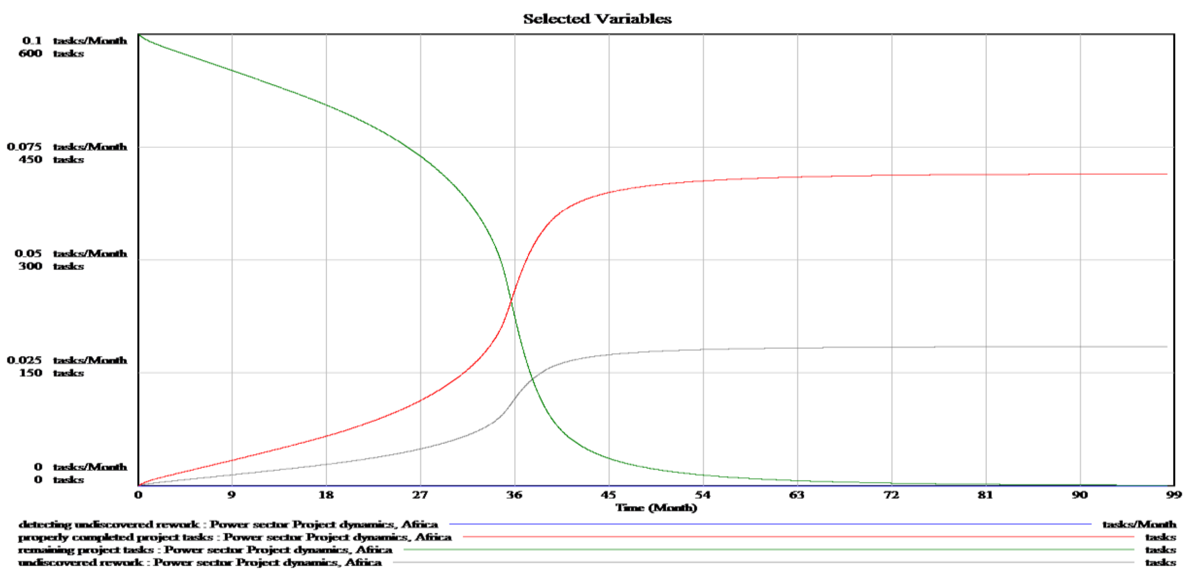

Figure 6.63: Simulation results when testing personnel is fixed at 0 persons

Figure 6.64 also indicates that when *"testing personnel"* is fixed at 400 persons, "*detecting undiscovered rework*" (red colour) rises to a peak of about 10 tasks/person/month at 36 months project time, while "*properly completed project tasks*" rises (green colour) to 600 tasks at 60 month project time. *Undiscovered rework* (black colour) stays constant during the project period at near zero. This is a reasonable expectation.

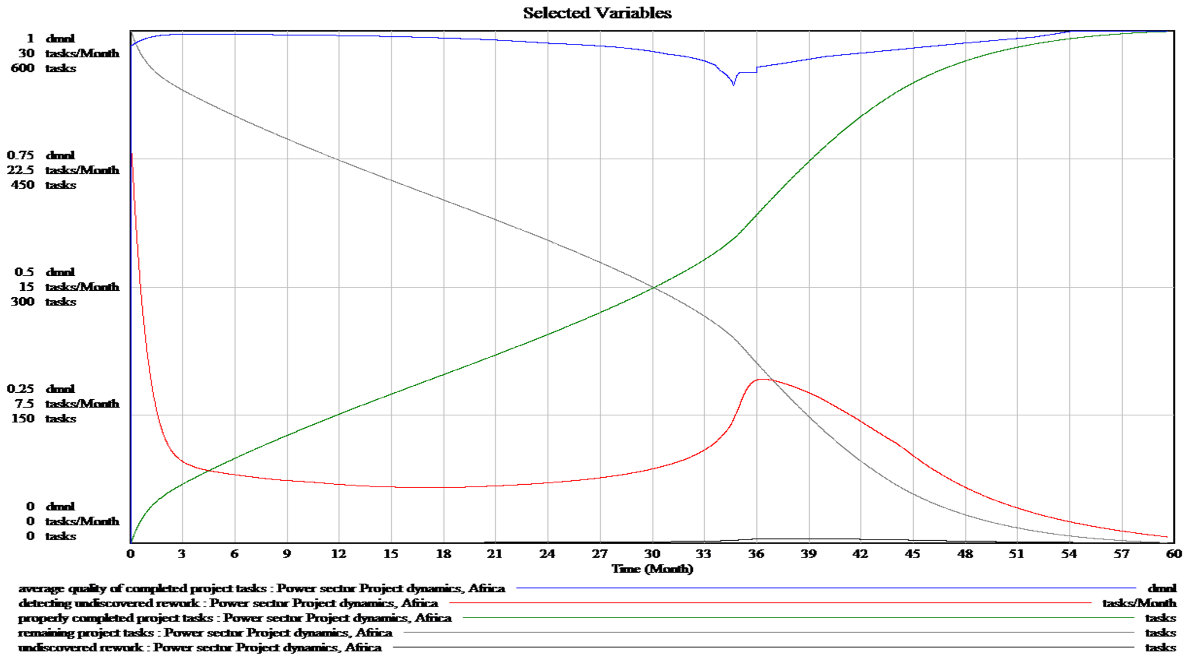

Figure 6.64: Simulation results when testing personnel is fixed at 400 persons

The "*fraction of personnel for testing"* is modeled as;

fraction personnel for testing = WITH LOOKUP (reported fraction detection undiscovered rework,

([(0,0)-1,1)],(0,0.1), (0.1,0.09), (0.2,0.1), (0.3,0.14), (0.4,0.16), (0.49,0.2), (0.59,0.24), (0.68,0.26),(0.76,0.27), (0.87,0.28), (0.99,0.3), (200, 0.3).*) (units: dimensionless)* (6.38)

When *"fraction personnel for testing"* is set at 0 and the basic model is simulated, the results as shown in figure 6.65 indicate that "*detecting undiscovered rework"* (blue colour) and "*testing personnel"* (grey colour) both stay constant at zero, "*undiscovered rework"* (green colour) rises and stays at 180 tasks, while "*properly completed project tasks"* (red colour) rises to 420 tasks. This is a reasonable expectation.

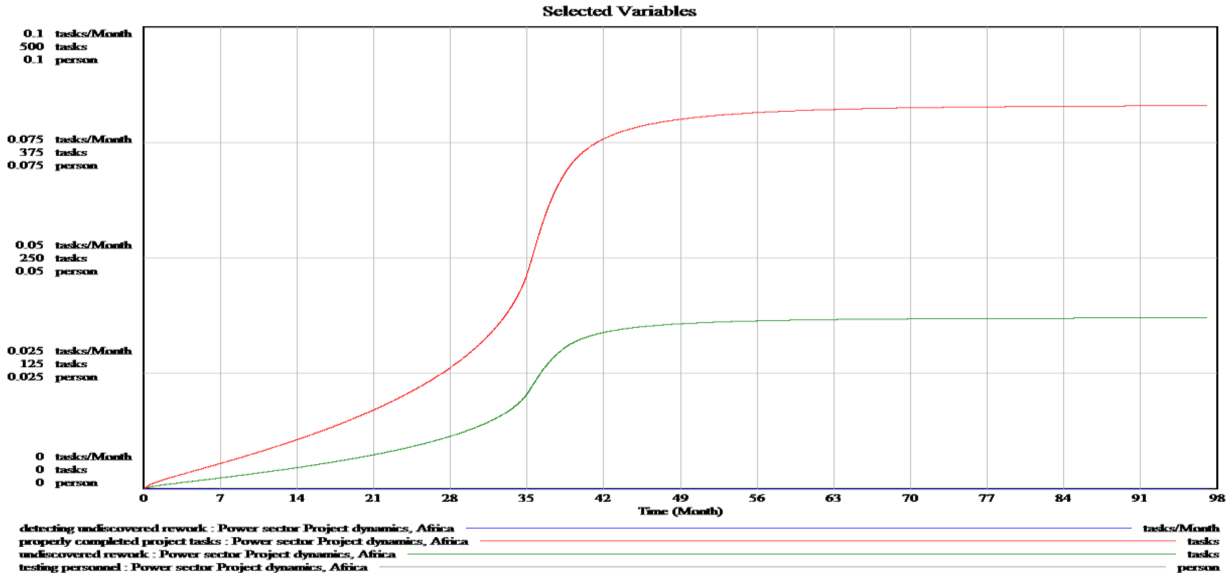

Figure 6.65: Simulation results when fraction personnel for testing is fixed at 0

When *"fraction personnel for testing"* is set at 1 and the basic model is simulated, the results as shown in figure 6.66 indicate that "*progress"* (blue colour) and "*project personnel"* (red colour) both stay constant at zero, while "*remaining project tasks"* (green colour) stays constant at 600 tasks. This is a reasonable expectation as all the project staff will be in testing.

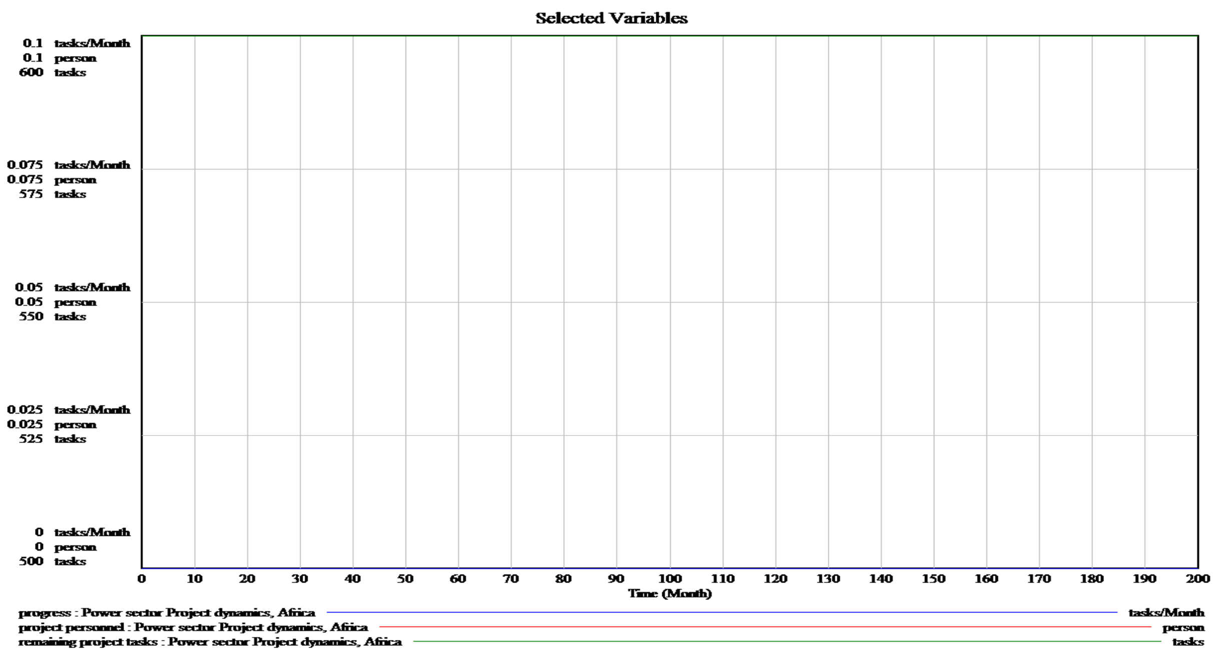

Figure 6.66: Simulation results when fraction personnel for testing is fixed at 1

6.3.3 Numerical sensitivity and Behavior Sensitivity tests

Numerical sensitivity analysis investigates if the numerical values change significantly under uncertainty, while the behavior sensitivity test focuses on sensitivity of model behavior to changes in parameter values. Khasawneh et al (2010) state that sensitivity analysis is studying the impact of input changes (nature and magnitude) on outputs. This view point is shared by Shannon et al (2013) when they state that sensitivity analysis is studying the impact input changes have on outputs. Specifically, analysts and decision makers are interested in understanding how much output variation is produced by varying the inputs of a system (Eker et al, 2014). It ascertains whether or not plausible shifts in model parameters can cause a model to fail behavior test previously passed. To the extent that such parameter values are not found, confidence in the model is enhanced (Sterman, 2000).

The behavior sensitivity test is typically conducted by experimenting with different parameter values and analyzing their impact on behavior (Wang et al 2012, Marimon et al 2013). Typically, the behavior of System Dynamic models is insensitive to plausible changes in most parameter values, and real systems are likewise insensitive. On the other hand, both real systems and models of real systems show behavior sensitivity to a few parameters. In such cases, one should ascertain if indeed the real system is likewise sensitive to the parameter in question. If it is, the sensitive parameter may be an important input for policy analysis (Forrester and Senge, 1980). Sensitivity analysis is usually done after the model has been found to replicate the problem behavior of the system under study (Ford, 2002).

The purpose of a System Dynamics intervention is to identify how structure and decision policies generate system behavior identified as problematic, so that structural and policy oriented solutions can be identified and implemented (Forrester, 1961; Sterman, 2000, Lorentz and Jost, 2006, Forrester, 2009). Sensitivity analysis not only determines the effect of variations in assumed information on the model output, but “it also helps to develop intuition about model structure and guides the data collection efforts” (Sterman, 2000). The first step of sensitivity analysis is one-variate sensitivity analysis, conducted with “one-at-a time approach” (Saltelli et al., 2000). On the same subject, Martinez and Otto (2001) note that in all models, parameters are likely to be uncertain, and the modeler is often unsure of their current values, and even more uncertain about their future values. Uncertainty is one of the primary reasons why sensitivity analysis is helpful in making decisions or recommendations. If parameters are uncertain, sensitivity analysis can give information such as; how robust the optimal solution is in the face of different parameter values; under what circumstances the optimal solution would change; and how the optimal solution changes in different circumstances (Martinez and Otto, 2001).

These views are supported by Sterman (2000) when he states that in nonlinear and complex models, one-variate sensitivity analysis is insufficient for a comprehensive study of the model because simultaneous changes in more than one parameters' values may create an unexpected output change because of the nonlinear relationships among different model components. Therefore, one-variate analysis should be followed by multi-variate sensitivity analysis. When building a system dynamics model, the modeler is usually somewhat uncertain about the parameter values they choose and must often use estimates (Koul et al, 2016).

Sensitivity analysis allows one to determine what level of accuracy is necessary for a parameter to make the model sufficiently useful and valid, and If the model behaves as expected from real world observations, it gives some indication that the parameter values reflect, at least in part, the "real world" (Breierova and Choudhari, 1996). Univariate and multivariate sensitivity analysis was done on the basic model presented in this research as a new model of project dynamics for electricity sector projects in Kenya, and the outcomes were checked over a wide range of inputs to ensure the numerical values do not change significantly. The modes of behavior generated by the model were also checked for significant changes.

In order to do sensitivity simulations, one needs to define what kind of probability distribution values for each parameter will be drawn from. The simplest distribution is the "Random Uniform Distribution", in which any number between the minimum and maximum values is equally likely to occur. The "Random Uniform Distribution" is suitable for most sensitivity testing and is selected by default in Vensim (Ventana Systems Inc., 2002). Sang and Anil (2009) note that in probability theory and statistics, the continuous uniform distribution or rectangular distribution is a family of symmetric probability distributions such that for each member of the family, all intervals of the same length on the distribution's support are equally probable. The support may be defined by the two parameters, ‘a’ and ‘b’, which are its minimum and maximum values. The probability density function of the continuous uniform distribution is thus given as follows:

$$f(x) = \begin{cases} \frac{1}{b-a} \; for \; a \le x \le b \\ 0 \quad for \; x < a \; or \; x > b \end{cases} \quad (6.39)$$

In conducting a sensitivity analysis, the process involves: listing the exogenous parameters and relations about which estimates were made; determining the possible range for each parameter; after picking the parameter that is likely to be important, running the model under a full range of different values for that parameter while holding everything else constant. Ordinarily, the model behaviour would not change significantly even when numerical values change, and confidence in the model would be achieved. If model behavior changes significantly, the model is sensitive to the selected parameter (Martinez and Otto 2001), though in system dynamics, the behavior patterns of model variables are more important than their numerical values (Hokimoglu and Barlas, 2010). From the basic model in Fig. 6.2, the exogenous variables as given in table 6.1 were derived as averages resulting from results of the exploratory study involving 60 experts from the electricity industry in Kenya as given in Appendix L. The minimum and maximum values as indicated by the participants were used directly into table 6.1 as the “Proposed Minimum value of variable” and “Proposed Maximum value of variable”.

Table 6.1: Exogenous variables with estimated values in the basic model in Fig. 6.2

Exogenous variable	Meaning	Estimated value in basic model	Proposed Minimum value of variable	Proposed Maximum value of variable	Guiding question in Appendix A
Time to adapt workforce	Time taken to familiarize and train new workforce so as to deliver satisfactory output in the project	0.5 (months)	0.3	0.7	Qstn. 38
Maximum productivity of testing	The maximum testing tasks that a testing engineer performs in a	2 (tasks/person/month)	1	3	Qstn. 39

	month				
Fraction properly completed	The fraction of tasks done well enough first time so as not to require rework	0.7 (dimensionless)	0.5	0.8	Qstn. 42

The proposed minimum and maximum values in table 6.1 are used in performing univariate and multivariate sensitivity analysis using the random uniform distribution in Vensim. Results of sensitivity testing can be displayed in terms of histograms which provide a cross section of values at a particular period in time. Histograms provide a mechanism for seeing the distribution of values for a variable over all the simulations done at a specified time or across time (Ventana Systems, 2012). Histograms of output results for multivariate sensitivity testing on the simulation model in Fig. 6.2 are given in Appendix J.

6.3.3.1 Univariate analysis, 200 runs (Random uniform distribution)

a. “time to adapt workforce” varying from 0.3 months to 0.7months

In this analysis, 200 simulation runs are made on the basic model in figure 6.2, which is the new model of project dynamics in the electricity sector in Kenya, developed in this research. In each simulation run, the value of “time to adapt workforce” is randomly chosen from the range 0.3 to 0.7 months.

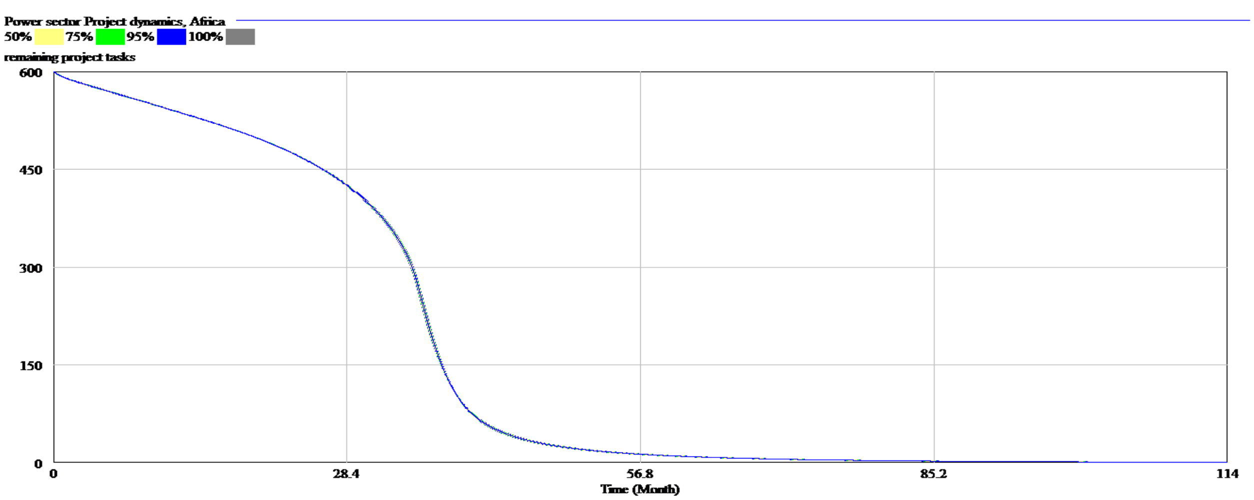

Fig. 6.67: Remaining project tasks sensitivity trace range under time to adapt workforce uncertainty

Fig. 6.67 shows the possible effect of time to adapt workforce on remaining project tasks, with minimal variations of remaining project tasks as a result of changes in time to adapt workforce, while Fig. 6.68 shows the possible scenarios of properly completed project tasks with uncertainty in time to adapt workforce, and shows that the trace for properly completed project tasks also changes minimally under time to adapt workforce uncertainty. In both traces, the original behavior pattern is maintained.

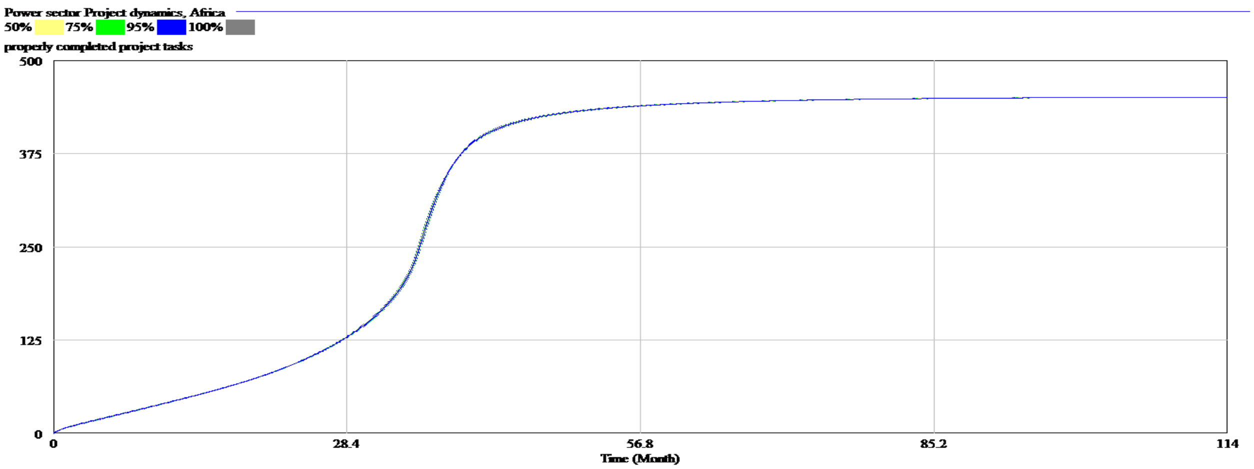

Fig. 6.68: Properly completed project tasks sensitivity trace ranges under time to adapt workforce uncertainty

Fig. 6.69 shows the possible scenarios of Average quality of completed project tasks with uncertainty in time to adapt workforce, and shows minimal changes in the trace under time to adapt workforce uncertainty.

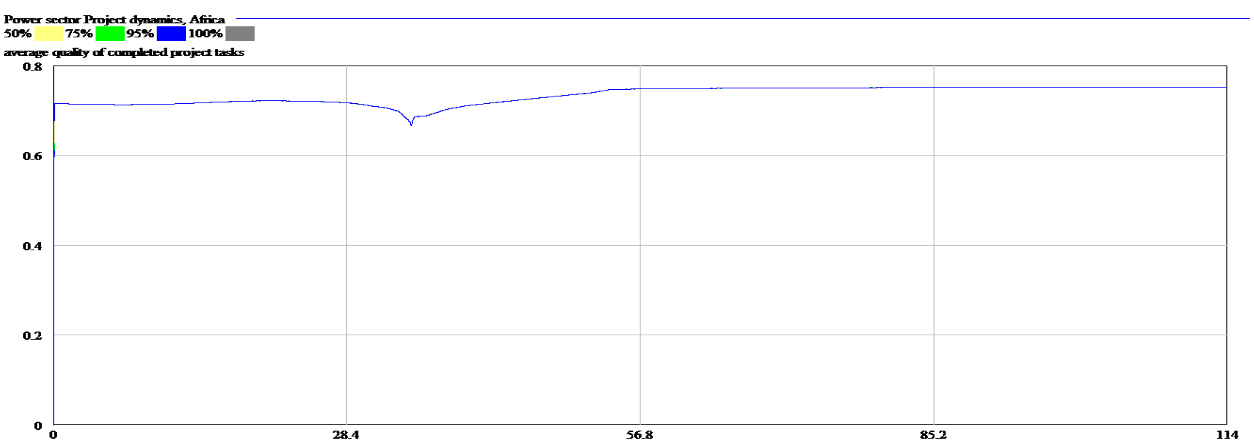

Fig. 6.69: Average quality of completed project tasks sensitivity trace range under time to adapt workforce uncertainty

b. With "maximum productivity of testing" changing from 1 to 3

In this analysis, 200 simulation runs are made on the basic model in figure 6.2 while in each simulation run, the value of "maximum productivity of testing" is randomly chosen from the range 1 to 3.

Fig. 6.70 shows the possible effect of productivity of testing on remaining project tasks, with minimal variations in the remaining project tasks trace. The original behavior pattern is maintained.

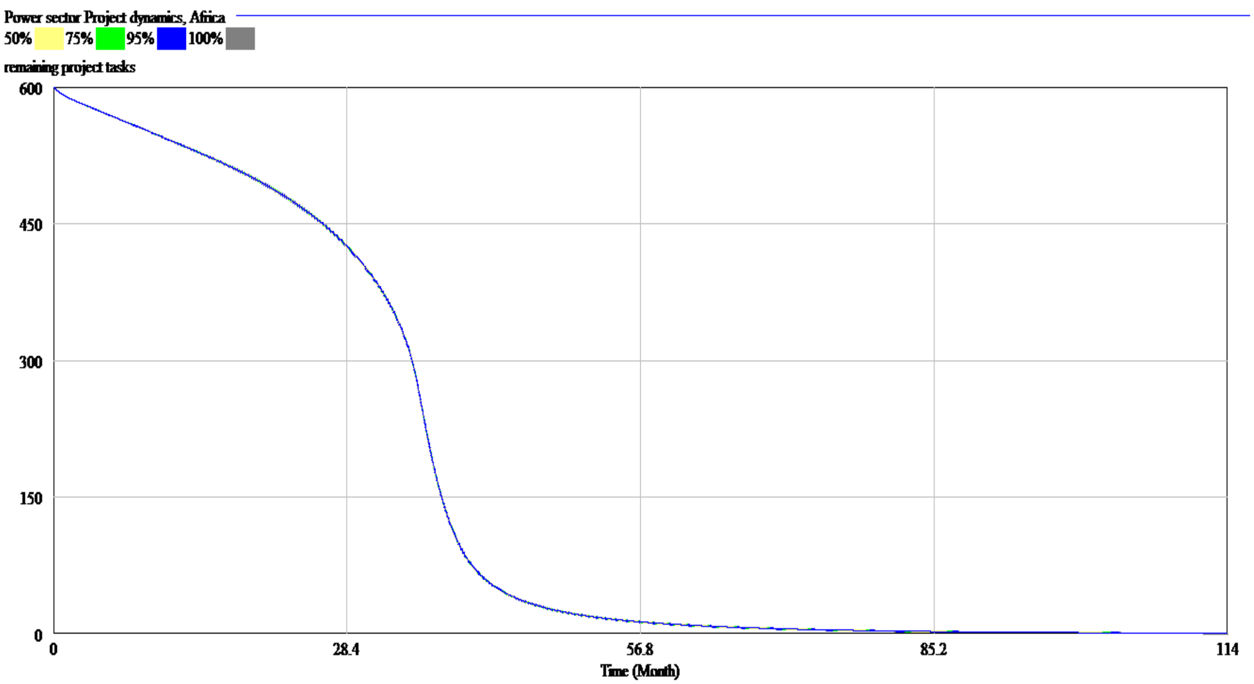

Fig. 6.70: Remaining project tasks sensitivity trace ranges under maximum productivity of testing uncertainty

The possible scenarios for properly completed project tasks levels with uncertainty in maximum productivity of testing is shown in Fig. 6.71, with minimal numerical variations noted, while maintaining the original behavior pattern.

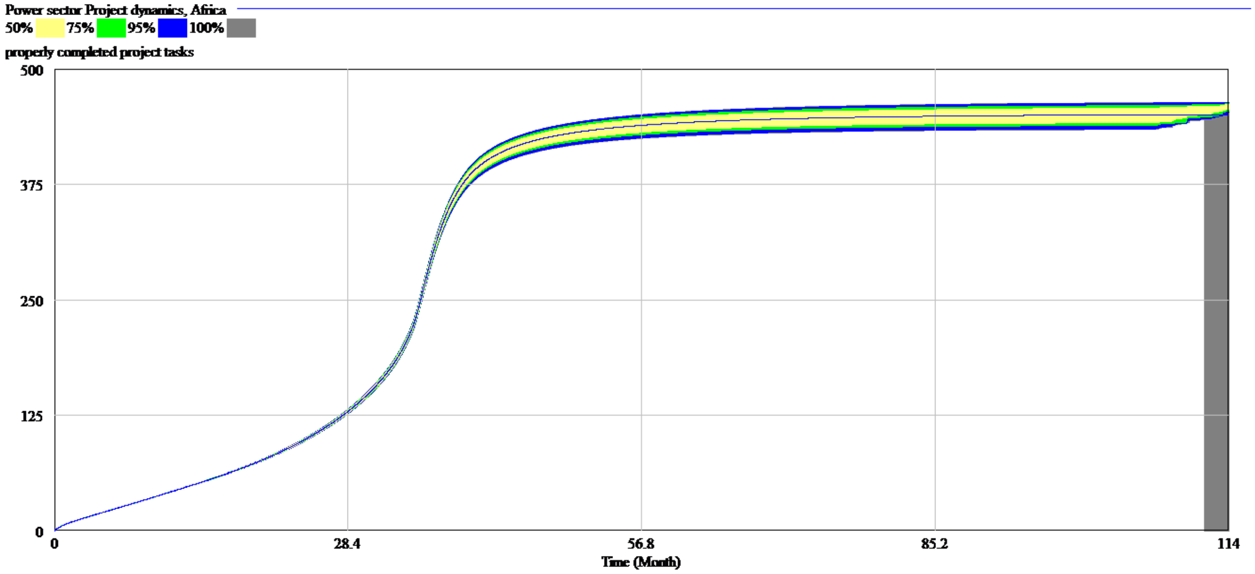

Fig. 6.71: Properly completed project tasks sensitivity trace ranges under maximum productivity of testing uncertainty

Similarly, the possible scenarios for average quality of completed project tasks levels with uncertainty in maximum productivity of testing is shown in Fig. 6.72, with minimal numerical variations noted, while maintaining the original behavior pattern.

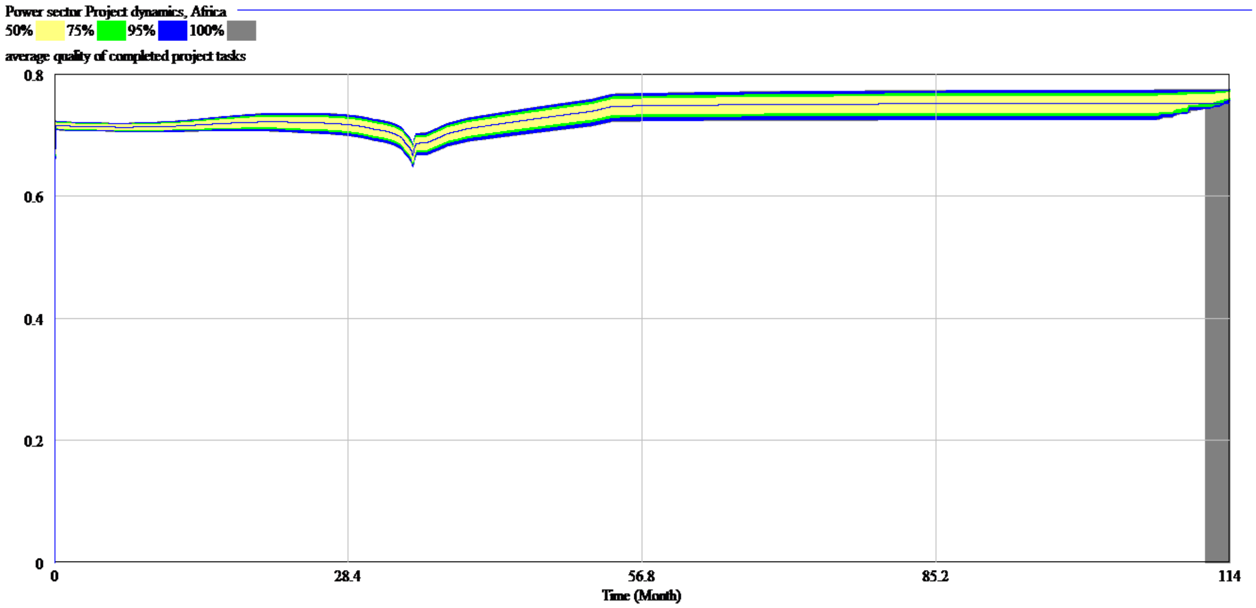

Fig. 6.72: Average quality of completed project tasks sensitivity trace ranges under maximum productivity of testing uncertainty

c. With “fraction properly completed” changing from 0.5 to 0.8

In this analysis, 200 simulation runs are made on the basic model in figure 6.2 while in each simulation run, the value of “fraction properly completed” is randomly chosen from the range 0.5 to 0.8 months.

Fig. 6.73 shows the possible effect of fraction properly completed on remaining project tasks, with minimal numerical variations noted, while maintaining the original behavior pattern.

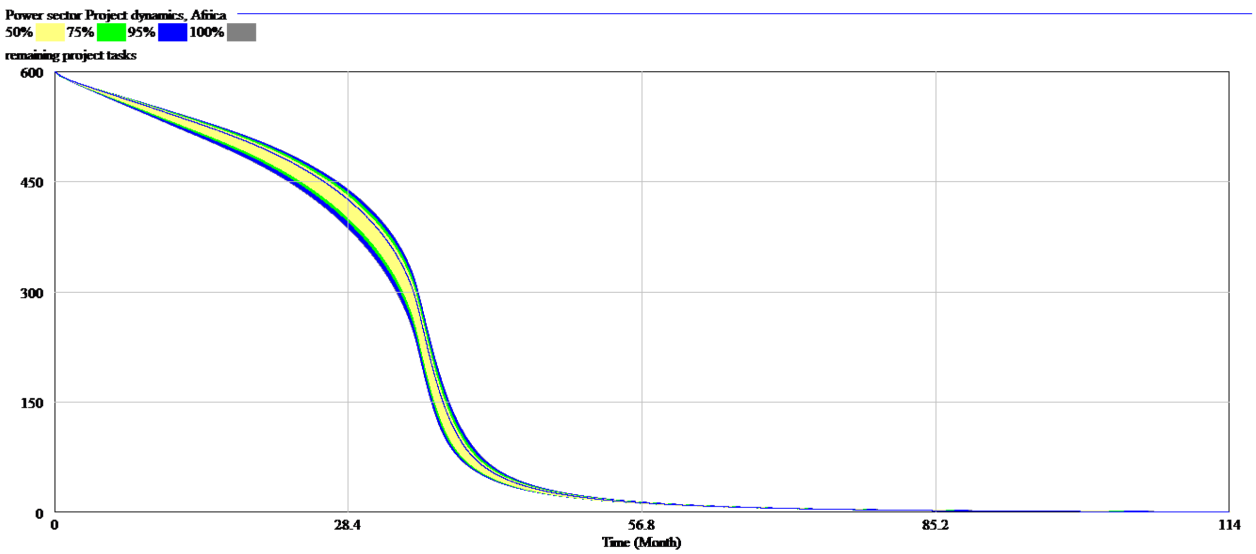

Fig. 6.73: Remaining project tasks sensitivity trace ranges under fraction properly completed uncertainty

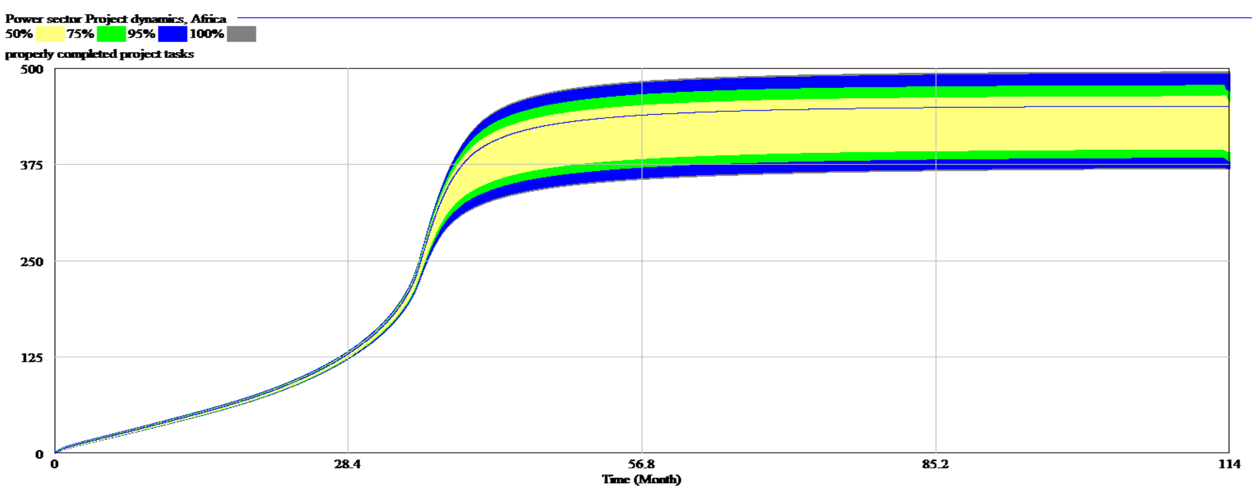

Fig. 6.74: Properly completed project tasks sensitivity trace ranges under fraction properly completed uncertainty

The possible scenarios for properly completed project task levels with uncertainty in fraction properly completed is shown in Fig. 6.74 with properly completed project task levels peaking and leveling off at about 56 months, with levels of properly completed project tasks ranging from 350 tasks to 475 tasks. The original behavior pattern is maintained.

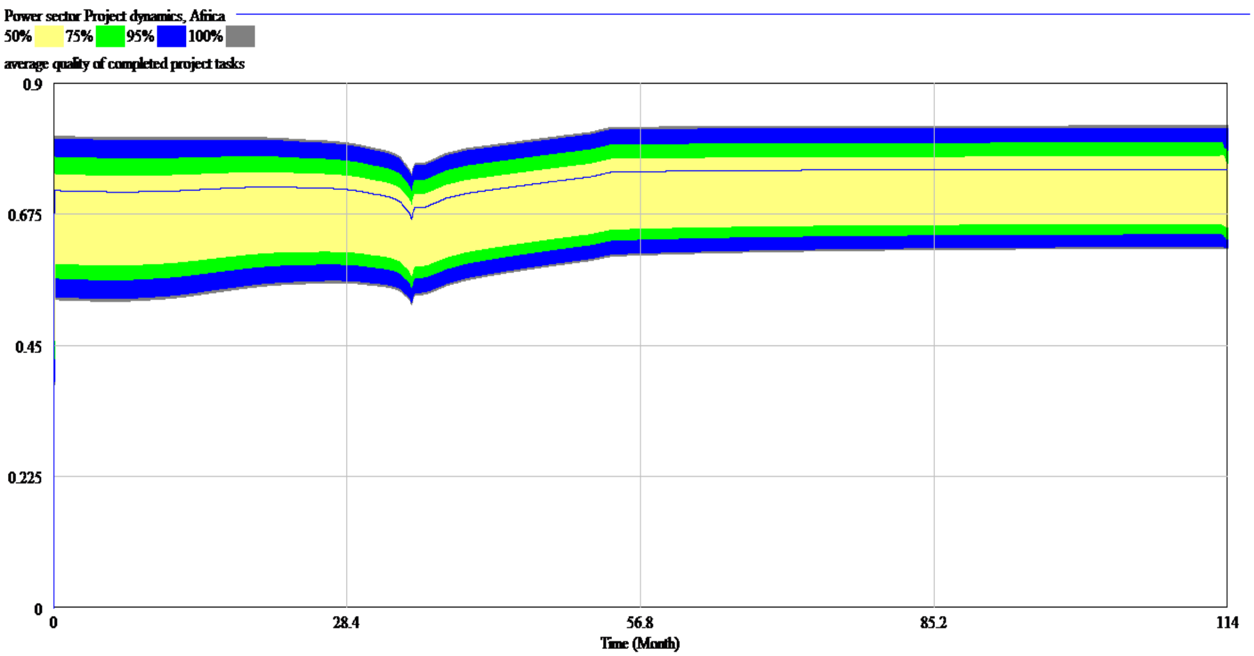

Fig. 6.75: Average quality of completed project tasks sensitivity trace ranges under fraction properly completed uncertainty

Fig. 6.75 shows the possible effect of fraction properly completed variations on average quality of completed project tasks, with a numerical variance of 0.6 to 0.8 noted at about 56 months of project time. The original behavior pattern is maintained.

6.3.3.2 Multivariate analysis, 200 runs (with random uniform distributions)

Multivariate analysis was done by having all the three variables in table 6.1 randomly but uniformly changing together during the sensitivity simulation runs, and the results are given in Fig. 6.76 to Fig. 6.80.

a. With “time to adapt workforce” changing from 0.3 months to 0.7months
b. With “maximum productivity of testing” changing from 1 to 3
c. With “fraction properly completed” changing from 0.5 to 0.8

Fig. 6.76 shows possible scenarios of remaining project tasks spread under multivariate uncertainty, with minimal numerical variations, while the original behavior pattern is maintained.

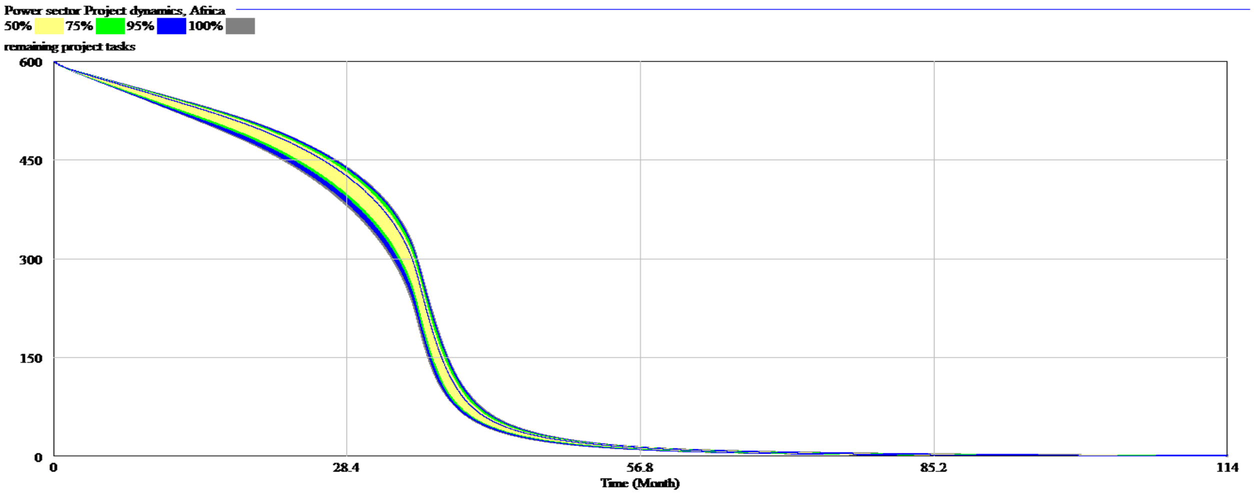

Fig. 6.76: Remaining project tasks sensitivity trace ranges under multivariate uncertainty

Fig. 6.77 shows possible scenarios of properly completed project tasks spread under multivariate uncertainty, and at about 56 months, it shows a wide dispersion of possible properly completed project tasks spread ranging from 350 tasks to 500 tasks due to the multivariate effect. However, the original behavior pattern is maintained in the trace.

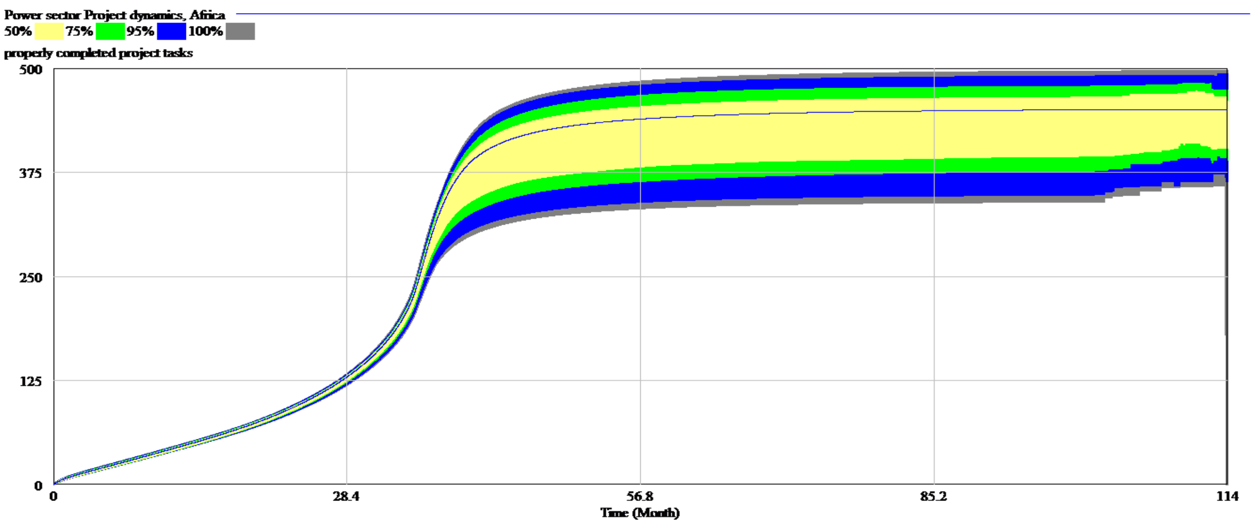

Fig. 6.77: Properly completed project tasks sensitivity trace ranges under multivariate uncertainty

Fig. 6.78 shows possible scenarios of average quality of completed project tasks spread under multivariate uncertainty, and at about 56 months, the average quality of completed project tasks spread shows changes from 0.6 to 0.8. The original behavior pattern is maintained in the trace.

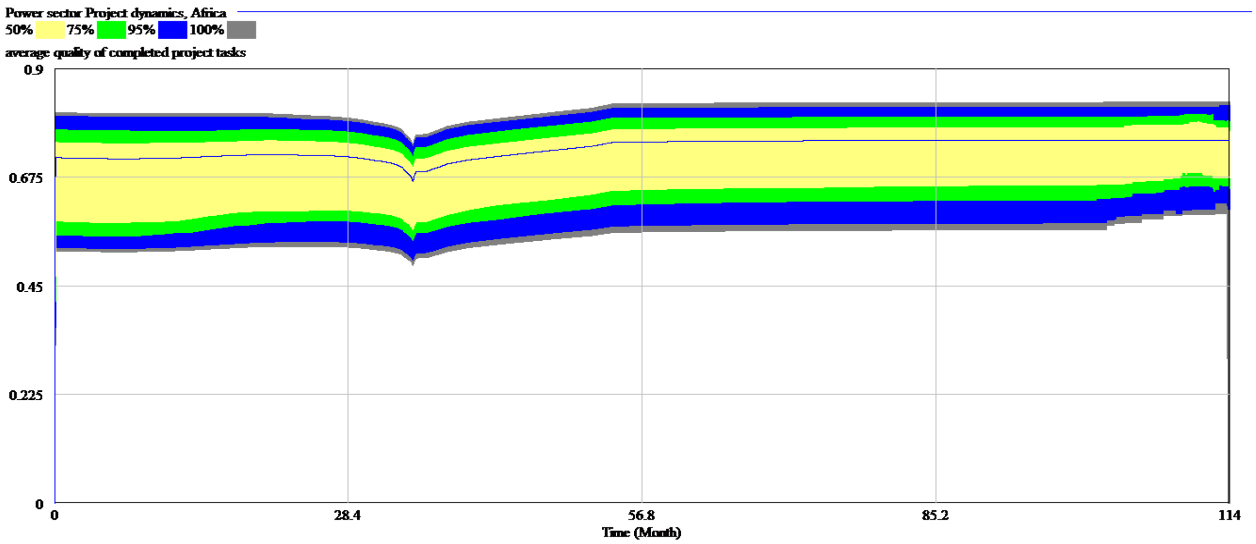

Fig. 6.78: Average quality of completed project tasks sensitivity trace ranges under multivariate uncertainty

Similarly, Fig. 6.79 shows possible scenarios of progress spread under multivariate uncertainty, and at about 36 months, it shows a dispersion of possible progress spread ranging from 58 tasks/month to 78 tasks/month. The original behavior pattern is also maintained in this trace.

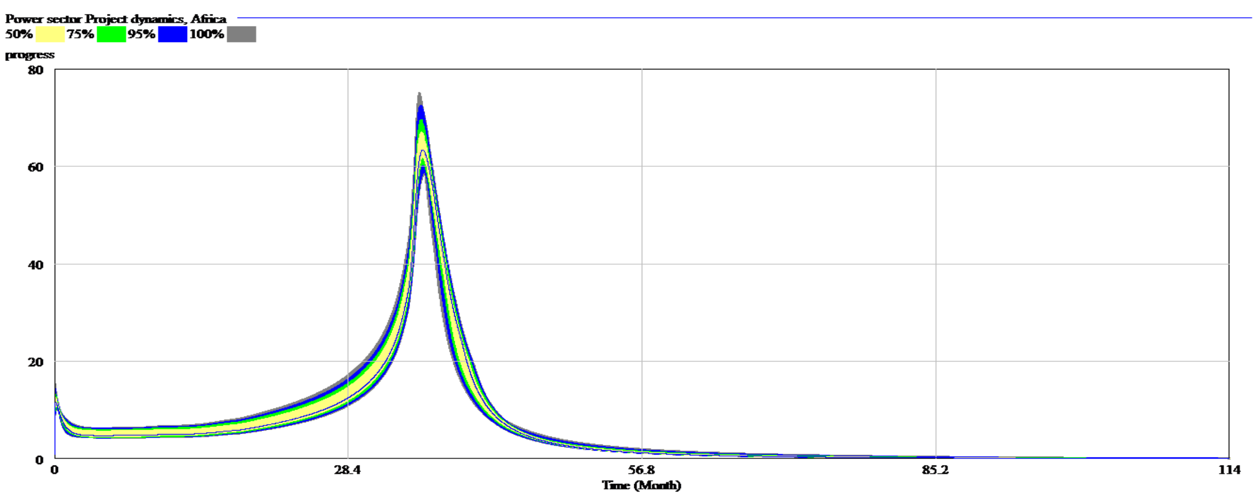

Fig. 6.79: Progress sensitivity trace ranges under multivariate uncertainty

Fig. 6.80 shows possible scenarios of testing personnel spread under multivariate uncertainty, and at about 36 months, it shows a dispersion of possible testing personnel spread ranging from 5 persons to 23 persons. The original behavior pattern is maintained in this trace.

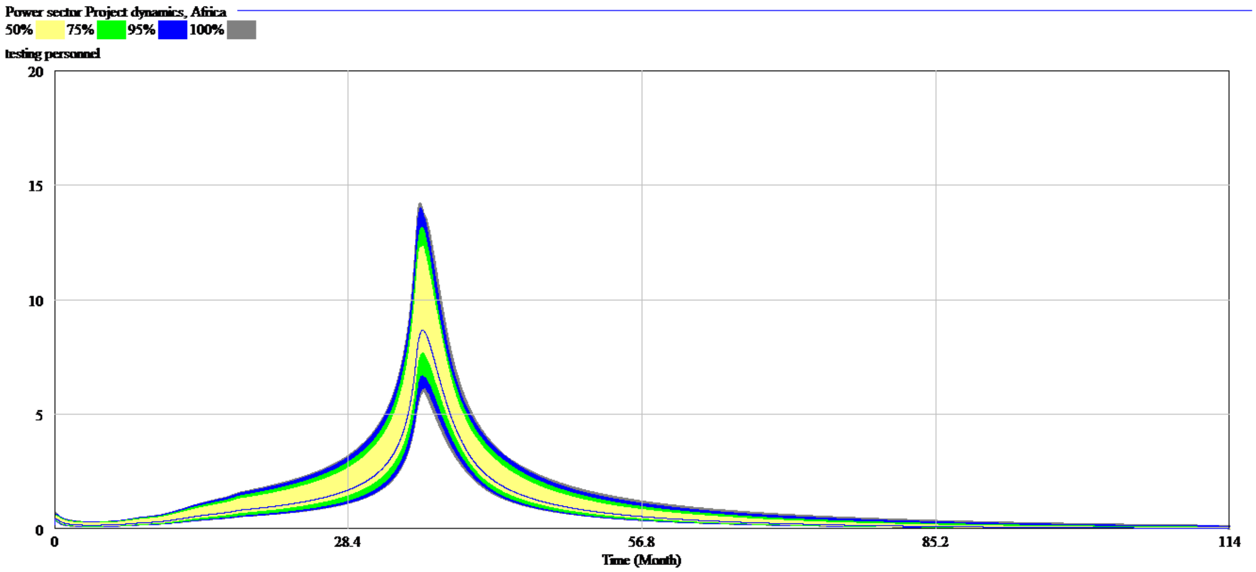

Fig. 6.80: Testing personnel sensitivity trace ranges under multivariate uncertainty

6.4 Behavior Pattern tests

Behavior pattern test is done by the comparison of the simulated behavior of the basic model to check that it reproduces the behavior as observed in the real system, while also checking for any surprise or anomalous behavior (Sterman, 2000). During this research, behavior reproduction test, behavior anomaly test and surprise behavior test were done as presented in section 6.4.1 to 6.4.3.

6.4.1 Behavior reproduction test

During this test, the basic model was simulated and the results checked and compared with reference mode results from the real system (see Appendix D) to check if the model behavior reproduces the behavior of interest in the system and to confirm if the model generates the various modes of behavior observed in the real system.

The following questions guided the analysis;

Does the model reproduce the behavior of interest in the system (qualitatively and quantitatively)?

(Related to and contributes to the answer of research question 1 in section 1.5; what are the project dynamics in the electricity industry in Kenya?)

Does the model generate the various modes of behavior observed in the real system?

(Related to and contributes to the answer of research question 1 in section 1.5; what are the project dynamics in the electricity industry in Kenya?)

Does it endogenously generate the symptoms of difficulty motivating the study?

*(*Related to and contributes to the answer of research question 2 in section 1.5; how do the prevalent risks and other elements interact with each other in a dynamic project set up?)

In answering the questions, model output and data were compared qualitatively, and this included comparison of model outputs to reference modes of behavior as well as comparison of shape of variables. According to Forrester and Senge (1980), tests involving point by point measures of goodness of fit are generally less appropriate for System Dynamics models because predicting the exact future values of a real system is not sound for evaluating assumptions in a System Dynamics model.

From the comparison of the results, the model behavior reproduces the behavior of the real system.

6.4.2 Behavior anomaly test

During this test, the outputs of the basic model were checked for anomalous behaviors when assumptions of the model were changed or deleted. This was done by zeroing out key effects and checking the outputs. Once the behavioral anomaly is traced to the elements of model structure responsible for the behavior, one often finds obvious flows in model assumptions Forrester and Senge (1980).

During the extreme condition test, the following variables were set to zero as part of the test;

Political risk index, Unforeseen technical difficulties, Remaining project tasks, Properly completed project tasks, Progress, gross productivity of project personnel, net hiring of personnel, Workforce, desired workforce, perceived effort remaining, perceived productivity, Perceived cumulative progress, Cumulative effort , Detecting undiscovered rework, poor completion of project tasks, undiscovered rework , productivity of testing, Maximum productivity of testing, fraction undiscovered rework, testing personnel, fraction personnel for testing.

Anomalous behavior was detected when "*Unforeseen technical difficulties"* was set to zero, as the "*poor completion of project tasks"* also became zero. Yet "*Unforeseen technical difficulties"* was designed so that *"Unforeseen technical difficulties = 0"* would imply technical difficulties are not seen and therefore *"poor completion of project tasks"* should be high.

The equation: *Poor completion of project tasks = progress*(1 - fraction properly completed)*Unforeseen technical difficulties;* (6.40)

was therefore corrected to:

Poor completion of project tasks = progress(1 - fraction properly completed)/Unforeseen technical difficulties* (6.41)

Anomalous behavior was detected when *Unforeseen technical difficulties* and *perceived productivity* were set to zero, and this led to the appropriate adjustments which were made on the related model equations to correct the flows.

6.4.3 Surprise Behavior test

The better and more comprehensive a System Dynamics model, the more likely it is to exhibit behavior that is present in the real system but which has gone unrecognized over time. When unexpected behavior appears, the model builder must first understand causes of the unexpected behavior within the model, then compare the behavior with that of the real system. When this procedure leads to identification of previously unrecognized behavior in the real system, the surprise behavior test contributes to confidence in a model's usefulness (Forrester and Senge 1980).

During this test, model outputs were checked for indications of any previously unobserved or unrecognized behavior, and if the model successfully anticipates the response of the system to novel conditions. The model was also used to simulate likely future behavior of the system, while all discrepancies between model behavior and the real system were resolved.

In this research, model outputs were checked for any surprise behavior however, model outputs did not exhibit any surprise behavior.

6.5 Simulation Results after model verification and Validation

All the Vensim System Dynamics simulation results shown in this section for the model portrayed in Fig. 6.2 have been obtained using numerical integration with the fourth order Runge Kutta method and time intervals of 0.0078125 year.

The simulation trends in figure 6.81 show that as the project progresses towards the planned completion time of 36 months, undiscovered rework tends to rise to about 115 tasks, and this depresses the properly completed project tasks since the tasks requiring rework would feed into remaining project tasks. This trend invariably leads to project delays.

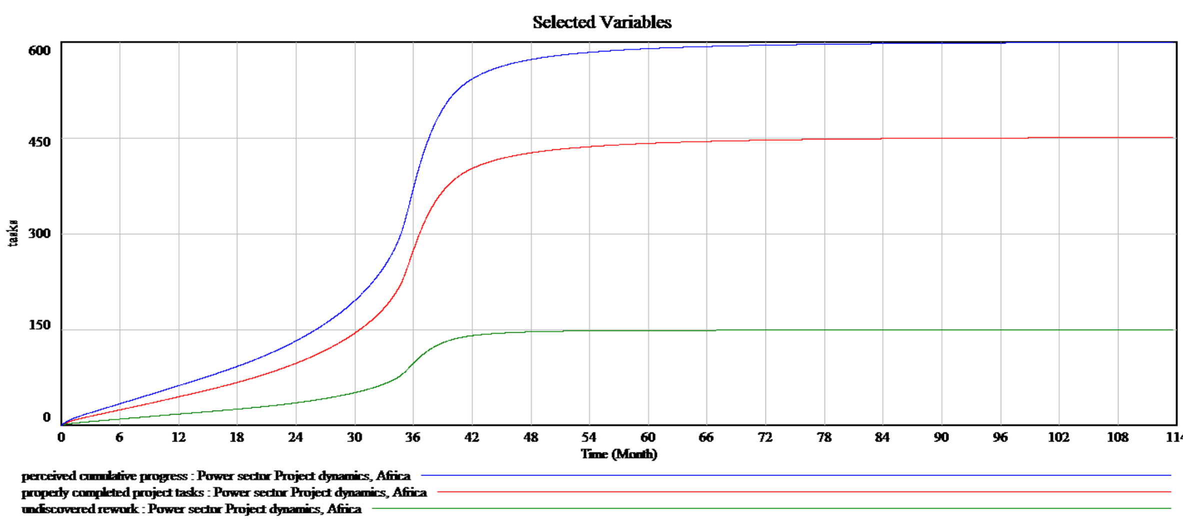

Fig. 6.81: Comparison of trends of perceived cumulative progress, properly completed project tasks and undiscovered rework

The simulation trends in figure 6.82 show that as the unforeseen technical difficulties become prominent between month 30 and month 40, the average quality of completed project tasks also dips down before recovering again as the technical difficulties are attended to by the project team. This period between month 30 and month 40 in the life cycle of the project also sees the undiscovered rework to a peak of about 115 tasks, and as the rework is detected and attended to by the project team, the average quality rises further.

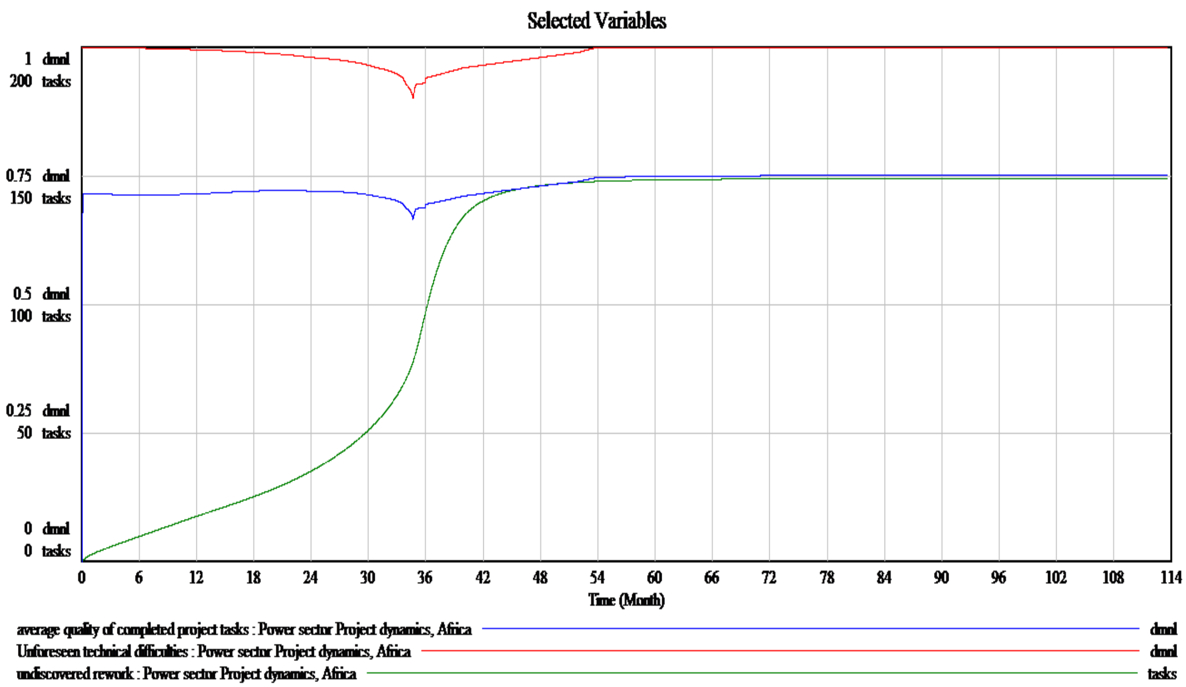

Fig. 6.82: Comparison of trends of average quality of completed project tasks, unforeseen technical difficulties and undiscovered rework

The simulation trends in figure 6.83 show that the perceived cumulative progress rises with the rise in the number of properly completed project tasks. This is driven by the significant rise in the number of testing personnel between month 30 and month 40, which is the resource critical in detecting undiscovered rework that tends to rise in the same period.

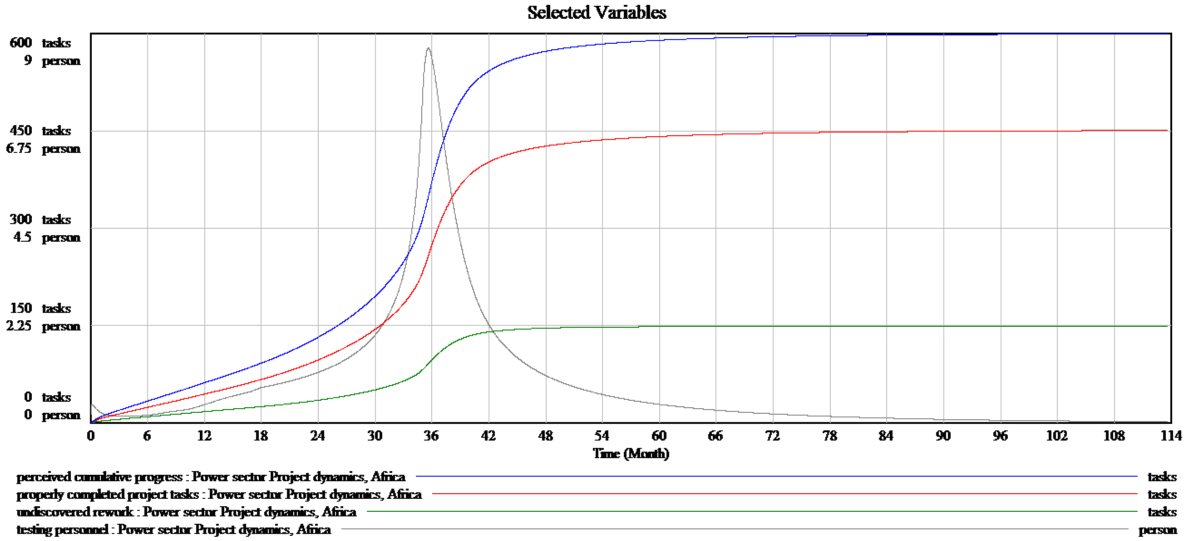

Fig. 6.83: Comparison of trends of perceived cumulative progress, properly completed project tasks, undiscovered rework and testing personnel

The simulation trends in figure 6.84 show that the workforce, project personnel and testing personnel all rise to a maximum at about 34 months to 38 months of project time. This is the time when the project should be nearing completion, but this is also the time when undiscovered rework also becomes significant, leading to repeat jobs. The workforce is the sum of project personnel and the testing personnel.

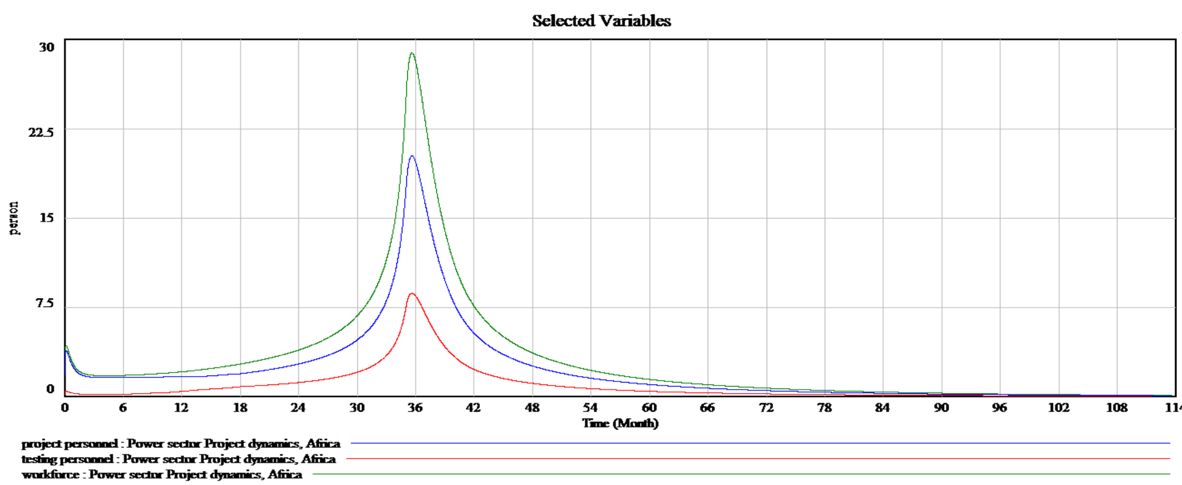

Fig. 6.84: Comparison of trends of project personnel, testing personnel, and workforce

The simulation trends in figure 6.85 show that while remaining project tasks drops from 600 tasks to about 10 tasks in month 60 of project time, undiscovered rework rises to peak at about 120 tasks at 40 months of project time before leveling off at 100 tasks at 60 months. The properly completed project tasks rise to about 500 tasks at month 60 of project time, presumably because of the tasks remaining as undiscovered rework at 60 months of project time. This implies that not all project tasks are completed to 100% quality level.

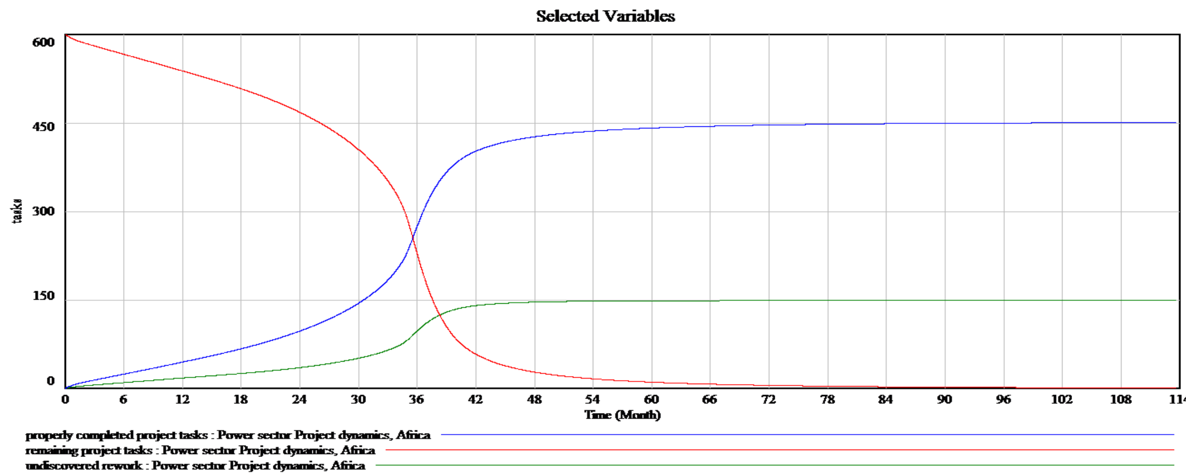

Fig. 6.85: Comparison of trends of properly completed project tasks, remaining project tasks, and undiscovered rework

The simulation trends in figure 6.86 show that detecting of undiscovered rework rises as the number of testing personnel rises towards the initial project completion time of 36 months, to peak at about 35 months of project time. This causes delays in completion of project tasks, as the detection of undiscovered rework creates additional tasks to be done.

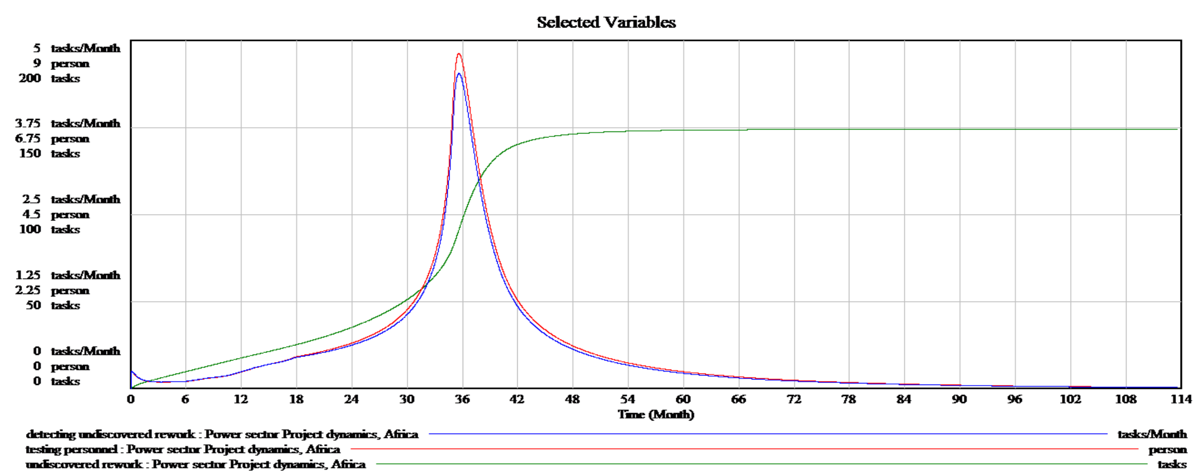

Fig. 6.86: Comparison of trends of detecting undiscovered rework, testing personnel, and undiscovered rework

The simulation trends in figure 6.87 show that progress is slow at the beginning of the projects, but rises sharply to a high at between 30 months and 40 months of project time before slowing down again. Similarly, perceived fraction completed also rises sharply between 30 and 40 months before slowing down considerably, achieving 0.98 fraction completed by 60 months.

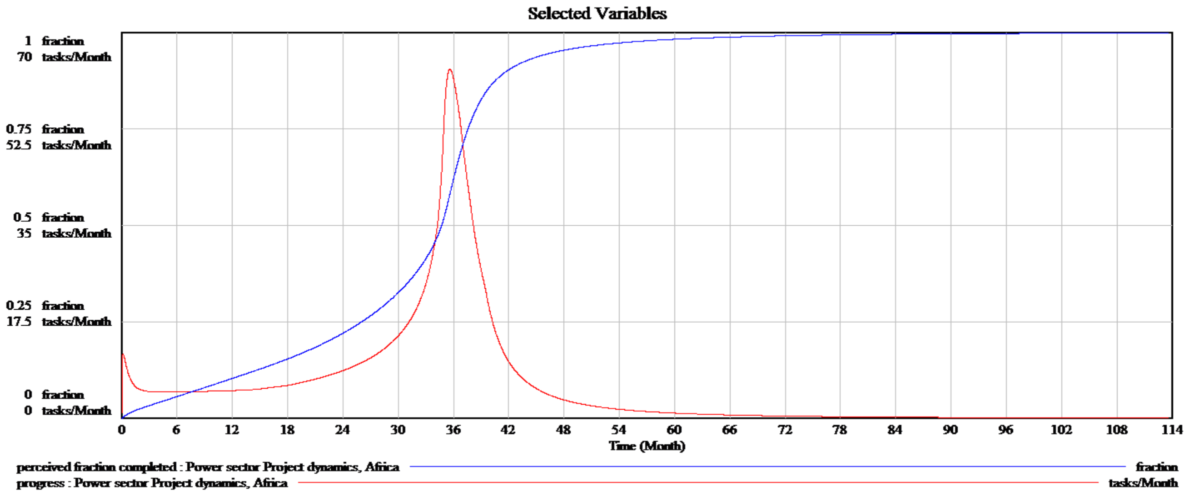

Fig. 6.87: Comparison of trends of perceived fraction completed and progress

The simulation trends in figure 6.88 show that the desired workforce rises and falls with the workforce, but is always slightly more than the workforce before the peak, resulting in a positive trend in net hiring of personnel between 24 months and 36 months of project time and a negative trend in hiring of personnel at between 36 months and 48 months of project time.

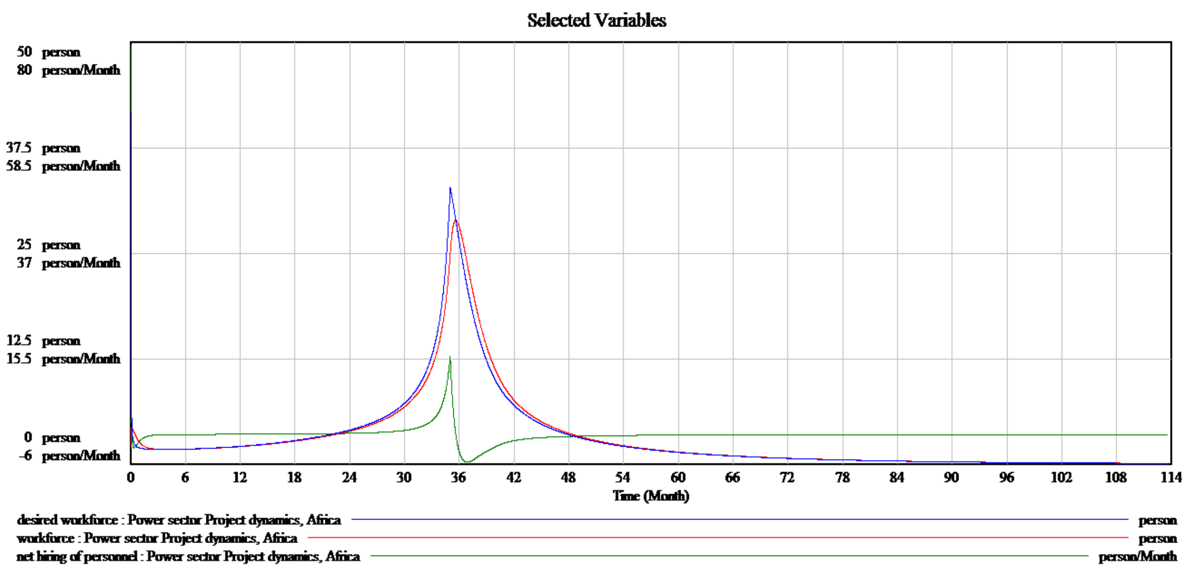

Fig. 6.88: Comparison of trends of desired workforce, workforce and net hiring of personnel

The simulation trends in figure 6.89 show that as the insurance index rises, the political risk adjustment factor also rises, and because progress is a function of the political risk adjustment factor (progress = gross productivity of project personnel*project personnel*political risk adjustment*multitasking), this has the overall effect of speeding up progress of the project.

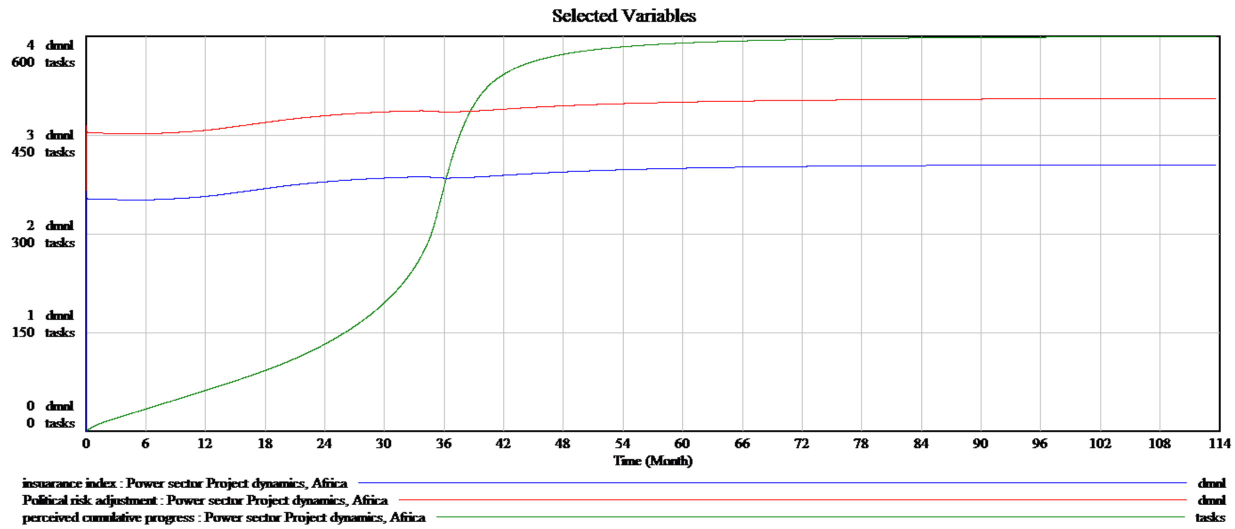

Fig. 6.89: Comparison of trends of insurance index, political risk adjustment and perceived cumulative progress

The simulation trends in figure 6.90 show that the average quality of completed project tasks rises from about 0.7 (70%) to about 0.75 (75%) at 54 months of project time, save for period between 30 and 42 months of project time, when quality is depressed due to effects of unforeseen technical difficulties. The project management competence mirrors a similar trend, rising from about 0.55 to about 0.58, again getting depressed at between 30 months and 42 months of project time due to effects of unforeseen technical difficulties.

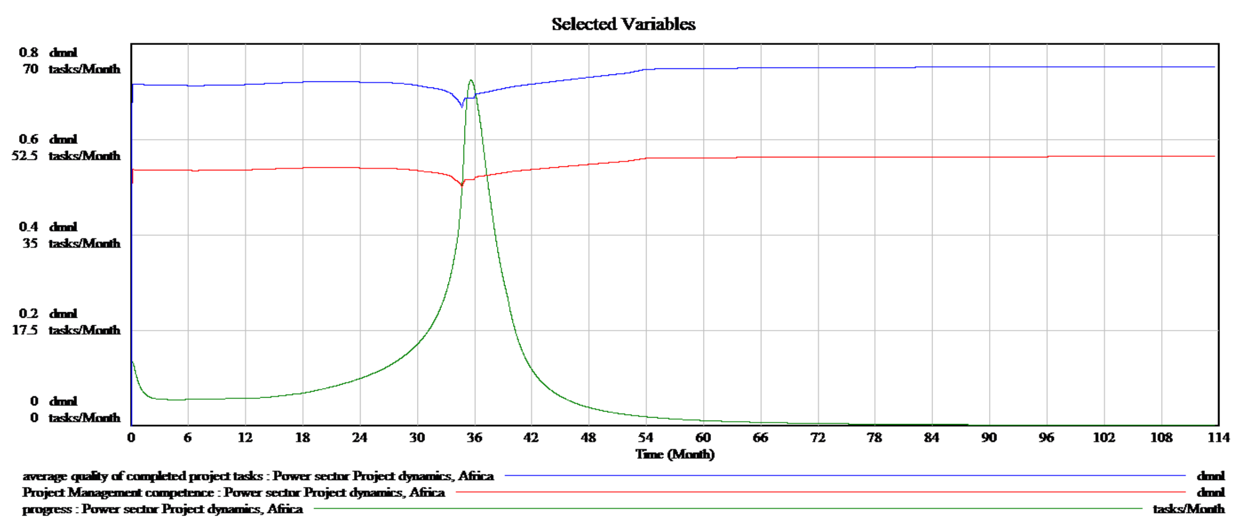

Fig. 6.90: Comparison of trends of average quality of completed project tasks, project management competence and progress

6.6 Policy Analysis and Design

Policy Analysis is an interdisciplinary field of knowledge and specialized applied (social) science research that applies systematic forms of inquiry, evaluation and argumentation, theories and methods to support decision makers in exercising their judgement (Thissen and Walker, 2013). The public policy process is at the heart of effective policy making and good public policy. Howlett et al (2009) have posited that the policy process involves six distinct phases, namely agenda setting, policy formulation, decision making, implementation, evaluation and termination or renewal as indicated in figure 6.91.

Agenda setting is the first step in the policy cycle; it is concerned with the identification of problems that need attention. The policy formulation stage is the process of trying to legitimize the options, providing legitimate choices and ensuring that all of the policy options that are submitted are credible. Once the analysis is complete, the optimal decision is chosen as the rational course of action. Implementation is the stage of the policy process that describes the translation of the policy decision into action, including the effort, knowledge, and resources that are expended by policy actors to do so.

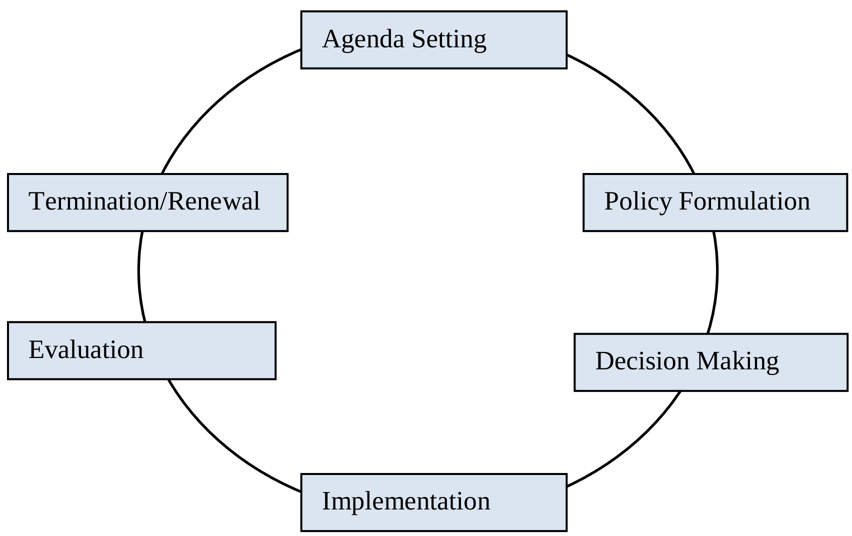

Fig. 6.91: Public Policy Process (Howlett et al, 2009)

Evaluation is to examine the outcome to verify that the distress such as delay in completion of projects has been alleviated, or that the policy goals have been successfully achieved. Policy termination is the deliberate conclusion or cessation of specific programs or policies (Howlett, Ramesh and Pearl, 2009). This research will limit itself to policy formulation and decision making areas arising from the analysis of the basic system dynamics model that has been developed, tested and verified.

According to Sterman (2000), policy design includes the creation of entirely new strategies, structures, and decision rules. Since the feedback structure of a system determines its dynamics, most of the time high leverage policies will involve changing the dominant feedback loops by redesigning the stock and flow structure, or fundamentally reinventing the decision processes of the actors in the system. Attempts to intervene in complex systems often fail when policy makers fail to account for important sources of compensating feedback from the environment, and traditional tools that lack a feedback approach may fail to anticipate the best policy actions. At the same time, long delays between actions and their consequences make effective experiential learning difficult (Rahmandad, 2008; Rahmandad et al., 2009). The robustness of policies and their sensitivity to uncertainties in model parameters and structure must be assessed, including their performance under a wide range of alternative scenarios. The interactions of different policies must also be considered, because real systems are highly nonlinear, and the impact of combination policies is usually not the sum of their impacts alone (Sterman, 2000).

Although parameter testing alone is insufficient for policy design, it is necessary because it helps a modeller estimate the potential impact of a general strategy for influencing key feedback loops in a problematic system. Policy design modelling may require the modification in the stock and flow structure of the base case model that replicated the problematic dynamic behavior, essentially because a systems' stock and flow feedback structure determines its endogenous dynamic behavior, and if endogenously induced behavior was problematic in the past, then a modification in the structure is a pre-requisite for better behavior in the future (Wheat, 2010).

When designing policies to improve system behavior, changes made in the model are only those that could also be changed in the real world and possible model-based structural changes include;

adding/breaking/changing feedback loops related to information flows in the model; adding/breaking/changing (physical) stock-flow structures; strengthening/weakening feedback loops and/or flow variables; changing high leverage policy parameters that have large effects for relatively small changes by means of sensitivity analysis (Pruyt, 2013).

In this research, the projects in the electricity energy sector in Kenya and the region at large are designed to be completed in about 36 months, yet projects often delay, and may be completed in as much as 60 months, while the quality of the completed projects is below expectations in many instances, and these findings are mirrored in the results of the basic model developed in this research. The agenda in policy design and analysis is therefore to explore various policy scenarios and eventually adjust and design the model to achieve on time delivery of projects with the expected quality levels.

6.6.1 What-if scenario analysis and Policy Scenario generation

Once confidence in the model has been attained, the generation of policy solutions is based on experimentation, policy solutions can also be generated based on exhaustive what-if scenario analysis (Morecroft, 1988). According to Willis and Cave (2014), a scenario is a description of a possible and plausible future situation, and the path or paths leading to that future. Scenario thinking or scenario planning is the use of scenarios to support thinking about the future, including setting goals, formulating strategy and undertaking detailed planning (Bishop and Collins 2007, Meissner and Torsten 2013). These approaches rely on trial-and-error simulation, changing parameter values or switching individual links and feedback loops on and off to discover important system elements and derive policy recommendations (Oliva et al, 2010).

In this research, a range of illustrative scenarios are presented, including: Business as usual (Scenario 1); Project Management competence improvement (through hiring of staff with knowledge in project management skills as Scenario 2); Equitable spread of workforce (Scenario 3); increased role for testing and commissioning personnel by increasing the overall percentage of technical staff (Scenario 4) and Combinations of the above policies (Scenario 5).

6.6.1.1: Scenario 1 - Business as usual

The business as usual scenario or base case scenario assumes that the current trends and policies related to projects in the electricity energy sector in Kenya and the region will continue into the future as represented by the basic model developed in this research and as presented in figure 6.2. The simulation model outputs for the business as usual scenario are as given in figures 6.81 to 6.90 obtained after model verification and validation. The business as usual scenario provides the benchmark against which all the other proposed intervention scenarios have been compared. In summary, it presents the prevailing situation where projects targeted at 36 months' completion time may take up to 60 months to complete, with properly completed project tasks at 450 tasks by the end of the project against an initial 600 tasks, and the average quality of completed project tasks at 0.75 (75%) by the end of the project.

6.6.1.2: Scenario 2 - Project Management Competence Improvement

In the basic model, project management competence is modeled as a function of the average quality of completed project tasks, and was found to vary from a level of about 54% at the beginning of the project to about 57% at the end of the project as shown in figure 6.92 under the "Business as usual" trend in red. The increase in the project management competence as the project progresses was found to hold true as a result of knowledge gained during the course of the project.

*Project Management competence = 0.75*MAX(average quality of completed project tasks, 0.1)*
~dmnl (6.42)

Through the hiring of project technical staff knowledgeable in project management skills, project management competence can be increased significantly. Assuming the factor of 0.75 in the equation for project management competence is increased to 0.95 so that the equation becomes;

*Project Management competence = 0.95*MAX(average quality of completed project tasks, 0.1)*
~ dmnl (6.43)

The result on simulation is that the level of project management competence would then vary from about 68% at the beginning of the project to about 72% at the end of the project as shown in figure 6.92 under the "improved PM competence" trend in blue.

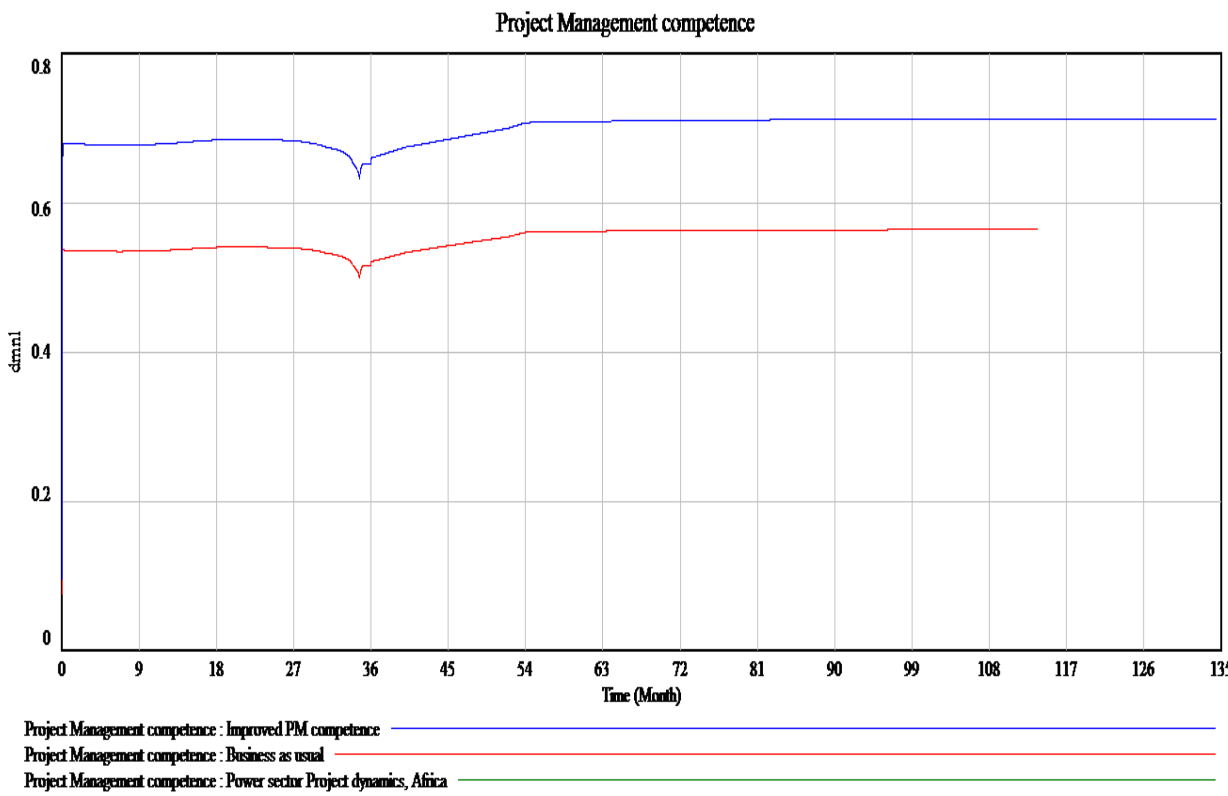

Fig. 6.92: Project Management competence trends under Business as usual and Improved PM competence scenarios

The immediate effect of this change in project management competence will be improved productivity. This is witnessed through the "*perceived productivity"* variable, which in the basic model rises to 1.3 tasks/person/month before leveling off at 0.8 tasks/person/month by the end of the project 60 months later as shown in figure 6.93 in red, but now improves and rises to 1.7 tasks/person/month before dropping and leveling off at 1.2 tasks/person/month at month 60 as shown in figure 6.93 in blue.

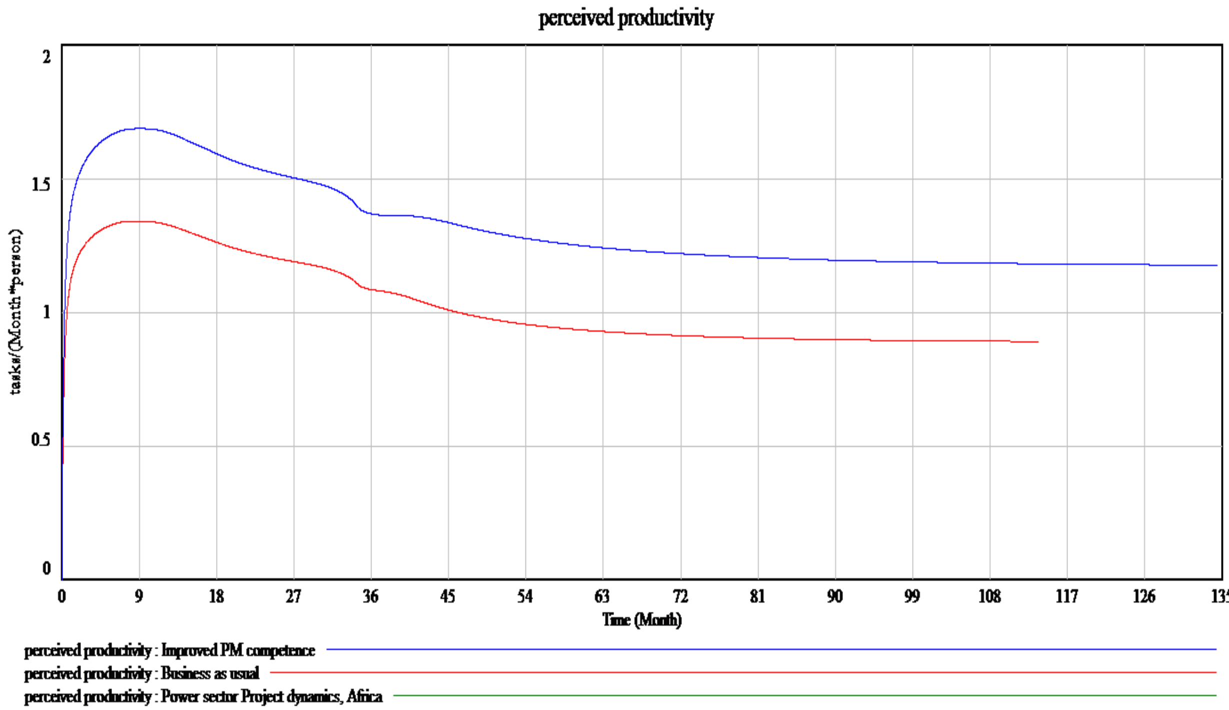

Fig. 6.93: Perceived productivity trends under Business as usual and Improved PM competence scenarios

In addition, poor completion of project tasks is modeled as;

Poor completion of project tasks = progress(1 - fraction properly completed)*unforeseen technical difficulties (units: tasks/Month)* (6.44)

The increased competence of project personnel through the hiring of competent technical staff with project management skills, is expected to result into the *fraction properly completed* of project tasks which is at 0.7 in the basic model to rise because work will be properly scheduled and matched with resources.

Assuming *fraction properly completed* changes from 0.7 to 0.9 due to increased competence of project personnel and the model is simulated, the results as shown in figure 6.94 indicate that *properly completed project tasks* rise to about 540 tasks (in blue) from the previous 450 tasks in the basic model (red).

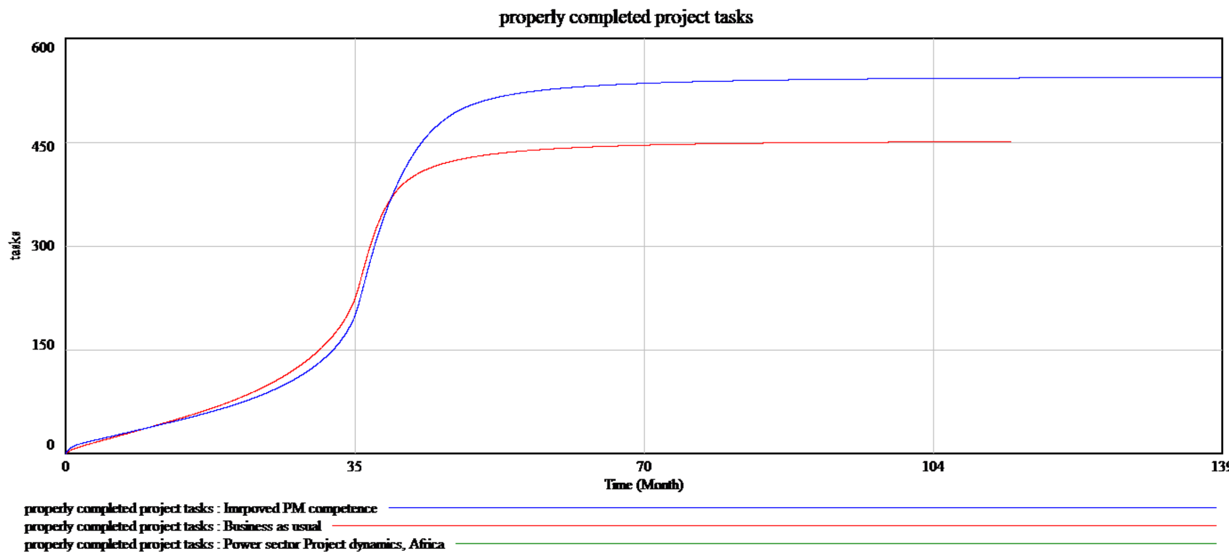

Fig. 6.94: Properly completed project tasks trends under Business as usual and Improved PM competence scenarios

At the same time, *undiscovered rework* reduces to peak at a high of about 55 tasks (blue) from the previous 150 tasks (red) as shown in figure 6.95. The rate of *poor completion of project tasks* reduces from a peak of about 19 tasks/month to a new peak of about 6 tasks/month, as shown in figure 6.96.

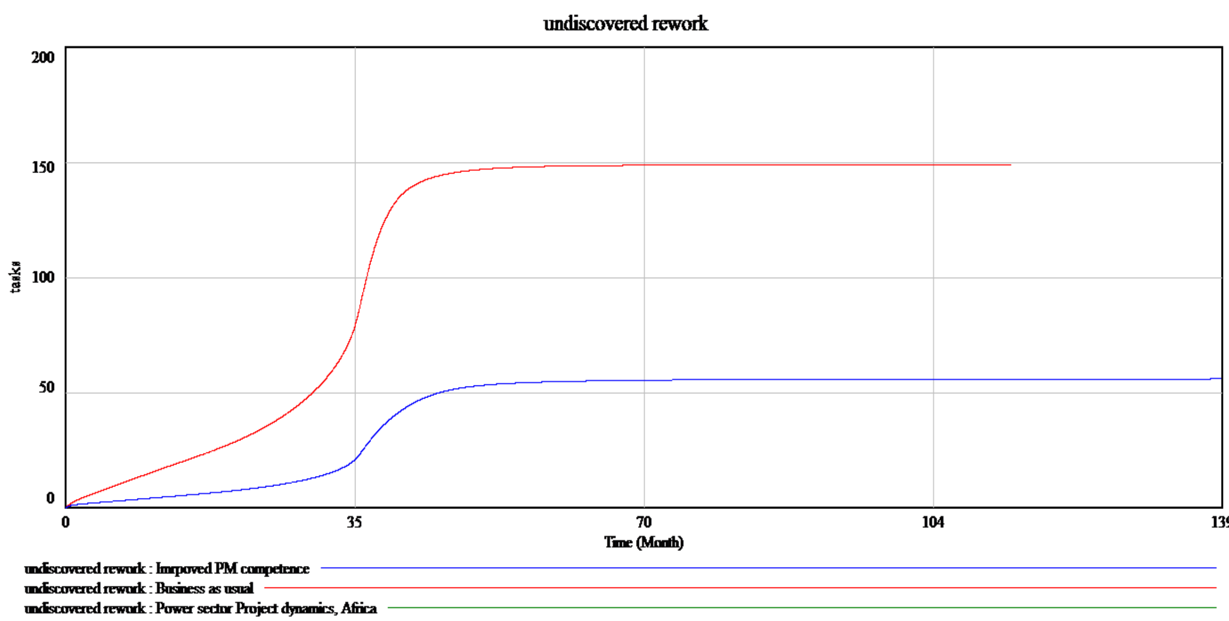

Fig. 6.95: Undiscovered rework trends under Business as usual and Improved PM competence scenarios

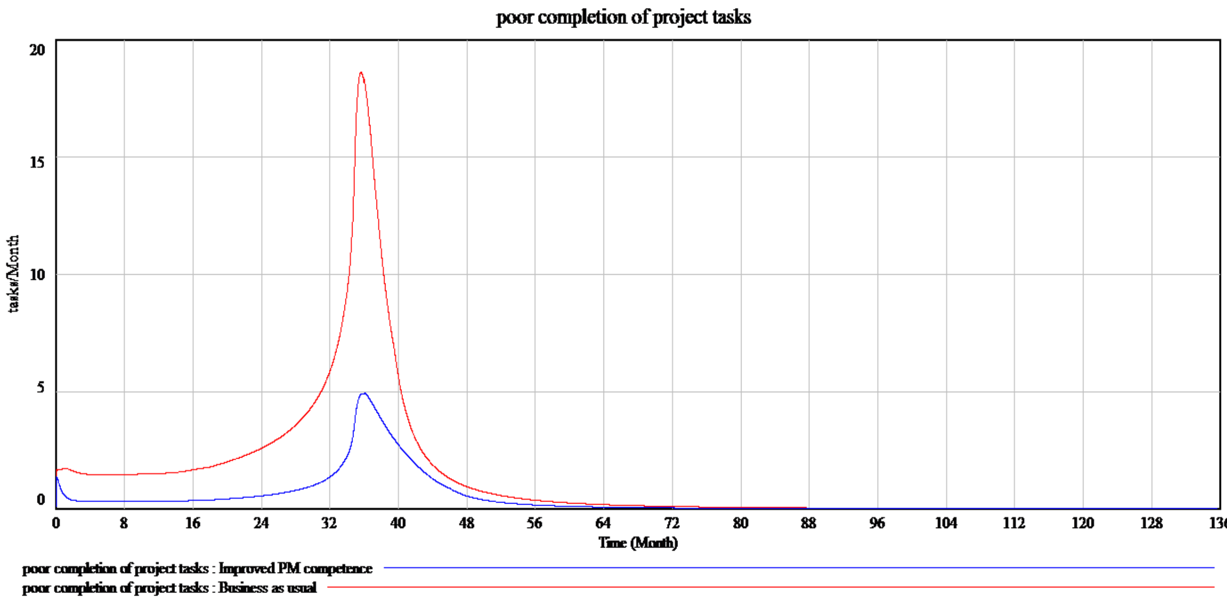

Fig. 6.96: Poor completion of project tasks trends under Business as usual and Improved PM competence scenarios

With improved project management competence, the *average quality of completed project tasks* rises from about 0.75 at 60 months in the basic model to about 0.92 as shown in figure 6.97.

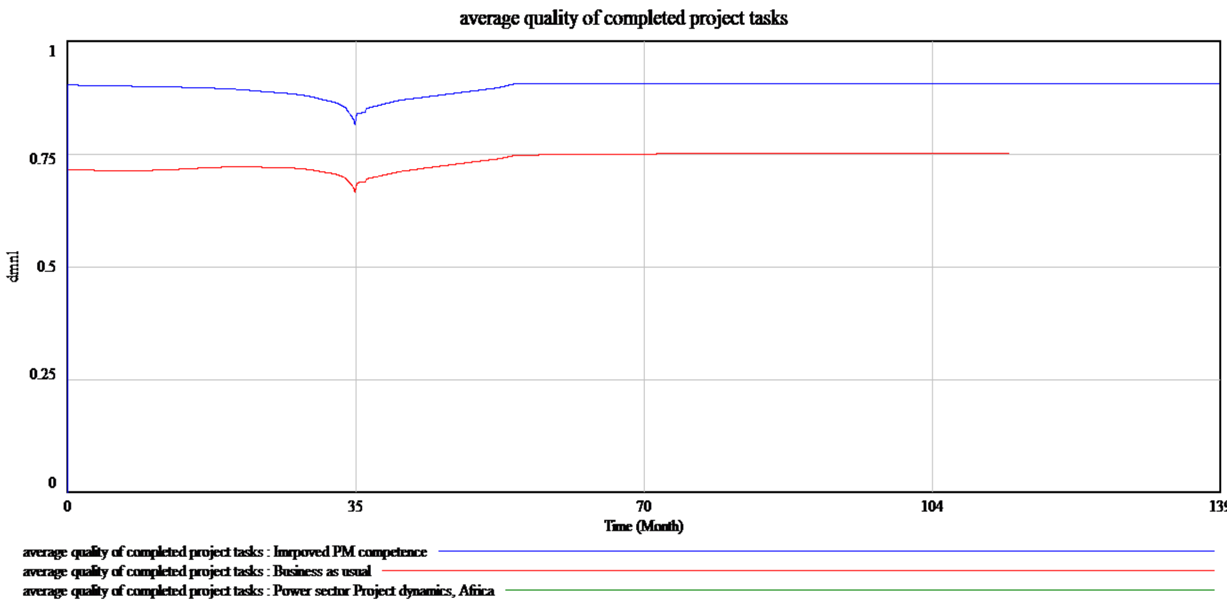

Fig. 6.97: Average quality of completed project tasks trends under Business as usual and Improved PM competence scenarios

6.6.1.3: Scenario 3 - Equitable spread of workforce

In the basic model, the *desired workforce* is modeled as;

desired workforce = (perceived effort remaining/perceived time remaining)/8 ~ person (6.45)

This has the effect that *workforce, project personnel* and *testing personnel* all peak at between 34 months and 38 months of project time when the project is supposed to be completed as shown in figure 6.98.

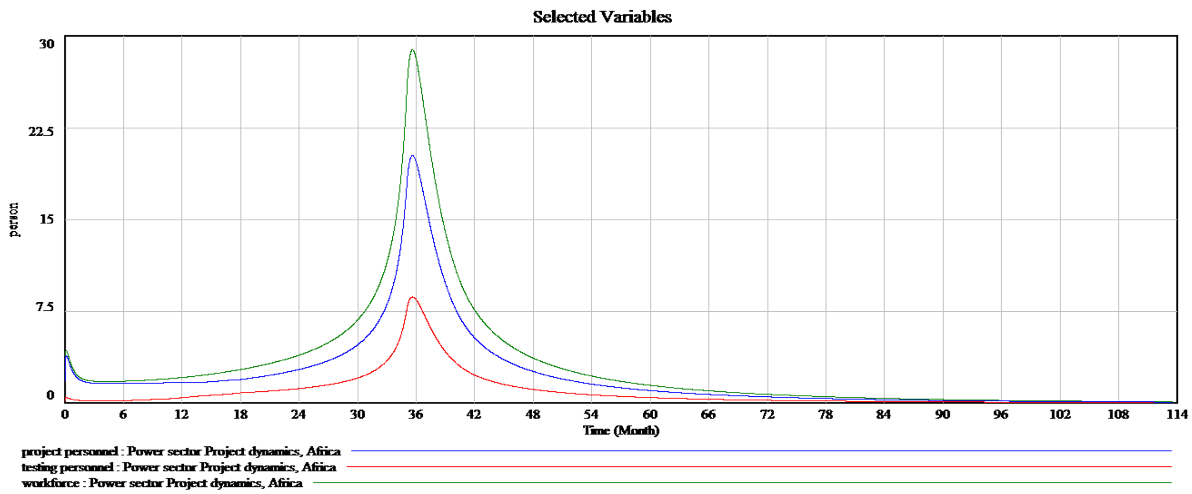

Fig. 6.98: Workforce, Project personnel and testing personnel trends, basic model

However, progress on the project would improve by having better trained and more competent workers spread throughout the project life time, hence reducing the effects of steep peaking of workers towards the end of the project life, which results into project delays. The effect of spreading the workforce can be achieved in the model by changing the equation for *desired workforce* to;

Desired workforce = perceived effort remaining / perceived time remaining (6.46)

The factor of 8 shown in equation 6.45 in the equation for *"Desired workforce"* was used to achieve the peaking of workforce between the 34 and the 38 months of project time in the basic model as is the practice in projects in the electricity sector in Kenya, and was used following the results from the workshop with experts in the sector as indicated in Appendix M.

Figure 6.99 shows the results of the spread of *workforce*, *project personnel* and *testing personnel* on simulating the model after this change.

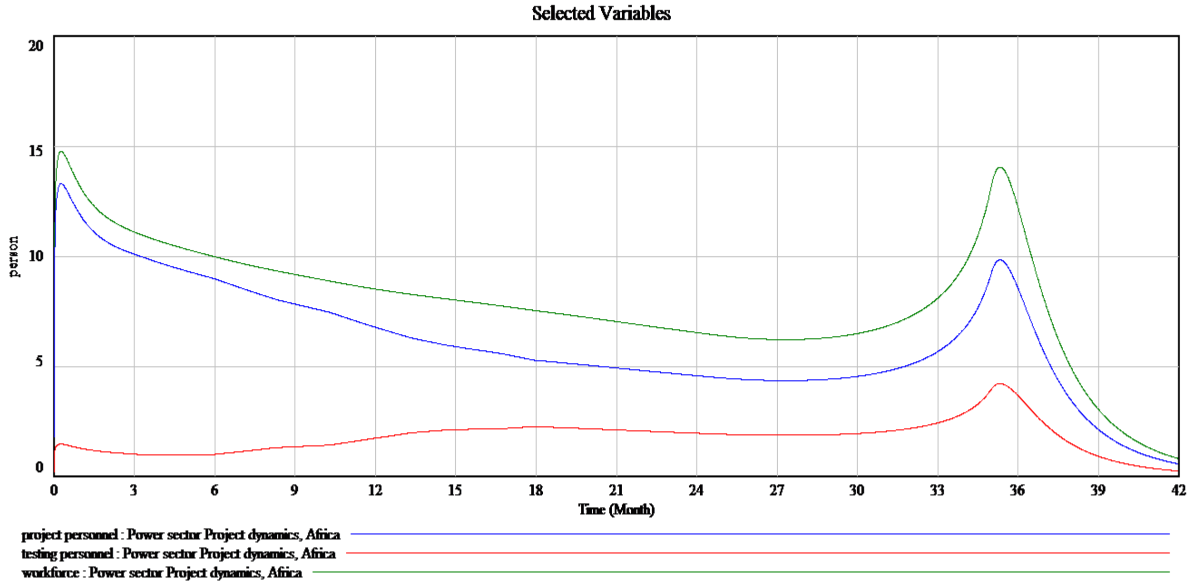

Fig. 6.99: Spread of Workforce, Project personnel and testing personnel trends

The effect of this spread of workforce can be seen from the changes in the time taken to project completion through *properly completed project tasks* and *remaining project tasks* of about 60 months in the basic model to the simulation results as shown in figure 6.100 that show that the project will now likely be completed in about 38 months.

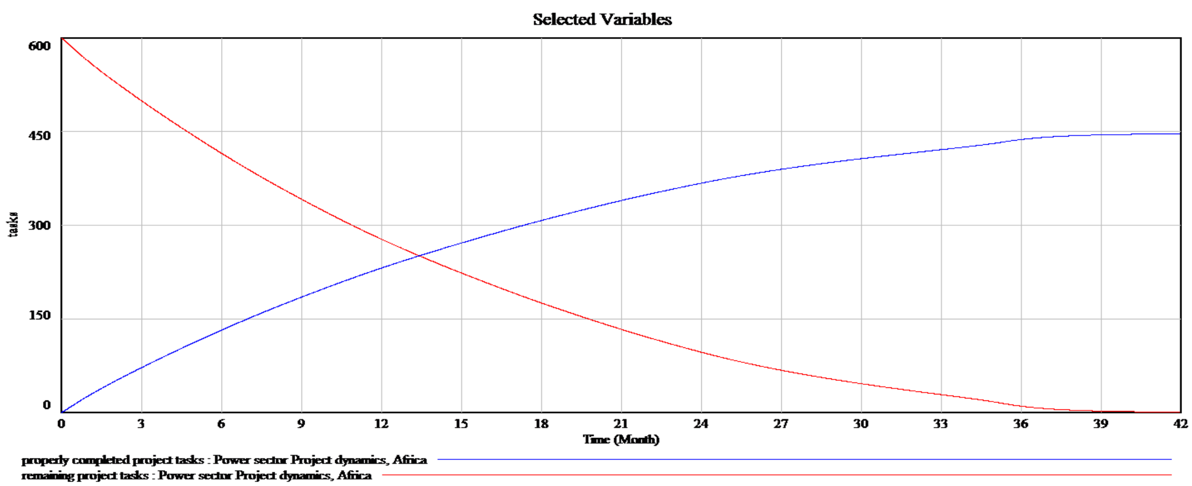

Fig. 6.100: Trend analysis, properly completed project tasks & remaining project tasks with the spread of workforce

6.6.1.4: Scenario 4 - Increased role for testing and commissioning personnel

During the workshop meetings with the stakeholders in Kenya, the issue of persistent shortage of competent commissioning engineers was noted as contributing to delays and quality challenges experienced by projects in the electricity energy sector in Kenya. This was noted as a major contributing factor to unforeseen technical difficulties which emerge towards the end of the project. Apart from spreading the workforce, the hiring of competent and qualified engineers and technicians by the project teams will be necessary. These competent engineers and technicians are useful for commissioning and testing functions especially one year into the project, when equipment assembly and hence testing of sub-system functions and operations is critical. It is therefore desirable that the percentage of testing / commissioning personnel should take the larger portion of the workforce one year into the project, based on comments of experts as given in Appendix M.

This effect can be achieved by adjusting the equation for *fraction personnel for testing* in the basic model to;

fraction personnel for testing= WITH LOOKUP (Time / perceived time remaining, ([(0,0)-(1,1)],(0,0.1),(0.2,0.15),(0.4,0.17),(0.6,0.3),(0.8,0.55),(1,0.8))) ~ dmnl (6.47)

Equation 6.47 has the effect of changing the trend of fraction personnel for testing that earlier peaked at about 30% in the basic model as shown in figure 6.101 in red to the trend in figure 6.101 in blue where the fraction of personnel for testing rises to peak at about 75% within 18 months of project time, as suggested by experts in a workshop done in March 2014, extracts from results are given in Appendix M. At the same time, the number of testing personnel in the project increases significantly as shown in figure 6.102 where it peaks at 58 persons between the 32^{nd} and 40^{th} month of project time unlike in the business as usual trend in red where it peaked at 10 persons over the same period of time.

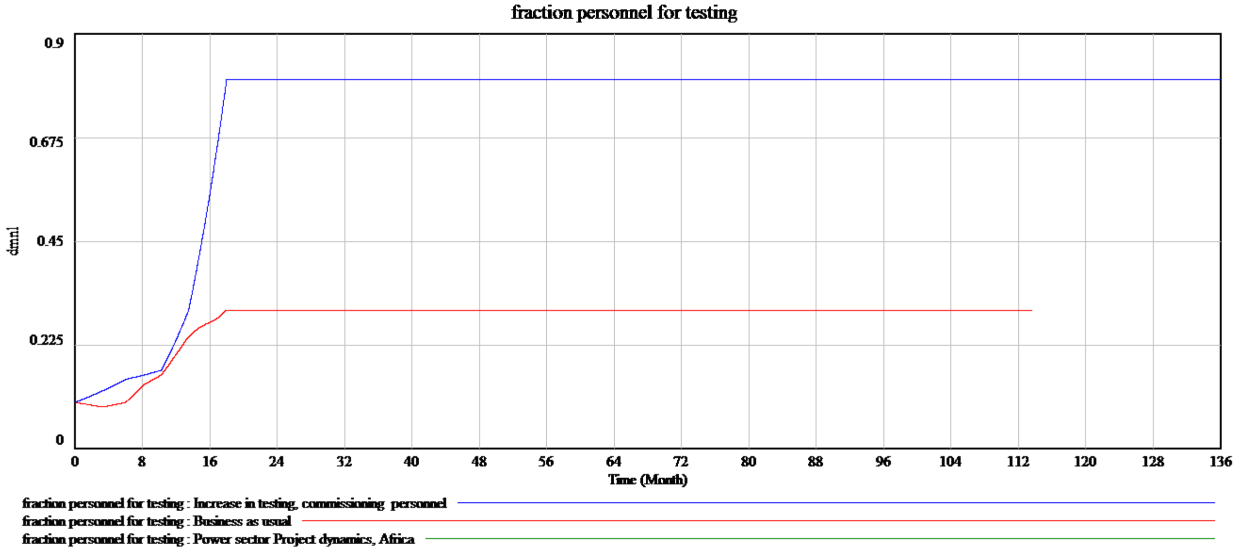

Fig. 6.101: Fraction personnel for testing trends under Business as usual and Increase in testing / commissioning personnel scenarios

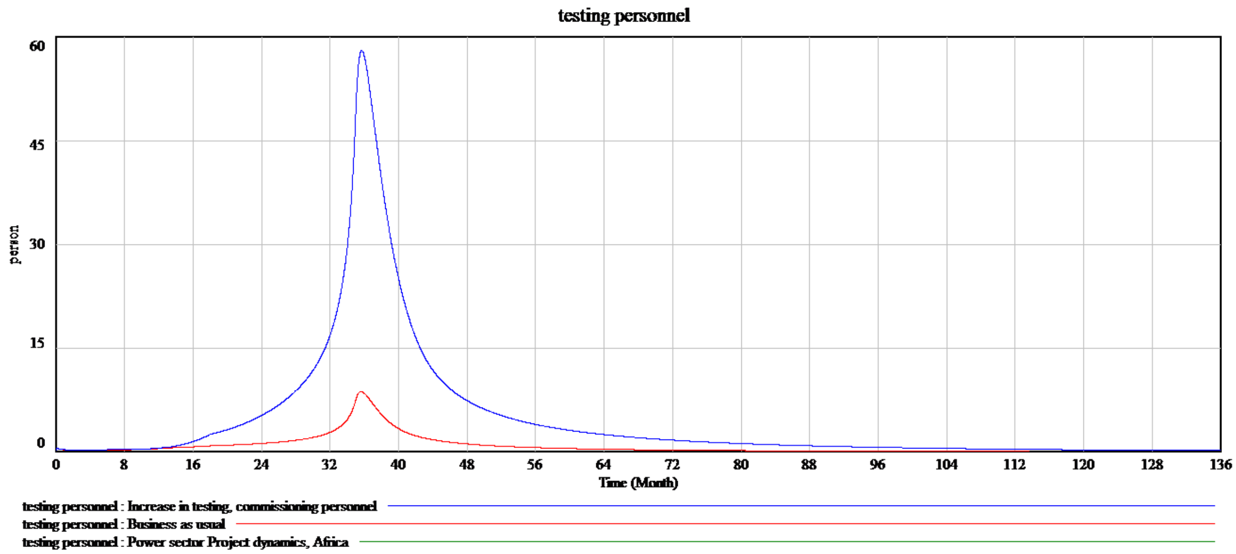

Fig. 6.102: Testing personnel trends under Business as usual and Increase in testing / commissioning personnel scenarios

The increase in testing personnel also has the effect of reducing the peaking of *undiscovered rework* from 150 tasks in the basic model to 70 tasks as shown in figure 6.103, raising the *average quality of completed project tasks* from 0.75 in the basic model to 0.89 as shown in figure 6.104, raising the *properly completed project tasks* from 450 tasks in the basic model to 525 tasks as shown in figure 6.105, and raising the *detecting undiscovered rework* from an initial peaking value of 4 tasks/month to 16 tasks/month as shown in figure 6.106.

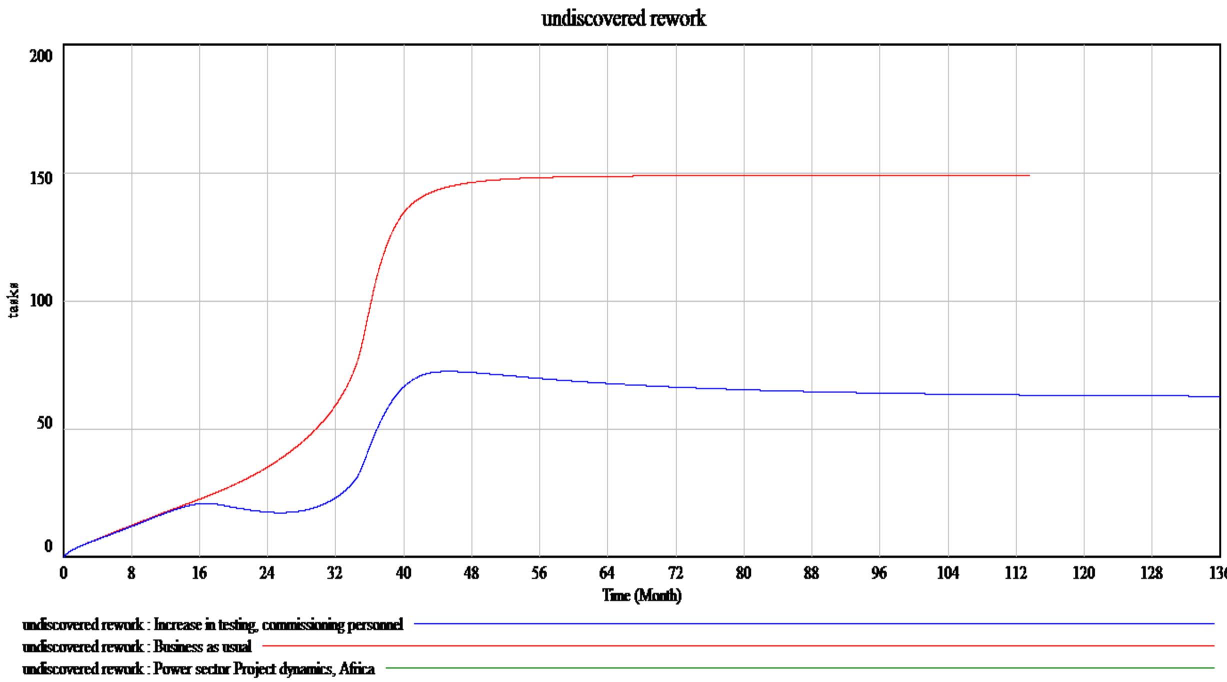

Fig. 6.103: Undiscovered rework trends under Business as usual and Increase in testing / commissioning personnel scenarios

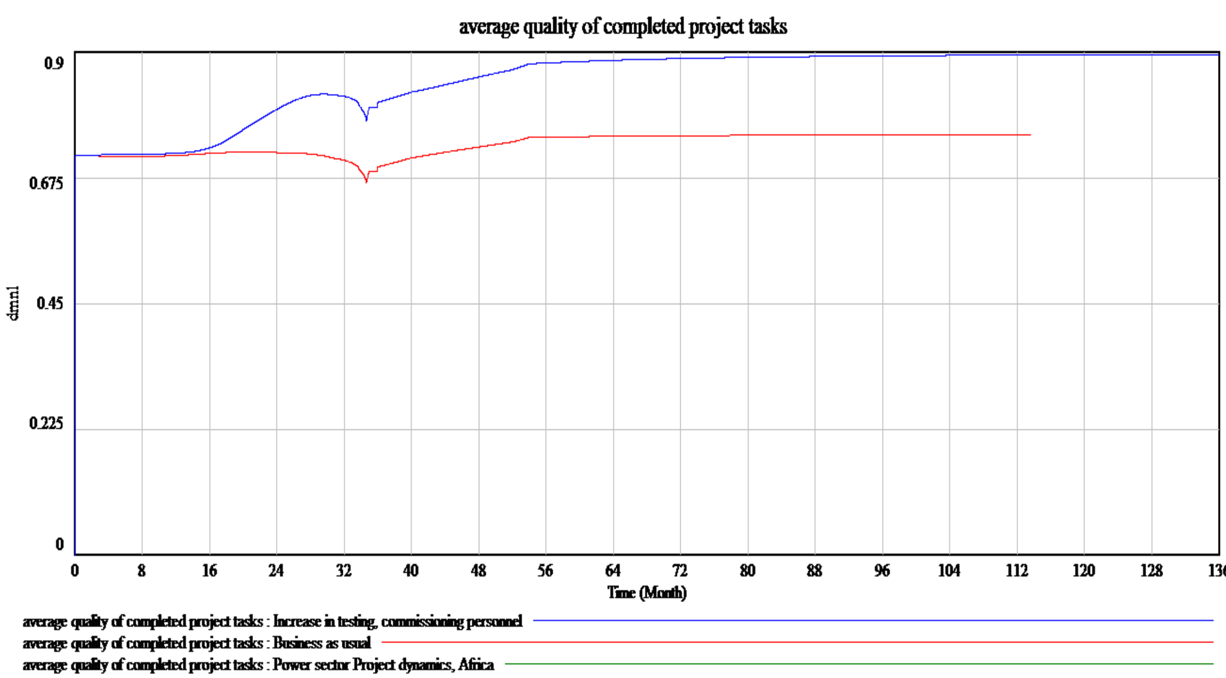

Fig. 6.104: Average quality of completed project tasks trends under Business as usual and Increase in testing / commissioning personnel scenarios

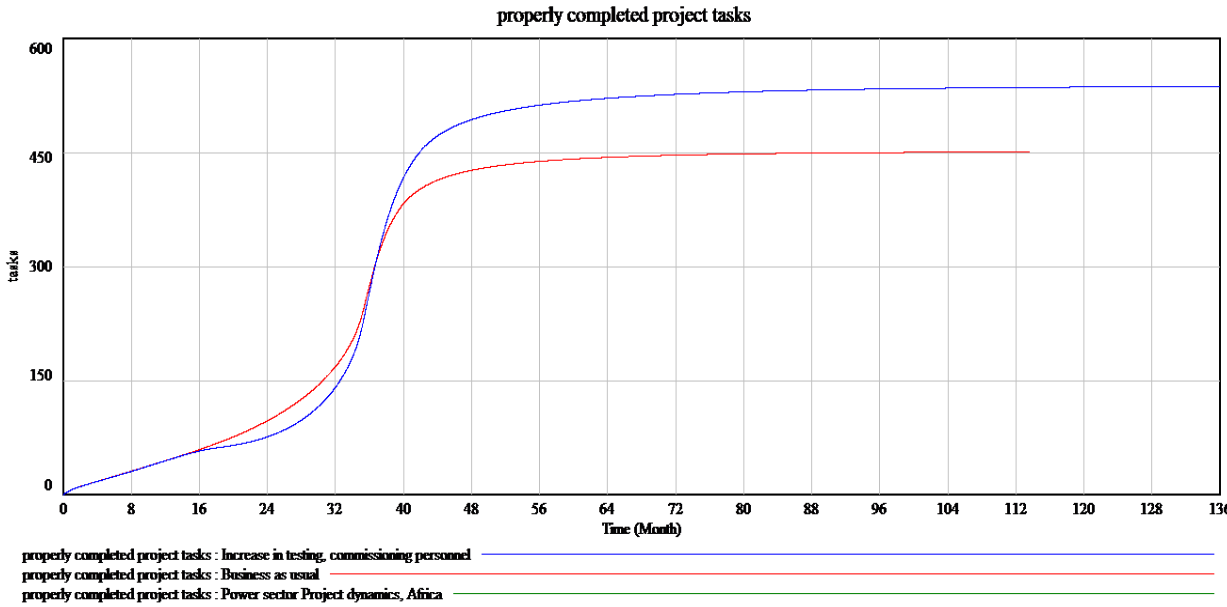

Fig. 6.105: Properly completed project tasks trends under Business as usual and Increase in testing / commissioning personnel scenarios

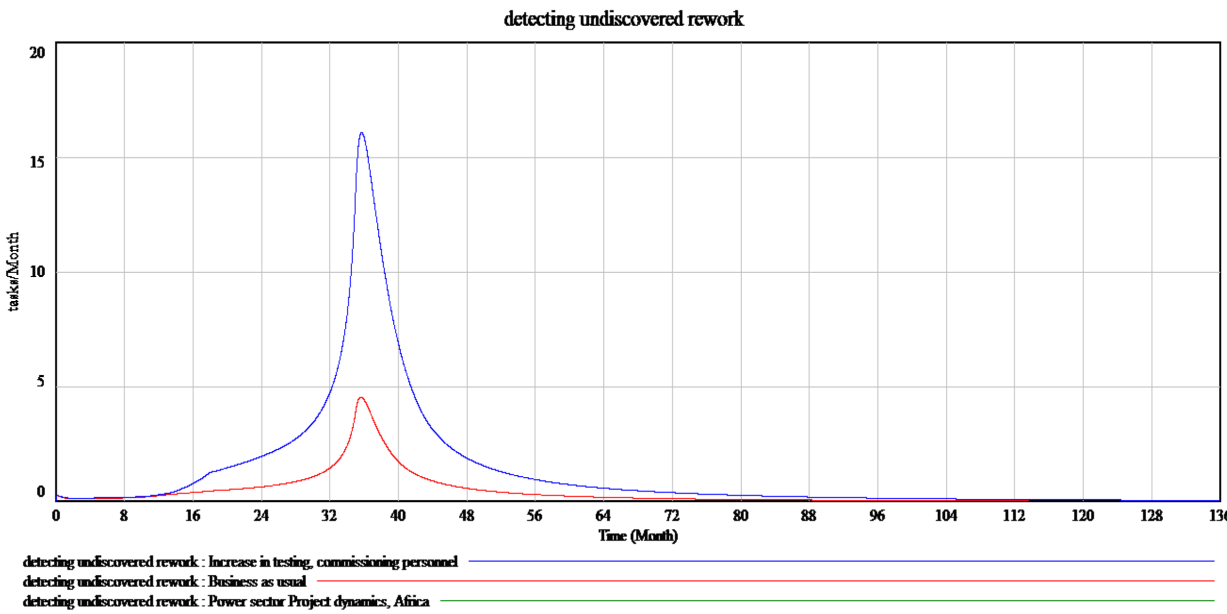

Fig. 6.106: Detecting undiscovered rework trends under Business as usual and Increase in testing / commissioning personnel scenarios

At the same time and due to the increased number of testing personnel, the fraction of undiscovered rework drops from 0.26 in the business as usual scenario to 0.14 at month 32 of project time as shown in figure 6.107.

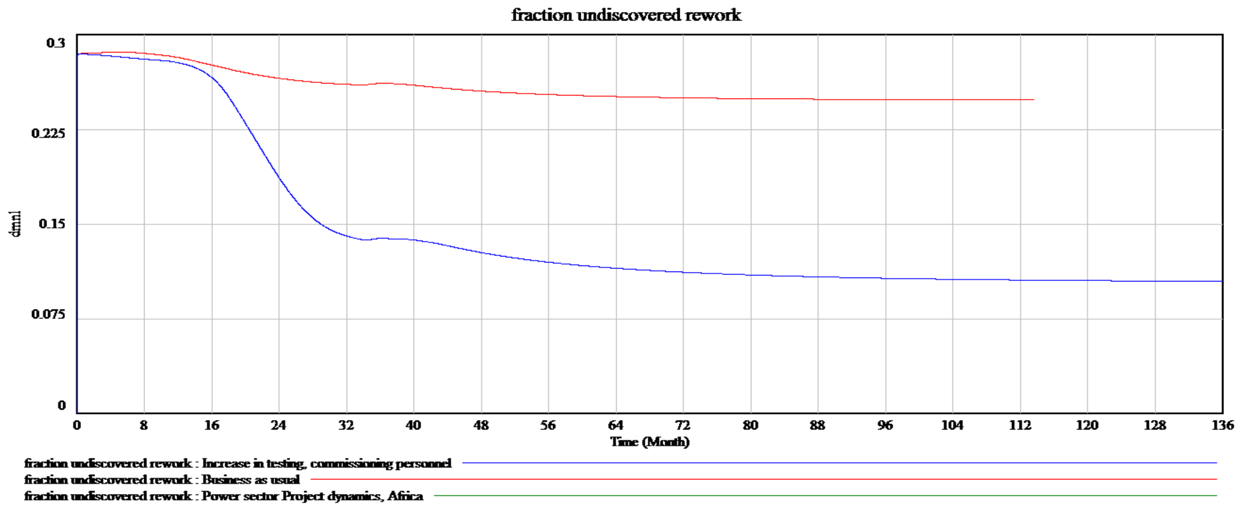

Fig. 6.107: Fraction undiscovered rework trends under Business as usual and Increase in testing / commissioning personnel scenarios

Following the reduction in undiscovered rework as shown in figure 6.103, the increase in average quality of completed project tasks as shown in figure 6.104, the increase in the number of completed project tasks as shown in figure 6.105, the significant increase in the detection of undiscovered rework as shown in figure 6.106, and the significant drop in the fraction of undiscovered rework as shown in figure 6.107, the overall effect of the increased fraction and competence of personnel for testing is the reduction of the effect of *unforeseen technical difficulties* to near zero, and so *unforeseen technical difficulties* is deleted in the new model.

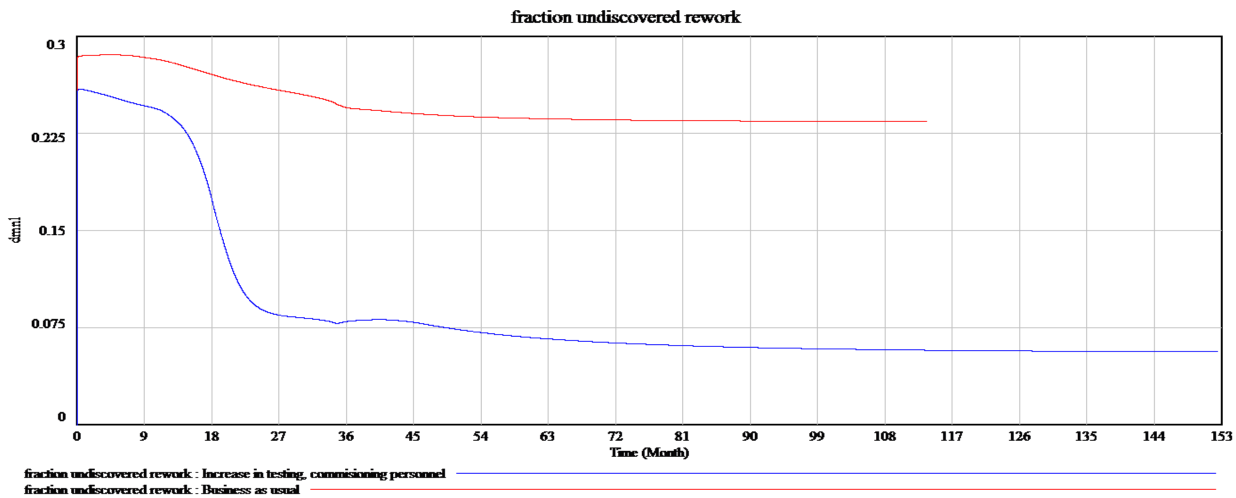

Fig. 6.108: Fraction undiscovered rework trends under Business as usual and Increase in testing / commissioning personnel scenarios

The *maximum productivity of testing* is modeled as equal to a constant 2 in the basic model. By increasing the role and overall percentage of testing and commissioning technical staff, this will also result in the projects having more engineers and technicians who play a major role during commissioning of the various equipment assembled in the projects, leading to improved efficiency in testing. Assuming this results into the maximum productivity of testing increasing to 6 and the model is simulated, the results as shown in figure 6.108 indicate that *fraction undiscovered rework* drops further by month 36 of project time to approximately 0.075.

6.6.1.5: Scenario 5 - Combined policies

The combined policies scenario makes changes to the basic model in figure 6.2 as given in scenario 2, scenario 3, and scenario 4 into the model in figure 6.2 and then simulating the model. Namely;

In figure 6.109, the equation for project management competence becomes;

*Project Management competence = 0.95*MAX(average quality of completed project tasks, 0.1)*
~ dmnl *(6.48)*

The equation for fraction properly completed becomes;

fraction properly completed = 0.9 *(6.49)*

The equation for desired workforce becomes;

Desired workforce = perceived effort remaining / perceived time remaining ~ person *(6.50)*

fraction personnel for testing= WITH LOOKUP (Time / perceived time remaining,
([(0,0)-(1,1)],(0,0.1),(0.2,0.15),(0.4,0.17),(0.6,0.3),(0.8,0.55),(1,0.8))) ~ dmnl *(6.51)*

maximum productivity of testing = 6 tasks/person/month *(6.52)*

The new model is given in figure 6.109, while the model as text is given in Appendix N. All the variables and arrows marked in green in the model are new and the product of this research and so represent the new contributions this research has made to the body of knowledge.

By combining all the effects of the four policies at the same time, the results as given in figure 6.110 indicate that the *workforce*, *project personnel* and *testing personnel* are more spread out during the duration of the project unlike before where more staff were hired towards the end of the project. It also shows that testing and commissioning personnel becomes the bigger percentage of workforce after the initial 18 months.

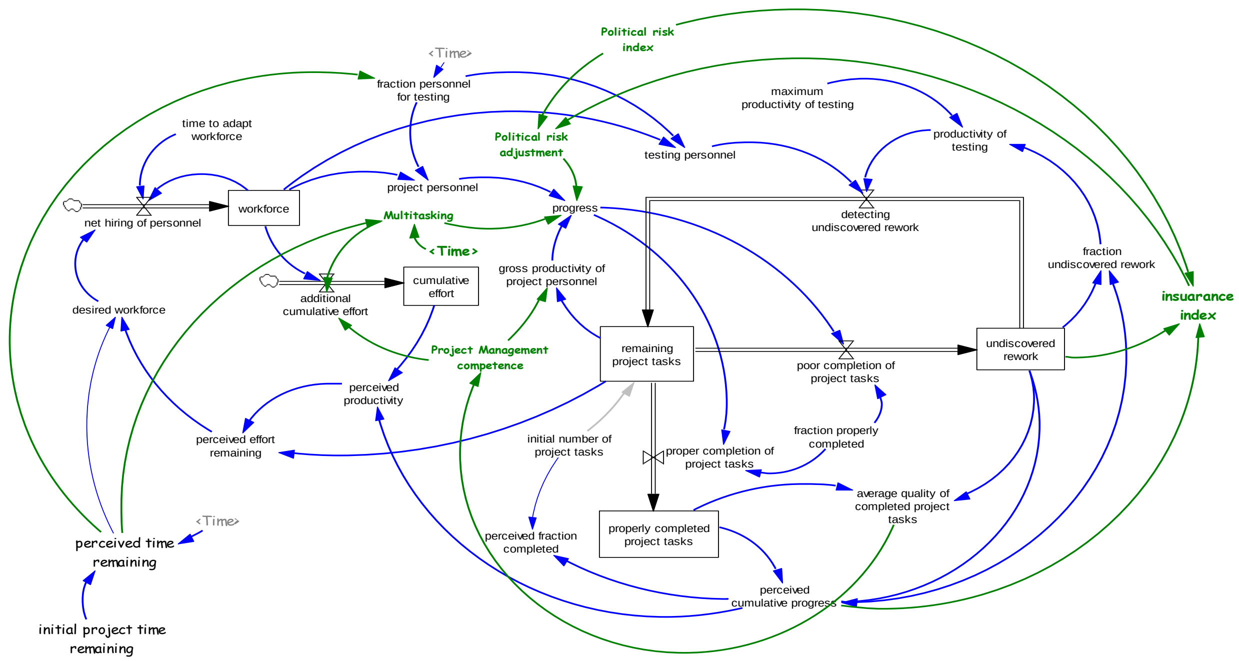

Fig. 6.109: New model developed using scenario 5, (Project Management competence improvement + Equitable spread of workforce + increased role for testing and commissioning personnel)

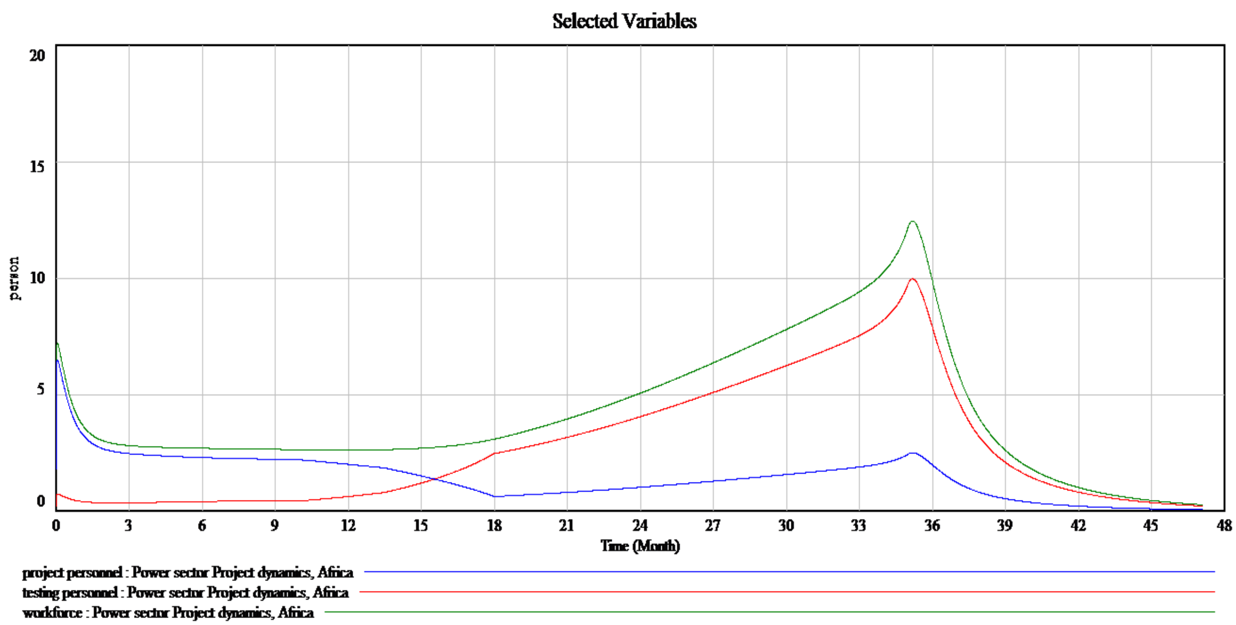

Fig. 6.110: Simulation results of Workforce, Project personnel and testing personnel trends

Figure 6.111 also indicates that the *remaining project tasks* drops from a high of 600 tasks at the beginning of the project to zero at about 38 months of project time, while *properly completed project tasks* rise to a high of about 580 tasks in 38 months of project time. The *average quality of completed project tasks* rises from about 0.9 at the beginning of the project to about 0.95 by end of the project in 38 months.

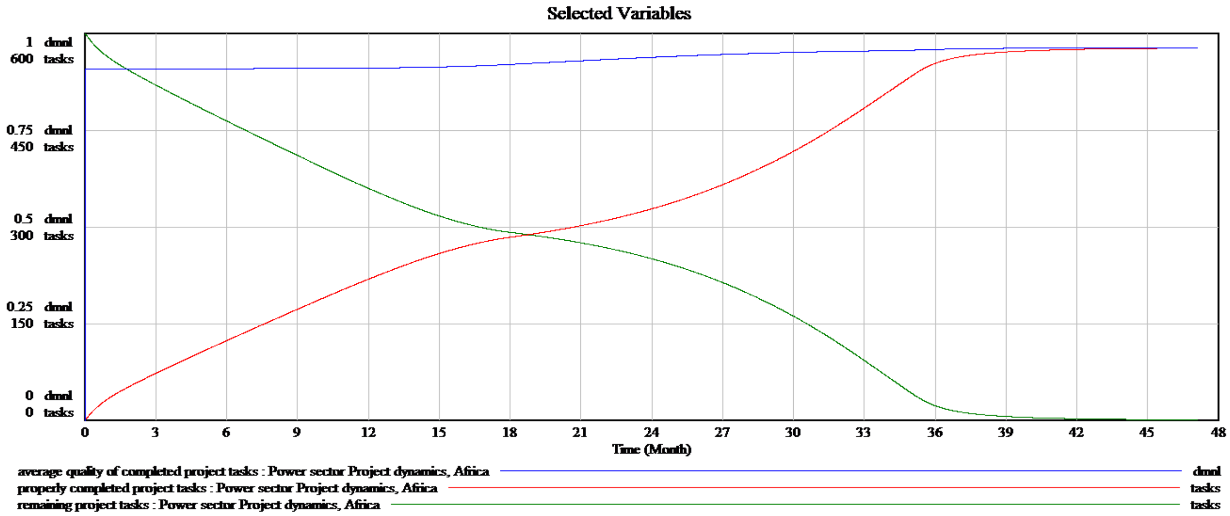

Fig. 6.111: Simulation results for average quality of completed project tasks, properly completed project tasks and remaining project tasks

At the same time, the *perceived productivity* rises to peak at about 5 tasks/person/month before dropping and leveling off at about 2 tasks/person/month as shown in figure 6.112, while *undiscovered rework* rises to about 25 tasks before dropping to about 23 tasks by 38 months of project time.

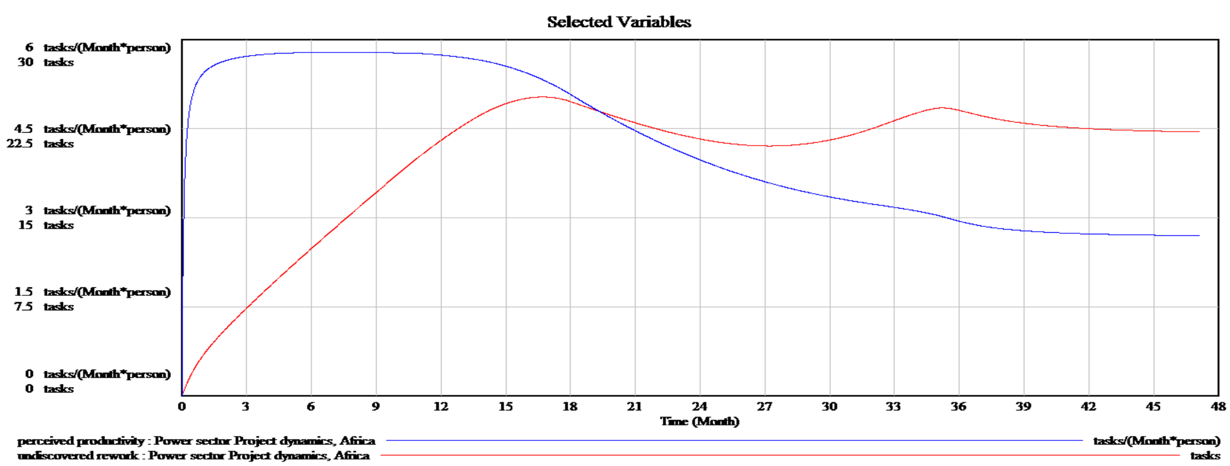

Fig. 6.112: perceived productivity and undiscovered rework trends under combined policies scenario

The *remaining project tasks* drops from the initial 600 tasks to 0 at approximately 38 months in the combined policies scenario, unlike the 72 months in the business as usual scenario as shown in figure 6.113, while *properly completed project tasks* rise from 450 tasks in the business as usual scenario to 580 tasks in the combined policies scenario as shown in figure 6.114.

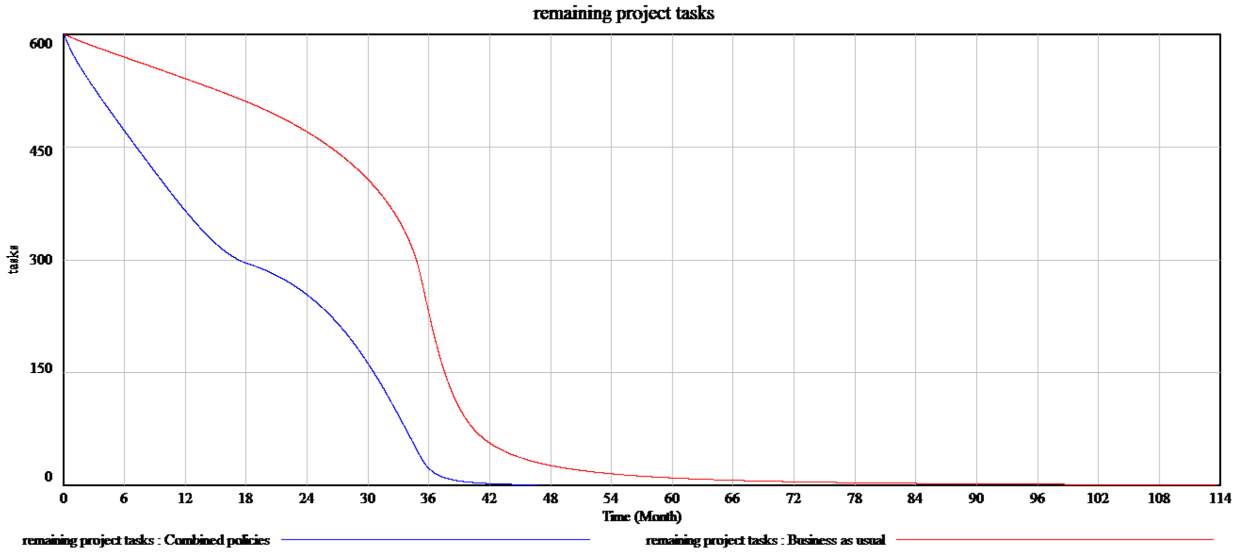

Fig. 6.113: remaining project tasks trends under business as usual and combined policies scenarios

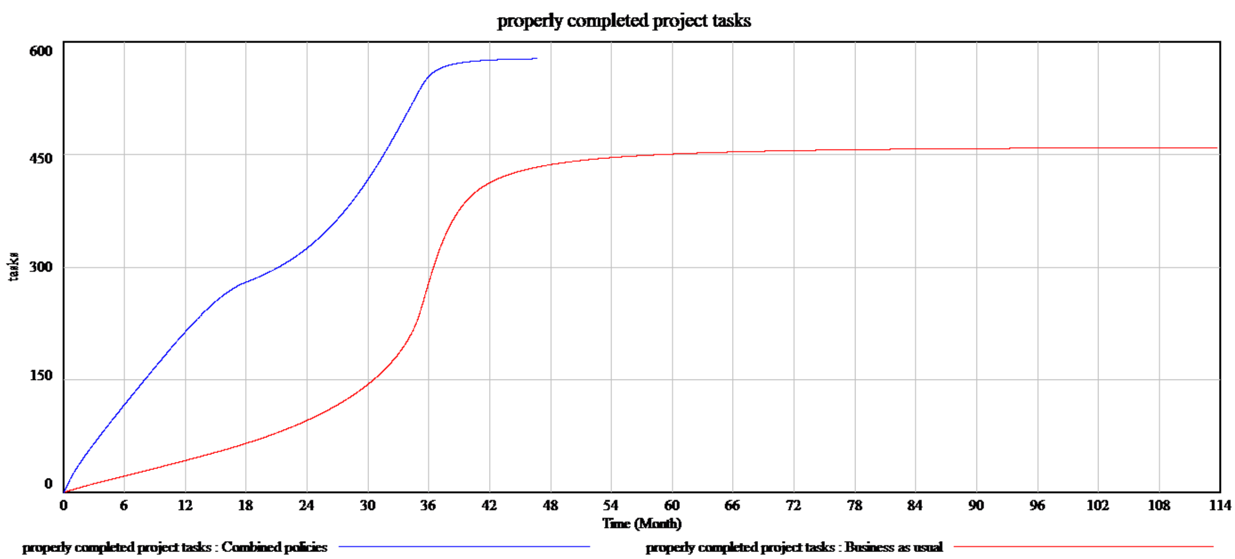

Fig. 6.114: Properly completed project tasks trends under business as usual and combined policies scenarios

Undiscovered rework of 140 tasks in the business as usual scenario in figure 6.115 drops to approximately 23 tasks in the combined policies scenario, while average quality of completed project tasks rises from 0.75 in the business as usual scenario to 0.95 in the combined policies scenario as shown in figure 6.116.

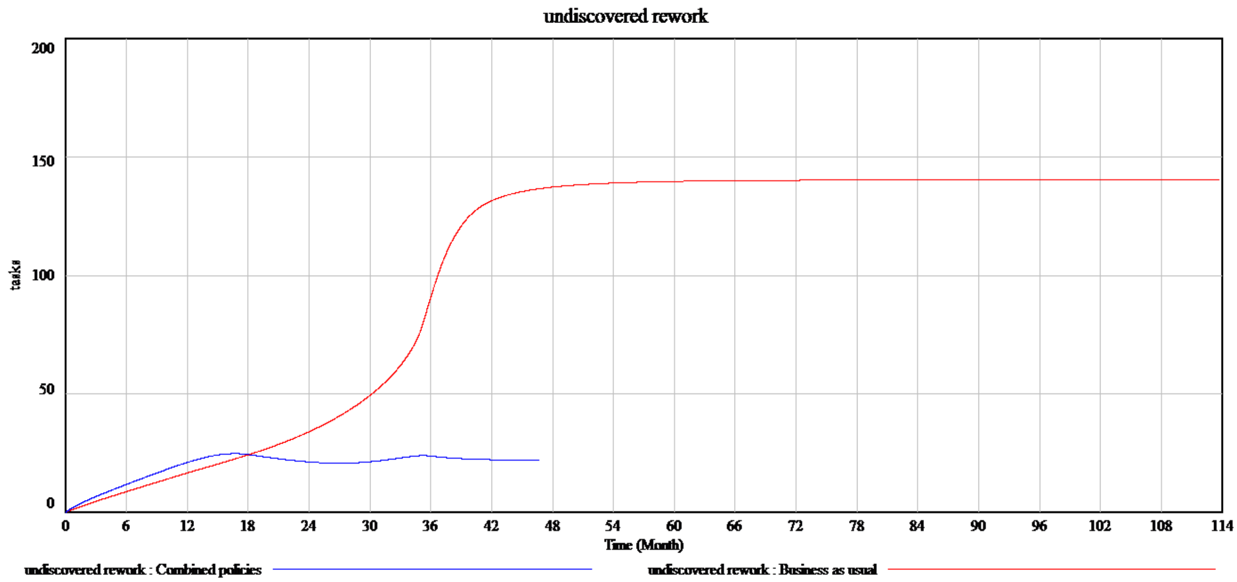

Fig. 6.115: undiscovered rework trends under business as usual and combined policies scenarios

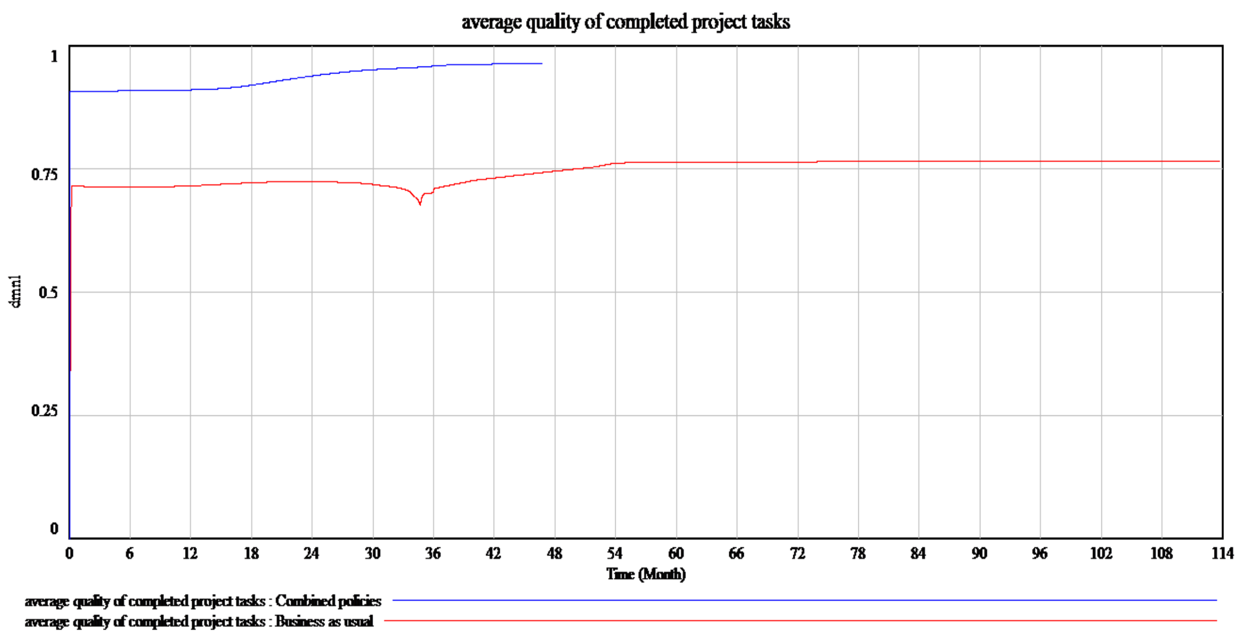

Fig. 6.116: Average quality of completed project tasks trends under business as usual and combined policies scenarios

Table 6.2 compares and contrasts simulation results from the 5 policy options, and from the table, it can be deduced that scenario 5 that combines the effects of the other scenarios gives the best results in terms of perceived productivity, fraction of project tasks properly completed, number of properly completed project tasks, lowest number of undiscovered rework tasks, highest average quality of completed project tasks and shortest project completion time. scenario 5 is therefore recommended as the best policy option.

Table 6.2: Comparison of the simulation results and outputs from the 5 policy scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Perceived productivity (tasks/person/month)	1.3	1.7	1.4	2.24	5.5
Fraction properly completed (dmnl)	0.7	0.9	0.7	0.7	0.9
properly completed project tasks (tasks)	450	540	450	525	580
undiscovered rework (tasks)	140	55	150	70	25
average quality of completed project tasks (dmnl)	0.75	0.92	0.75	0.89	0.95
Project completion time (months)	60	60	38	60	38
Rate of detecting undiscovered rework (tasks/month)	4	4		16	
Maximum productivity of testing (tasks/person/month)	2	2	2	6	6
Project Management competence (dmnl)	57%	72%			90%

The new model with policy scenario 5 as given in Fig. 6.109 is a significant improvement on the initial basic model in Fig. 6.2 because it incorporates the improvement of project management competence from an earlier maximum of 57% to 90% which can be achieved through the enforcement of hiring of staff competent in project management practice. The new model has also taken into account the proposed spreading of the workforce during the project life, whose effect will be a reduction in the steep peaking of workers towards the end of the project life. Also included in the model in Fig. 6.109 is the hiring of competent and qualified engineers and technicians by the project teams, who will be useful for commissioning and testing functions achieved through the increased fraction and competence of personnel for testing in the new model, and this has the other effect of a drastic reduction of "*unforeseen technical difficulties"* to near zero, and so "*unforeseen technical difficulties"* is deleted in the new model in Fig. 6.109.

6.6.2: Policy Sensitivity test

During this test, policy implications are checked for significant changes when assumptions about parameters and boundary are varied over the plausible range of uncertainty. Optimization methods are used to find the best parameters and policies, and to find parameter combinations that generate implausible results or reverse policy outcomes (Sterman 2000, Khasawneh et al 2010).

6.6.2.1: Univariate analysis, 200 runs (random uniform distributions)

a. "fraction properly completed" changing from 0.6 to 0.99

In this analysis, 200 simulation runs are made on the model in figure 6.109 while in each simulation run, the value of "fraction properly completed" is randomly chosen from the range 0.6 to 0.99.

The possible scenarios for workforce levels with uncertainty in fraction properly completed is shown in Fig. 6.117 with workforce levels fairly spread out and peaking at about 35-36 months, with fairly significant variations in levels of workforce shown under fraction properly completed likely due to the need for fewer numbers of workers with employment of a more competent workforce capable of finishing the tasks to the quality standards expected, leading to a higher value for fraction of tasks that are properly completed. This is a reasonable and expected trend.

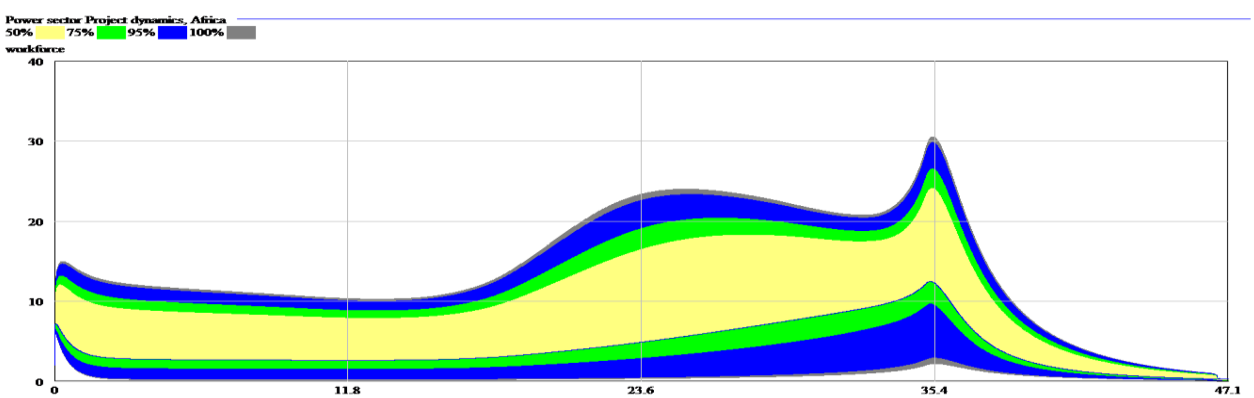

Fig. 6.117: Workforce sensitivity trace ranges under fraction properly completed uncertainty

Fig. 6.118 shows the possible effect of fraction properly completed on remaining project tasks, with an initial significant variation in remaining project tasks during the first 24 months of project time though the final few months to the completion of project tasks shows minimal variance. This is a reasonable expectation, as the final project completion time may depend on factors other than the fraction properly completed.

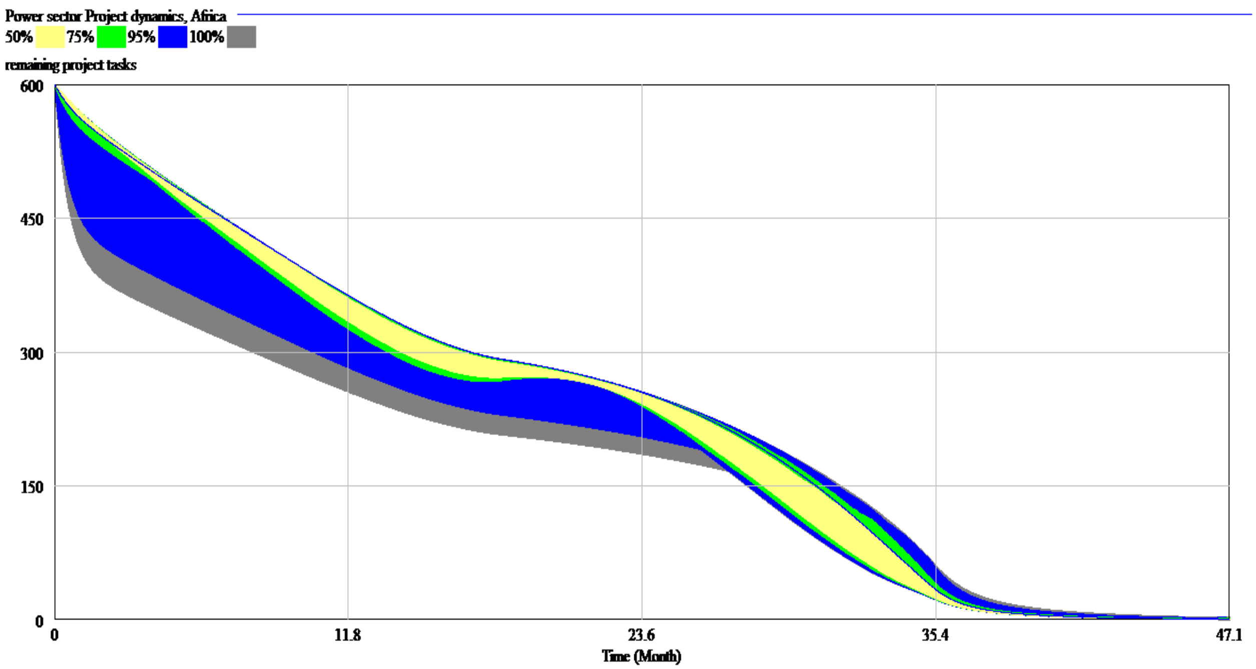

Fig. 6.118: remaining project tasks sensitivity trace ranges under fraction properly completed uncertainty

Fig. 6.119 shows the possible effect of fraction properly completed on properly completed project tasks, with an initial significant variation in properly completed project tasks during the first 24 months of project time but with a minimal variation in properly completed project tasks shown during the final few months to the completion of the project. This is a reasonable expectation, as the final project completion time may depend on factors other than the fraction properly completed.

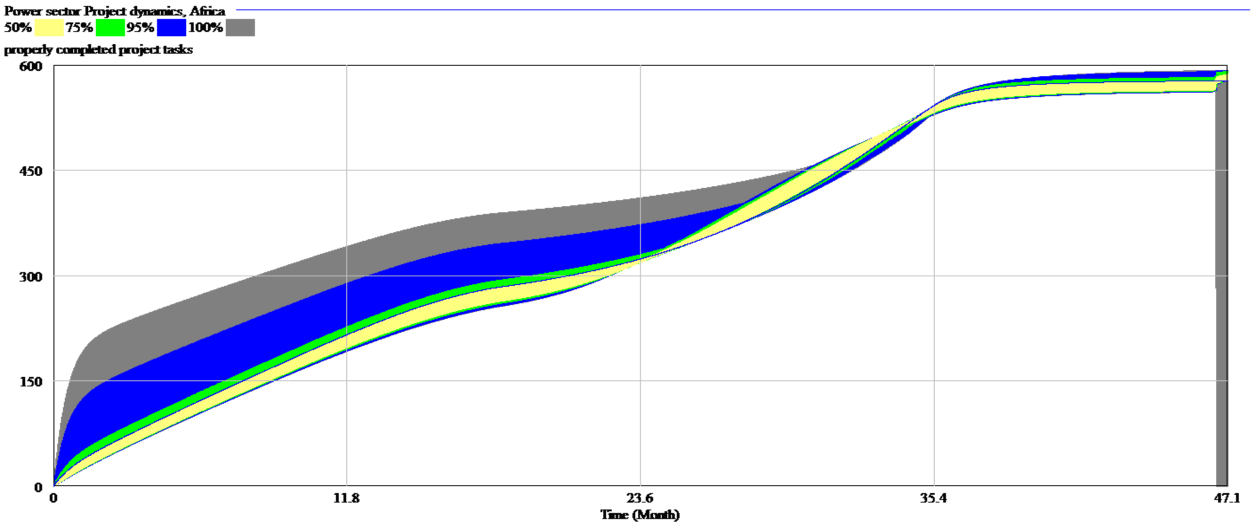

Fig. 6.119: Properly completed project tasks sensitivity trace ranges under fraction properly completed uncertainty

Fig. 6.120 shows the possible effect of fraction properly completed on undiscovered rework, with a significant variation in undiscovered rework during the course of the project. This is a reasonable expectation, as the changes in fraction properly completed have a direct bearing on the magnitude of undiscovered rework.

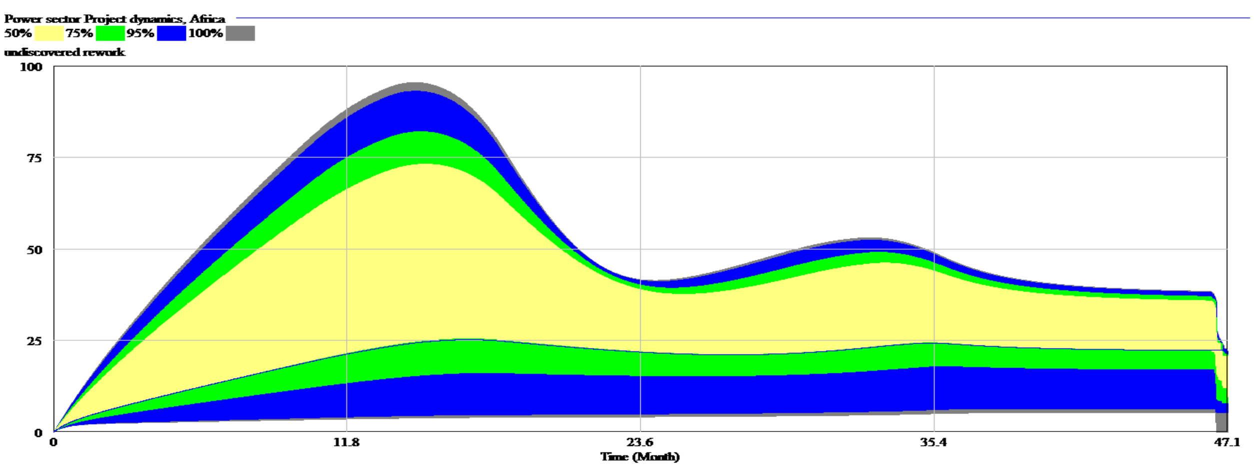

Fig. 6.120: undiscovered rework sensitivity trace ranges under fraction properly completed uncertainty

Fig. 6.121 shows the possible effect of fraction properly completed on average quality of completed project tasks, with a significant variation in average quality of completed project tasks during the course of the project. This is a reasonable expectation, as the changes in fraction properly completed have a direct bearing on the quality of completed project tasks.

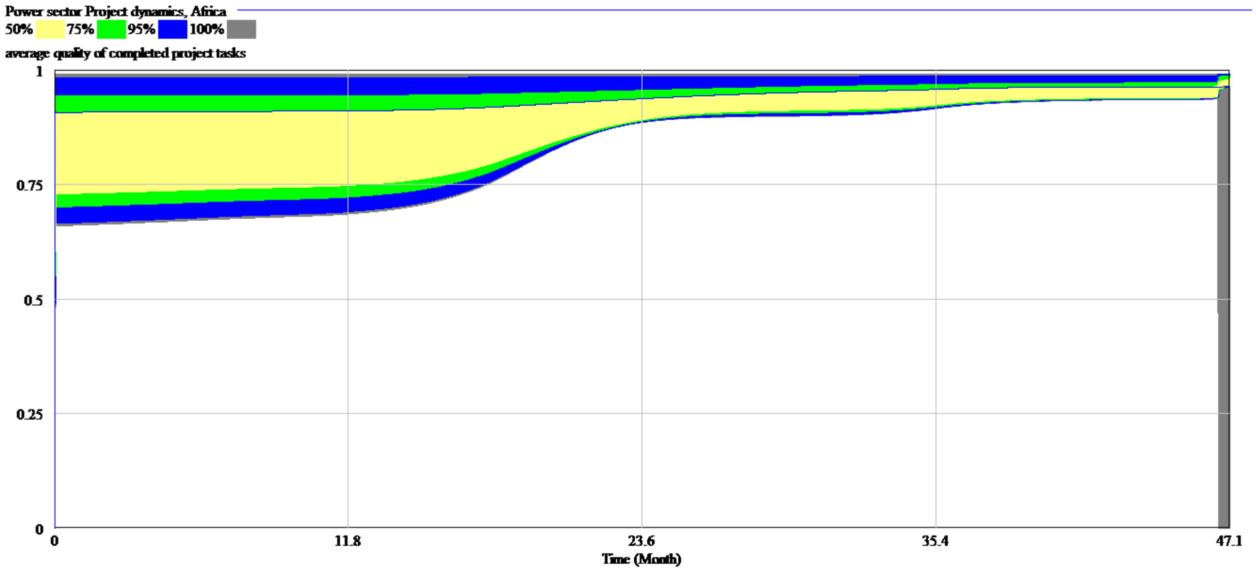

Fig. 6.121: average quality of completed project tasks sensitivity trace ranges under fraction properly completed uncertainty

6.6.2.2: Univariate analysis, 200 runs (random uniform distributions)

b. "maximum productivity of testing" changing from 2 to 8

In this analysis, 200 simulation runs are made on the basic model in figure 6.109 while in each simulation run, the value of "maximum productivity of testing" is randomly chosen from the range 2 to 8 tasks/person /month.

Fig. 6.122 shows the possible effect of maximum productivity of testing variations on workforce levels, with a significant variation in workforce levels as from 24 months of project time to the completion of the project. This is a reasonable expectation, as the effects of maximum productivity of testing are likely to be felt during the second half of the project when equipment has been delivered to site and testing and commissioning of the project sub-systems is in progress.

Fig. 6.123 on the other hand shows the possible effect of maximum productivity of testing variations on remaining project tasks, with a minimal variation of remaining project tasks shown during the course of the project. This is a reasonable expectation, as the productivity of testing would ordinarily not affect the remaining project tasks in a significant manner.

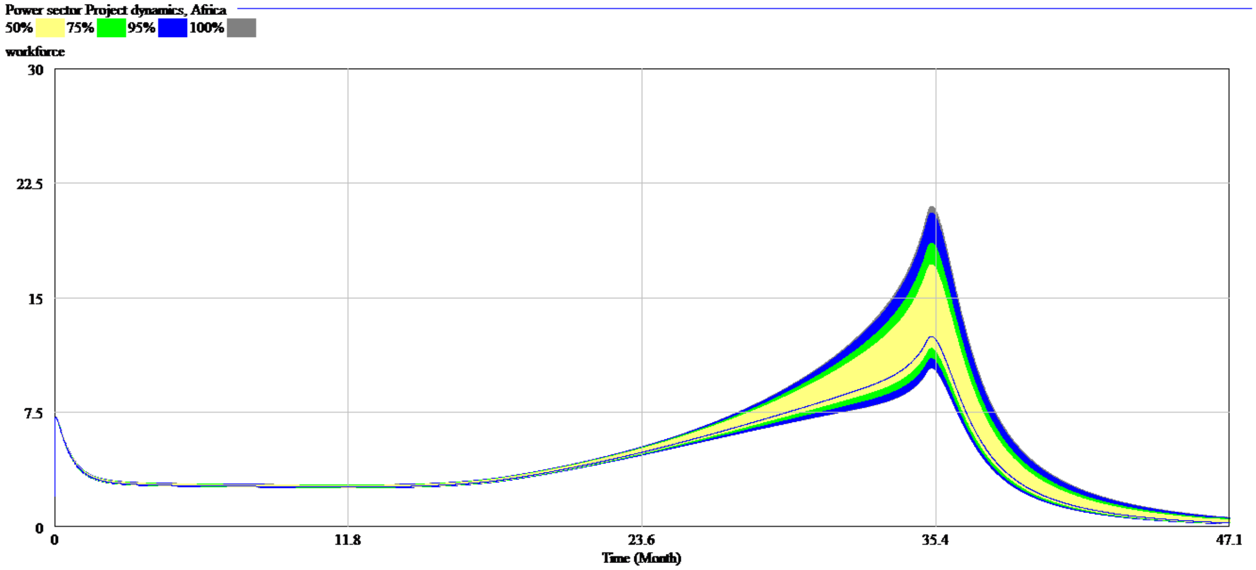

Fig. 6.122: workforce sensitivity trace ranges under maximum productivity of testing uncertainty

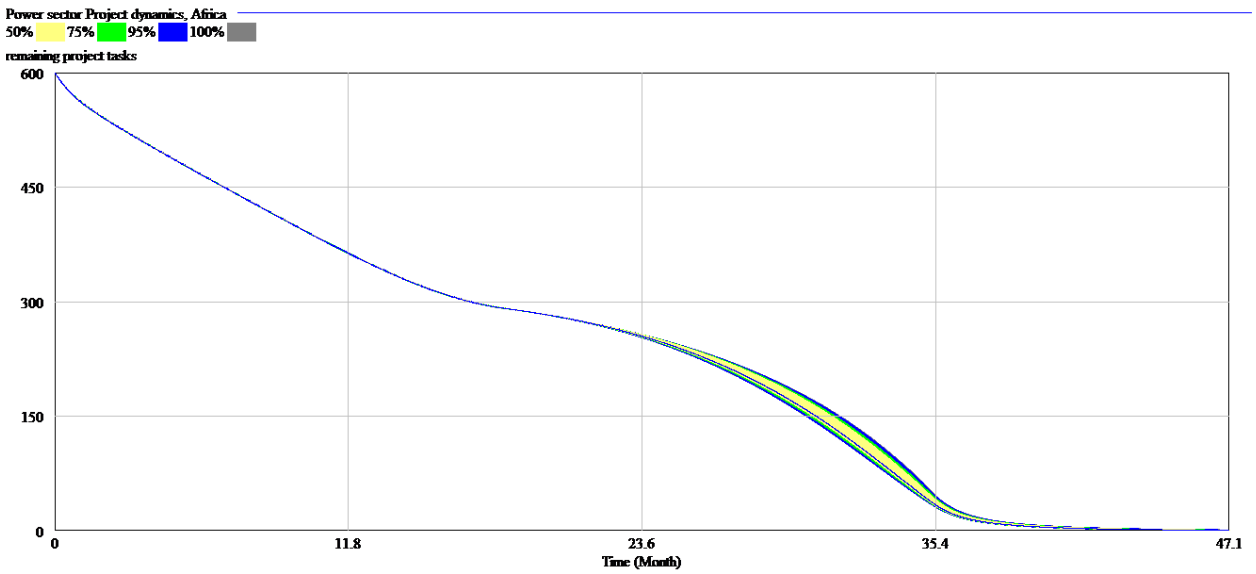

Fig. 6.123: remaining project tasks sensitivity trace ranges under maximum productivity of testing uncertainty

Fig. 6.124 shows the possible effect of maximum productivity of testing variations on properly completed project tasks, with a variation of properly completed project tasks from 550 tasks to 580 tasks shown during the course of the project. This is a reasonable expectation.

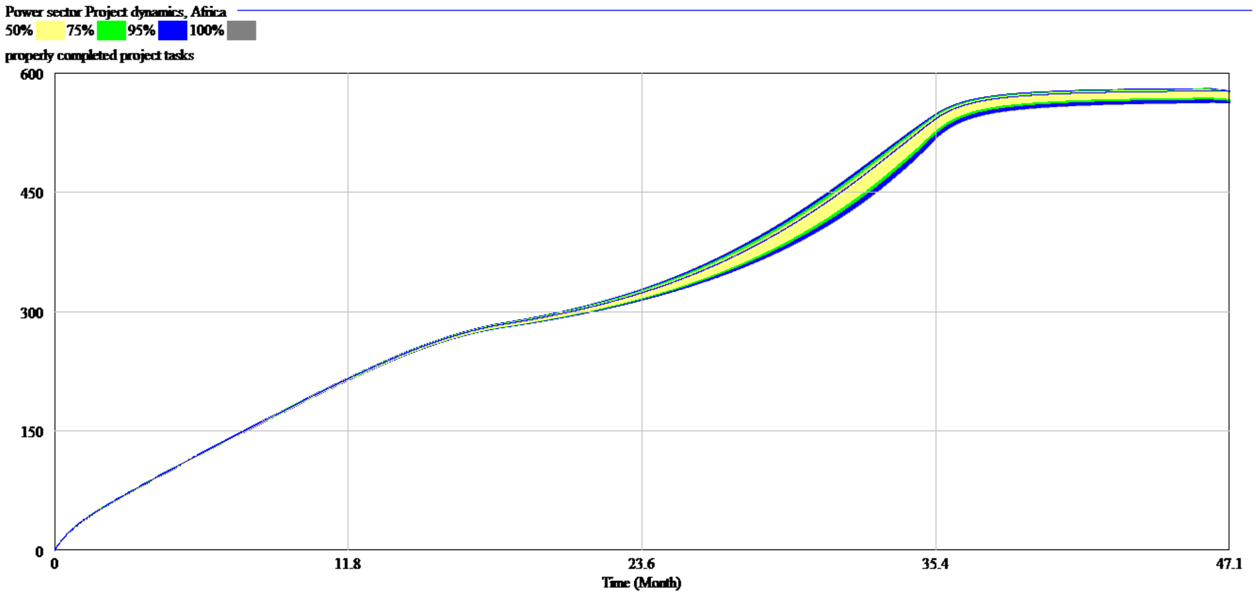

Fig. 6.124: properly completed project tasks sensitivity trace ranges under maximum productivity of testing uncertainty

Fig. 6.125 shows the possible effect of variations in maximum productivity of testing on undiscovered rework, with a significant variation in the number of tasks of undiscovered rework shown during the course of the project. This is a reasonable expectation, as it is through testing that undiscovered rework is detected and added back into the stock of remaining project tasks to be attended again.

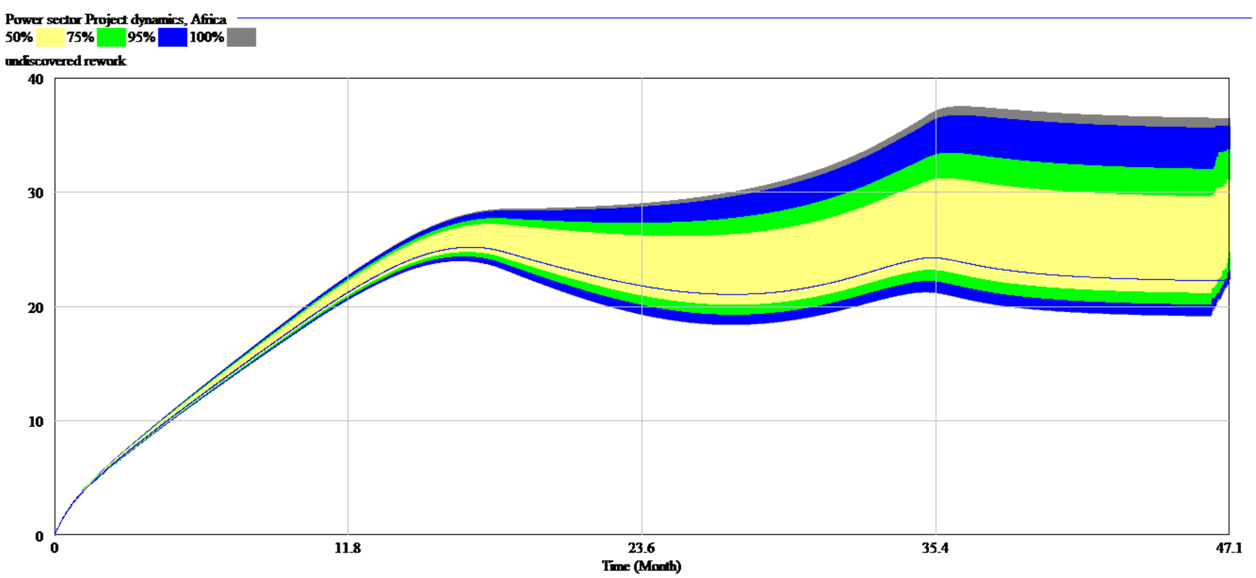

Fig. 6.125: undiscovered rework sensitivity trace ranges under maximum productivity of testing uncertainty

Fig. 6.126 shows the possible effect of variations in maximum productivity of testing on average quality of completed project tasks, showing a variation in the average quality of completed project tasks from 0.9 to 0.95 at the project completion time of about 38 months. This is a reasonable expectation.

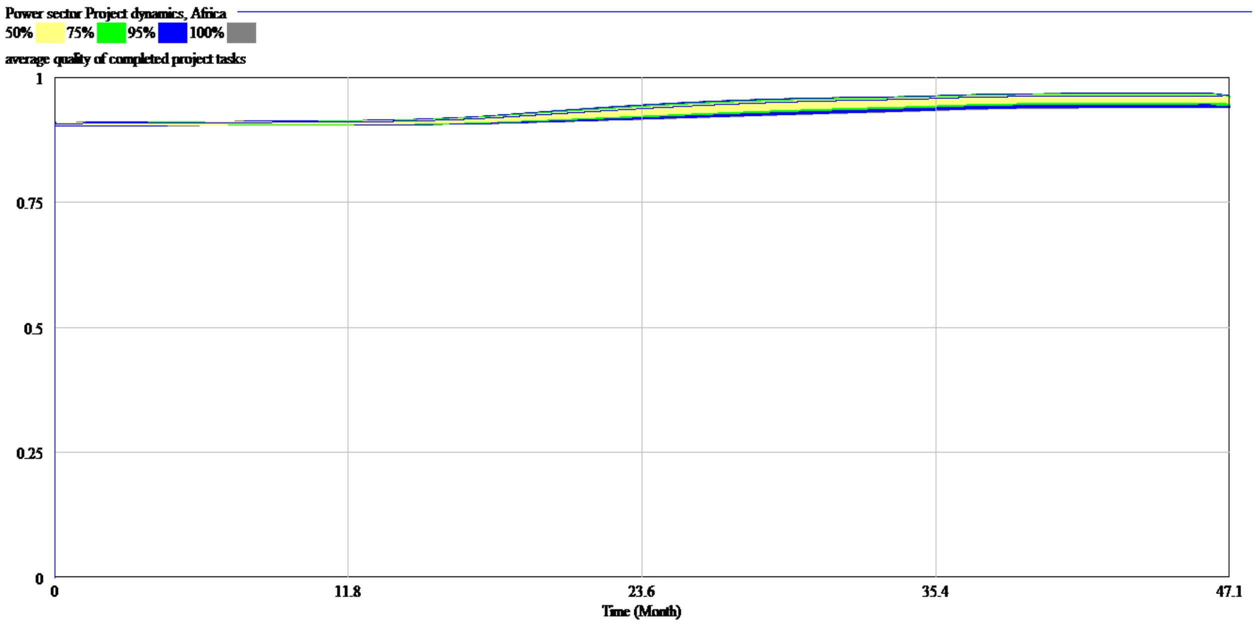

Fig. 6.126: Average quality of completed project tasks sensitivity trace ranges under maximum productivity of testing uncertainty

6.6.2.3: Multivariate analysis, 200 runs (with random uniform distributions)

Sensitivity testing is the process of changing assumptions about the value of constants in the model and examining the resulting output for change in values, and multivariate sensitivity analysis checks for the combined effect of input uncertainty on the model outputs (Shannon et al, 2013). Multivariate analysis was done by having the two variables "a" and "b" randomly but uniformly changing together during the sensitivity simulation runs done on model in figure 6.109.

a. With "maximum productivity of testing" changing from 2 to 8 tasks/person/month
b. With "fraction properly completed" changing from 0.6 to 0.99

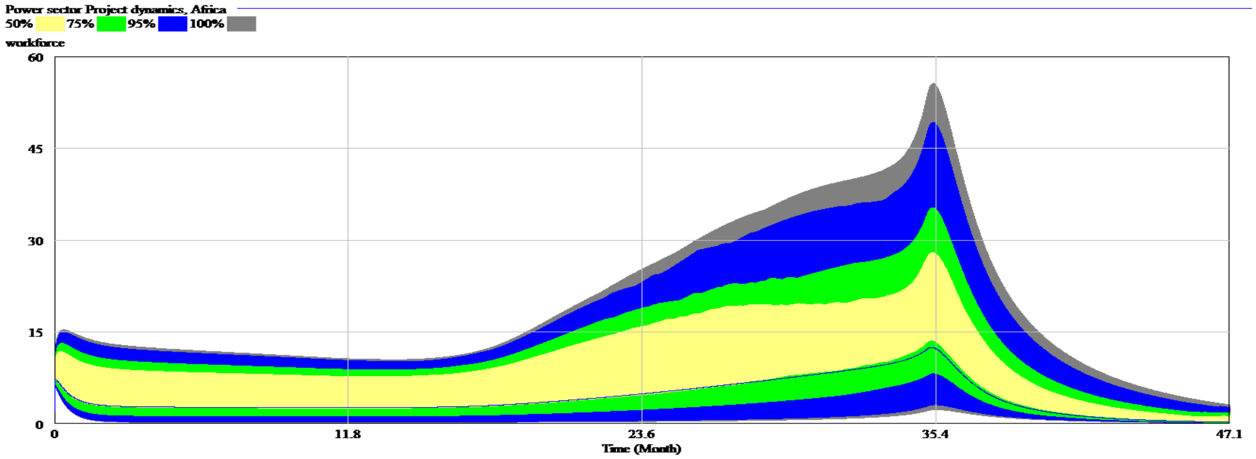

Fig. 6.127: Workforce sensitivity trace ranges under multivariate uncertainty

Fig. 6.127 shows possible variations of workforce spread under multivariate uncertainty, and at between 35 to 36 months when workforce is at its maximum, it shows a wide dispersion of possible workforce spread ranging from 5 to 55 persons. This points to a link between maximum productivity of testing, fraction of tasks properly completed and the competence of the staff on the project, so that where project personnel are fairly competent leading to a higher efficiency in testing, the project overall would need fewer personnel. This is a reasonable expectation.

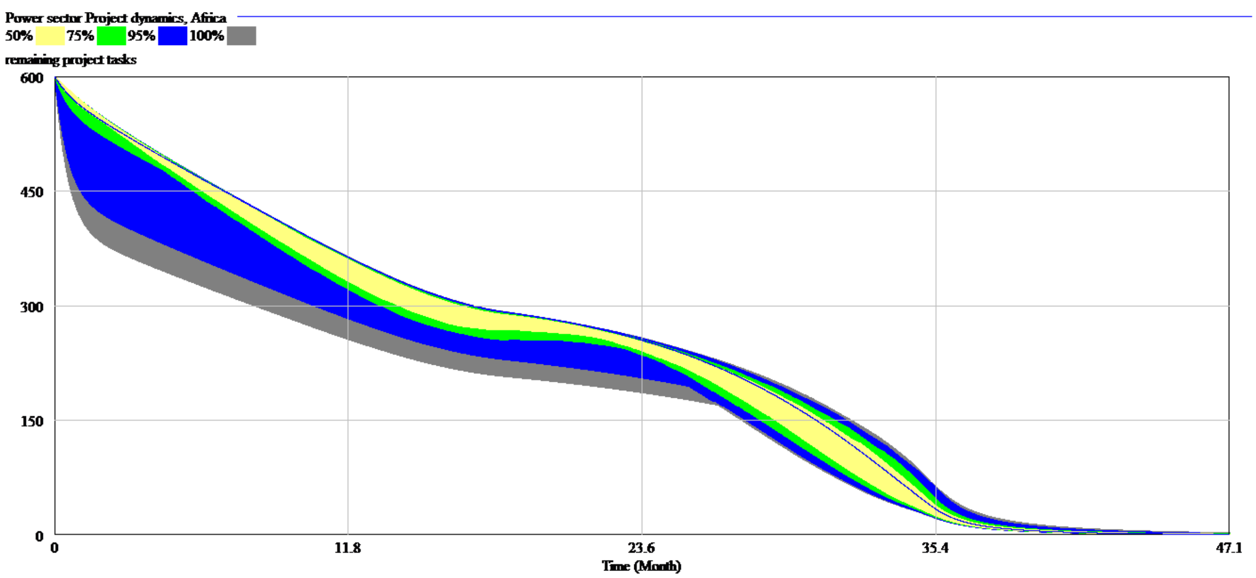

Fig. 6.128: remaining project tasks sensitivity trace ranges under multivariate uncertainty

Fig. 6.128 shows possible variations of remaining project tasks spread under multivariate uncertainty, showing significant variations on levels of remaining project tasks during the initial

24 months of project time due to comined effects of variations on maximum productivity of testing and fraction of tasks properly completed. This is a reasonable expectation.

Fig. 6.129 shows possible variations of properly completed project tasks spread under multivariate uncertainty, showing significant variations from 550 tasks to 590 tasks of the propelry completed project tasks at 38 month of project time. This is a reasonable expectation.

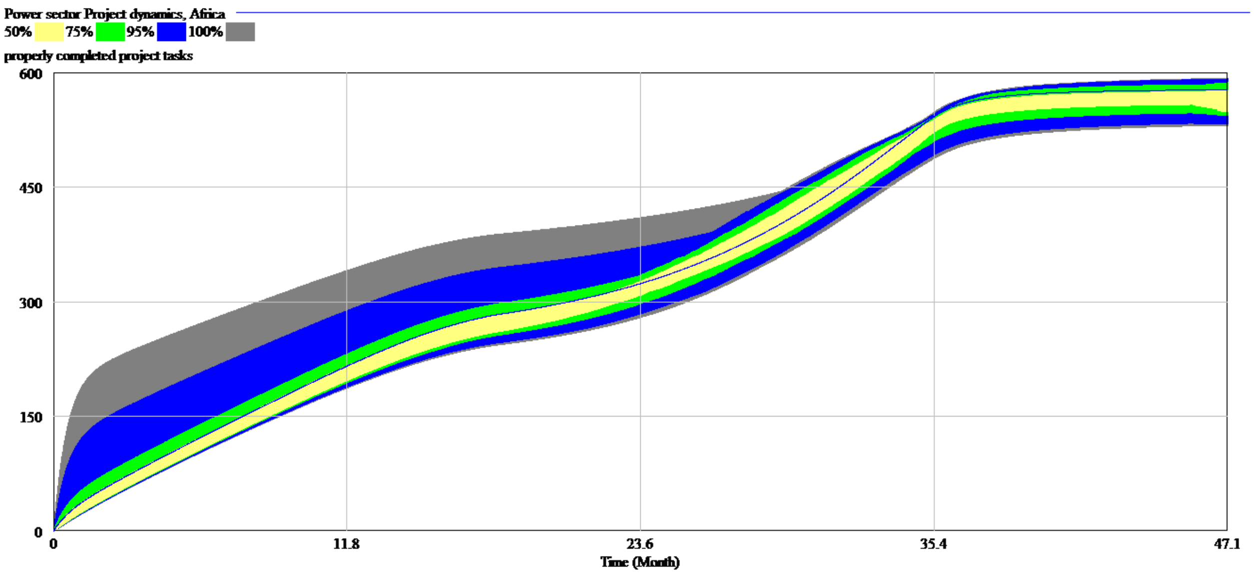

Fig. 6.129: properly completed project tasks sensitivity trace ranges under multivariate uncertainty

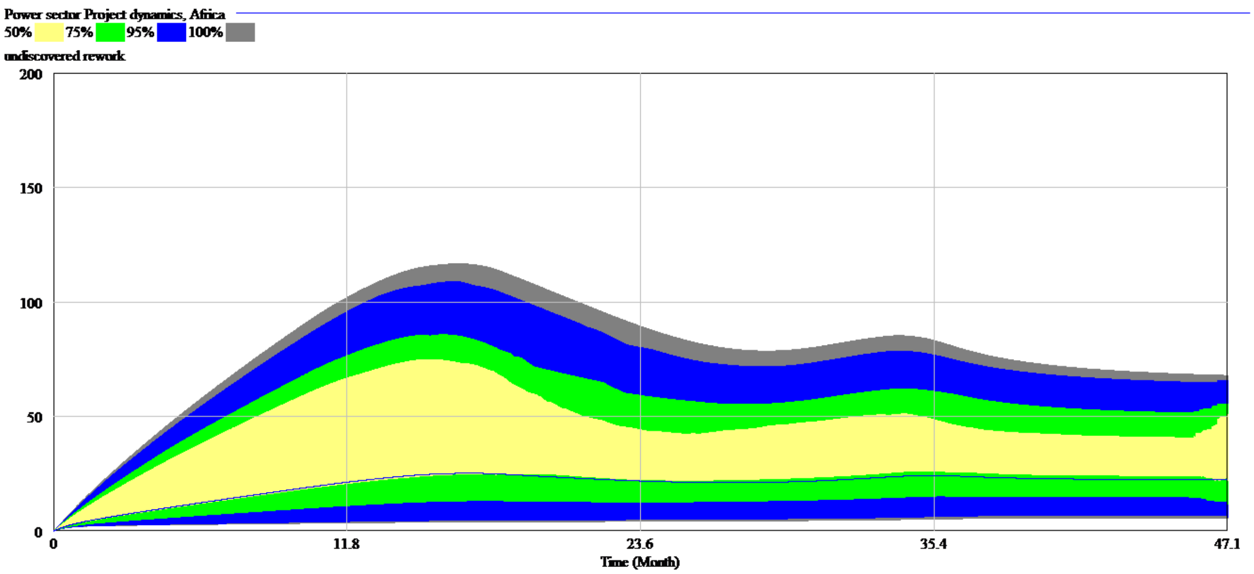

Fig. 6.130: undiscovered rework sensitivity trace ranges under multivariate uncertainty

Fig. 6.130 shows possible variations of undiscovered reowork spread under multivariate uncertainty, showing significant variations in the undiscovered rework tasks during the course of the project. This is a reasonable expectation as variations in both the maximum productivity of testing and fraction of tasks properly completed would ordinarily impact the level of undiscovered rework.

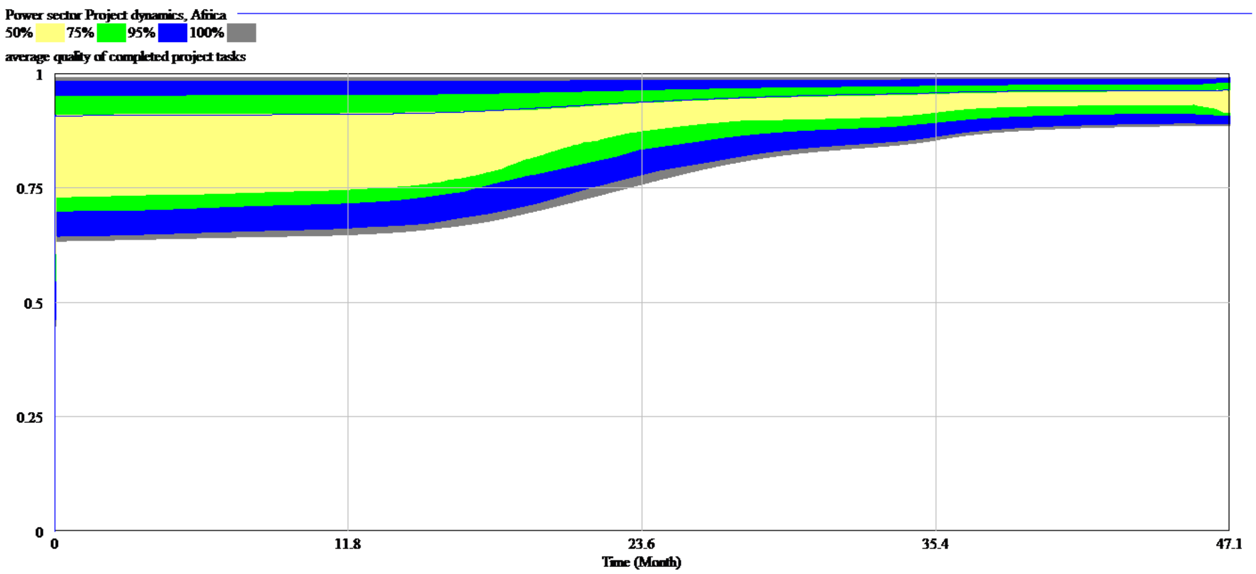

Fig. 6.131: average quality of completed project tasks sensitivity trace ranges under multivariate uncertainty

Fig. 6.131 shows possible variations of average quality of completed project tasks spread under multivariate uncertainty, showing significant variations from 0.9 to 0.99 of the average quality of completed project tasks at 38 month of project time. This is a reasonable expectation.

6.7 Chapter Summary

In this chapter, the model was subjected to direct structure tests comprising structure confirmation test, dimensional consistency test and parameter confirmation tests which the model passed. The model was also subjected to indirect structure tests comprising Extreme condition test, Boundary adequacy test, Numerical sensitivity test and Behavior sensitivity test. During the boundary adequacy test, project management competence was changed from a constant and made endogenous to vary with the average quality of completed project tasks arising from insights gained during the workshop with stakeholders in the electricity sector in

Kenya. Similarly, an insurance index was introduced to help mitigate the effects of political risk and to encourage early completion of the projects.

Extreme condition test was done on all the model variables and in the process, adjustments were made on the equations for the "poor completion of project tasks" as well as on the equation for "perceived effort remaining". All the other variables passed the extreme condition tests. The basic model also passed the numerical sensitivity tests and behavior sensitivity tests. The model was also subjected to behavior pattern tests which it passed. A range of policy scenarios comprising Business as usual (Scenario 1); Project Management competence improvement (through hiring of staff with knowledge in project management skills as Scenario 2); Equitable spread of workforce (Scenario 3); increased role for testing and commissioning personnel by increasing the overall percentage of technical staff (Scenario 4) and Combinations of the other four policies (Scenario 5) were analyzed, with the result that scenario 5 emerged as the option giving the best results.

The new model developed in this research and as shown in figure 6.2 therefore represents fairly well project dynamics in the electricity energy sector in Kenya and the wider Sub Saharan Africa region, as well as in many developing countries, and will be useful to policy makers and electricity utilities in the region. The policy scenario analysis as done in this chapter also offers important options for policy makers to use in addressing project delays and quality challenges in the electricity energy sector in the region, and if implemented, should lead to improved efficiency in project delivery and help the region as whole to avoid the rationing of electricity. The new model as developed in this research has therefore contributed to new knowledge that can be applied in the electricity industry to gain positive results.

The following chapter discusses and elaborates on the results as obtained in this research project, and further offers insights gained and draws conclusions from the research.

PART III: EXPLANTION OF RESULTS / CONCLUSIONS / IMPLICATIONS FOR PROJECTS IN THE ELECTRICITY INDUSTRY

CHAPTER 7: Discussion of Results

7.0: Introduction

This chapter starts by outlining and restating the purpose of this research with the aim of examining if this purpose has been achieved. It then restates the research questions, and elaborates on how each of the research questions has been answered through the research efforts. Thereafter, the contributions this research has made to new knowledge are given. In more details, the effort and knowledge gained from chapter 3 is used in the exploratory study as described in section 4.5.4 to aid in answering the sub-research question in section 1.5 (b) namely; "How can the interaction of project risks in the electricity sector in Kenya be studied and analyzed in a dynamic setting?, while the effort and knowledge gained from chapter 4 is used as described in section 4.5.4 in answering the first research question namely "What are the project dynamics in the electricity industry in Kenya?" as well as in answering the sub-research question in section 1.5 (c) namely; "What research strategy and paradigm can be employed in studying project risks in the electricity sector?".

Similarly, the effort and knowledge gained in chapter 5 is used in answering the sub-research question 1.5 (d) namely "What forces create the problems that lead to project delays and quality challenges experienced in projects in the electricity sector in Kenya?" This is also used in answering the second research question as given in section 1.5 "How do the prevalent risks and other elements interact with each other in a dynamic project set up?" while in chapter 6, two sub-set questions as indicated in 1.5(e) and 1.5(f) are answered namely "What policy scenarios derived from the project dynamics in the electricity sector in Kenya can be used to improve project delivery time?" and "What policy scenarios derived from the project dynamics in the electricity sector in Kenya can be used to improve the quality of the delivered projects?" and subsequently, this is used in answering the third research question as indicated in section 1.5 namely "What policy scenarios derived from the resulting model are available that can help stakeholders in the sector to better manage such projects so as to deliver value?"

7.1: Purpose and objectives of this research

The purpose of this research was to model the project management dynamics in the electricity energy sector in Sub Saharan Africa, focusing on risks prevalent in the sector. This was aimed at developing a means and method by which risk can be better managed in projects in the energy sector, and was done in this research by identifying risks that prevail in the industry and investigating interactions of these risks in a dynamic setting, using the System Dynamics method. In doing this, views from key stakeholders in the industry such as contractors, utility companies and the Ministry of Energy were solicited through an exploratory research that gave rise to the conceptual System Dynamics model developed in this research. The new model was developed by expanding Richardson's (2013) conceptual project model to include extra variables identified through the exploratory study in this research. Through this effort, a new conceptual model representative of project dynamics in Kenya was developed as given in figure 5.3, and the new model will be especially useful to stakeholders in the electricity sector in Kenya as it incorporates variables such as political risk, multitasking, project management competence, and unforeseen technical difficulties that are prevalent in Kenya and the region at large, and that influence the pace and outcome of projects in the region.

Developing the simulation model was a key objective of this research, and this was achieved using the System Dynamics approach applying Vensim language. The new model developed in this research was presented to a workshop comprised of stakeholders in the power industry in Kenya, and through sharing the simulation results, there was concurrence that the simulation results from the model mirrored the reality of project dynamics in the industry. The other key objective was to test and validate the model, which was done by performing direct structure tests to assess the validity of the model structure by comparing the model structure with knowledge of the real system, indirect structure tests such as extreme condition tests which were done by subjecting the model to extreme conditions. The new model passed all the tests, and therefore the model developed in this research is deemed to be sound for the intended purposes. Sensitivity analysis, which is the study of how input changes have on outputs, was also done on the model developed in this research, which passed the tests as given in chapter 6 as all the simulation results due to model input variations showed uniform behavior patterns. This reinforced confidence in the new model, and therefore simulation results from the model would mirror the reality of the project dynamics in the electricity sector in Kenya and the wider Sub Saharan Africa region, as indicated in Appendix B, Appendix D and Appendix K.

The simulation results of the model after testing and validation as given in chapter 6 indicate that undiscovered rework is quite prominent and significant in projects in the electricity sector in Kenya, rising to a high of about 150 tasks that remain as undiscovered rework by the end of the project. This would likely result into quality challenges, as the results also indicate that properly completed project tasks at the end of the projects is at about 450 tasks out of the original 600 tasks. The simulation results also show that the workforce, project personnel and testing personnel rise significantly between the 30th month and the 34th month of the project, which point to the hiring of more staff when the project is nearing completion. This is a new and important insight as it likely points to a shortage of qualified project personnel within the contractor staff in the region to adequately undertake the many projects in the electricity energy sector in the region, leading to multitasking and often results into chronic project delays.

7.2: Research questions

To investigate the first research question stated in section 1.5(1); "What are the project dynamics in the electricity industry in Kenya?" an explorative study was undertaken, and the findings showed that multitasking, political risk, low project management competence, and unforeseen technical difficulties were common risks to projects in the electricity sector in Kenya, in addition to other risks previously identified by other researchers such as Richardson (2013). The results of the exploratory study were used to build the conceptual model. This model then provided a basis to investigate the second research question stated in section 1.5 (2); "How do the prevalent risks and other elements interact with each other in a dynamic project set up?" which was done with the help of Vensim computer based simulation. The basic model was tested and validated, after which the resultant model was used to investigate the third research question stated in section 1.5(3); "What policy scenarios derived from the resulting model are available that can help stakeholders in the sector to better manage such projects so as to deliver value?" which was done through what-if scenario analysis, leading to policy scenario generation as given under section 6.6 of this research.

7.3: Contributions to Knowledge

According to Turner (2010), project management and project portfolio management are relatively young disciplines, and the research approaches and standards are still in transition. The field of project management continues to evolve and with ongoing standardization of processes, refinement of concepts, and development of software and applications, project management is becoming more of a science than art (Seymour and Hussein, 2014). Globalization, limited resources, stakeholders, competition, economics and many other factors are contributing to the transformation of organizations and business environment (Construction Industry Institute, 2014).

The mainstream research into projects and project management has been criticized in the recent years for its heavy reliance on the functionalist and instrumental view of projects and organizations which tended to emphasize scheduling, cost estimation and control (Kreiner 1995, Packendorff 1995, Hodgson 2002, Cicmil and Hodgson 2006, Christophe 2016), and where the function of project management is taken to be the accomplishment of some finite piece of work in a specified period of time, within a certain budget, and to agreed specification. While scheduling, cost estimation and control remain crucially important, project management has been redefined to include subject matter from a wide range of fields such as operations management, systems thinking, new product development, risk management, the quality movement, organizational dynamics, industrial psychology and various other aspects of commercial management (Steyn, 2010).

Cicmil and Marshall (2005) have drawn on theory of complexity to propose a critical framework for the conceptualization of the complex nature of construction projects. They proposed a framework where the complex nature of projects can be studied as cooperative inquiry where the researchers and the researched cooperate in interpreting the “lived” experience to achieve the research aims. The research in this thesis borrowed from this experience by working together with the stakeholders in the electricity energy sector in Kenya to build the model presented in this research. The new model as given in figure 5.6 was verified, validated, tested and subsequently improved to come up with the model in figure 6.2. Simulation results from the model in figure 6.2 give important insights into project dynamics caused by the interaction of different risks in projects in the electricity energy sector in Kenya and the wider Sub Saharan Africa Region.

Projects in the electricity energy sector in Kenya are generally expected to be completed in 36 months. However, simulation results from figure 6.2 show that as the project progresses towards the planned completion time of 36 months, undiscovered rework tends to rise as well, and this has the effect of adding more tasks in to the remaining project tasks, and this trend invariably leads to project delays. The late discovery of tasks needing rework also implies that unforeseen technical difficulties become prominent between month 30 and month 40 of project time, causing a momentary dip into the average quality of completed project tasks, further causing project delays as the technical difficulties are attended to. On a positive note, the results also show that the cumulative progress on the project rises with the rise in the number of properly completed project tasks, though this is driven by the significant rise in the number of testing personnel between month 30 and month 40, which is the resource critical in detecting undiscovered rework that tends to rise in the same period.

Overall, the System Dynamics simulation results show that the workforce, project personnel and testing personnel all rise to a maximum at about 34 months to 38 months of project time, and this points to the tendency of contractors to start the project with a small workforce, and only tend to increase the workforce late into the project, probably driven by a desire to save on staff costs. The results also show clearly that projects in the sector may take up to 60 months to complete and even then, undiscovered rework remains at a high of between 140 tasks and 150 tasks, which is a clear pointer to the reason quality happens to be a familiar challenge in projects in the electricity sector in Kenya. This is a significant contribution to knowledge in this research as concerns projects in the electricity energy sector in Kenya and the region at large, as it offers a plausible explanation as to why many projects appear to take longer than expected to complete and even then, some projects are handed over with some incomplete tasks as exemplified by the example in Appendix K. While political risk is ever present in projects in the electricity sector, the introduction of an insurance index that rises to mitigate the political risk by encouraging improved progress is an important addition to the model, and may be used to effectively mitigate the risks associated with political risk which is widespread in many countries in the Sub Saharan Africa region.

From the knowledge gained by studying the simulation model in figure 6.2, it can be deduced that the forces that cause project delays and quality challenges in the electricity sector in Kenya include a critical shortage of testing / commissioning engineers that lead to multitasking and late discovery of tasks that require rework, as the few available engineers move from one project to another. Political risk, unforeseen technical difficulties and as well as average project management skills is also a major contributing factor to the delays, while overall shortage of adequate numbers of project personnel, leading to the peaking of project workforce between month 30 and month 40 of project time, exacerbates the problem by delaying corrective action.

Policy scenario 3 on equitable spread of workforce shows that time taken to project completion through *remaining project tasks* reducing from 600 tasks to zero in 38 months of project time as compared to 60 months in the business as usual scenario, while in scenario 5, the *remaining project tasks* reduce from a high of 600 tasks at the beginning of the project to zero at 38 months of project time. Scenario 5 also indicates that the number of properly completed project tasks would rise to 570 tasks by month 38 of project time, while undiscovered rework would level off to a high of only 25 tasks, compared to 140 tasks in the business as usual scenario. Therefore, policy scenarios 3 and policy scenario 5 as derived from the project dynamics in the electricity sector in Kenya can be used to improve project delivery time from 60 months in the business as usual scenario to 38 months. This is new knowledge that is the result of this research study, based on the simulation results derived from the new model developed in this research, and would likely contribute significantly to new policy interventions with positive results when applied to projects in the electricity energy sector in Kenya, the Sub Saharan Africa region and other developing countries by ensuring projects are completed in time. The knowledge gained could also be useful in guiding future project procurement processes in the region by putting more weight on project workforce.

Scenario 2 shows that improvement in project management competence has the effect of raising perceived productivity of project workers from peaking at 1.3 tasks/person/month before leveling off at about 0.8 tasks/person/month, to peaking at 1.7 tasks/person/month before dropping and leveling off at 1.2 tasks/person/month. Further, the fraction of project tasks that are properly completed also rises from approximately 0.7 to 0.9, and therefore improvement of project management competence to a level proposed in scenario 2 would result into an improvement of average quality of project tasks from 75% to 92% as shown in Table 6.2. Scenario 4 which involves hiring more testing / commissioning engineers to the levels proposed would result into a reduction of undiscovered rework from 140 tasks to 70 tasks, a rise in properly completed project tasks from 450 tasks to 525 tasks, the peaking in the detection of undiscovered rework from 4 tasks/month to 16 tasks/month, the reduction of fraction of undiscovered rework from 0.26 in the business as usual scenario to 0.075 at month 32 of project time, and these effects result into an improvement of average quality of project tasks from 75% to 89% as shown in Table 6.2. Scenario 5 which combines the effects of scenario 2, 3 and 4, results into an improvement of average quality of project tasks from 75% to 95% as shown in Table 6.2. it is therefore safe to say that policy scenario 2, scenario 4 and scenario 5 derived from the project dynamics in the electricity sector in Kenya would likely improve the quality of the delivered projects in the sector.

Histograms from simulated activity levels after multivariate sensitivity analysis are shown in Appendix J, which indicate a remarkable improvement in the most probable indicators for the "business as usual" policy scenario at month 60 of project time to the "combined scenario" policy as given in scenario 5 at month 38 of project time for "remaining project tasks" from 14 tasks to 6-9 tasks, the "average quality of completed project tasks" of 0.68 - 0.72 in business as usual to 0.93 - 0.945 in the combined scenario policy, and "undiscovered rework" from 180 – 200 tasks in business as usual to 27 – 34 tasks in the combined scenario. This shows the great potential likely to be gained from the application of the new knowledge gained from this research.

The next chapter gives the overall conclusion to for this research, managerial implications and learning that can be derived from this research, and points out the opportunities for future research in relation to and arising from this research study.

CHAPTER 8: Conclusions and implications for research and industry

8.0: Conclusions

Li (2006) pointed out that engineering risk management should be regarded as a 'system', and that the achievement of an optimal level of risk for a particular participant cannot be realized without making use of the methods of systems engineering. These views are shared by Haimes (2012) when he states that by its nature, risk analysis is an intricate, dynamic process, an amalgamation of the arts and sciences, and that Systems Engineering is distinguished by a practical philosophy that advocates holism in cognition and in decision making, and the philosophy is grounded on the arts, natural and behavioral sciences, and engineering, supported by a complement of modeling methodologies, optimization and simulation techniques. The complexity of a project leads to the existence of a network of interdependent risks (Fang and Marle 2012), where complex phenomena may occur which is hard to anticipate and hard to keep under control.

This doctoral research set off with the aim of developing a suitable model capable of helping management in electricity utility companies in Sub Saharan Africa to explore the dynamics at play in projects in the sector, with a focus on the risks prevalent within projects in the sector thought to be the cause of project delays and challenges in quality of the completed projects in the industry. The System Dynamics method was chosen as the suitable method for model development in this study primarily because it has previously been successfully applied in similar studies. Its' suitability lies in its capability to capture feedback relations between variables, and to present the simulation results in graphical forms that are visually easy for users and stakeholders to understand.

The need for the conceptual model was informed by the need to understand the interactions of risks at play in projects in the industry, which the conceptual model brings out in a manner that is easy to understand by use of feedback loops. The conceptual model was subsequently developed into a simulation model that mirrored the project dynamics in the industry in Kenya. The resultant simulation model was successful in generating results that stakeholders confirmed represented the reality of project outcomes in the electricity sector. The results of the study showed that project delays and quality problems in the power sector projects in the region are caused by rework which comes from use of workforce that are not adequately skilled especially in in technical areas, multitasking likely caused by a shortage of key technical personnel such as commissioning engineers, and low levels of project management competence.

The exploratory study in this research involved soliciting views from a large group of stakeholders in the energy sector in Kenya, and used the views from the participants to develop the System Dynamics conceptual model of interacting project risks based on knowledge gained from the stakeholders and literature as reviewed in this research by employing a systems approach. The conceptual model was thereafter shared with a group of experts and following suggestions and input by the experts, the System Dynamics simulation model that likely mirrors the present reality and project dynamics in infrastructure projects in the electricity power industry in Kenya was formulated as presented in this research in figure 5.6. The basic model was subsequently verified, validated and tested and in the process improvements / corrections were made to the basic model in figure 5.6 so as to finally arrive at the model in figure 6.2. Policy analysis was then undertaken, which revealed several scenarios that can be used to improve project delivery time as well as quality of the completed project as whole.

The results of the study show that political risk, average competency levels in project management skills, multitasking and unforeseen technical difficulties as interacting project risks, contribute significantly to slow down projects in the electricity sector in Kenya and by extrapolation, the wider Sub Saharan Africa Region. The same variables contribute quality challenges to projects in the electricity sector in the region. A critical shortage of testing /commissioning engineers was identified as an impediment in the delivery of projects in the electricity industry in Kenya, while the tendency by project contractors to wait till late into the project to increase the project workforce results into slow start and slow progress in the projects.

From the scenarios generated through policy analysis, the study reveals that through employment of more competent project managers and engaging of skilled testing and commissioning engineers in adequate numbers, projects in the sector will likely finish on time and with improved quality. This can be achieved at the tendering stage, by requiring contractors to engage competent personnel as a prerequisite for being awarded the contracts. The study also reveals that inclusion of an insurance component in the procurement process for the project contractors can be used to mitigate the effects of political risk. This new knowledge gained from this research will be useful to decision makers in the electricity energy sector in Kenya, the Sub Saharan Africa region and developing countries at large, and contributes as an addition to the body of knowledge in project management. At policy level, the new knowledge points to the need and value to be gained from the training of personnel in the region on project management skills and a bigger pool of commissioning engineers so as to eliminate the sharing of the few available commissioning engineers between projects.

8.1: Managerial implications

Research acts as a source of new ideas, and therefore active implementation of research into practice is important. The results of this research through policy analysis done in chapter 6 indicate that the management of electricity utilities in the power sector in Kenya and the wider Sub Saharan Africa need to emphasize training in project management as this was shown to significantly improve productivity, raise the fraction of properly completed project tasks, raise the number of properly completed project tasks, and significantly reduce undiscovered rework as shown in table 6.2. The power sector in sub-Saharan Africa offers a unique combination of transformative potential and attractive investment opportunity, but the inadequacy of electricity supply is a fact of life in nearly every Sub-Saharan Africa country (Castellano et al, 2015). Implementation of the results at policy level would therefore make a significant difference in value gained from projects in the electricity sector in the region, improve adequacy of electricity supply, and the investment opportunities in the region. The new knowledge gained from this research therefore has the potential of increasing electricity access, installed capacity and to reduce electricity shortages for both residential and industrial sectors in the region.

The results also indicate that spreading the workforce, rather than having a skeleton workforce at the beginning of the project, would be more desirable as it would help eliminate effects associated with multitasking that contribute to project delays. Testing and commissioning is an area that also requires attention by increasing the number of qualified commissioning engineers, and a combination of these interventions would result into significant improvement of project completion time from about 58 months currently to about 37 months against a target of 36 months. In donor funded projects in Kenya, a large number of projects may be tendered out at the same time, and in many such occasions, few contractors end up wining many such projects, but later fail to raise the required resources to keep all the projects running concurrently without having to rely on multitasking of a few key technical personnel. It would be advisable for policy makers to introduce some kind of "project execution rule" in the process that limits each contractor to a maximum number of projects that can be won by a single contractor.

While the procurement of "EPC Turnkey" contracts follow a fairly rigid tendering process that ends up with selection of the lowest price bid after going through the technical evaluation process, this research has shown that ending up with a contractor not having adequate human resource capacity in skill and personnel numbers can be of detriment to the overall project delivery time and quality. It will be important for policy makers in the energy sector in Kenya to re-evaluate the procurement process of these kind of projects with a view to introducing stringent due diligence requirements even if it means the projects end up initially costing more than they do presently. The benefits of on time delivery and quality delivery to Kenya and the wider Sub Saharan Africa region if they assimilate the findings of this research into policy would in time make the total life cycle cost of the projects lower than at present.

8.2: Limitations of the study and opportunities for future research

This research was done by focusing on projects in the electricity industry in Kenya, and though the project environment in the Sub Saharan Africa is fairly similar from one country to another, more research needs to be done in future to cover the other countries in Sub Saharan Africa, especially to conduct more focus group studies and comparisons from one country to another. Further research could also focus on including more variables into the conceptual model and developing new System Dynamics simulation models. Such variables may include right of way challenges arising from the need to secure power line corridors, which in many occasions has caused serious project delays (Njoroge et al, 2013). During policy analysis and scenario generation, assumptions were also used to arrive at the effect of improvements in variables such as project management competence that would arise from project management training, fraction of properly completed project tasks and increase in the fraction of testing personnel as a result of hiring of more testing and commissioning engineers.

This research has also taken all projects in the electricity energy sector as being similar, and while this may largely be true, differences exist in regard to generation type projects that ordinarily take longer than 36 months from conception to completion. Other distribution type projects may also take shorter periods of time, such as 24 months from inception to completion, and therefore future research could also explore the effect on the variability of expected project execution duration on the expected project outcomes. In addition, newer projects in the electricity sector in the region include renewable type of energy projects such as wind power and solar power type of projects, that may face additional challenges such as access to sites where large wind generation may be installed as the wind turbines have to be moved by road to these sites, and new environmental conservation regulations.

In soliciting views from experts in the electricity sector projects in Kenya, views were sought from key players in the sector including Ministry of Energy officials, and views from engineers handling projects in Kenya Power and Lighting Company Ltd. Future research may need to explore a similar conceptual model presented to contractors who take part in such projects in Kenya and the region at large, especially those dealing with the EPC type contracts that have become the common mode for project delivery. In the public policy process as given in figure 6.91, it is clear that this research has only gone as far as policy formulation and decision making. Future research may also explore the areas of policy implementation and evaluation in a practical setting in the electricity industry within Sub Saharan Africa region. However, the successful verification and validation of the model, testing the model, and presenting the model to experts familiar with projects of this nature, should offer confidence to the overall validity of the research and its findings, as well as its contribution to new knowledge.

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Appendix A: Questions template: Exploratory research study Interviews

1) What is your experience with scope changes in projects in the electricity sector in Kenya?
2) Does selection of technology affect project delivery? How?
3) What equipment and material risks have you witnessed?
4) Have you ever experienced engineering & design changes?
5) What unavoidable incidences have you experienced during project execution and how did these impact the project? How did you handle such situations when they occurred?
6) How has the inflation changed during the course of the project?
7) Have there been any changes in government policy that impacted the project?
8) How does change of government affect projects in the sector? Have projects been affected by strike action, terrorism?
9) In your opinion, what are the prevalent project risks in electricity infrastructure projects in Kenya?
10) How would you rate the procuring utility's capability in packaging projects in the sector? How would you rate the contractor's capability in packaging projects in the sector? How would you rate the consultant's capability in packaging projects in the sector?
11) Do contractors perform quality inspections and tests on completion of construction works?
12) Do utility project supervisors witness quality inspections and tests on completion of construction works?

13) Do you always get environmental clearance on time? Is the site handed over and ready when the project commences? Are there other clearance needed from government bodies before or during the course of the project?

14) What forces create the problems that lead to project delays and quality challenges experienced in projects in the electricity sector in Kenya?

15) How easy is it to secure financing locally? Comments about interest rates at the local banks? Are there fluctuations? Are taxes payable known and determinable for period of project?

16) Whose responsibility is it to design the project? Comments on the designs? Do variations arise? Why?

17) Is project time fixed and part of contract?

18) Are planning approvals needed, are approvals received in good time?

19) Are there cases of disruption to existing services? How do you make good?

20) Are there cases of strikes or other forms of industrial disputes?

21) How would you rate asset availability and performance on project completion?

22) How would you rate the repair and maintenance costs of the completed projects?

23) Is security thought of and taken care of during project design and delivery?

24) Are there cases where latent defects occur during the project delivery?

25) Does the utility deploy adequate and competent technical staff for supervision of contractors?

26) Do contractors have adequate and competent supervision?

27) Are there cases of uninsurable loss or damage to assets? Who bears responsibility?

28) Are there cases where the design components were affected by obsolescence?

29) How do you deal with public or third party liabilities?

30) Are there incidences of armed conflicts such as civil wars during the course of the project? How does this affect the project?

31) Are there instances where projects are dependent on incentives such as tax or custom exemptions? Are there any challenges or delays in approvals? How does this affect the project?

32) Are there cases where local laws in Kenya have proved difficult for the project environment?

33) Have you experienced cases of conflict between authorities responsible for governance of the project environment? Explain what happened.

34) Are there cases when projects have delayed due to difficulties in gaining the necessary approvals from government bodies?

35) Have you experienced any other risks not previously mentioned during the discussion?

36) How would you rate project management competence in the projects in the electricity sector in Kenya?

37) In your opinion, what policies can be used to improve project delivery time in electricity sector projects in Kenya?

38) In your opinion, what would you say is the time needed to adopt the workforce in electricity sector projects in Kenya?

39) In your opinion, what would you estimate as the maximum testing tasks that a testing engineer performs per month in electricity sector projects in Kenya?

40) In your opinion, what policies can be used to improve the quality of the delivered projects in electricity sector projects in Kenya?

41) From your experience, projects in the electricity sector comprise of how many tasks?

42) In your opinion, what fraction of tasks would normally be rated as properly completed?

Appendix B: Extracts from raw data: Exploratory study interviews

Interview	Date	Job role	Significant quote from Interviewee	Conceptual Model variable directly informed by interview data
Interview # 1	Jan. 8 2013	Project Engineer, MOE	Contractors working in the power industry in Kenya handle many projects, and they often share skilled human resources from one project to another, leading to delays. Some projects delivered to KPLC have had high repair and maintenance costs soon after delivery	Multitasking Average quality of completed project tasks
Interview # 2	Jan. 9 2013	Project Engineer, MOE	Project managers from both KPLC and a majority of contractors lack project management skills, and I would rate competence at about 60%.	Project Management Competence
Interview # 3	Jan. 11 2013	Project Engineer, MOE	Delays in projects in the energy sector is of major concern to the government	Initial project time remaining
Interview # 4	Jan. 11 2013	Project Engineer, MOE	Many contractors use technicians rather than qualified engineers to perform highly skilled testing and commissioning functions in new substations leading to low productivity in the testing function, which affects progress	Productivity of testing Progress
Interview # 5	Jan. 21 2013	Project Manager, KPLC	I estimate the fraction of tasks properly completed at about 0.5	Fraction properly completed
Interview # 6	Jan. 23 2013	Project Manager, KPLC	Most contractors working in electricity projects in Kenya deal with risks as they occur, no prior planning on risk management is done. I would rate project management competence at about 58%	Project Management Competence
Interview # 7	Jan. 23 2013	Project Engineer, KPLC	Contractors working in the sector bid for many projects, and end up employing project staff with limited technical skills, hence low productivity, which affects progress of the entire project	Gross productivity of project personnel Progress
Interview # 8	Jan. 25 2013	Project Engineer, Contractor	The time to adapt the workforce is approximately 2 weeks from start of the project to the point where the workforce gain peak performance	Time to adapt workforce
Interview # 9	Feb. 5 2013	Project Engineer, KPLC	Selection of technology has a significant influence on final quality of project deliverable. In recent turnkey projects, many winning bidders source materials and equipment from their home countries at bargain prices. Some of the equipment are of low quality and affect overall project quality, while leading to technical hitches as well	Average quality of completed project tasks Unforeseen technical difficulties
Interview # 10	Feb. 5 2013	Project Engineer, KPLC	A majority of project engineers and project managers from KPLC as well as the contracting firms have no formal training in	Project Management Competence

			project management, and I rate project management competence at about 62%	
Interview # 11	Feb. 7 2013	Project Engineer, KPLC		
Interview # 12	Feb. 12 2013	Project Engineer, KPLC	Many new substations delivered through turnkey have developed some equipment failures, and 3 have caught fire that burnt the switchgear	Testing personnel, detecting undiscovered rework, Average quality of completed project tasks
Interview # 13	Feb. 13 2013	Project Engineer, KPLC	Commissioning and testing engineers are few in the country, and this leads to sharing of the few available between projects, causing delays	Multitasking
Interview # 14	Feb. 15 2013	Project Engineer, KPLC	Many project managers on the side of KPLC who supervise projects done by contractors basically have engineering training, but lack project management training. I rate competence in project management at between 55% to 65%	Project Management Competence
Interview # 15	Feb. 15 2013	Project Engineer, KPLC		
Interview # 16	May 7 2013	Project Engineer, KPLC	Equipment for new substations sometimes comes from different manufacturers from different countries, and this causes technical difficulties during commissioning	Unforeseen technical difficulties
Interview # 17	May 8 2013	Project Engineer, KPLC		
Interview # 18	May 8 2013	Project Engineer, KPLC	Project managers and project engineers are appointed after the award of the projects, making it difficult to influence the projects to deliver required outcomes	Project Management Competence
Interview # 19	May 8 2013	Project Engineer, KPLC	Some equipment installed by contractors are of poor quality, leading to technical challenges during commissioning of projects	Average quality of completed project tasks Unforeseen technical difficulties
Interview # 20	May 10 2013	Project Engineer, KPLC		
Interview # 21	May 20 2013	Project Engineer, KPLC	Poor workmanship by contractor personnel leads to technical problems during testing, resulting into repeat jobs	Rework cycle
Interview # 22	May 21 2013	Project Engineer, KPLC		
Interview # 23	May 23 2013	Project	Many contractors rely on semi-skilled labor,	Rework cycle

		Engineer, KPLC	resulting into rework during the final phase of the project	
Interview # 24	May 23 2013	Project Engineer, KPLC	Contractors engage few testing and commissioning engineers, who are shared from one project to another	Multitasking Detecting undiscovered rework
Interview # 25	June 4 2013	Project Manager, contractor	It takes about 15 days for the workforce to adapt and gain the confidence in working for the project	Time to adapt workforce
Interview # 26	June 4 2013	Project Manager, contractor	The lead contractor is often motivated by profit margins, and bargains for the most affordable equipment from manufacturers, leading to technical problems during commissioning of turnkey projects	Average quality of completed project tasks Unforeseen technical difficulties
Interview # 27	June 6 2013	Project Manager, contractor	Projects in the sector comprise of about 600 tasks	Initial number of project tasks
Interview # 28	June 7 2013	Project Manager, contractor		
Interview # 29	June 17 2013	Project Manager, contractor	The project managers from the utility KPLC are basically engineers, with limited project management skills. I rate their competence in project management at about 60%	Project Management Competence
Interview # 30	June 17 2013	Project Manager, contractor	Projects in the sector usually has between 550 to 650 tasks	Initial number of project tasks
Interview # 31	June 20 2013	Project Manager, contractor		
Interview # 32	June 21 2013	Project Manager, contractor	The lead contractor uses standard project durations sourced from previous similar projects when bidding, without input from local conditions , this may lead to under estimation, leading to project delays	Initial project time remaining
Interview # 33	July 8 2013	Project Engineer, contractor	It takes approximately 10 working days for the workers to be comfortable with their roles in the project	Time to adapt workforce
Interview # 34	July 9 2013	Testing Engineer, contractor	Lead contractor relies on one team of testing and commissioning engineers for all his projects in the country and the East African region	Multitasking, Detecting undiscovered rework
Interview # 35	July 9 2013	Project Engineer, contractor		
Interview # 36	July 9 2013	Project Engineer, contractor	The lead contractor does not offer training in project management, or require knowledge of project management when employing project supervisors	Project Management Competence
Interview # 37	July 10 2013	Project Engineer,		

		contractor		
Interview # 38	July 11 2013	Project Engineer, contractor	I would put the fraction of project tasks properly completed at between 0.4 to 0.6	Fraction properly completed
Interview # 39	July 23 2013	Project Engineer, contractor	Many project personnel working for the lead contractor specialize in one area such as civil works, then move from one project to another performing the same task	Multitasking
Interview # 40	July 25 2013	Project Engineer, contractor	Projects in the sector comprise of about 575 tasks	Initial number of project tasks
Interview # 41	Sep. 3 2013	Project Engineer, contractor		
Interview # 42	Sep. 4 2013	Project Engineer, contractor	Many turnkey contractors prefer to employ semi-skilled or unskilled workers who are paid less than the skilled workers, but it takes more time to train and orientate these workers into the project	Time to adapt workforce
Interview # 43	Sep. 4 2013	Project Engineer, contractor		
Interview # 44	Sep. 6 2013	Project Engineer, contractor		
Interview # 45	Sep. 16 2013	Project Engineer, contractor	Compensation for right of way is a process, and this takes time, leading to delays in the project	Political risk
Interview # 46	Sep. 18 2013	Project Engineer, contractor		
Interview # 47	Sep. 19 2013	Project Engineer, contractor	Securing right of way and wayleave consents takes time, leading to delays in projects	Political risk
Interview # 48	Oct. 2 2013	Project Engineer, contractor		
Interview # 49	Oct. 3 2013	Project Engineer, contractor	In turnkey projects, the lead contractor uses standard designs from previous projects, without reference to challenges at specific sites. This causes variations and design changes in the course of the project, leading to delays	Rework cycle Perceived cumulative progress
Interview # 51	Oct. 3 2013	Project Engineer, contractor	Projects tasks in the sector vary from 560 tasks to 600 tasks	Initial number of project tasks
Interview # 52	Oct. 14 2013	Project Engineer, contractor		
Interview # 53	Oct. 14 2013	Project Engineer, contractor	Shortage of local workforce with necessary technical skills, especially in testing and commissioning new substations, results in key functions being performed by semi-skilled personnel, leading to rework and negatively affecting progress	Productivity of testing, Detecting undiscovered rework

				Rework Progress
Interview # 54	Oct. 15 2013	Project Engineer, contractor		
Interview # 55	Oct. 17 2013	Project Engineer, contractor		
Interview # 56	Oct. 18 2013	Project Engineer, contractor	Risks working in Kenya include terrorism, fluctuations in rate of inflation, and political instability during elections. New governments give priority to different projects, leading to delays in older projects	Political risk
Interview # 57	Oct. 22 2013	Project Engineer, contractor		
Interview # 58	Oct. 23 2013	Project Engineer, contractor	Risks include inflation, corruption and fluctuations in price of fuel and politically motivated changes in energy sector policy	Political risk
Interview # 59	Oct. 23 2013	Project Engineer, contractor		
Interview # 60	Oct. 25 2013	Project Engineer, contractor	Shortage of local workforce competent in project management skills is a significant risk, while the local electricity utility, KPLC, packages projects in a uniform manner, without proper project justifications. Some recently completed substations have recorded overload soon after commissioning	Project Management competence, Gross productivity of project personnel

Appendix C: Comparison of variables identified from exploratory study with variables in Richardson's conceptual project model

Variables from Exploratory study similar to those in Richardson's (2013) conceptual project model	*Variables from Exploratory study additional to Richardson's (2013) conceptual project model*
Time to adapt workforce	Multitasking
Initial project time remaining	Political risk index
Gross productivity of project personnel	Political risk
Testing personnel	Project Management Competence
Productivity of testing	Unforeseen technical difficulties
Detecting undiscovered rework	insurance index
Average quality of completed project tasks	
Remaining project tasks	
Properly completed project tasks	
Undiscovered rework	
Desired workforce	
Proper completion of project tasks	
Perceived cumulative progress	
Progress	
Initial number of project tasks	
Fraction properly completed	

Appendix D: Time charts (Reference Mode graphs) of typical projects in the Electricity sector in Kenya

Fig. 9.1 and Fig. 9.2 give sketches of the reference mode trends of key variables of projects in the electricity energy sector in Kenya. The trends represent insight gained from historical data on past projects in the sector in Kenya as well as mental models arising from interviews with key stakeholders in the sector comprising project engineers and Ministry of Energy personnel. The past projects reviewed were the following;

Name of Project	**Brief scope**	**Contractor**
Tononoka substation	Construct 1 x 23Mva 33/11kv substation on EPC Turnkey	Siemens (India)
Ruaraka Complex	Construct 2 x 23Mva 66/11kv substation on EPC Turnkey	Schneider Electric & Power Technics
Thika North	Construct 1 x 23Mva 66/11kv substation on EPC Turnkey	Electric Trade Ltd.
Villa Franca	Construct 2 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)
Lower Kabete	Construct 2 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)
Lukenya substation	Construct 2 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)
Tala substation	Construct 1 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)
JKUAT substation	Construct 1 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)
Rironi substation	Construct 2 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)
Githunguri substation	Construct 2 x 23Mva 66/11kv substation on EPC Turnkey	KEC International (India)

Ruaraka substation upgrade	66kv busbar + 66/11kv substation	Areva India
Kipevu substation upgrade	GIS Switchgear indoor 33/11kv substation	Schneider Electric & Power Technics

The trend in Fig. 9.1 in green colour marked "1" represents the number of remaining project tasks over time from an initial 600 tasks, the trend in blue colour marked "2" represents the cumulative progress as perceived over time, the trend in red colour marked "3" represents the number of properly completed project tasks, while the trend in black marked "4" represents the project tasks needing rework which are not yet discovered over project time.

1: Remaining project tasks 2: Cumulative progress 3: Properly completed tasks 4: Undiscovered rework

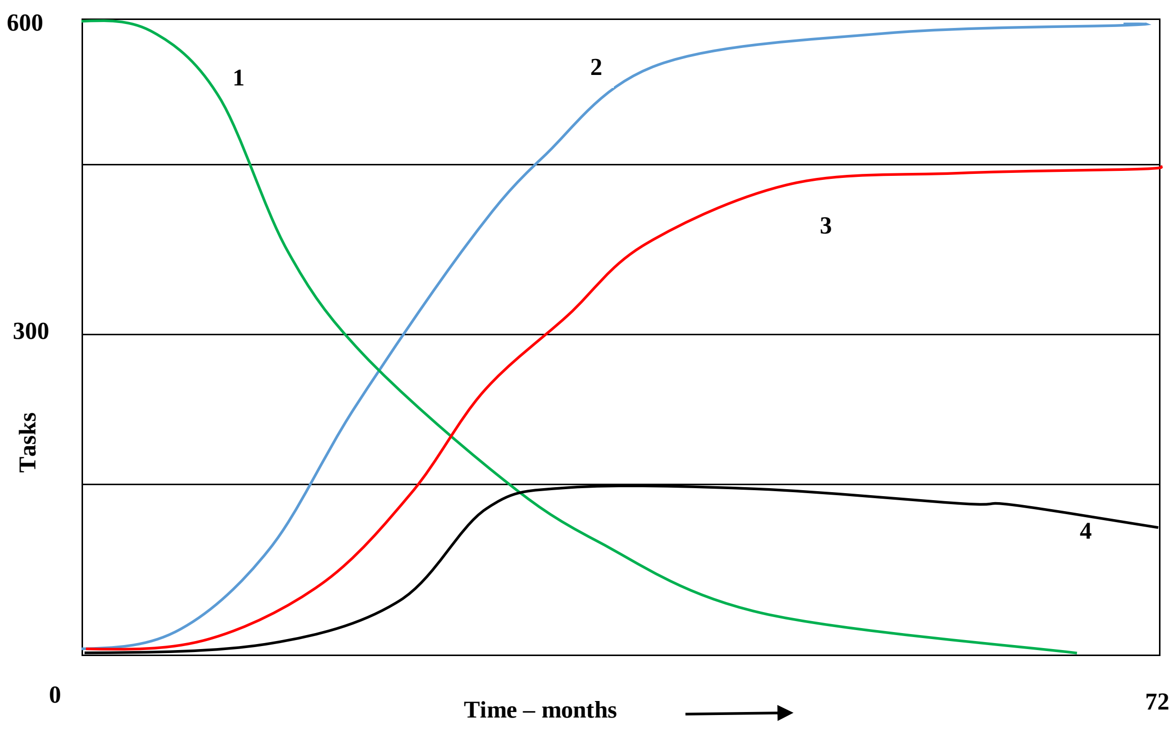


Fig. 9.1: Reference mode of projects in the electricity sector in Kenya (1)

Due to the late discovery of tasks needing rework, this tends to slow the project between 30 and 40 months of project time, when ideally, the project should be completed. As a result, some tasks needing rework cannot be fully attended to the required standards, and therefore by the project completion time of about 60 months, only about 440 tasks are classified as properly completed.

The trend in Fig. 9.2 in blue colour marked “1” represents the average quality of completed project tasks over time (dimensionless), the trend in black colour marked “2” represents the workforce employed in the project over time, the trend in red colour marked “3” represents the number of project personnel, while the trend in green marked “4” represents the project personnel engaged in testing and commissioning.

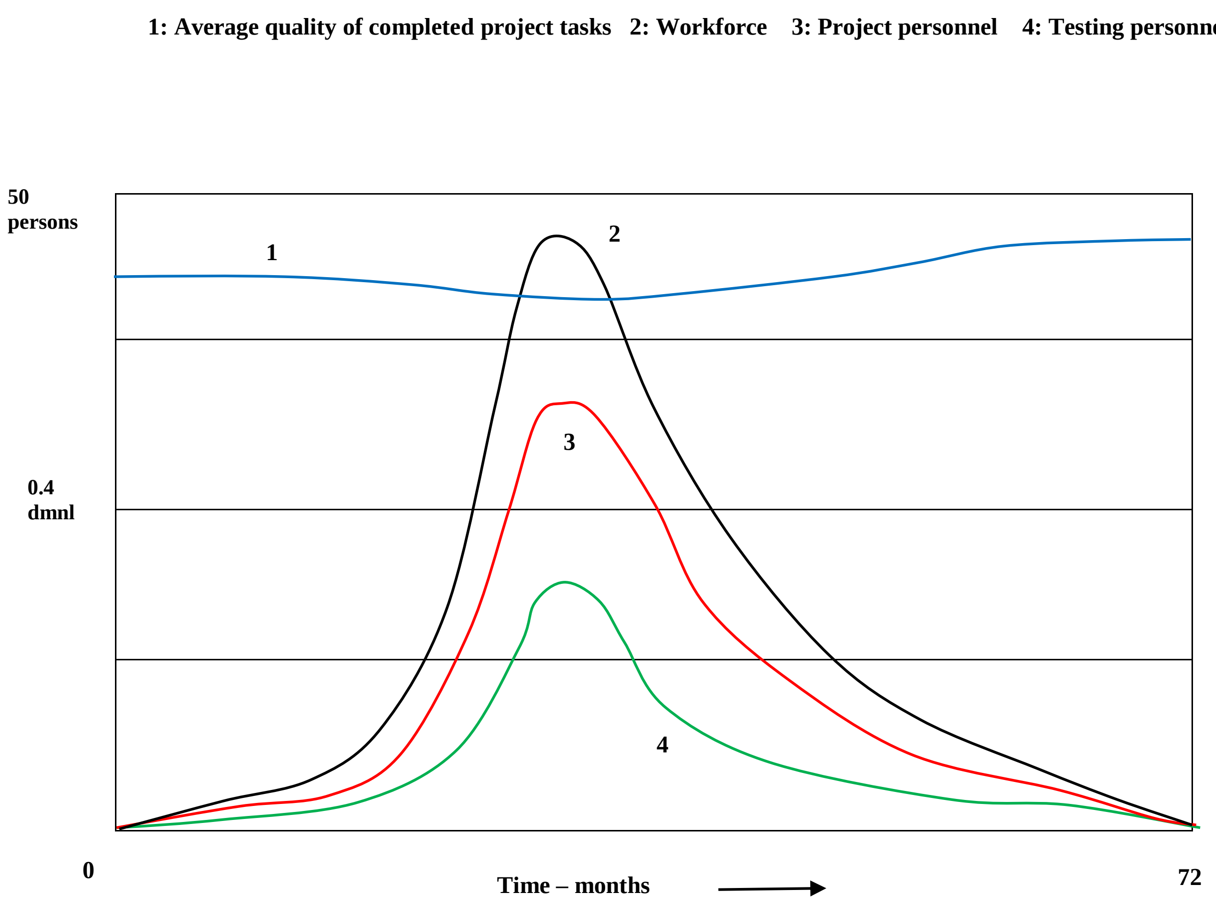


Fig. 9.2: Reference mode of projects in the electricity sector in Kenya (2)

From Fig. 9.2, the project starts at a slow pace with a few members of workforce, and usually, the numbers of both the project personnel and the testing personnel that together form the workforce, appear to only increase sharply between the 24th and the 40th months of project time. the testing personnel are subsequently used to unearth technical hitches in the project, which have to be attended to by the project personnel. The more the number of technical problems and the later they are discovered, the more time it takes to address them, and in the process, some technical problems are not fully addressed by the time the project finishes and is handed over. This leads to the final quality of completed project tasks at between 70 – 75% of the expected quality level.

Appendix E: Schedule of Stakeholder workshop on Model Validation, November 2014

Schedule of the workshop

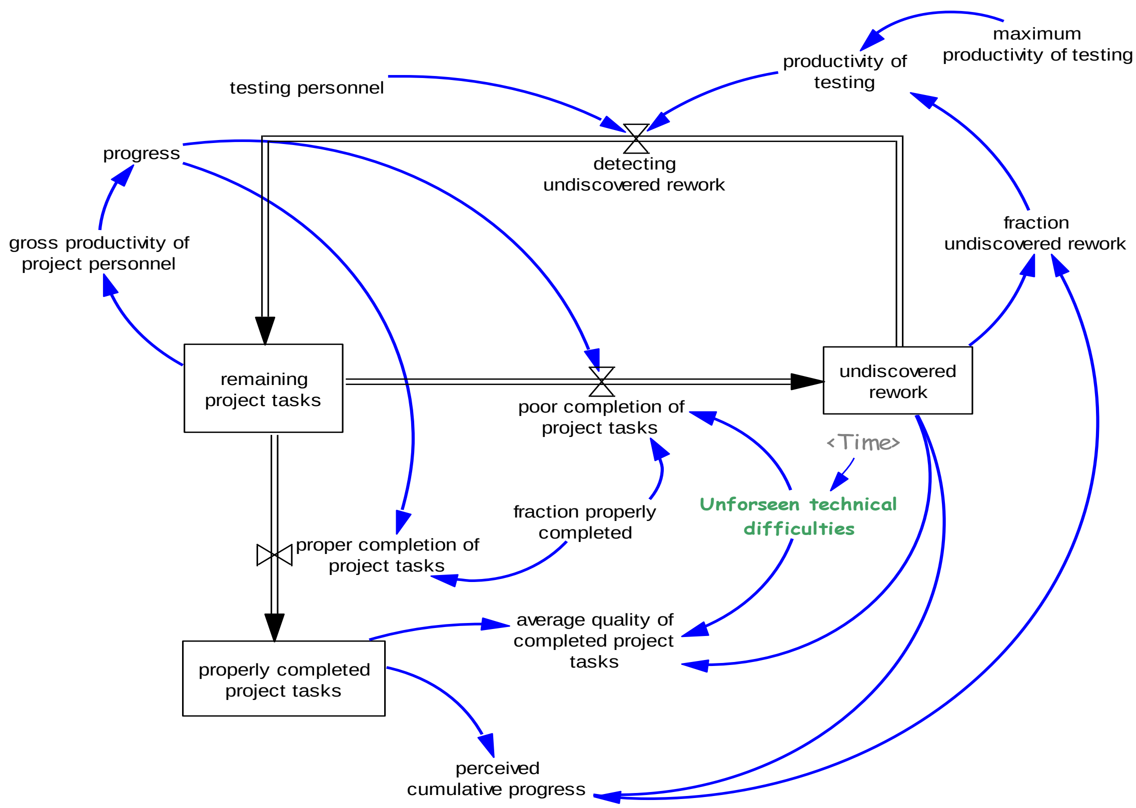
Time	**Topic**
09:00-09:15	Introduction, background to the research
09:15-09:25	Introduction of the participants
09:25-09:50	Warm-up, discussing project dynamics in the sector in general, basics of causal diagramming and systems thinking
09:50-11:00	Presentation and discussions on the feedback loops and simulation results in the basic model of the Project dynamics in electricity sector in Kenya as given in Fig. 6.2
11:00-11:30	Tea Break
11:30-12:15	Discussions on model validation, verification and testing
12:15-12:30	Closing Reflections
12:30-13:30	Lunch

Appendix F: Examples of Questions for the quantitative model during Model Validation in November, 2014:

- What do you think about the feedback loops and how they influence the project dynamics during the simulation?
- What do you think about the simulated trends in view of the projected completion time?
- Can you sketch how you perceive projects usually progress on dimensions of percentage of completion and project time?
- Can you draw a graph depicting how the sense of urgency changes as a project gets closer to its deadline?
- Seeing the graphs of the simulation results from the basic model, would you say this mirrors the situation as it unfolds in your projects?
- How do you think sharing the findings of this work with other project managers can improve project management in the sector?

Appendix G: The variable removed from the final model after the validation workshop

"*Unforeseen technical difficulties*" was removed from the final model presented in Chapter 6 (Fig. 6.2) based on the policy analysis described in chapter 6 (*see section 6.1.4: Scenario 4 - Increased role for testing and commissioning personnel)*. This was after the effect of the "increased fraction and competence of personnel for testing" resulted into the reduction of the effect of *unforeseen technical difficulties* to near zero, and so *unforeseen technical difficulties* was deleted in the final model after scenario analysis recommended scenario 5 (section 6.6.1.5).



Appendix H: Global Risk Index (2014). Source: PRS Group (Countries ranked in ascending order of political risk)

	04/2014	2013	2012	2011
GLOBAL AVERAGES	72	72	72	72
1. Canada	93	94	93	94
1. Hong Kong	93	92	92	92
3. Norway	91	89	88	87
4. Singapore	90	92	89	89
4. Taiwan	90	90	90	89
6. Australia	88	88	88	88
6. Austria	88	87	87	87
8. Sweden	87	87	88	89
9. Czech Republic	86	84	83	84
9. Oman	86	86	85	85
9. Switzerland	86	86	86	86
9. United Arab Emirates	86	86	84	85
13. Chile	85	85	82	81
13. Japan	85	86	84	82
15. Botswana	84	83	82	82
15. Finland	84	84	84	86
17. New Zealand	83	82	83	80
17. South Korea	83	80	78	73
17. Trinidad & Tobago	83	80	82	83
20. Denmark	82	82	82	80
20. Germany	82	82	82	80
20. Netherlands	82	84	84	88

20. United Kingdom	82	80	80	80
24. Bulgaria	81	80	83	82
24. Israel	81	81	80	79
24. Kuwait	81	80	76	77
24. Poland	81	82	82	78
24. United States	81	80	80	79
29. Belgium	80	82	79	80
29. Mexico	80	79	75	74
31. Panama	79	77	77	76
31. Uruguay	79	79	80	80
33. Peru	78	78	76	70
33. Saudi Arabia	78	78	77	77
33. Slovakia	78	78	79	83
36. Costa Rica	77	76	77	74
36. Ireland	77	76	76	74
36. Malaysia	77	80	80	79
39. Azerbaijan	76	71	72	71
39. Colombia	76	74	71	70
39. Romania	76	71	73	74
39. Spain	76	75	76	73
43. France	75	73	74	75
43. Paraguay	75	72	72	73
43. Thailand	75	77	76	72
46. Jamaica	74	71	70	68
46. Portugal	74	72	75	77
48. Cameroon	73	71	72	73
48. Congo	73	73	72	72

48. Gabon	73	73	73	74
48. Suriname	73	73	73	72
52. Hungary	72	70	69	69
52. Indonesia	72	72	73	72
52. Italy	72	72	72	72
52. Nicaragua	72	71	70	72
52. Papua New Guinea	72	73	71	71
52. Philippines	72	73	73	68
52. Turkey	72	73	70	68
59. Brazil	71	71	73	73
59. El Salvador	71	73	72	73
59. Sri Lanka	71	68	69	67
62. China	70	70	70	69
62. Ghana	70	71	70	71
62. Morocco	70	69	69	68
65. Bolivia	69	66	67	66
65. Dominican Republic	69	68	68	66
65. Guatemala	69	69	70	71
65. Kazakhstan	69	67	67	64
65. Kenya	**69**	**67**	**67**	**66**
65. Zambia	69	69	68	72
71. Côte d’Ivoire	68	67	66	66
71. Greece	68	68	68	68
71. Honduras	68	68	69	70
71. Tunisia	68	66	69	70
75. Angola	67	68	68	68
75. Guyana	67	66	65	67

75. South Africa	67	68	70	69
75. Vietnam	67	64	64	65
79. Algeria	66	68	68	68
79. India	66	68	69	68
81. Bangladesh	63	59	59	60
81. Haiti	63	63	62	62
81. Myanmar	63	66	65	56
84. Argentina	59	59	57	59
84. Egypt	59	59	67	65
84. Russia	59	60	62	61
87. Nigeria	58	59	59	58
88. Ecuador	56	56	53	53
88. Guinea	56	56	54	53
88. Pakistan	56	55	52	53
88. Ukraine	56	61	62	62
92. Iraq	55	56	58	58
93. Congo DR	54	54	57	57
94. Cuba	51	49	50	49
95. Libya	50	55	57	56
95. Sudan	50	48	50	51
97. Iran	47	45	45	48
98. Syria	44	49	53	50
98. Venezuela	44	45	47	48
100. Zimbabwe	43	41	45	46

Appendix I: The Basic Model Equations

Political risk index = 0.67 (units: dimensionless)

Multitasking = WITH LOOKUP (Time,
([(0,0)-
(52,10)],(0,1),(4,1),(8,1),(12,0.85),(16,0.75),(20,0.7),(24,0.7),(28,0.65),(32,0.65),(36,0.75),
(40,0.8),(44,1),(48,1),(52,1),(200,1)) (Units: dimensionless)

Project Management competence = 0.6 (units: dimensionless)

Unforeseen technical difficulties = WITH LOOKUP (Time,
([(0,0)-(60,10)],(0,1),(2,0.99),(6,0.98),(10,0.97),(14,0.96),(16,0.95),(20,0.9),(24,0.8),(26,0.8),
(28,0.92), (30,0.95),(36,0.97),(36,0.97),(38,0.98),(40,1),(44,1),(48,1),(52,1),(54,1),(60,1),(200,1)
) (Units: dimensionless)

initial number of project tasks = 600 (units: dimensionless)

Proper completion of project tasks = progress * fraction properly completed (units: tasks/month)

Remaining project tasks = INTEG(detecting undiscovered rework-poor completion of project tasks-proper completion of project tasks) (units: Tasks)

Properly completed project tasks = INTEG (proper completion of project tasks) (units: Tasks)

Progress = gross productivity of project personnel*project personnel*Political risk*Multitasking (units: Tasks/month)

gross productivity of project personnel= WITH LOOKUP (remaining project tasks*Project Management competence,
([(0,0)-(600,1)],(0,0.2),(50,0.85),(75,0.95),(100,1),(200,1),(600,1)) (units: Tasks/person/month)

net hiring of personnel = (desired workforce – workforce)/time to adapt workforce
(units: person/month)

Workforce = INTEG (net hiring of personnel)   (units: person)

time to adapt the workforce = 0.5   (units: Month)

desired workforce = perceived effort remaining / perceived time remaining   (units: person)

perceived time remaining = MAX(1, initial project time remaining - Time)   (units: month)

perceived effort remaining = remaining project tasks/MAX(perceived productivity,1)
(units: person*Month)

perceived productivity = perceived cumulative progress/cumulative effort
(units: tasks/person/Month)

Perceived cumulative progress = properly completed project tasks + undiscovered rework
(units: tasks)

additional cumulative effort = workforce*Multitasking*Project Management competence
(units: person)

Cumulative effort = INTEG (additional cumulative effort) (units: person*Month)

perceived fraction completed = perceived cumulative progress/initial number of project tasks
(units: fraction)

detecting undiscovered rework = productivity of testing*testing personnel (units: tasks/Month) poor completion of project tasks = progress*(1 - fraction properly completed)*Unforeseen technical difficulties (units: tasks/Month)

fraction properly completed = 0.5 (units: dimensionless)

undiscovered rework = INTEG (poor completion of project tasks – detecting undiscovered rework) (units: tasks)

productivity of testing = maximum productivity of testing*fraction undiscovered rework (units: tasks/ (person*Month)

Maximum productivity of testing = 2 (units: tasks/person/month)

Average quality of completed project tasks = (properly completed project tasks*unforeseen technical difficulties)/MAX ((properly completed project tasks + undiscovered rework), 1) (units: dimensionless)

fraction undiscovered rework = undiscovered rework/MAX (perceived cumulative progress, 0.01) (units: dimensionless)

testing personnel = fraction personnel for testing*workforce (units: person)

fraction personnel for testing = WITH LOOKUP (reported fraction detection undiscovered rework,
([(0,0)-1,1)],(0,0.1), (0.1,0.09), (0.2,0.1), (0.3,0.14), (0.4,0.16), (0.49,0.2), (0.59,0.24), (0.68,0.26),(0.76,0.27), (0.87,0.28), (0.99,0.3), (200, 0.3).) (units: dimensionless)
initial project time remaining= 36 (units: Month)

Workforce is comprised of project personnel + fraction of personnel for testing, and therefore project personnel is modeled as;

*project personnel= (1-fraction personnel for testing)*workforce (units: person)*

Political risk is derived directly from the Political risk index in equation (5.1), and therefore Political risk is modeled as;

Political risk = Political risk index (units: dimensionless)

Appendix J: Time Histograms of Key Variables from Sensitivity Analysis of Fig. 6.2 and Fig. 6.109

Fig. 9.3 is a histogram of simulated activity level values for remaining project tasks at month 60 of project time, when the project is likely to be completed. It shows a minimum value of 10 to 11 tasks, most probable value of 14 tasks, and maximum value of 15 tasks by the end of the project.

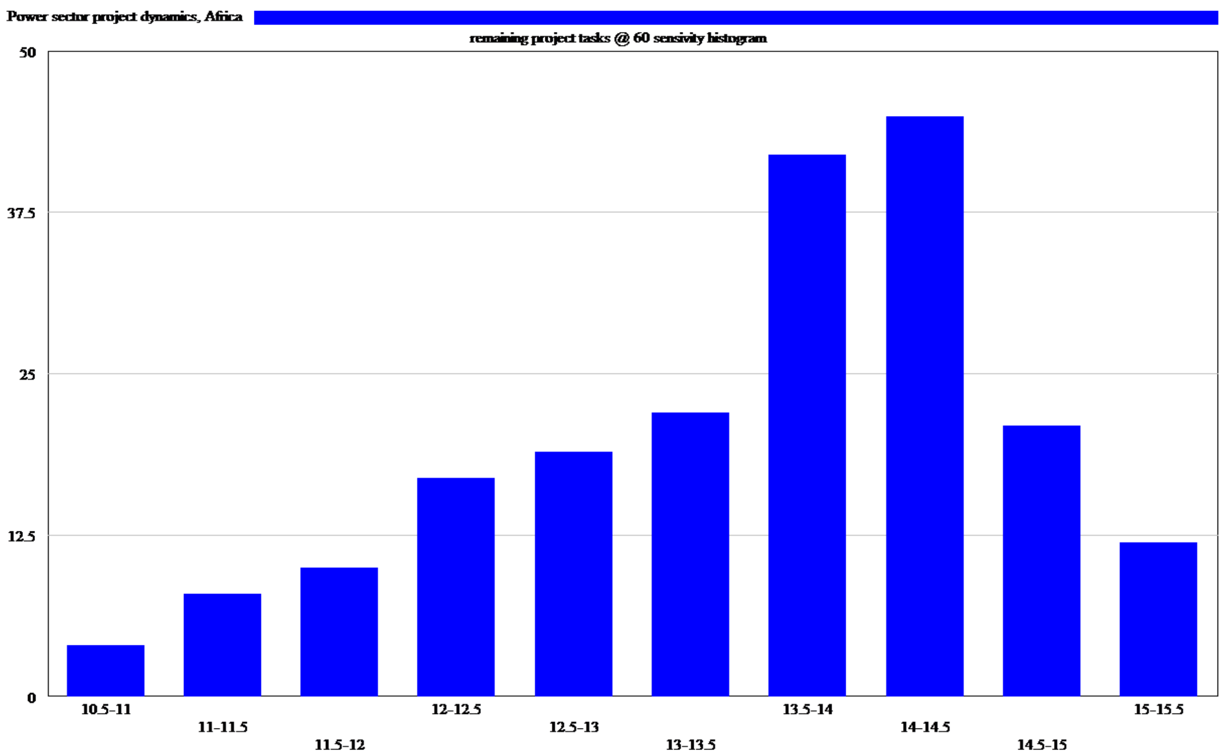


Fig. 9.3: Typical sensitivity histogram of remaining project tasks

Fig. 9.4 is a histogram of simulated activity level values for properly completed project tasks at month 60 of project time, when the project is likely to be completed. It shows a minimum value of 320 to 340 tasks, most probable value of 380 to 400 tasks, and maximum value of 480 to 500 tasks by the end of the project.

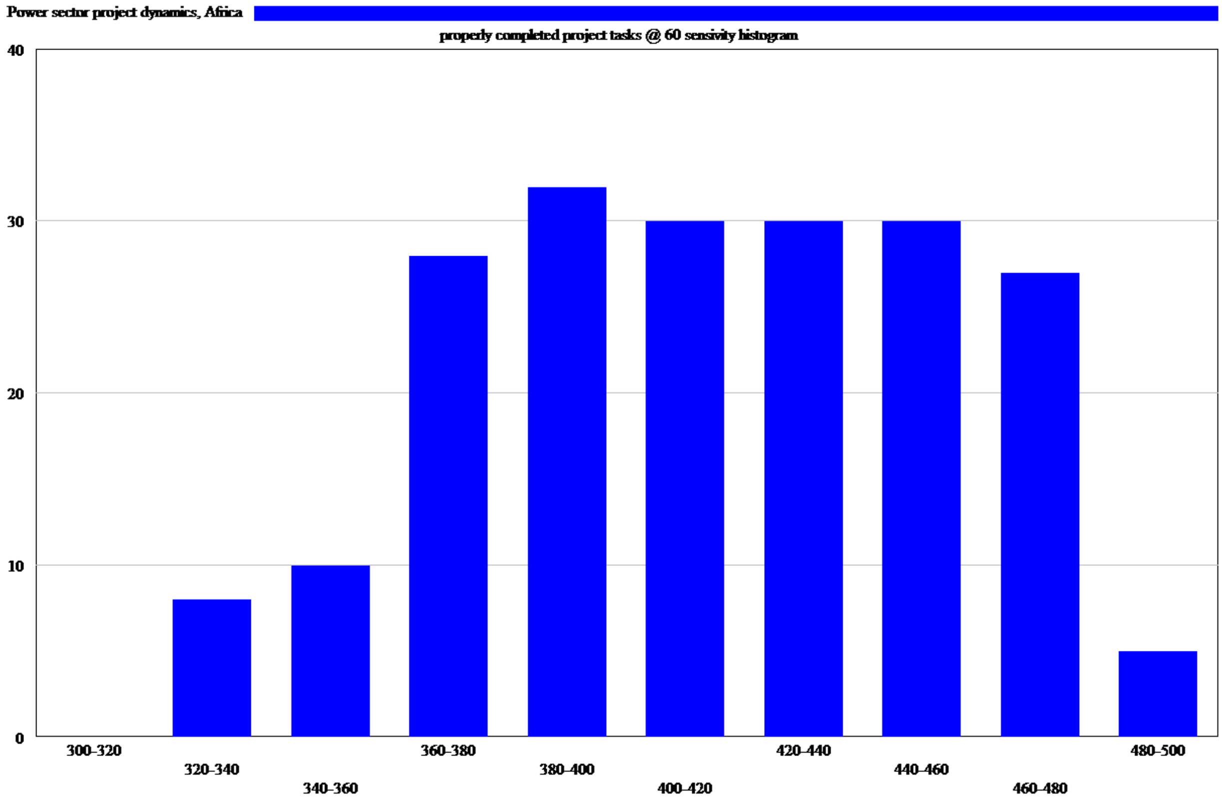


Fig. 9.4: Typical sensitivity histogram of properly completed project tasks

Fig. 9.5 is a histogram of simulated activity level values for average quality of completed project tasks at month 60 of project time, when the project is likely to be completed. It shows a minimum value of 0.52 to 0.56, most probable value of 0.68 to 0.72, and maximum value of 0.8 to 0.84 by the end of the project.

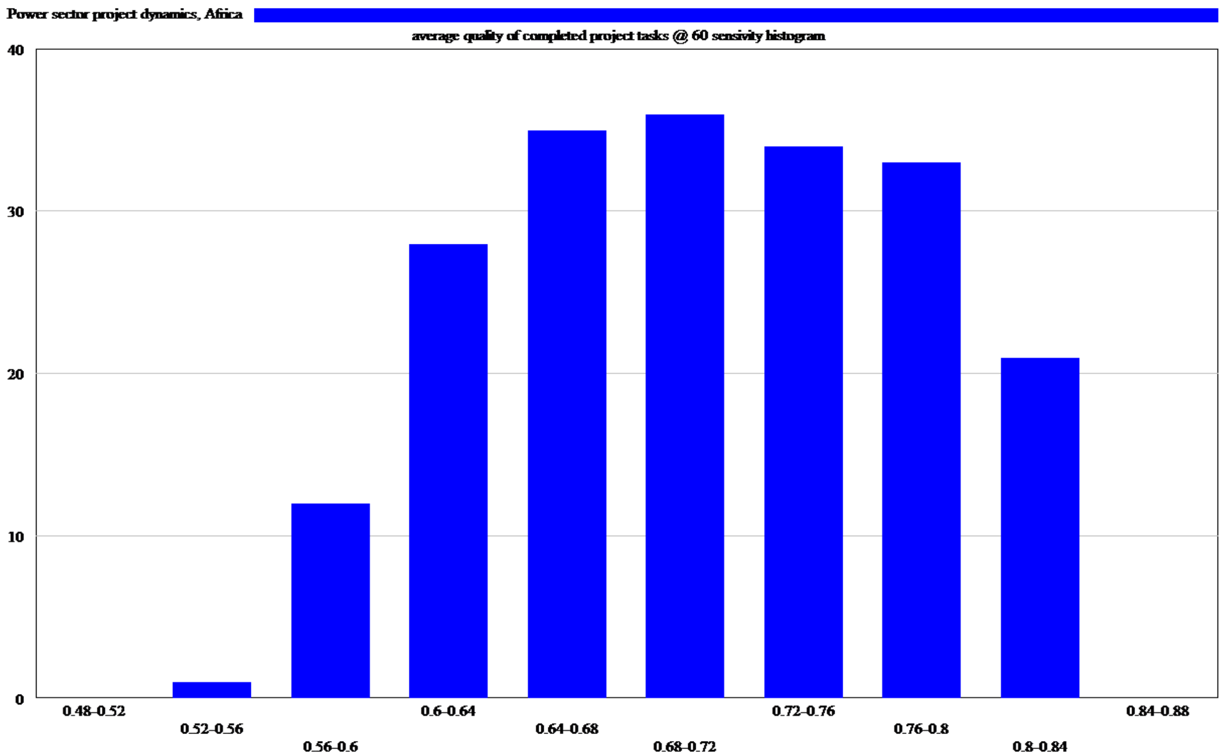


Fig. 9.5: Typical sensitivity histogram of average quality of completed project tasks

Fig. 9.6 is a histogram of simulated activity level values for undiscovered rework at month 60 of project time, when the project is likely to be completed. It shows a minimum value of 100 to 120 tasks, most probable value of 180 to 200 tasks, and maximum value of 240 to 260 tasks by the end of the project.

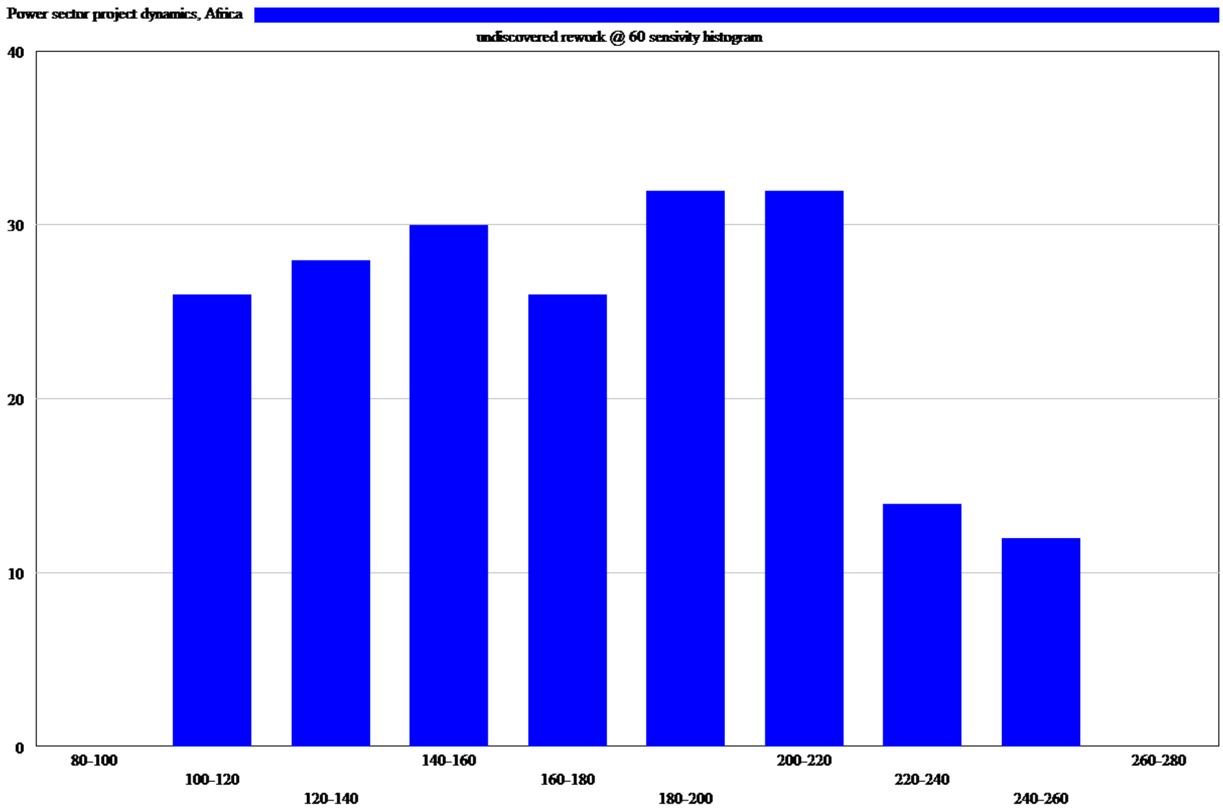


Fig. 9.6: Typical sensitivity histogram of undiscovered rework

Fig. 9.7 is a histogram of simulated activity level values for remaining project tasks at month 38 of project time, when the project is likely to be completed with the combined policy scenario. It shows a most probable value of 6 to 9 tasks, and maximum value of 19 to 21 tasks by the end of the project.

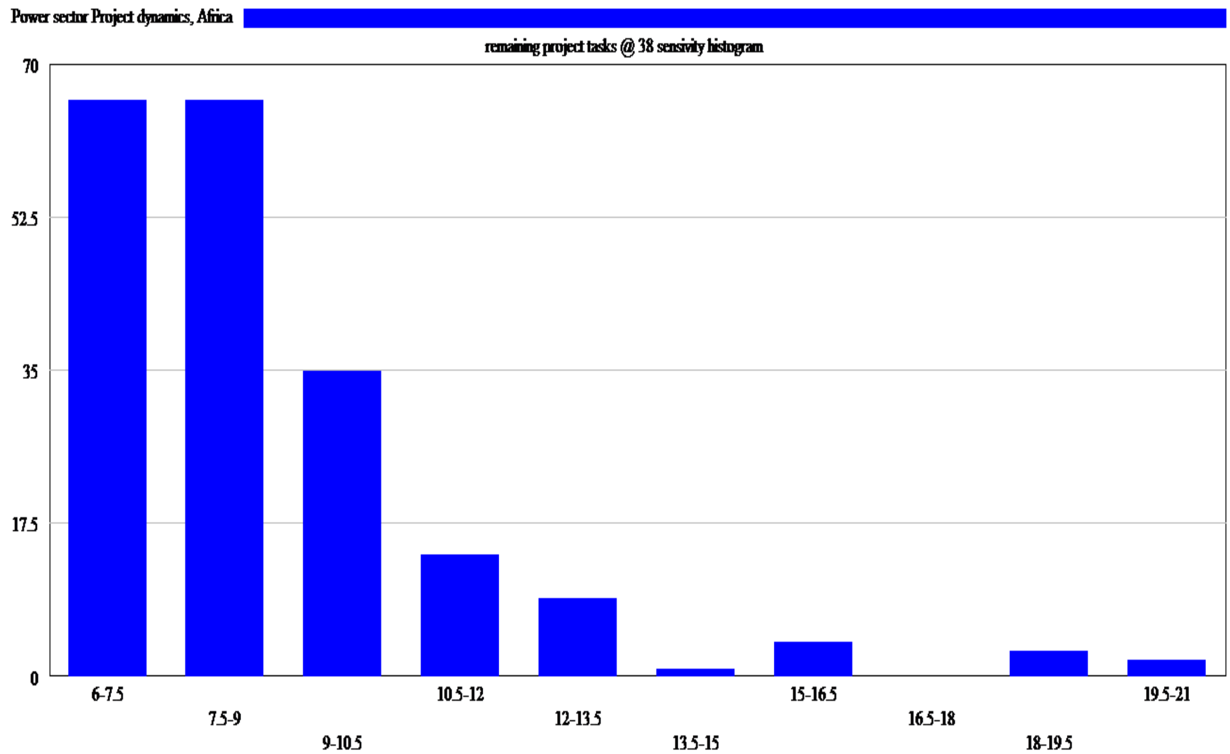


Fig. 9.7: Typical sensitivity histogram of remaining project tasks with the combined policy scenario

Fig. 9.8 is a histogram of simulated activity level values for properly completed project tasks at month 38 of project time, when the project is likely to be completed with the combined policy scenario. It shows a most probable value of 555 to 562 tasks, and maximum value of 570 to 577 tasks by the end of the project.

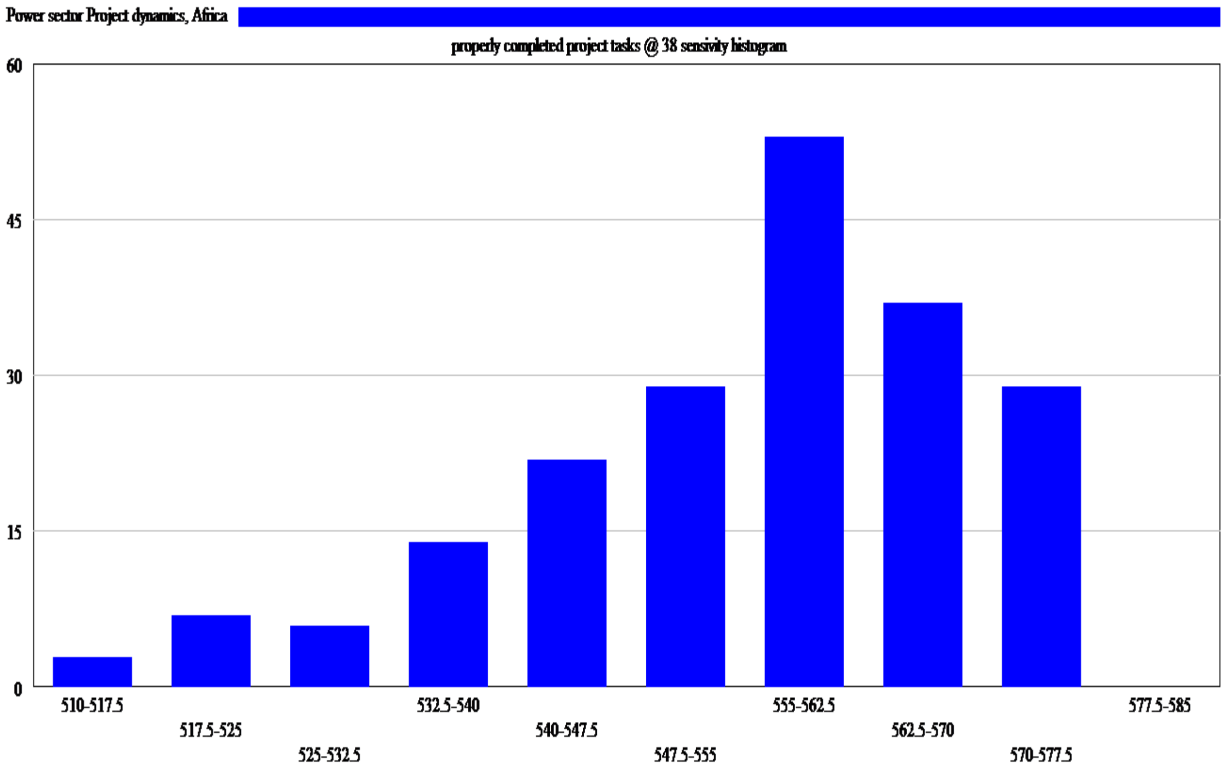


Fig. 9.8: Typical sensitivity histogram of properly completed project tasks with the combined policy scenario

Fig. 9.9 is a histogram of simulated activity level values for average quality of completed project tasks at month 38 of project time, when the project is likely to be completed with the combined policy scenario. It shows a most probable value of 0.93 to 0.945, and maximum value of 0.99 to 1.0 by the end of the project.

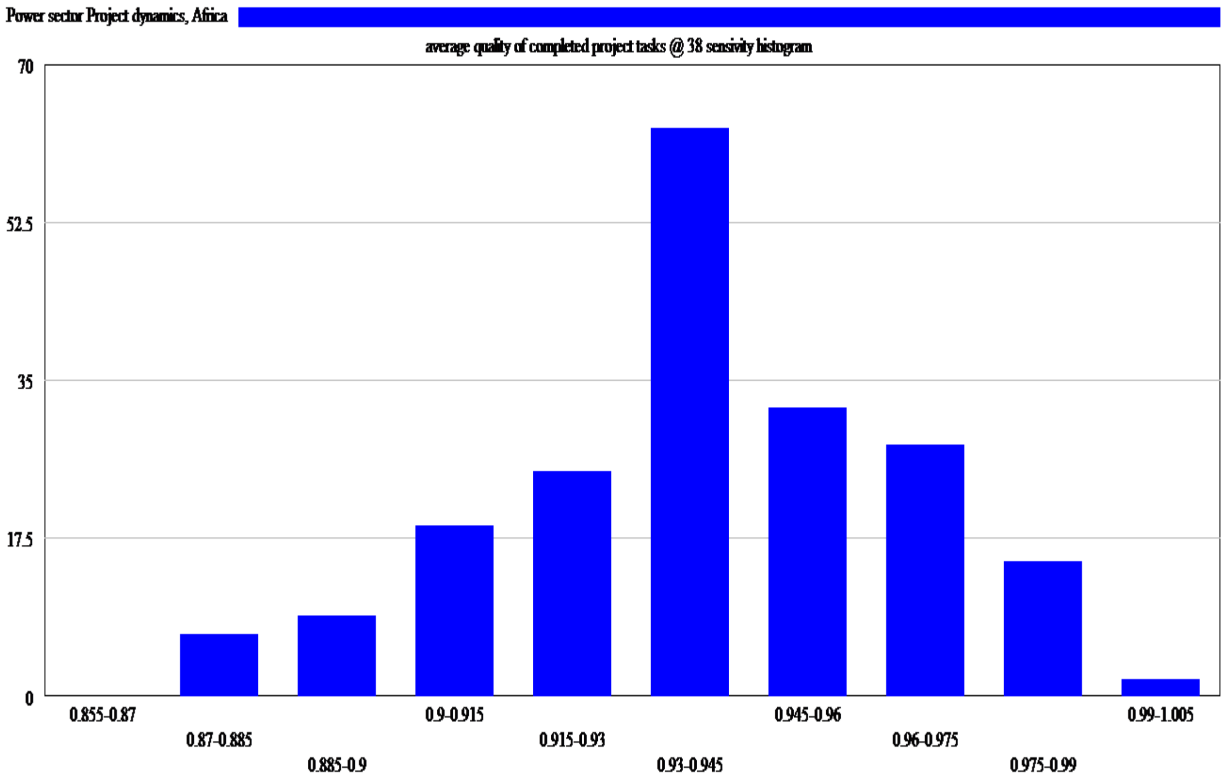


Fig. 9.9: Typical sensitivity histogram of average quality of completed project tasks with the combined policy scenario

Fig. 9.10 is a histogram of simulated activity level values for undiscovered rework at month 38 of project time, when the project is likely to be completed with the combined policy scenario. It shows a most probable value of 27 to 34 tasks.

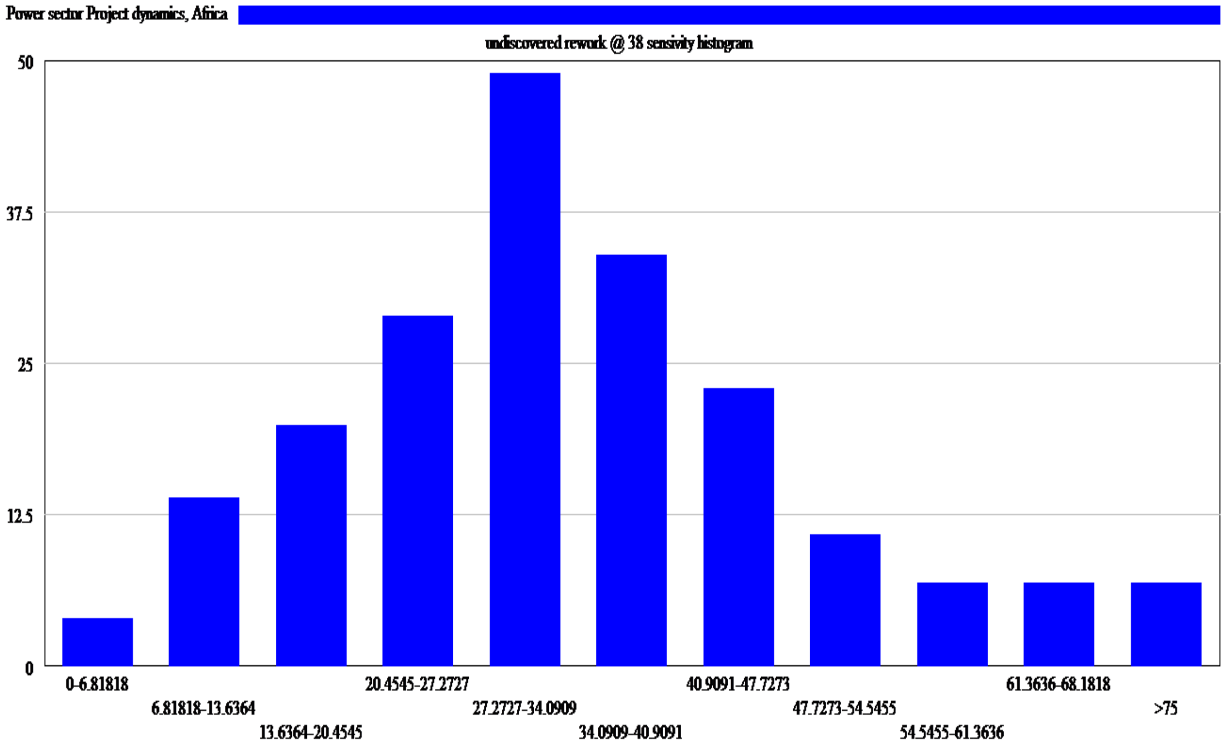


Fig. 9.10: Typical sensitivity histogram of undiscovered rework with the combined policy scenario

Appendix K: Kenya Energy Sector Recovery Project: Distribution Reinforcement & Upgrade, Contract II

(Extracted from a Project Progress Report by: Norconsult AS - Project Consultant)

Background

The "Distribution Reinforcement and Upgrade Project" was a component of the Energy Sector Recovery Project (ESRP) in Kenya and was financed by the Government of Kenya, the International Development Association (IDA), the Agence Française de Developpment (AFD), European Investment Bank (EIB) and the Nordic Development Fund (NDF). The Kenya Power and Lighting Company Ltd (KPLC) was the implementing agency for the following packages under the programme:

(i) Distribution network reinforcement and upgrade
(ii) Replacement, upgrade and expansion of the SCADA /EMS systems
(iii) Installation of a radio trunking system for Mt. Kenya Region in Kenya

The objective of the Distribution Reinforcement and Upgrade project was to improve electricity power supply quality and reliability and reduce losses through removal of overloads in substations and lines, as well as meet the additional power supply demand. Many of the changes in the works were necessitated by inaccuracies in the contractual scope of work as identified by the parties during the contractors' initial site surveys.

This is an extract from a progress report by Norconsult AS, the project consultant in respect of Contract II, a portion of the distribution part of the Energy Sector Recovery Project (ESRP) in Kenya that was contracted to Areva T&D India Ltd as an EPC Turnkey project, and was prepared at the request of the employer (Kenya Power and Lighting Company Ltd). The contract, comprised renewal of fourteen (14) existing substations and construction of two new 66/11 kV substations, including a submarine cable and 11 / 33 kV line works. The contract which was executed on 15th March 2007, was awarded to Areva T&D India Ltd. after the evaluations, while the contract commenced (effective date) on 1st June 2007. Contract duration was 24 months and the original contractual completion date was 31st May 2009. However, the contract was estimated at 80% completion by the date of the report on April 2011.

The contract was delayed and substantial site works were still ongoing at Ruaraka, Kipevu, New Bamburi and Voi substations as by April 2011. Contract delays at employers' risk included delay awarded due to "Force Majeure", following the post-election unrest in Kenya in 2008 and time extension due to customs delays. Major changes were implemented at Ruaraka substation due to a major road expansion works that included acquisition of part of the substation land at the time, the Thika road construction works, and 180 days of time extension was awarded to the contractor due to disruptions arising from this.

Changes in contract elements were additionally necessitated by inaccurate / incomplete scope of works in comparison to actual requirements. Change processing including re-engineering, commercial approvals / agreements and material procurement delays resulted in project delays blamed on both parties (Kenya Power and Areva T&D India Ltd.) beyond the time extensions granted through the change orders. Contract delays attributable fully to the contractor (Areva T &D India Ltd.) included three (3) months delay following occurrence of a fatal accident in 2009, while further delays were occasioned by disputes between the contractor and its suppliers (2 months). The contractor (Areva T&D India Ltd.) experienced challenges in design and workmanship during the project, while their store experienced undersupply of consumable lot items and theft of materials. The contractor also experienced staffing challenges and cited work-permit issuance delays / declinations by immigration department in Kenya.

While the employer on several occasions addressed the contractor pertaining to non-performance, the contractor also claimed delay by the employer citing among others failure to issue customs exemptions in good time, failure to grant timely shut-downs and payment delays. The employer on 14th March 2011 issued a "Notice for intended Termination of Work" due to contractors' default, citing failure to submit progress reports, failure to attend to outstanding issues, failure to address deficiencies and defects as agreed between the parties as well as general lack of expected progress. The contractor responded to the employers' letter on 16th March 2011 and issued its own "Notice of intended Suspension of Work" citing employers' delay in payments, employers' declination to take over some sites with deficiencies, and employers' declination to approve retention payments. A joint inspection and a consultative meeting was held in March 2011 whereupon both parties explained their positions, and an agreement for a new completion date for the contract was agreed on as August 2011. *(This would amount to a 27 months delay from the original completion date of May 2009 on a contract that should have been completed in 24 months).*

Contractors' claims

The following formal contractual claims from the contractor for compensation or extension of time for completion of the contract had been lodged by April 2011:

i. **Post-election violence in Kenya after the December- 2007 general elections:** The contractor was unable to mobilize subcontractors and expatriate staff for site works for a period due to the unrest, while the unrest also caused disruptions to some shipments of materials from overseas. The contractor claimed 4 months of time extension in reference to the force majeure clauses of the contract. *(This is part of the political risk that projects of this nature may face)*

ii. **Customs Delay:** The contractor claimed 2 months of time extension on the project schedule caused by "Customs Clearance" delays arising from failure to obtain the "Exemption Codes" from the Kenya Revenue Authority (KRA) at the Mombasa port even after receipt of an exemption letter from the employer and submission of the same to the clearing agent at the port. The contractor also claimed for demurrage reimbursement.

iii. **Delayed payments:** The contractor claimed 4 months of time delay on account of over 40 days delay in release of payments by the employer. The employer on the other hand declined the claim on the grounds that the contract allowed for payment of interest and not extension of time in case of delayed payments.

iv. **Decline to arrange for shut-downs / cancellations of planned shut-downs by employer:** The contractor submitted several claims for "Extension of Time" and cost compensation following declined or cancelled shut-downs citing impediment of work by the employer, as listed in following table.

Ref & Date	Site	Delay claim
Ref 015 dated 14-Jul-09	Athi River substation; Shut-down declined by employer	2 weeks
Ref 029 dated 16-Sep-09	33kV Malindi Line; Shut-down declined by employer	6 months
038 dated 15-Oct-09	11kV Changamwe feeder ex KPRL substation; Shut-down declined by employer	1 month
Ref 071 dated 13-Oct-09	Utange & Athi River substations; Shut-down declined by employer	125,000 US$ Mobilization / demobilization claim
Ref 037 dated 10-Oct-09	Utange substation; Shut-down declined by employer	4 months
Ref 041 dated 12-Oct-09	11kV Shimo-La-Tewa feeder Shut/down cancelled by employer	4 months
Ref 047 dated 22-Jan-10	33kV Shanzu feeder and 11kV Kiembeni feeder shut downs cancelled by employer	4 months
Ref MSA/003 dated 23-Feb-09	Diani 33kv line shut down cancelled by employer	3 months
Ref MSA/051dated 06-10-09	Galu 33kv line shut down cancelled by employer	4 months
	Makande substation; Shut-downs declined by employer (due to lack of alternative supply to sensitive installations in Mombasa town)	12 months

v. **Nairobi City Council approvals**

Contractor vide ref 073 of 30/11/09 claimed that approval of Ruaraka building drawings by the local authorities had been delayed. However, the contractor neither provided details nor pursued its claim.

vi. **Late Engineering Requirements**

The contractor claimed that the employers' Project Management teams gave late comments that were not initially included in the approved design drawings such as:

- Requirement for replacement of battery-charger cables with Fuse units
- Requirement for interlock cables
- Kipevu substation control building floor finish was changed from tiles to terrazzo by the employer's project team

The contractor stated that the late requirements resulted in delays. However, the contractor neither quantified nor pursued the claims.

Consultants' Recommendations

Based on events and experience gained during the implementation of this contract, the consultant made the following recommendations;

a) Performance of Areva T &D India Ltd.: Bidder's Eligibility

Areva T &D India Ltd. was pre-qualified for the contract on the condition that a satisfactory "Letter of Comfort" from the mother company would be provided as part of the bid. A "Letter of Comfort" was provided from the mother company, Areva T&D Holding of France, which confirmed that Areva T&D India would if necessary, have access to intra group funding in the form of an internal line of credit of up to USD 4.4 million if awarded the contract, together with any technical support as may be required. This offer, together with Areva T&D India's own liquid funds as presented in the bid, was considered adequate to cover the cash flow needs for project execution.

During implementation however, the contractor did not receive technical or financial support from its mother company, and experienced cash-flow problems that resulted into delays in some of the projects awarded to it. The contractor lacked specialized engineering capability and commissioning expertise commensurate with Areva T & D Group's reputation. The consultant therefore recommended that during future project evaluations, the employer takes into account the fact that country branches of major construction firms have become increasingly independent and should be evaluated as independent entities.

(Areva T&D India did not have adequate technical staff to concurrently deliver the works in 16 substation sites at the same time, and the experience was such that some sites would be idle as they concentrated on other sites, and concerns raised by the employer would result into movement of technical staff from one site to another, thereby leading to multitasking. Due to limitations on competency of Areva project staff, several project tasks had to be re-worked following inspections and site visits by the employer's project team. Unforeseen technical difficulties also cropped up towards the end of the projects, making it difficult for the contractor to fully complete the projects, and sites such as Ruaraka substation were handed back to the

employer to complete the remaining works. The contractor lacked expertise on tasks such as 33kv and 11kv cable jointing and terminations, which had to revert to the employer).

b) ***Scope of Work***

The description of the scope of work in the contract, and correspondingly in the bidding documents was very brief on many key items, and was rather inaccurate on the quantities of some key items. This resulted in the need to work out, negotiate and implement a high number of changes to the contract, which negatively affected the progress of the contract works. The consultant recommended that considerably more time and effort be put into describing the scope in more detail by the employers' project teams. *(This was due to lack of Project Management Expertise in the employer's project teams).*

Consultant's advice on next course of action / concluding remarks on contract II

The consultant concluded as follows;

1. Accountability for the delay to the projects be shared between the parties. The contractor did not deploy adequate resources while the employer did not provide site access as per contractual requirements, and the employer did not make payments within contractual limits.

2. The substantial delays affected the projects significantly.

3. The employers' "Notice of intended Termination of Works" was valid and was free to decide termination /continuation.

4. The contractors' "Notice of intended Suspension of Works" was valid and was free to decide termination /continuation.

5. The projects under "Contract II" were at advanced stages by April 2011.

6. There was a significant risk of a legal stalemate if the contract was terminated by Kenya Power and Lighting Company Ltd. at this stage. This was because the contractor had demonstrated an unambiguous disagreement with Kenya Power regarding the cause of the

delays, and the fact that there was much at stake for the contractor financially. The contractor could take legal action which could indefinitely halt any continuation of the works by Kenya Power, whether such action would be deemed justified or not.

7. A win-win situation would be realized by continuation of the project.

8. To enable the contractor to continue, the consultant recommended that a negotiated "Time Extension" for shut-downs previously declined or cancelled by the employer be agreed between the parties. Such a gesture was expected to be well received by the contractor and possibly achieve final momentum to complete the remaining works.

9. It was expected that the contractor would attend to the minor outstanding issues at completed substations and those sites nearing completion in order to achieve "Operational Acceptance" and invoice for final retention. Alternatively, the employer could eventually cash the performance security.

10. The consultant proposed that interest payable to the contractor for delayed payments by the employer could be negotiated to be settled against liquidated damages for delayed completion at the close of the project.

(A majority of project sites under "Contract II" were eventually completed but with below average quality levels, while Kenya Power constituted a project team to complete the remaining outstanding works at Ruaraka 132 / 66kv substation in May 2016. The new Kipevu substation completely burnt down soon after commissioning, while 66kv isolators at Athi River substation failed soon after commissioning and were by-passed, awaiting replacement by Kenya Power. While the contract had warranty cover, the warranty was covered by similar equipment from similar sources, and therefore of similar quality levels).

Appendix L: Exogenous Variables as they were estimated by the 60 participants in the Exploratory study

Time to adapt workforce (Months) (A)	0.3	0.4	0.5	0.6	0.7	SUM(AXB)/60	Rounded to 1 decimal point
No. of participants who estimated value "A" (B)	4	12	29	8	7	↓	↓
A X B	1.2	4.8	14.5	4.8	4.9	0.503333	0.5
Max. productivity of testing (C) (Tasks/person/month)	1		2		3	SUM(CXD)/60	Rounded to 1 decimal point
No. of participants who estimated value "C" (D)	11		36		13	↓	↓
C X D	11	0	72	0	39	2.033333	2.0
Fraction properly completed (E) (Dimensionless)	0.5	0.6	0.7	0.75	0.8	SUM(EXF)/60	Rounded to 1 decimal point
No. of participants who estimated value "E"(F)	2	9	31	9	9	↓	↓
E X F	1	5.4	21.7	6.75	7.2	0.700833	0.7

Appendix M: Extracts from results of workshop of March 2014 with experts from the Electricity sector in Kenya

Discussion question item	**Results from discussions with participants**
After seeing the conceptual models presented (Fig 5.1, 5.2 & 5.3) and based on your experience, are there model variables that should be added?	- Political risk index may not vary much during the course of the projects - Shortage of competent commissioning / testing engineers - Fraction of undiscovered rework
What are your comments on cause of delays in projects in the electricity sector in Kenya?	- Contractors deploy few staff at the start of the project, then beef up the staff towards end of project, between month 30 and 40 into the project - Low competence of project staff in project management skills - Delays in handing over of project sites / slow process of approvals by officials concerned
What are your comments on cause of quality challenges in projects in the electricity sector in Kenya?	- Shortage of testing engineers; Contractors need to be compelled to hire more testing personnel in form of Engineers & Technicians so as to increase this level of personnel to about 75% of workforce 18 months into the project - Need to define the projects better during the tendering process

Appendix N: Model with combined policies scenario as text

Average quality of completed project tasks= (properly completed project tasks)/MAX((properly completed project tasks+undiscovered rework),1) ~ dmnl

poor completion of project tasks= progress(1 - fraction properly completed) ~ tasks/Month*

insuarance index= Political risk index(perceived cumulative progress/MAX(undiscovered rework , 0.01)) ~ dmnl*

*gross productivity of project personnel= WITH LOOKUP (remaining project tasks*Project Management competence, ([(0,0)-(600,1)],(0,0.2),(50,0.85),(75,0.95),(100,1),(200,1),(600,1))) ~ tasks/(Month*person)*

fraction personnel for testing= WITH LOOKUP (Time / perceived time remaining, ([(0,0)-(1,1)],(0,0.1),(0.2,0.15),(0.4,0.17),(0.6,0.3),(0.8,0.55),(1,0.8))) ~ dmnl

Multitasking= WITH LOOKUP (Time/perceived time remaining,
([(-5,0)-(200,10)],(-4.89297,7.10526),(0,1),(4,0.99),(8,0.98),(12,0.97),(16,0.96),(
20,0.95),(24,0.96),(26,0.97),(28,0.98),(30,0.99),(32,0.99),(36,1),(40,1),(44,1),(48
,1),(52,1),(56,1),(60,1),(64,1),(68,1),(74,1),(200,1))) ~ dmnl

time to adapt workforce= 0.5 ~ Month

initial project time remaining= 36 ~ Month

perceived time remaining= MAX(1, initial project time remaining - Time) ~ Month

desired workforce= perceived effort remaining/perceived time remaining ~ person

Political risk index= 0.67 ~ dmnl

Political risk adjustment=Political risk index + insuarance index ~ dmnl

*progress= gross productivity of project personnel*project personnel*Political risk adjustment* Multitasking ~ tasks/Month*

*Project Management competence = 0.95*MAX(average quality of completed project tasks , 0.1) ~ dmnl*

*productivity of testing = maximum productivity of testing*fraction undiscovered rework ~ tasks/(person*Month)*

remaining project tasks= INTEG (detecting undiscovered rework-poor completion of project tasks-proper completion of project tasks)

*additional cumulative effort= workforce/(Multitasking*Project Management competence) ~ Month*person/Month*

fraction undiscovered rework= undiscovered rework/MAX(perceived cumulative progress,0.01) ~ dmnl

*project personnel= (1-fraction personnel for testing)*workforce ~ person*

*maximum productivity of testing= 6 ~ tasks/(person*Month)*

*detecting undiscovered rework= productivity of testing*testing personnel ~ tasks/Month*

*testing personnel= fraction personnel for testing*workforce ~ person*

*perceived effort remaining= remaining project tasks/MAX(perceived productivity,0.05) ~ person*Month* *undiscovered rework= INTEG (poor completion of project tasks - detecting undiscovered rework,) ~ tasks*

*cumulative effort= INTEG (additional cumulative effort, 0.001) ~ person*Month*

properly completed project tasks= INTEG (proper completion of project tasks, 0) ~ tasks

*proper completion of project tasks= progress*fraction properly completed ~ tasks/Month*

net hiring of personnel= (desired workforce - workforce)/time to adapt workforce

~ *person/Month*

perceived cumulative progress= properly completed project tasks + undiscovered rework

~ *tasks*

FINAL TIME= IF THEN ELSE(perceived fraction completed<0.999,200,Time)

~ *Month*

~ *The final time for the simulation.*

perceived fraction completed = perceived cumulative progress/initial number of project tasks

~ *fraction*

fraction properly completed= 0.9 ~ dmnl

initial number of project tasks= 600 ~ tasks

INITIAL TIME = 0 ~ Month

~ *The initial time for the simulation.*

perceived productivity = perceived cumulative progress/cumulative effort

~ *tasks/person/Month*

SAVEPER = TIME STEP ~ Month

~ *The frequency with which output is stored.*

TIME STEP = 0.0078125

~ *Month*

~ *The time step for the simulation.*

workforce= INTEG (net hiring of personnel, 2)

~ *person*

Appendix P: Extreme condition test results with Unforeseen technical difficulties set to 0.05

The simulation results in figure 6.4 in page 153 were done with "*Unforeseen technical difficulties"* at a very small value which was set to 0.000000001, thereby making it hard to view the non-linearity in the lines because the horizontal axis was too broad. Figure 9.11 shows the same simulation results when "*Unforeseen technical difficulties"* is increased and set to 0.05 and the basic model is simulated, the results are as shown in figure 6.5 where "*poor completion of project tas*ks" (in red colour) rises to a high of 38 tasks/month at about project time 36 months, while *undiscovered rework* (in green colour) rises to approximately 530 tasks at project time 48 months. At the same time, the *"Average quality of completed project tasks"* varies from 0.00625 at the beginning of the project to 0.0075 at month 48 of project time. This is a reasonable expectation.

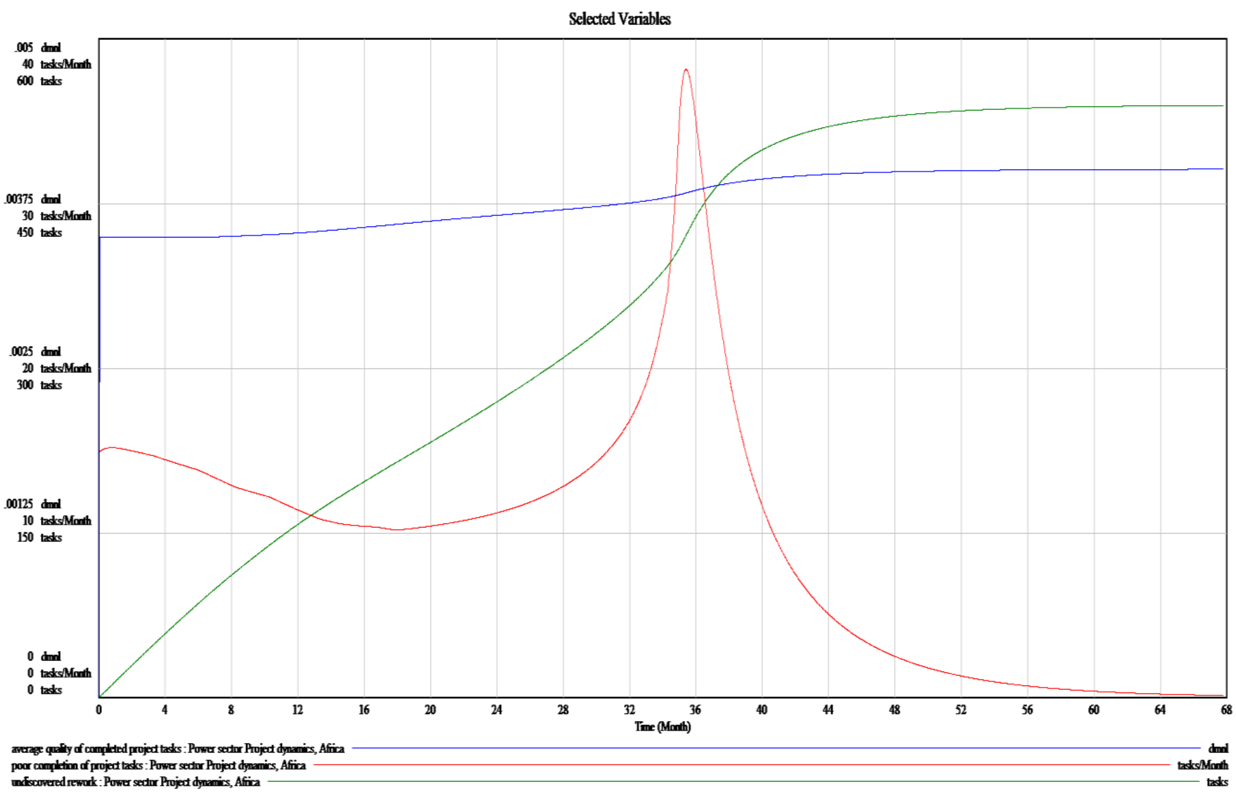


Fig. 9.11: Simulation results when unforeseen technical difficulties is set to 0.05