MANAGEMENT OF PROJECT RISKS IN THE ELECTRICITY INDUSTRY IN SUB SAHARAN AFRICA

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Abstract
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. The primary motivation of this research was to expand the understanding of the dynamics at play in risks in the electricity energy sub-sector in Sub Saharan Africa as a region. A qualitative research approach was used, designed as a guided participative cooperative enquiry based on active interviewing and sharing of model development with stakeholders. The results of the research study showed that project delays and quality problems in the power sector projects in the region are caused by among others, rework from use of workforce not adequately skilled, multitasking likely caused by a shortage of key technical personnel, low levels of project management competence, political risk, and unforeseen technical difficulties. Policy scenarios generated as part of the research indicated how these challenges may be surmounted.

Keywords: project risks; dynamic simulation; policy analysis and scenarios

Introduction and Background
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. This paper reports on research whose objective 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.

Research Approach
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 (Sterman 1992, Eriksson 2005, Elsobki et al 2009, Volk 2013). A qualitative research approach was used in the research study, designed as a guided participative cooperative enquiry based on active interviewing as well as sharing of results with experts in the electricity sector in Kenya for discussions and in the process, incorporation of valuable insights form the experts.

To investigate the first research question namely “What are the project dynamics in the electricity industry in Kenya?” an explorative study was undertaken, and 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?” which was done with the help of computer based simulation. 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?" which was done through what-if scenario analysis, leading to generation of four new policy scenarios. Adequate energy has therefore been singled out as one of the key enablers of economic development in Kenya, and various projects are presently underway aimed at expanding the adequacy and reach of the electricity infrastructure across the country (Kendagor and Prevost, 2013). This research focuses on projects undertaken by Kenya Power, the local electricity utility which owns and operates most of the electricity transmission and distribution system in Kenya. Forrester (1980) proposes use of three types of data needed to develop the structure and decision rules in models; numerical, written, and mental data. 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 a source of data in this research in the form of data from past projects in the electricity sector in Kenya.

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 done to get qualitative data from key stakeholders in the sector, namely ministry of energy personnel, project managers at Kenya Power and project managers of key contractor firms active in the sector in Kenya. The field work for data collection for this exploratory study took approximately 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 1 comprising 60 participants. The knowledge gained from this phase of the study was used in the development of the conceptual model.

Table 1: A breakdown of the stakeholders interviewed

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

Contractors	47 interviewees	36 interviewees	Determine risks in projects in the energy sector in Kenya

The mode of data collection was face to face interviews covering stakeholders in the industry. The interviews lasted between 40 minutes and one hour, and 60 numbers of interviews were successfully conducted. The data from the interview notes was analyzed by searching for threads cutting across the data 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 prevalent in projects in the electricity sector in Kenya. The results from this exploratory study also gave insights into how the variables identified in the exploratory study may relate with each other, and were used to formulate relationships between the variables as well as to eventually build the conceptual system dynamics model.

The Modeling Process

The modeling process by Sterman (2000) was used for this research. It starts off with problem articulation which deals with finding what problem there is and the key variables while dynamic hypothesis lists the current theories of the problematic behavior, then 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. However at the model formulation stage, it was noted that some model variables as identified in the exploratory research phase of this research were similar to the variables previously used in the model by Richardson (2013), and therefore the agile model development process as described by Warren (2013) was found to be appropriate at the model formulation stage of this research. The agile model development process recommends use of standard structures to complement the other processes, which 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 in this research.

The average time projects in the sector take is 36 months. Delays of between 6 months and 12 months are common. In this research, 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, was also noted as a likely contributing factor. These insights were collated from 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 during the exploratory phase of the research. The conceptual model developed in this research is given in figure 1.

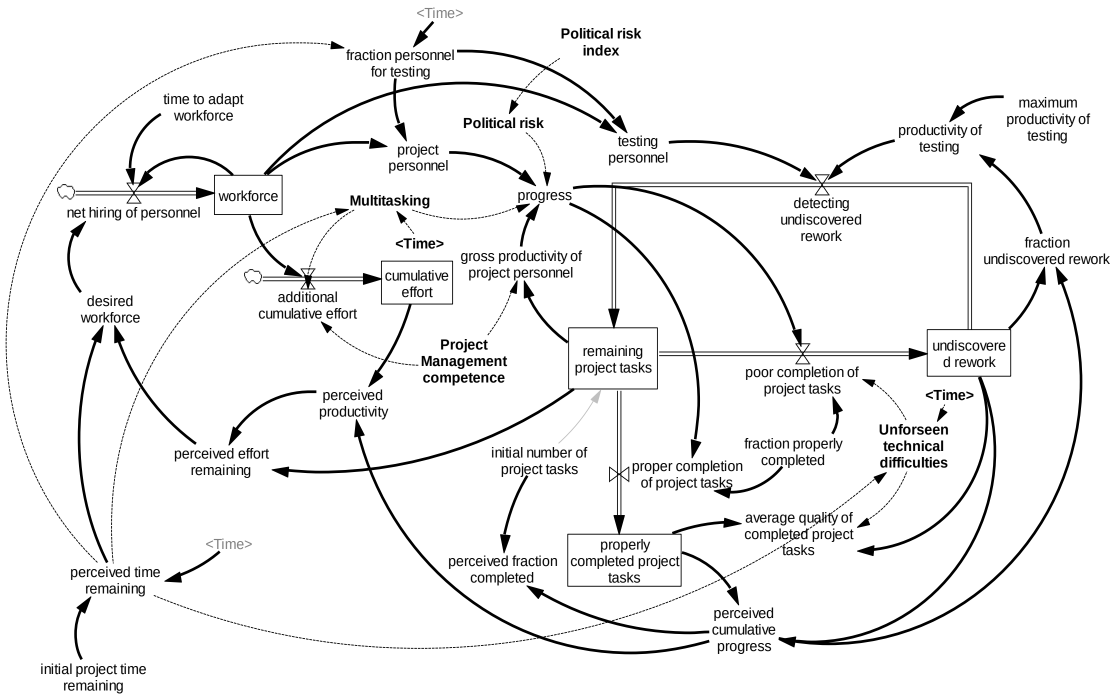

Fig. 1: Model of interacting project risks in the electricity sector in Kenya

"*Fraction undiscovered rework*" which is a function of "*undiscovered rework*" and "*perceived cumulative progress*" is 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*", was included arising from the exploratory study results. While the analysis of the exploratory study results had most of the variables that were in the project management conceptual model by Richardson (2013), four additional variables stood out as prevalent risk factors in the sector namely; "*multitasking", "political risk", "project management competence"* and *"unforeseen technical difficulties"*. These were constituted as variables in this research based on feedback from the exploratory study whose insights were used to formulate interrelationships with other variables and generate the new model as given in this paper as figure 1.

The new contributions, different from and in addition to 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 as influencing the "*gross productivity of project personnel"* as well as the "*additional cumulative effort"*. The four additional variables, together with the dashed arrows in figure 1 are all new based on feedback obtained from participants during the exploratory study in this research. The model in figure 1 therefore expands and extends the project model by Richardson through the inclusion of new variables mentioned as significant in the projects in the electricity sector in Kenya.

Workshop for model validation

After the development of the conceptual model, it was shared with experts 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 with a real project in Kenya Power, the local electricity utility company. The findings at this stage informed some modifications and improvement to the basic model as detailed under model validation. Table 2 gives a summary of, and schedule of the fieldwork during this stage of the research.

Table 2: 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

Model verification and model validation

Model verification is testing whether the model equations and the whole model is correctly coded and whether the units are consistent or inconsistent or whether there are numerical errors due to the use of an inappropriate combination of numeric integration method and step size while model validation refers to the entire range of tests to check whether a model meets the objectives of the modeling study (Pruyt, 2013). This research has made reference to Sterman (2000) who published tests for assessment of dynamic models and Barlas (1996, 2014). Direct structure tests involve comparison of model structure with the reality as represented in the reference mode (Barlas, 2014). During this research, structure confirmation, dimensional consistency and parameter confirmation tests were done on the basic model. For the structure confirmation test, 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 past projects in the electricity energy sector in Kenya in the form of reference mode graphs. During the discussions, the simulation results from the basic model in figure 1 which showed that projects often delay and may be completed in 60 months instead of the planned 36 months, while approximately 450 tasks out of the original 600 tasks end up as "properly completed project tasks" at the end of the project (as shown in figure 7 and figure 9), bear close similarity to the results of the projects in the electricity industry in Kenya. The general agreement was that the model structure as presented adequately represented the reality of projects in the sector. During the dimensional consistency test, each equation of the model was checked for dimensional consistency. 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). In parameter confirmation test, model constants were verified against observations in real life projects in the sector using the expert opinions of the participants of the stakeholders in workshop. The new model passed these tests, and 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.

The indirect structure tests conducted in this research included the extreme condition test, boundary adequacy test, numerical sensitivity test and behavior sensitivity test. The boundary adequacy (behavior) test considers whether or not a model includes the structure necessary to address the issues for which it is designed and involves conceptualizing additional structure that might influence behavior of the model (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 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. In the process, 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)

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))*

Political risk adjustment = Political risk index + insurance index

This was 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 arrived at based on data from the exploratory study, 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

The resultant new and adapted model is as given in figure 2. Dimensional consistency test was carried out on the three new equations which passed the test. All subsequent tests that follow were done using the model in figure 2 as the basic model. The arrow sections marked in bold black represent portions of the model that were inherited from the conceptual model by Richardson (2013), while all the sections marked in dashed arrows, together with the variables *Political risk index, Political risk adjustment, insurance index, Multitasking, unforeseen technical difficulties*, 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 2 is therefore an expansion of the previous model by Richardson which also includes the additional variables; political risk, political risk index, insurance index, multitasking, unforeseen technical difficulties, and project management competence as part of the project dynamics in the electricity sector in Kenya and by extension, the wider Sub Saharan Africa region. During the extreme condition 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. The model passed the tests.

Numerical sensitivity and Behavior Sensitivity tests

Sensitivity analysis is studying the impact input changes have on outputs (Shannon et al 2013). 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). The minimum and maximum values of the exogenous variables in the model as indicated by the participants in the workshop were used as given in table 3 as the "Proposed Minimum value of variable" and "Proposed Maximum value of variable" during the sensitivity testing in this research.

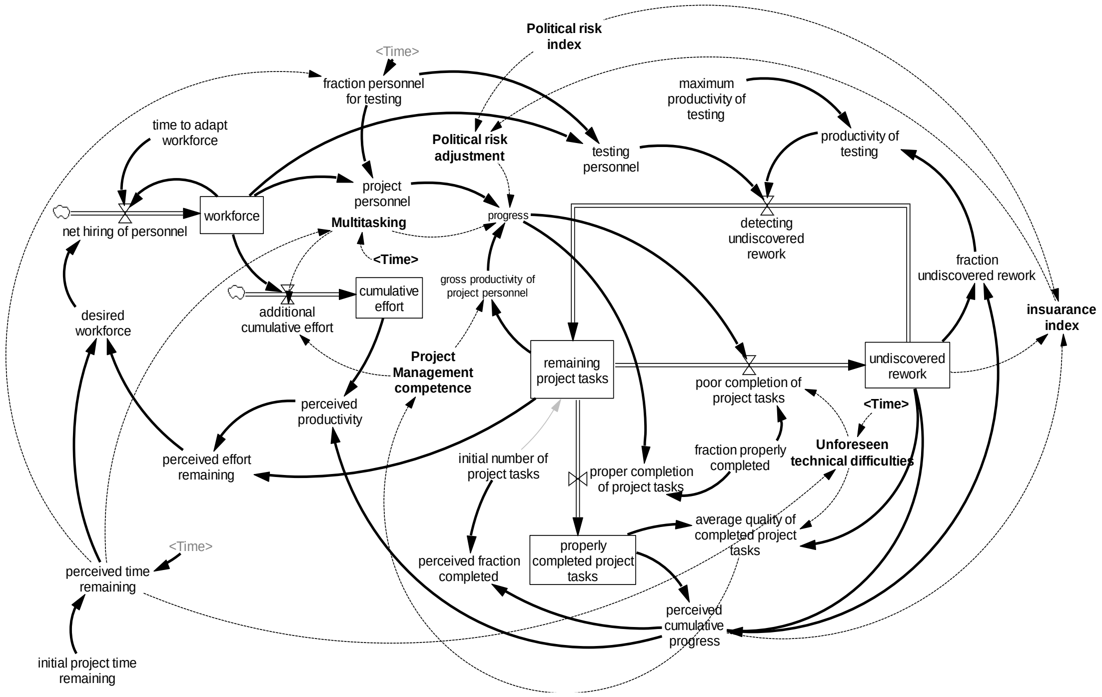

Fig. 2: Basic model with Political risk & Project Management competence made endogenous

Table 3: Exogenous variables with estimated values in Fig. 2

Exogenous variable	Meaning	Estimated value in basic model	Proposed minimum value of variable	Proposed maximum value of variable
Time to adapt workforce	Time taken to familiarize and train new workforce	0.5 (months)	0.3	0.7
Maximum productivity of testing	The maximum testing tasks that a testing engineer performs in a month	2 (tasks/person/month)	1	3
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

The proposed minimum and maximum values in table 3 were 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. Sample histograms of output results for multivariate sensitivity testing on the simulation model in Fig. 2 are given as figure 3 and figure 4. Fig. 3 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 under the basic model. 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. Going by the most probable value, this clearly indicates the quality challenge exhibited by most projects in the electricity sector in Kenya

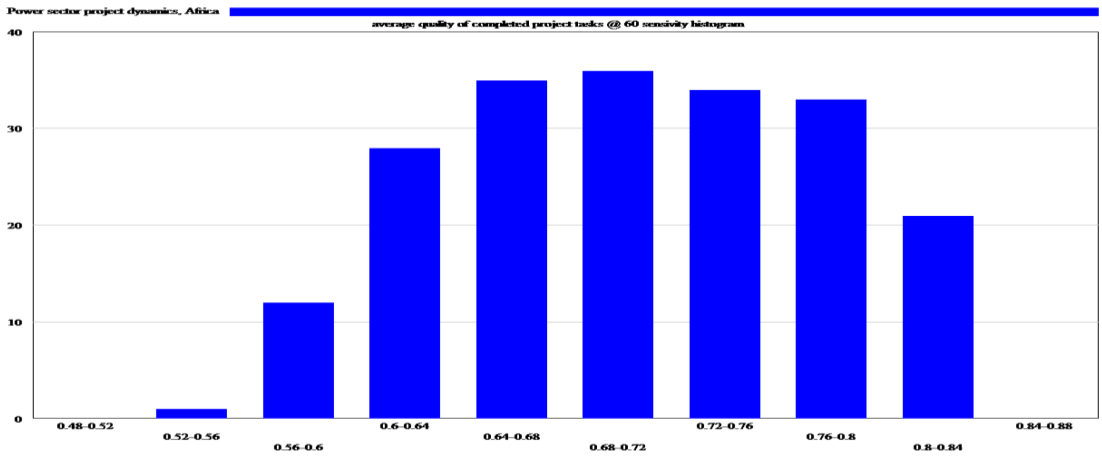

Fig. 3: Typical sensitivity histogram of average quality of completed project tasks

Fig. 4 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. The results showing as much as 200 tasks remaining as undiscovered rework by the end of the project further underlines the quality challenge facing projects in the electricity sector in Kenya.

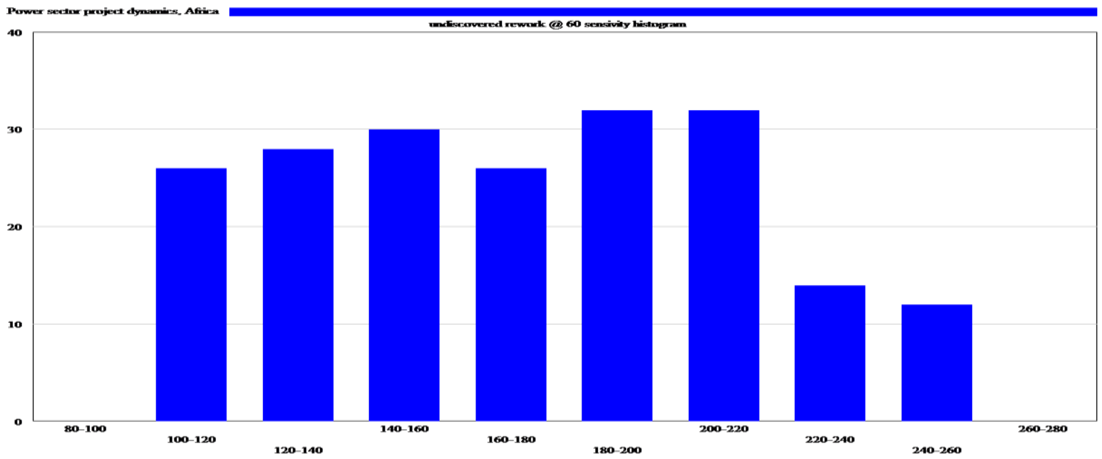

Fig. 4: Typical sensitivity histogram of undiscovered rework

Multivariate analysis, 200 runs (with random uniform distributions)
Multivariate analysis was done by having all the three variables in table 3 randomly but uniformly changing together during the sensitivity simulation runs, and sample results are given in Fig. 5 and Fig. 6.

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. 5 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.

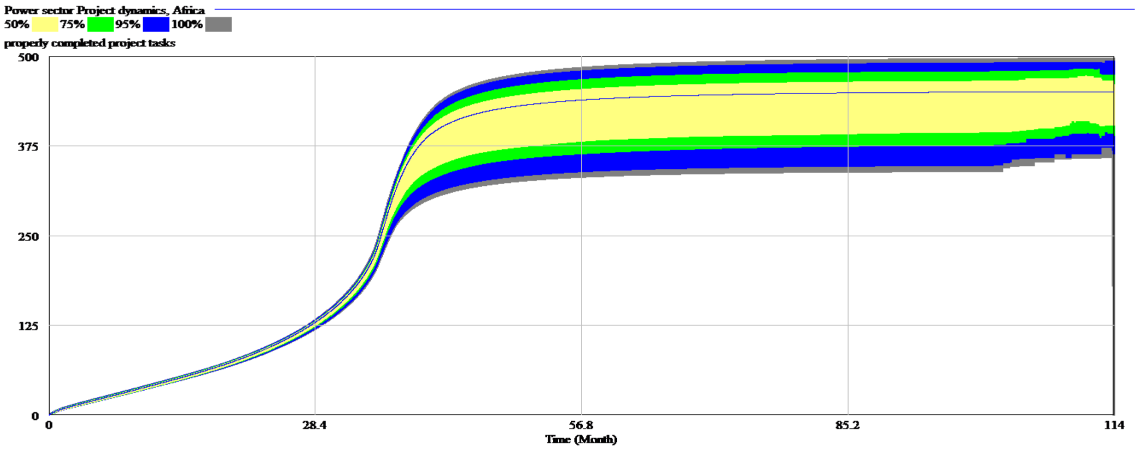

Fig. 5: Properly completed project tasks sensitivity trace ranges under multivariate uncertainty

Fig. 6 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.

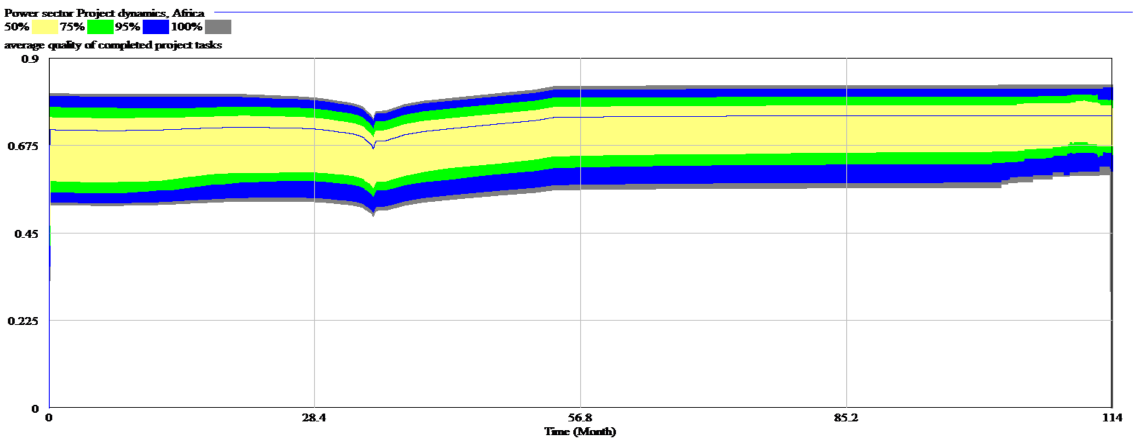

Fig. 6: Average quality of completed project tasks sensitivity trace ranges under multivariate uncertainty

Behavior Pattern tests

Behavior pattern test is done by the comparison of the simulated behavior trends from the basic model will the real system behavior as given in the reference mode trends. This is done to check that the behaviors as simulated in the basic model 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 was done by comparing simulated results from the basic model in figure 2 with reference mode graphs from historical data of previous projects. In addition, behavior anomaly test was done by setting to zero key variables and checking for anomalies in the outcome behaviors. Surprise behavior tests were also done on the new basic model in figure 2 in this research by having model outputs checked for any surprise behavior. However model outputs did not exhibit any surprise behavior.

Simulation Results after model verification and Validation

All the Vensim System Dynamics simulation results shown in this section for the model portrayed in Fig. 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 7 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.

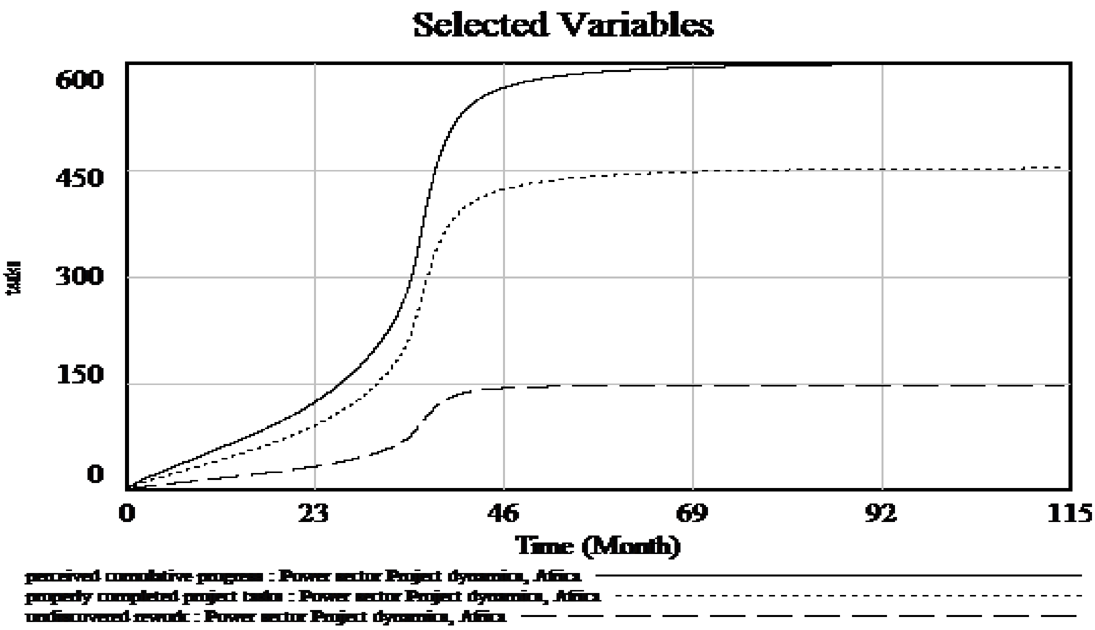

Fig. 7: Comparison of trends of perceived cumulative progress, properly completed project tasks and undiscovered rework

The simulation trends in figure 8 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*.

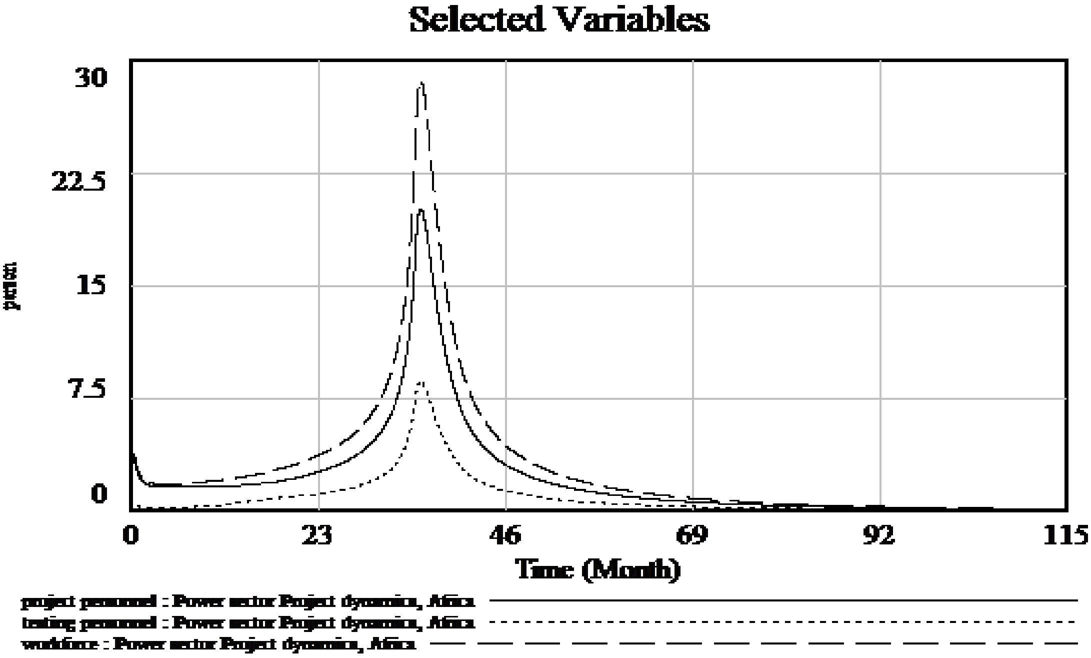

Fig. 8: Comparison of trends of project personnel, testing personnel, and workforce

The simulation trends in figure 9 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.

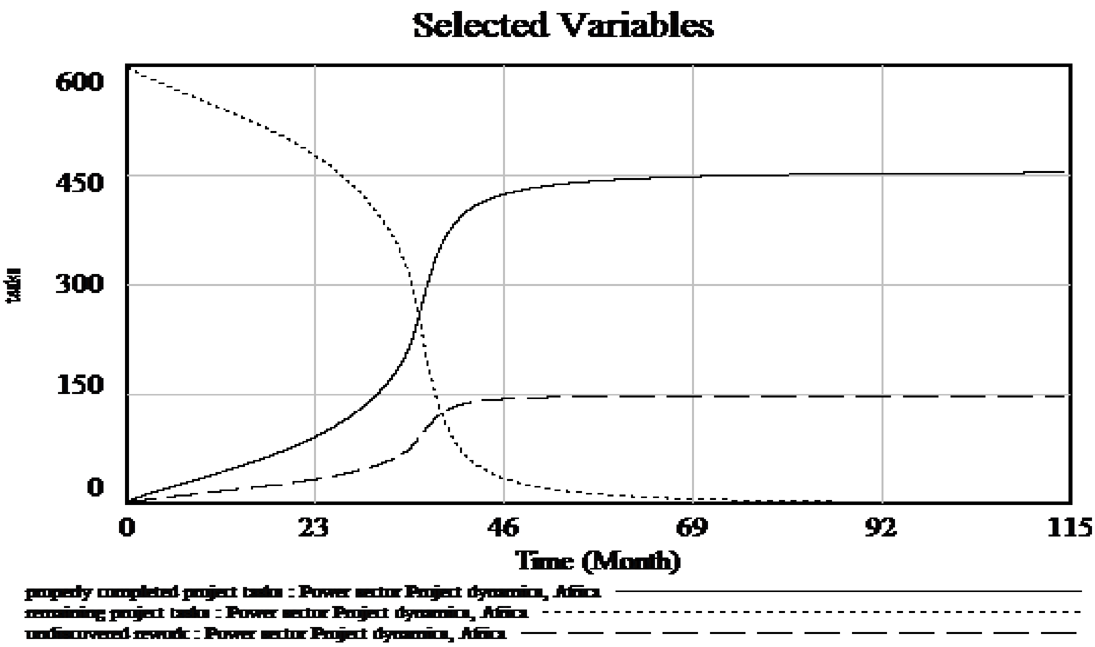

Fig. 9: Comparison of trends of properly completed project tasks, remaining project tasks, and undiscovered rework

Policy Analysis and Design

Howlett et al (2009) note that the policy process involves six distinct phases, namely agenda setting, policy formulation, decision making, implementation, evaluation and termination or renewal. This research paper limits itself to policy formulation and decision making areas arising from the analysis of the basic system dynamics model that was developed, tested and verified. According to Sterman (2000), policy design includes the creation of entirely new strategies, structures, and decision rules. When designing policies to improve system behavior, changes made in the model are only those that could also be changed in the real world (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 was 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.

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 paths leading to that future. In this research, a range of 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).

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 2. The simulation model outputs for the business as usual scenario are as given in figures 7 to 9 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.

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 under “Business as usual” scenario. 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, and therefore *Project management competence* was modeled as;

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

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*

The increased competence of project personnel through the hiring of competent technical staff with project management skills, will likely result into the *fraction properly completed* of project tasks which was at 0.7 in the basic model in figure 2, to rise because work will be properly scheduled and matched with resources. Through suggestions from the workshop with project experts in Kenya, it is assumed in this research that *fraction properly completed* will likely change from 0.7 to 0.9 due to increased competence of project personnel.

The effect of this change in project management competence was noticeable in the trends for *undiscovered rework* as shown in figure 10 which reduced to peak at a high of about 55 tasks (solid line) from the previous 150 tasks (dotted line). At the same time, the rate of *poor completion of project tasks* reduces from a peak of 19 tasks/month to a new peak of 6 tasks/month.

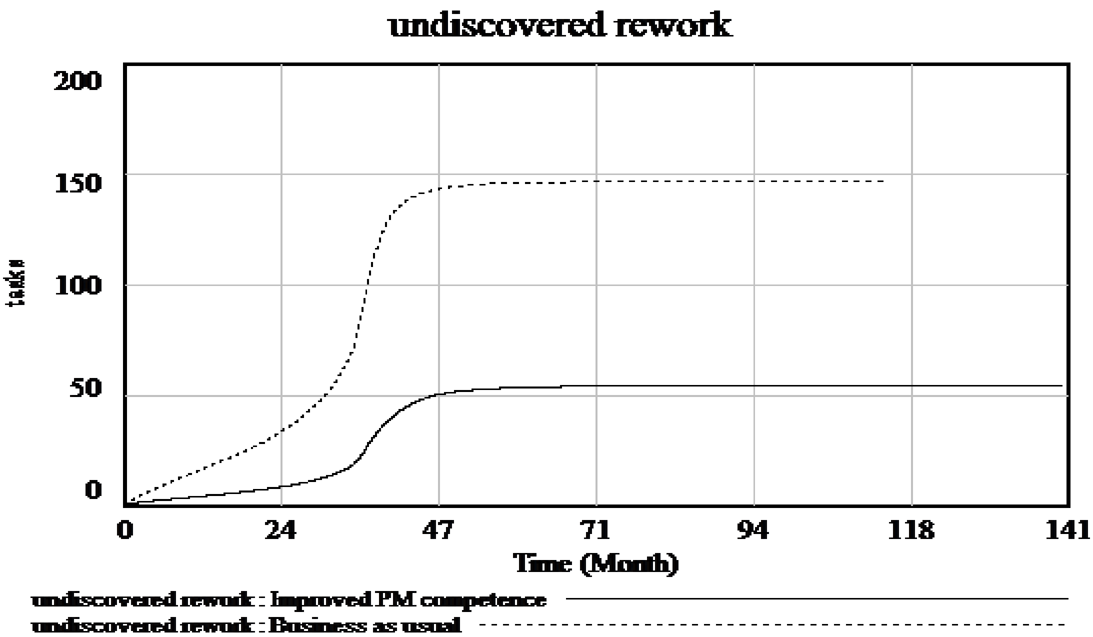

Fig. 10: Undiscovered rework trends under Business as usual and Improved PM competence scenarios

In addition, the change in project management competence has the effect of improving productivity. This was witnessed through the "*perceived productivity*" variable, which in the basic model rose 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 11 in dotted line, but improved and rose to 1.7 tasks/person/month before dropping and leveling off at 1.2 tasks/person/month at month 60 as shown in solid line under improved project management competence.

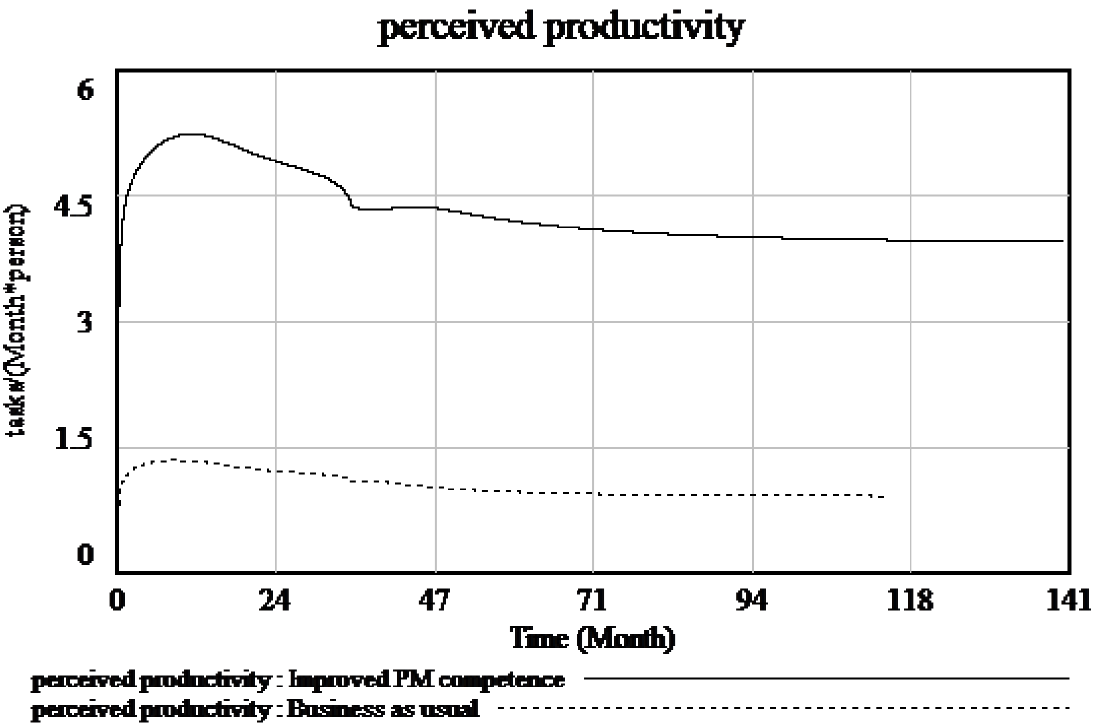

Fig. 11: Perceived productivity trends under Business as usual and Improved PM competence scenarios

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

The factor of 8 shown in 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 electricity sector. 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 ordinarily results into project delays. The effect of spreading the workforce could be achieved in the model by changing the equation for *desired workforce* to;

Desired workforce = perceived effort remaining / perceived time remaining

Figure 12 shows the results of the spread of *workforce*, *project personnel* and *testing personnel* on simulating the model after this change.

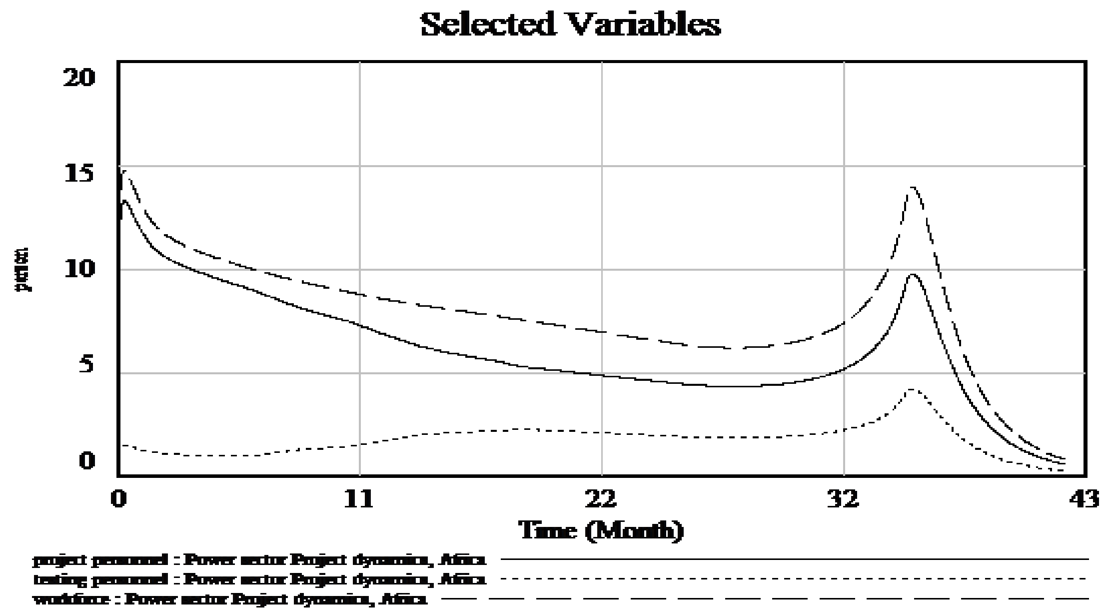

Fig. 12: Spread of Workforce, Project personnel and testing personnel trends

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 13 that show that the project will likely be completed in about 38 months due to this change.

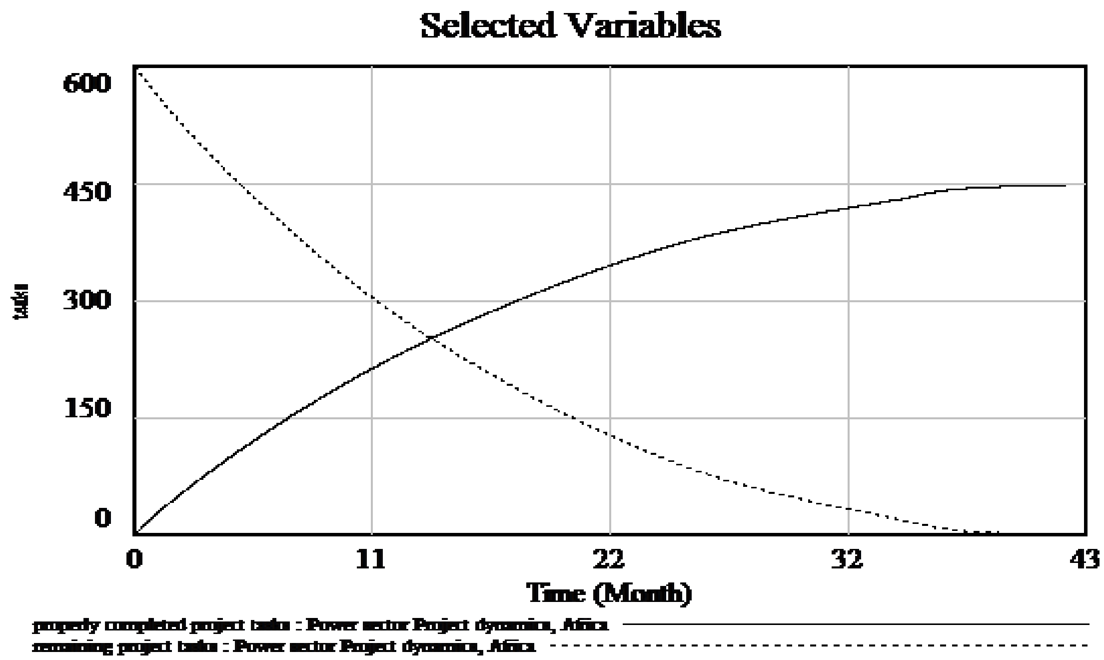

Fig. 13: Trend analysis, properly completed project tasks & remaining project tasks with the spread of workforce

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 was noted as necessary. These competent engineers and technicians are normally useful for commissioning and testing functions especially one year into the project in the sector, 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 during the workshop held in Kenya. It was agreed in the workshop that 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

The envisaged improvement in the fraction of testing and commissioning personnel as indicated in the new equation for *fraction personnel for testing* had the effect of changing the trend of fraction personnel for testing that earlier peaked at 30% of the workforce in the basic model to peak at about 75% within 18 months of project time, as suggested by experts in the workshop. The increase in testing personnel also had the effect of reducing the peaking of *undiscovered rework* from 150 tasks in the basic model to 70 tasks as shown in figure 14, raising the *properly completed project tasks* from 450 tasks in the basic model to 525 tasks, and raising the *detecting undiscovered rework* from an initial peaking value of 4 tasks/month to 16 tasks/month as shown in figure 15.

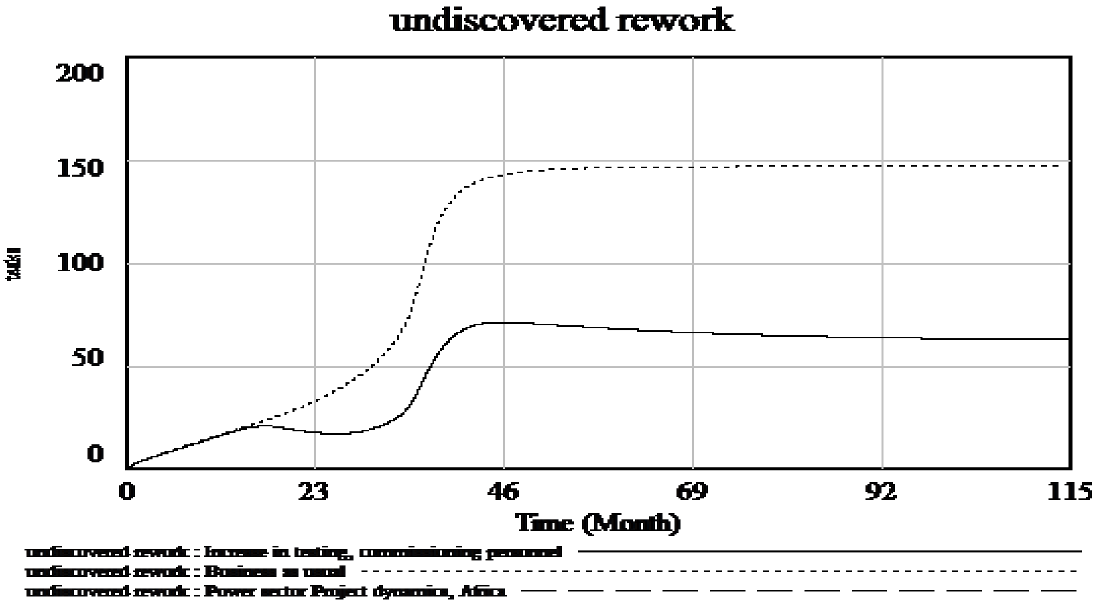

Fig. 15: Undiscovered rework trends under Business as usual and Increase in testing / commissioning personnel scenarios

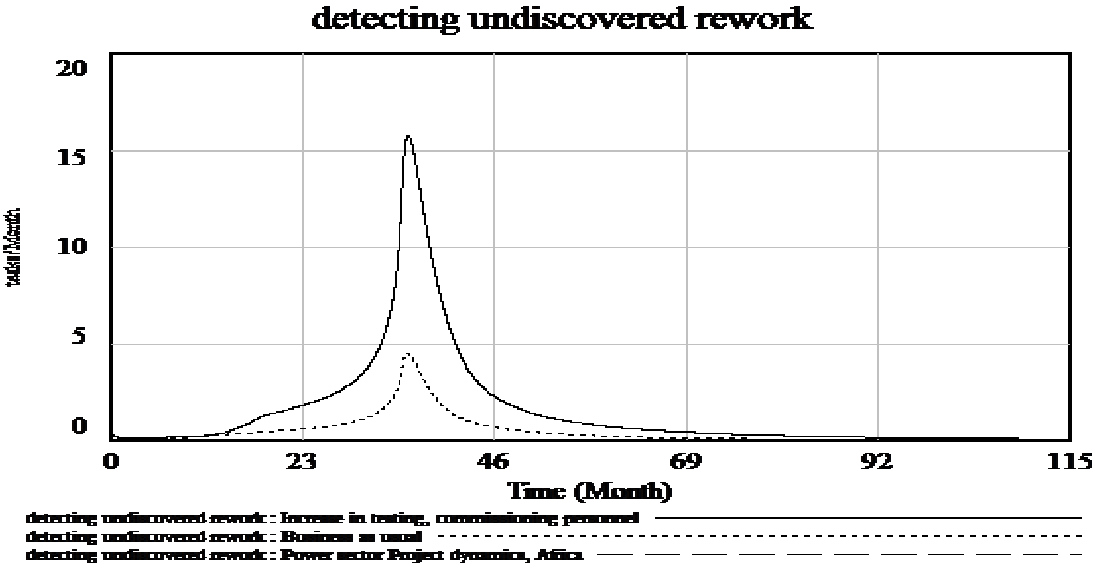

Fig. 15: Detecting undiscovered rework trends under Business as usual and Increase in testing / commissioning personnel scenarios

Scenario 5 - Combined policies

The combined policies scenario makes changes to the basic model in figure 2 by incorporating changes suggested in scenario 2, scenario 3, and scenario 4 into a new model as given in figure 16. The variables Political risk index, Political risk adjustment, insurance index, and Multitasking, together with arrows marked in dotted line 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.

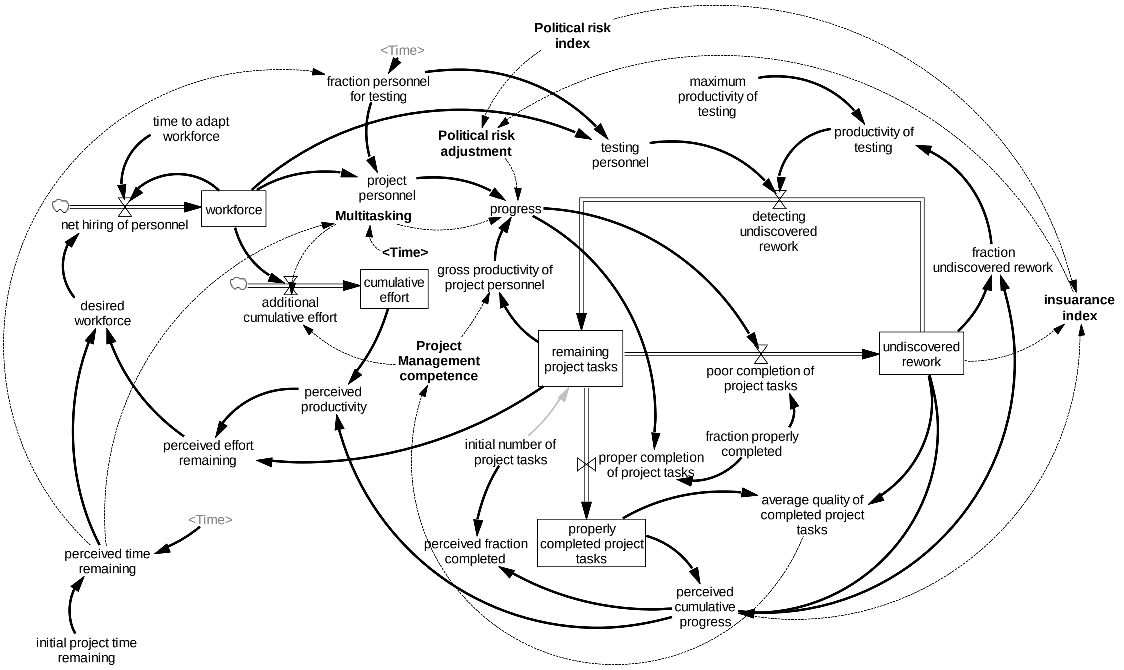

Fig. 16: New model developed using scenario 5, (Project Management competence improvement + Equitable spread of workforce + increased role for testing and commissioning personnel)

By combining all the effects of the four policies at the same time, the results as given in figure 17 indicate that the *remaining project tasks* drop from the initial 600 tasks to 0 by approximately 38 months in the combined policies scenario, unlike the 72 months in the business as usual scenario, while *properly completed project tasks* at the end of the project rise from 450 tasks in the business as usual scenario to 580 tasks in the combined policies scenario as shown in figure 18.

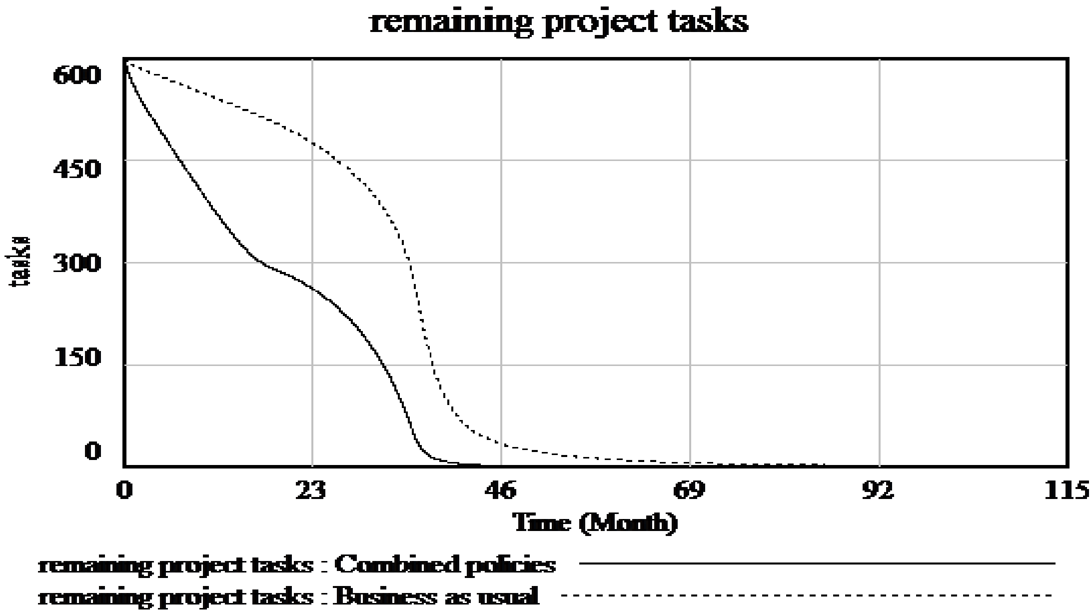

Fig. 17: remaining project tasks trends under business as usual and combined policies scenarios

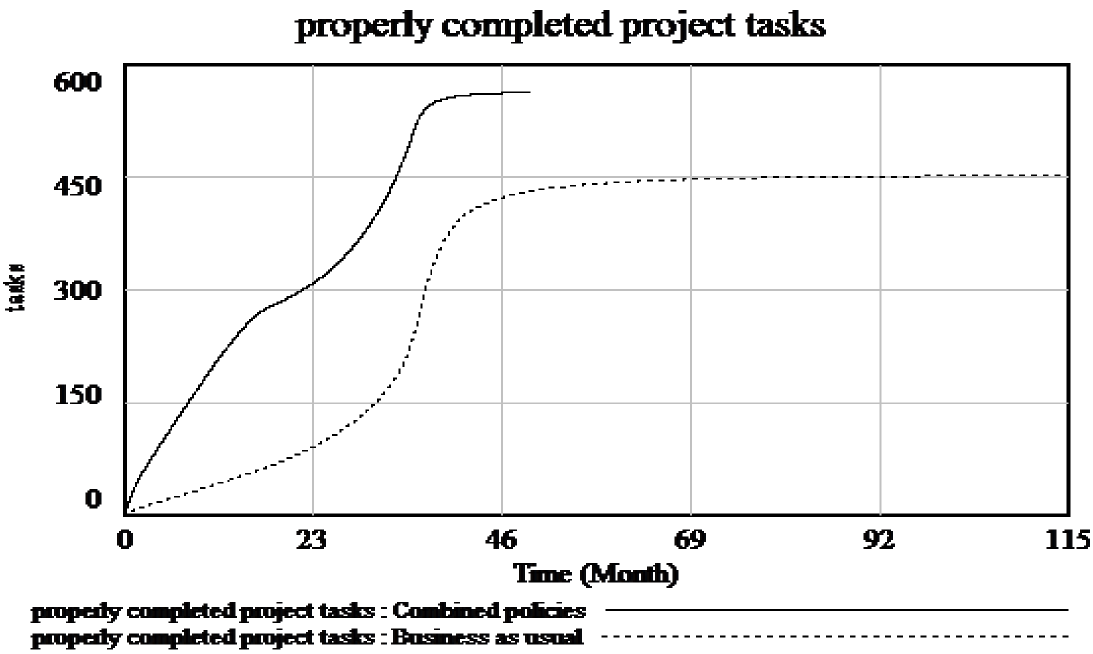

Fig. 18: Properly completed project tasks trends under business as usual and combined policies scenarios

At the same time, *Undiscovered rework* of 140 tasks in the business as usual scenario in figure 19 drops to approximately 23 tasks in the combined policies scenario.

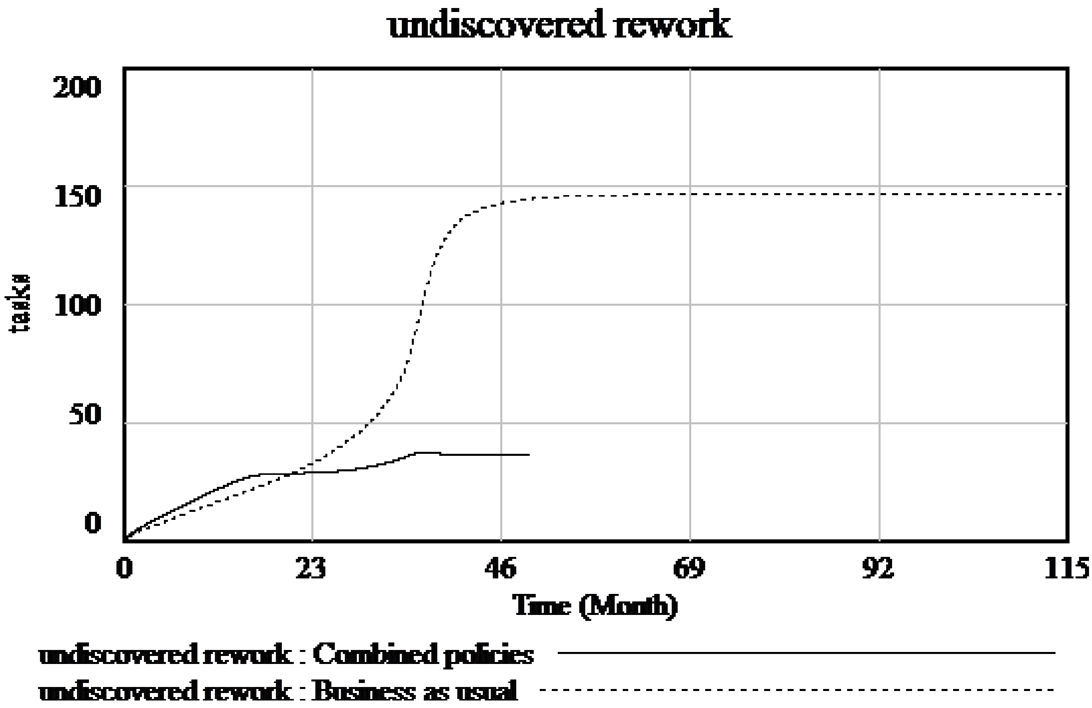

Fig. 19: undiscovered rework trends under business as usual and combined policies scenarios

Table 4 compares and contrasts simulation results from the 5 policy options, and gives additional simulation results from the scenarios generated in this research. 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 4: Comparison of 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 figure 16 is a significant improvement on the initial basic model in figure 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 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 figure 16.

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).

Figure 20 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 (model in figure 16). It shows a most probable value of 0.93 to 0.945 (compared to the earlier most probable value of 0.68 to 0.72 as in figure 3), and maximum value of 0.99 to 1.0 by the end of the project.

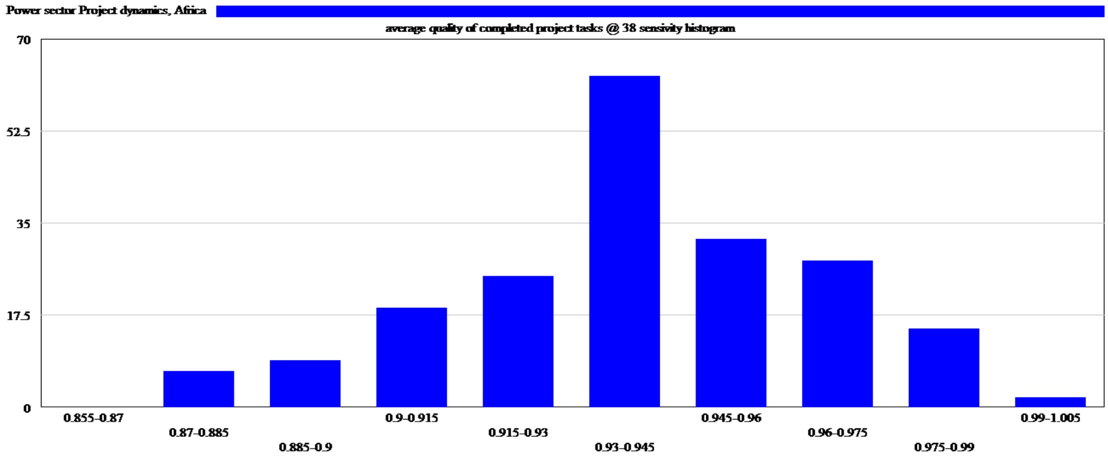

Fig. 20: Typical sensitivity histogram of average quality of completed project tasks with the combined policy scenario

Similarly, figure 21 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 (compared to the earlier most probable value of 180 to 200 tasks).

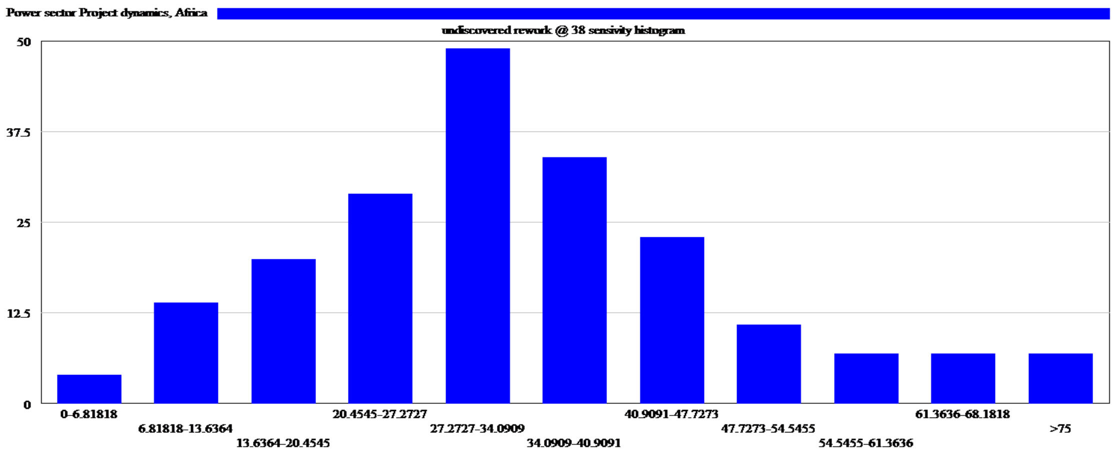

Fig. 21: Typical sensitivity histogram of undiscovered rework with the combined policy scenario

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 16.

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

Figure 22 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.

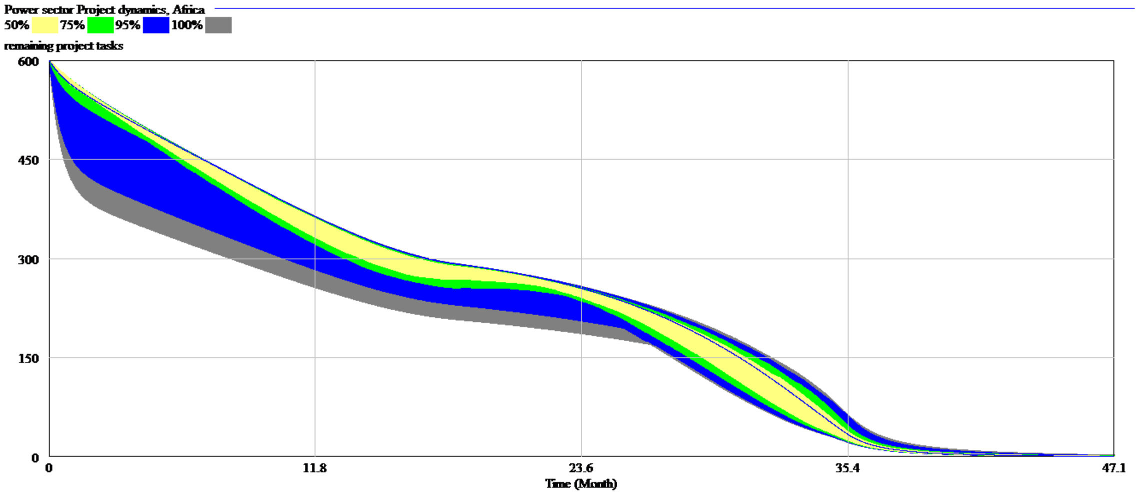

Fig. 22: remaining project tasks sensitivity trace ranges under multivariate uncertainty

Figure 23 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.

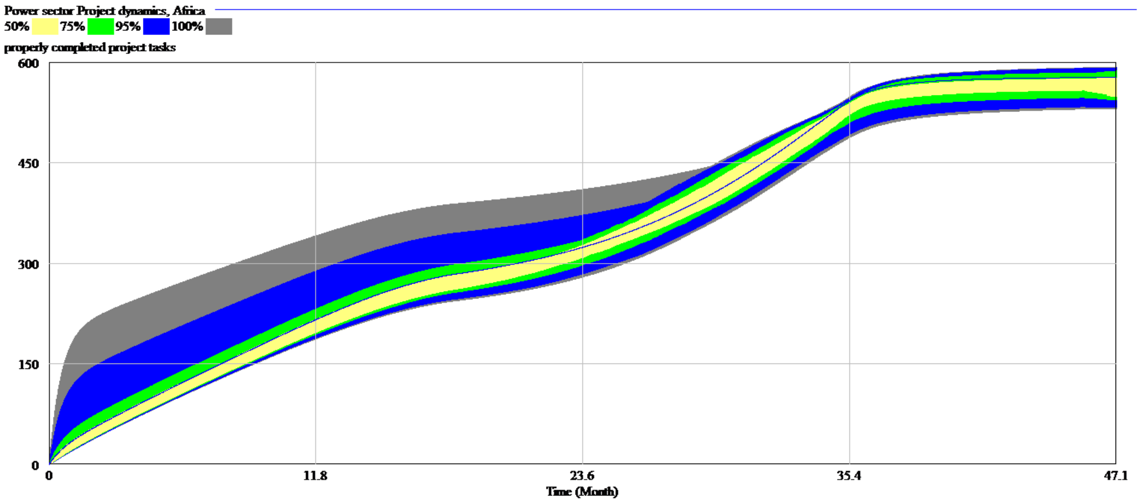

Fig. 23: properly completed project tasks sensitivity trace ranges under multivariate uncertainty

Figure 24 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.

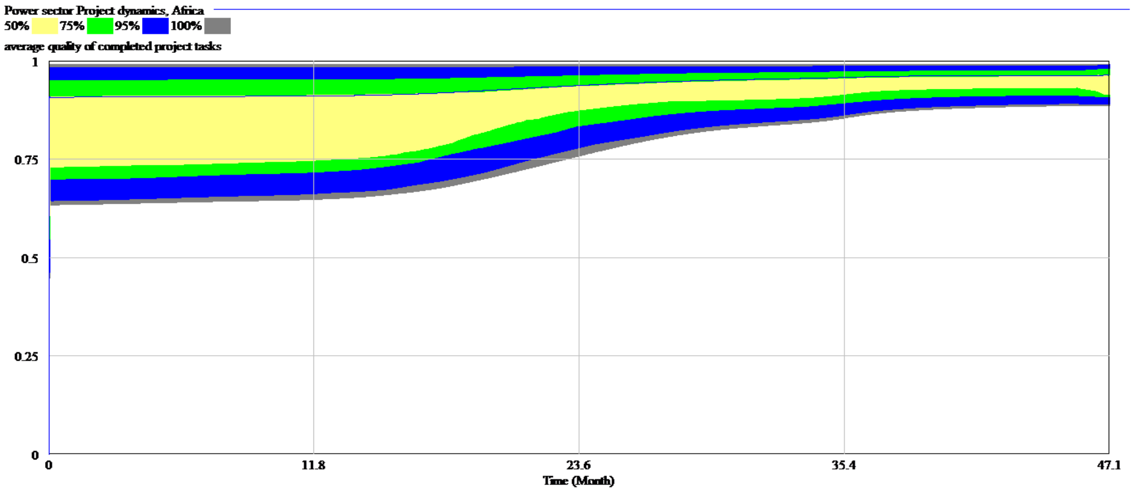

Fig. 24: average quality of completed project tasks sensitivity trace ranges under multivariate uncertainty

Discussion of Results and contributions to knowledge

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. The new model developed 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. The other key objective was to test and validate the new model, which passed the tests, and therefore the model developed in this research was deemed to be sound for the intended purpose. The test results reinforced confidence in the new model whose simulation results were found to mirror the reality of the project dynamics in the electricity sector in Kenya and the wider Sub Saharan Africa region. The simulation results of the model after testing and validation indicated that undiscovered rework is quite prominent and significant in projects in the electricity sector in Kenya, rising to a high of 150 tasks and often remain at this level by the end of the project. This likely resulted into quality challenges as observed in the new model, and the results also indicated that properly completed project tasks at the end of the projects is at 450 tasks out of the original 600 tasks.

From the knowledge gained by studying the simulation model developed in this research, it can be deduced that the forces that cause project delays and quality challenges in the electricity sector in Kenya include a shortage of testing and commissioning engineers that invariably leads 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 as well as below average project management skills is also a major contributing factor to the delays. 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 new knowledge would likely contribute 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.

Scenario 2 shows that improvement in project management competence has the effect of raising the fraction of project tasks that are properly completed 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%. Scenario 4 which involves hiring more testing and commissioning engineers, 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.

Conclusions

This 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 results of the study showed that project delays and quality problems in the power sector projects in the region are caused by among others, rework which comes from use of workforce not adequately skilled, multitasking likely caused by a shortage of key technical personnel such as commissioning engineers, and low levels of project management competence. The results also 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.

From the scenarios generated through policy analysis, the study reveals that employment of more competent project managers as well as the engagement of skilled testing and commissioning engineers in adequate numbers, will likely result into projects in the electricity sector finishing 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. The 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.

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. In donor funded projects in the Sub Saharan Africa region, many projects may usually be tendered out at the same time. In many such cases, 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. This study reveals the need for policy makers to introduce a kind of "project execution rule" in the process that limits each contractor to a pre-set maximum number of projects that can be won by a single contractor, and that must be completed before award of additional projects to contractors to improve on management of the projects.

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