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Risks and buffer analysis in critical chain management by system dynamics (Case study: Oil refinery)

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Abstract

In this paper, risks in oil construction projects are identified, analyzed and considered for buffers in system dynamics modeling. To do so, all important and effective variables and risks within an oil construction project are determined, including internal and external variables and then, conceptual model is developed using system thinking approach. Based on the conceptual model, state and flow model is obtained and the relations between variables are established. In order to show efficiency and effectiveness of the proposed method, a real case study is considered and solved. Moreover, sensitivity analysis is provided, by using real data and this model. The primary goal of this research is to investigate the impact of different risks that exist in oil construction risks on key variables; these key variables include human resources, facilities and materials. The results demonstrate that the initial plan of each resource is not consistent with the actual need of them. In other words, based on the existing risks in the model, the proposed approach determines what level the actual resources requirement would be placed at and given existing risks, which buffer should be considered for each resource. Furthermore, the impact of risks in performing activities is forecasted and the model shows what impact the risks have on the delay in initial progress of the project as time passes. Finally, it is studied how changes in key and input variables affect the all project.

Keywords: Critical chain, buffer management, dynamic system, risk management, oil refinery

1- Introduction

The project management contains principles on which the project will be undertaken to achieve specific objectives of the project. Part of risk management is to manage a project. Risk can be possibly defined as achieving results contrary to what is expected (Knechel, 2002). The extent and impact of significant risks and uncertainties in construction projects should not be underestimated. The size and magnitude of the project stressed on the importance of risk.

The influential risk depends not only on the size of the project, but also on other factors, including the complexity of the project, the construction speed, location and lack of customer projects (Perry, 1986), at most of the time the resource constraints will complicate the problem more (Ward & Chapman, 1991).

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The most important step in risk management is to limit the effect of risk, by controlling it. Other activities may prevent the occurrence of risk, using of insurance risk and or transferring it (Chapman, 2008; Szczepański & Światowiec-Szczepańska, 2012). In the risk management, it would better the business risks before they occur and cause loss are anticipated and managed (Barton et al., 2002). The project risk is an uncertain event, if happens, at least influencing on one of the project goals (quality, cost, time, etc.). The project risk management process includes planning, risk identification, qualitative and quantitative risk analysis, planning to respond to and monitor and control the risks. In addition, the risk management is one of the nine knowledge areas in project management and it enables the stakeholders to understand the impact of risk on project performance (PMI, 2008; Chapman & Ward, 2003).

Given the importance of forecasting and planning for risks and uncertainties in projects that can challenge the project at different levels, this article intends to introduce the concept of risk management in projects, especially in oil projects, to study and scrutinize the factors affecting the risk management of these projects. In oil refining projects in Iran, due to the existence of sanctions, it forced officials and managers to do things independently and without the cooperation and assistance of experienced organizations, and this carries risks, given that some had little experience and knowledge. However, in projects, errors may occur and affect performance/ success indicators. Therefore, we need a learning tool that can show the effects of these tests in different indicators and can make adjustments in different conditions. One of these settings is buffer, such as time buffer or buffer in project raw materials, etc., which helps a risk management.

Therefore, in this article, we want to use the system dynamics tool, which promotes the learning and improvement of the knowledge of those in charge of refining projects and increases the knowledge of those in charge of affairs and promotes the ability to recognize the problems of officials in issues and problems.

2- Background review

There is much work on this field. Perry (1986) provided a comprehensive approach to risk management process of a project in which the various components of risk management involve in identifying sources of risk, risk assessment, managerial respond to the risk and forecasting. He says that each of these stages has the right tools. Using the results from obtained and collected questionnaire. Simister (1994) assessed the level of use and knowledge of the techniques existing in the risk management project and examined the advantages of using such techniques.

Aleshin (2001) studied the risk management in a Russian international company. Raz & Michael (2001) reviewed existing tools for project management and particularly the project risk management. Arena et al. (2010) studied organizational dynamics in risk management using real data from 3 studies. Hartono et al. (2013) studied in Indonesia (as a developing country) and investigated the risk understanding in the public administration in developing countries compared with the developed world. Experimental results show that there is a significant gap between the views of stakeholders and underlying assumptions on the concept of risk. For example, the shareholders know the risk to be considered only as a negative sense, while the hypotheses are neutral towards it. Shimizu et al. (2013) compared issue of risk management practice between Korea and Japan. They examined two issues within the countries: 1) how companies in these countries manage the risk, and 2) if there is a difference between the two countries in the implementation of risk management. Marcelino-Sádaba et al. (2013) considered the risk management for small enterprises and provided a methodology. Hwang et al. (2013) investigated the risk management in small construction projects in Singapore. The study examined the current state of risk management. Heravi and Gholami (2018) determine the relationship between project risk management maturity, organizational learning, and project success aimed at measuring the influence of project risk management maturity and organizational learning on project cost, time, and quality. De Araújo Lima et al. (2021) finds highlight how project features (commitment type, innovativeness, strategic relevance and managerial complexity) and firms' characteristics (sector of activity, production system and access to public incentives) influence PRM adoption, leading to different levels and types of benefits and offers practical indications about PRM phases, activities, tools and organizational aspects to be considered in different contexts to ensure the project's success and, ultimately, the company's growth and sustainability .

The dynamic system and systems thinking would be of the effective approaches in the field of project risk management. Development of a holistic view for the assessment of business processes is known as "systems thinking" (Bell et al. 2002). System thinkers know organizations as a network of strengthening and regulating processes (Kim, 1999). The holistic view is necessary the system thinking to analyze, each process should be analyzed in respect to its relation with people and organizations which implement the process and also it would better consider its interaction with upstream and downstream processes (Haines, 2000). This system thinking helps administrators a fuller understanding of system behavior and identifying the events that need to be considered in the risk assessment process (O'Donnel, 2005). The dynamic system modeling is a method that allows a system to be displayed as a feedback system. Forrester (1961) has introduced the dynamic system as a decision-making methodology for industrial management issues.

Modeling of dynamic systems generally follows an iterative approach. In the first step, the variables influential on the problem are identified and then non-numerical model will be drawn, where the system structure is defined and key causal relationships are defined. Causal effect or feedback polarity is explained between elements in the model, this can be positive or negative polarity. Positive polarity indicates that the cause and effect are placed at the same direction and an increase (decrease) in element drawn as cause gives rise to an increase (decrease) in effect. It is contrary to negative polarity. In the quantitative model used in the end by a user, three types of variables are considered, including state, flow and transformer (Ford, 1999). The problem that this article solves is that, first of all, it identifies the types of influential variables in different areas in the space of oil refining projects and shows what the relationship between risks and buffers should be and allows setting buffers.

There are various software options for modeling dynamic systems. VenSim is one of the most powerful software in the field, used for modeling this research. In this paper, the issue of risk management project has been investigated; by using the dynamic system modeling and a case study using the methodology provided in the territory of refineries were analyzed. Using dynamic system is to how to model the problem and as well solving and analysis of case study is presented using sensitivity analysis in the following sections of this article.

3- Dynamic systems modeling and the research variables

In this paper to solve the problem analysis, dynamic system has been chosen as a solution methodology. Steps needed to model and solve the problem by this approach are as follows: 1) study of the problem and determination of its boundary, 2) formulation of dynamic hypotheses, 3) formulation of simulation models, 4) model testing, and 5) sensitivity analysis. Steps 1 and 2 in this section are described and the steps 3, 4 and 5 investigated in Section 3. The simulation model was done by VenSim PLE software.

The factors and variables in the model described above will be divided into three categories: endogenous variables within the model boundaries which producing system dynamic, exogenous variables outside the boundaries, and omitted variables when determining the system boundaries. These variables are shown in table 1, below.

Table 1. Model variables

Endogenous variables	Exogenous variables	Omitted variables
HR in need	Work Release without Considering Quality	Amount of projects ongoing by the organization
Rework	Initial HR Plan	
Provided HR	HR usage Rate for rework	
Total Cost, Quality Control Cost, Training Cost, Facilities Cost, etc.	External Enforcement for precipitation	
Supervision on Contractor	HR Budget Risk	
Tech Installation Problems	Inflation	
Supplied Facilities	Material Shortage Risk	
Facilities in Need	Managerial Capability of Facilities Risk Control	
Total Consumed Material	Facilities Budget Risk	
Supplied Material	Quality Control Level	
Material Shortage Probability	Facilities Reliability	
Total Material In Need	Initial Facilities Plan	
Remaining Materials	Facilities Usage for Rework rate	
Supplied Material	Material Budget Risk	
Material In Need	Initial Material Plan	
Material Loss	Unit Material Usage for Rework	
Mustiness	Contractor Efficiency in Material Usage (Material Loss Percentage	
Tendency to Low Quality Material	Material Usage Rate in Rework	
Weak Relationship	Design Changes Risk	
Initial Wrong Perception of Employer Requirements	Expected Extra Activities of Design Changes	
Planned Activities	Wrong Perception of Employer Requirements	
Total Planned Activities so far	Initial Activities Plan	
Maintenance Planning	Facilities Depreciation	
Performance	Facility Performance	
Performance Rate	HR Performance	
Unavailability of Resources	Material Performance	
Work Release	Error Detection Rate	
Performed Activities - Not Controlled	Error Detection in Controlled Activities	
Performed Activities – Controlled	Weather conditions	
Error Detection	Tech Utilizing Problems	
Reworking Rejected Activities	Training Motivation	
Work Complexity		
Training Planning		
Work Complexity		
Training Planning		
Material Quality		
HR Performance Quality		

4-Formulating dynamic hypotheses

After the introduction of variables that first sub-plot is introduced, then cause and effect diagrams and flow modes are presented in detail.

4-1- The following graph system

A subsystem diagram shows the overall architecture model. The major sub-systems is shown in the diagram and the flow of materials, money, goods, information, etc. between them are determined. As well as it describes some information about the interactions between endogenous and exogenous variables. Fig. 1 shows subsystem is designed for the problem. Fig 1 shows the overall architecture of the system. As can be seen, the main sub-system contains resources (HR, facilities and materials), project activities, training, cost and performed work within the project. The sub-system of resources is influenced by their initial plan, and also risk of funding and finally it determines that the how level of the resources have been supplied during implementing the project and accordingly, activities are performed. In sub-system of performed activities, the work mechanism is modeled and at last what volume the project is indicated to perform successfully at any certain time. The sub-system of activities shows what amount the activities must be performed at any certain time. The various costs of the project are modeled in the sub-system of cost. Personnel training section is modeled as training subsystem, too. Then, using these diagrams, we will examine the overall dynamics. Usually in the diagrams of sub-systems, the dynamics and feedback loops will not be dealt with and the main dynamics and final feedback loops would be described in cause and effect model which constitutes state and flow model. Some of these dynamics are as follows.

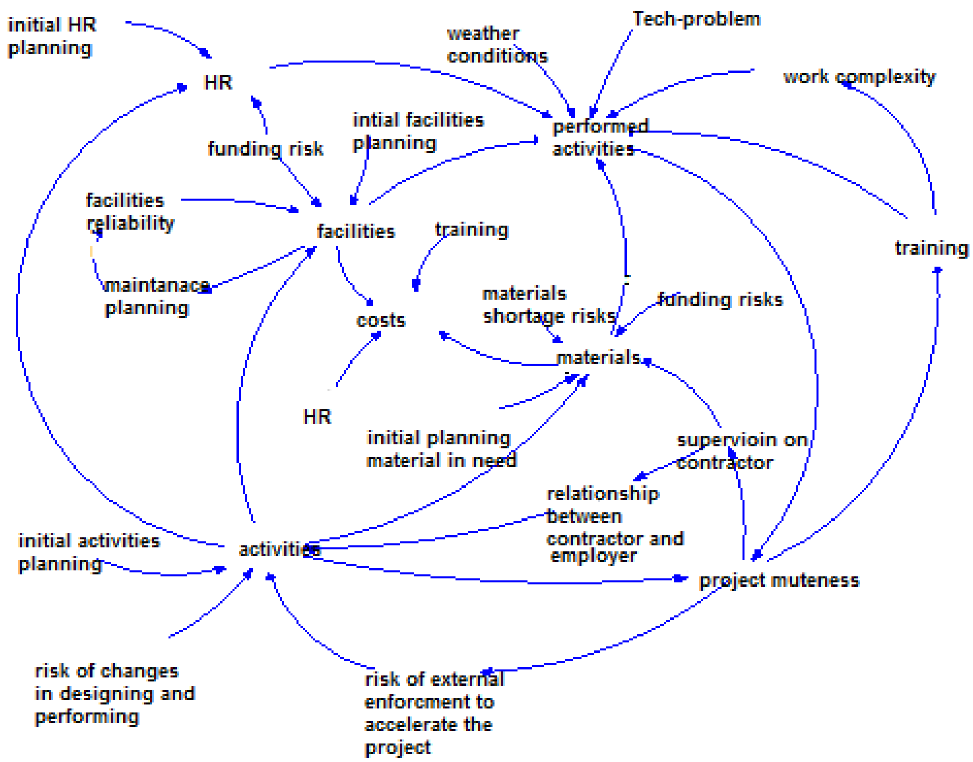

Fig 1. Study sub-system diagram

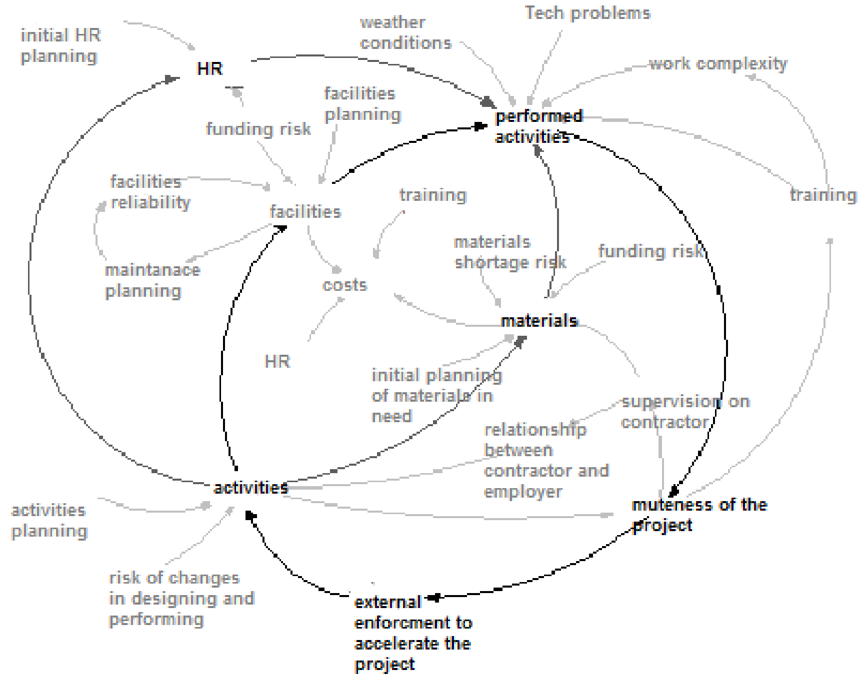

Fig 2. Dynamic of performed activities, muteness of the project, external enforcement to accelerate the project, activities, resources

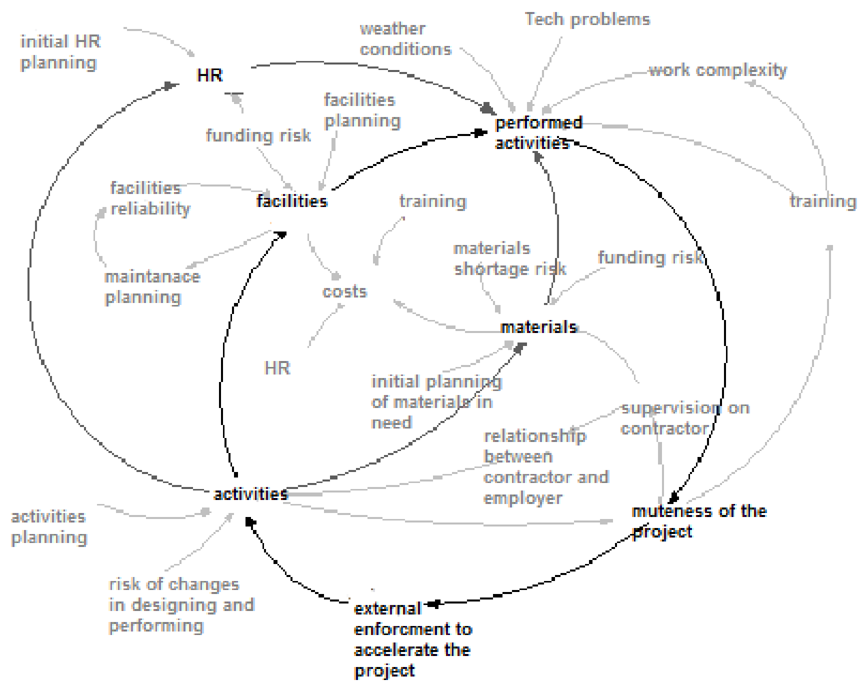

Fig 3. Dynamics of performed activities and enforcement to accelerate the project

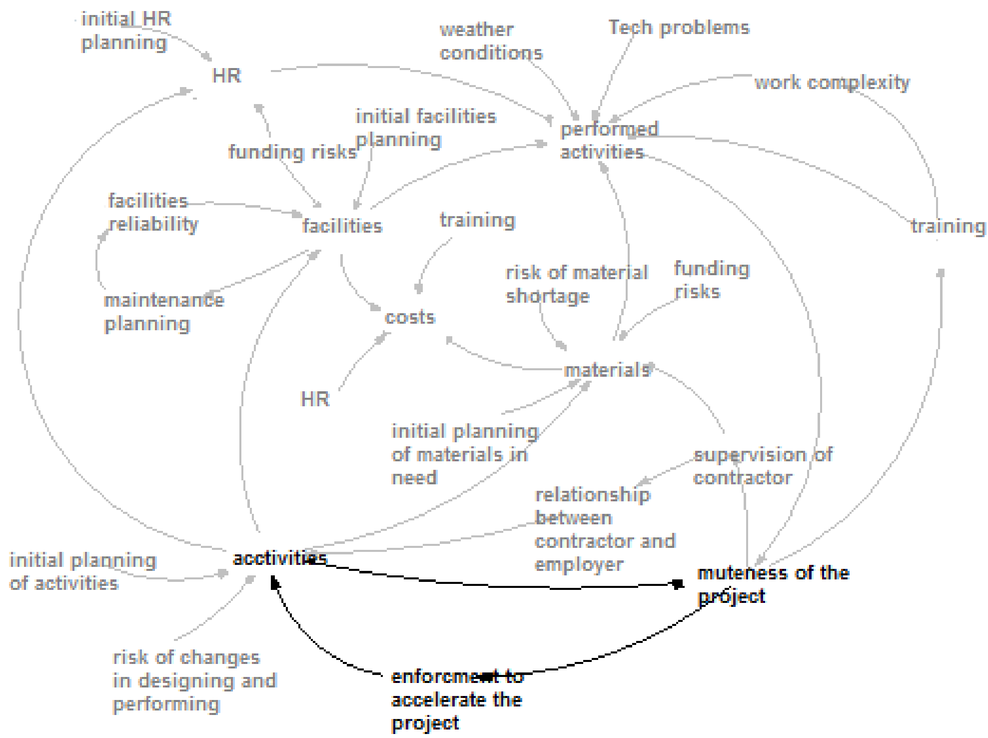

Fig 4. Dynamics of activities and enforcement to accelerate the project

5- State and flow diagrams

This diagram involves some sub-cause-and-effect-diagrams, including: facilities, human resource, materials, performed activities, and costs. Cause and effect diagrams are considered as an important tool showing the structure of feedback system. These diagrams can be used to implement in speed the assumptions relating to the system dynamics, to extract the different mental models of individuals and teams and determine the important feedbacks that produce the problem. A cause and effect diagram consists of variables with an arrow that specifies causal effect between variables. It is also detected in this diagram the important feedback loop.

The causal diagrams are incredibly useful in many situations. These are very suitable for showing dependence and feedback processes. However, these figures have limitations that may make improper use of them. One of the most important limitations is to have no ability of showing the model of flow and state structure of the system. While the state and flow would be two central concepts in the theory of dynamical systems. In fact, the states are considered as accumulations. They indicate the state of the system and provide the information on which it is made decisions and taken action. The variables of state create in memory inertia and it takes over role of the memory. Also, by accumulating the difference between the input and output, it leads to delay. It should be noted that there is a properly understanding of the state and flow and these variables are not used interchangeably.

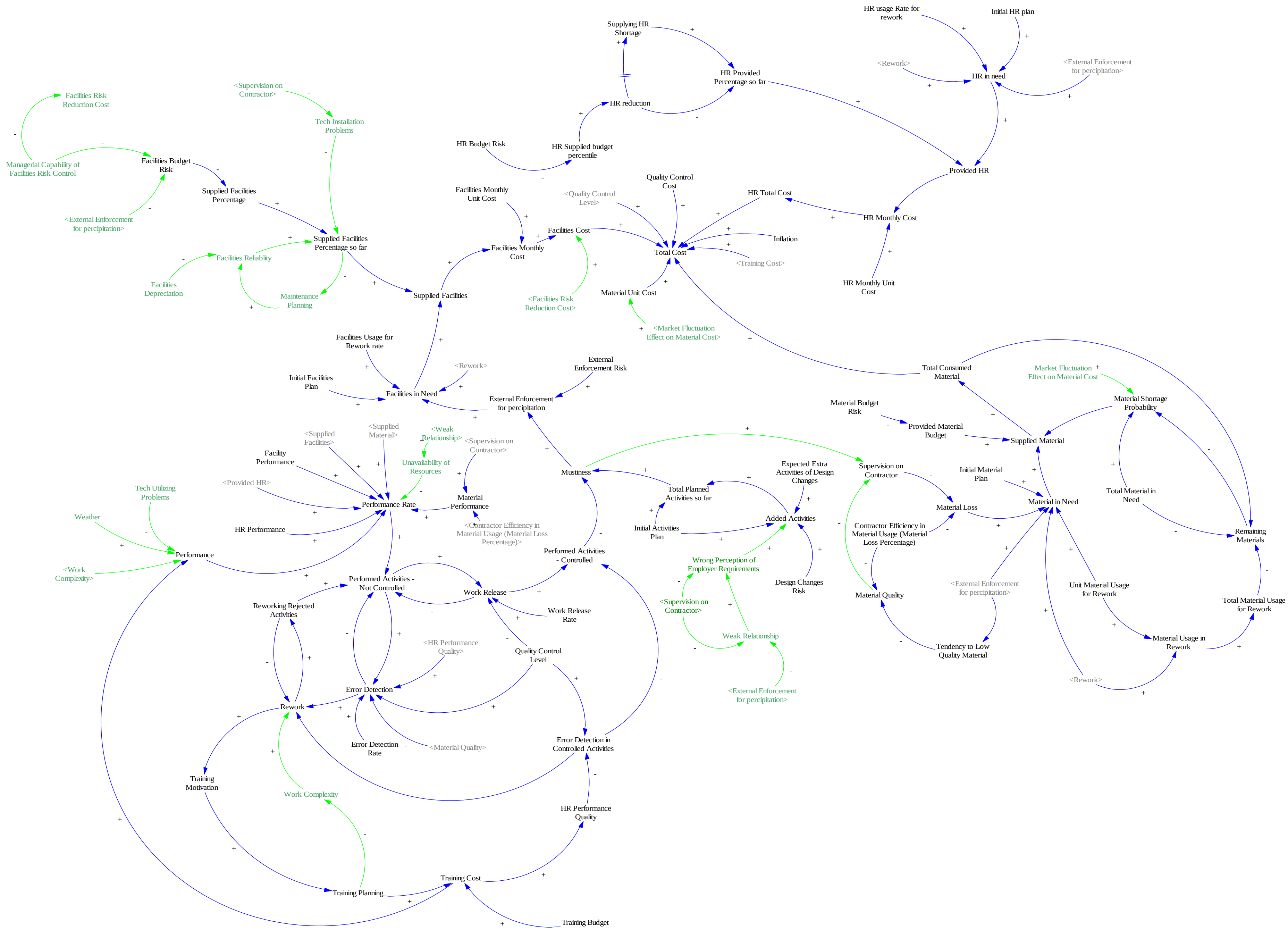

Fig 5. Final cause and effect diagram

In the state diagram, symbols besides ones used in the cause and effect diagram are employed: the states are displayed in the form of a rectangle, the input flow, by a tube (arrow) that appears to be out of state, valves control the flows, and clouds represent sources and sinks of our flows. A source revealed that a stream comes from outside the model boundaries. The sinks indicate that internally accumulated within the state exit by the output flow from the model boundary. The sources and sinks will have unlimited capacity. Table 2 shows the variables of state and flows in the model. In following, the state and flow diagram are provided.

Table 2. State and flow variables

Flow variables	State variables
Supplying HR Shortage	HR Provided Percentage so far
HR reduction	HR Total Cost
HR Monthly Cost	Facilities Cost
Facilities Monthly Cost	Total Planned Activities so far
Activity Plan	Enforcement Effect
Enforcement	Total Material Used in Rework
Material Usage in Rework	Performed Activities - Not Controlled
Performance Rate	Performed Activities – Controlled
Work Release	Rework
Reworking Rejected Activities	
Error Detection	
Error Detection in Controlled Activities	

6- State and flow simulation

The state and flow diagram is depicted as below, figure 6. State and flow diagram for performing activities is the most significant part of the problem, showing doing work. This includes 3 variables of state. First, done works but not controlled. Second, speed of doing work, and third, reworking rejecting activities. In this part, it is reworked and converted to the done but not controlled activities, as shown in figure 6.

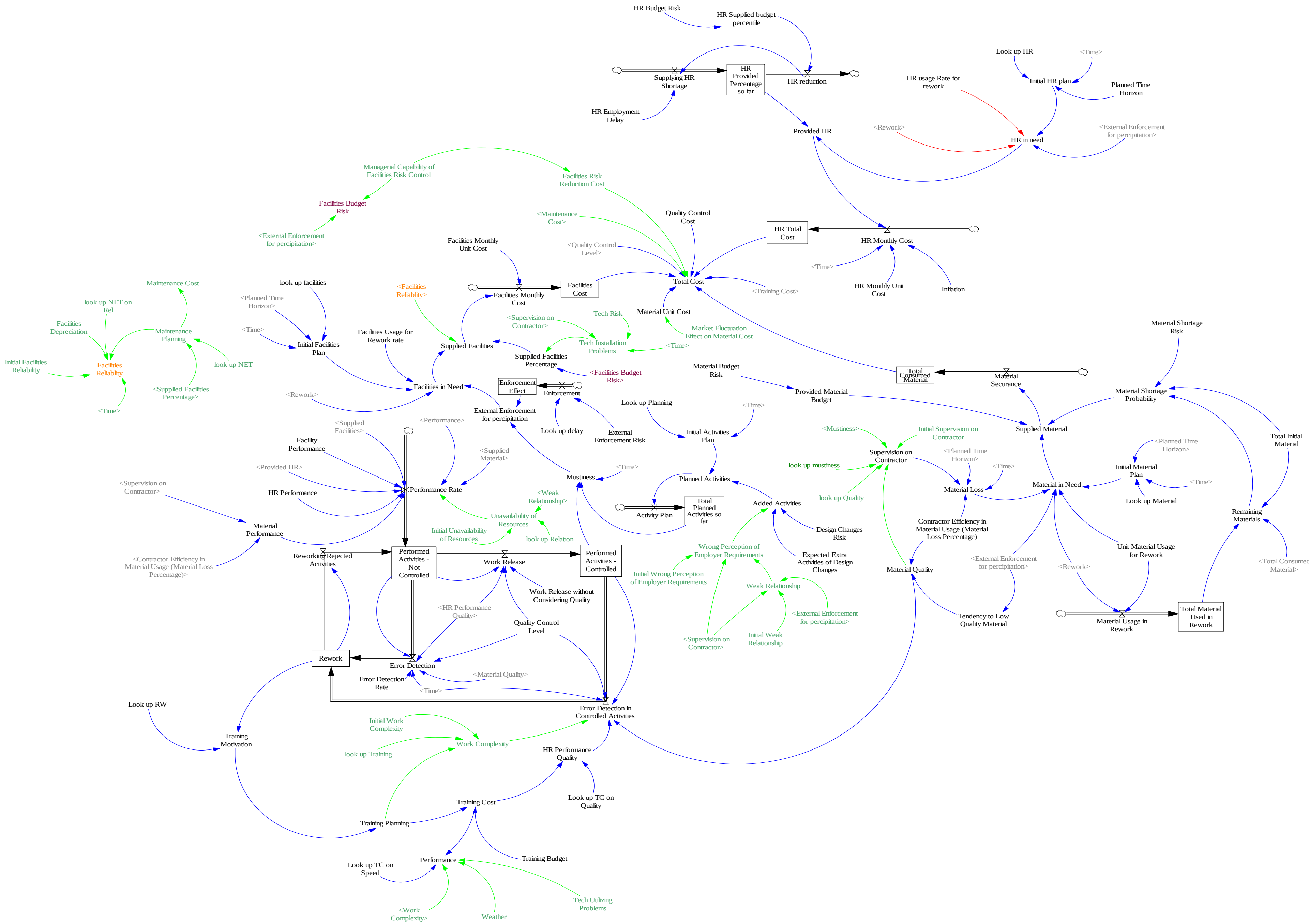

Fig 6. Simulation of state and flow diagram

Also the most important of the problem diagram of state and flow of performing activities. It includes 3 variables of state, including: Provided HR ،Supplied Material و Supplied Facilities shown in figure 7.

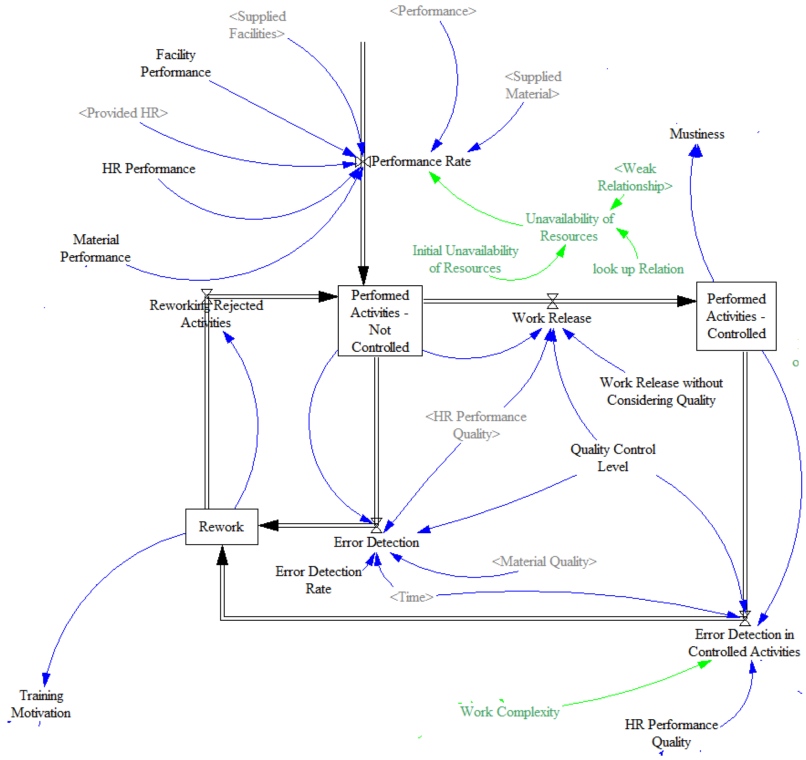

Fig 7. State and flow diagram of performing activities

7- Math formulae

In this section, a number of equations used in the state and flow variables of the model are expressed:

Table 3. State and flow variables

Flow variables	Equations
Supplying HR Shortage	HR reduction, HR Employment Delay .0
HR reduction	HR Supplied budget percentile-1
HR Monthly Cost	(1+Inflation)^Time * HR Monthly Unit Cost *Provided HR
Facilities Monthly Cost	Supplied Facilities*Facilities Monthly Unit Cost
Activity Plan	Planned Activities
Enforcement	Look up delay(External Enforcement Risk)
Material Usage in Rework	Unit Material Usage for Rework*Rework
Material in Need	(Initial Material Plan + Material Loss) + (Rework*Unit Material Usage for Rework)* External Enforcement for percipitation
Performance Rate	(Performance * (MIN(Supplied Facilities*Facility Performance, MIN (HR Performance*Provided HR , Material Performance *Supplied Material)))) * (1-Unavailability of Resources)
Work Release	((Quality Control Level + HR Performance Quality)/ 500+ Work Release without Considering Quality) *"Performed Activities - Not Controlled"
Reworking Rejected Activities	Rework
Error Detection	((Error Detection Rate + (15- Quality Control Level + Material Quality + HR Performance Quality) / " * (500 Performed Activities - Not Controlled") * (MAX(0,(60-Time)/60))
Error Detection in Controlled Activities	(30-Quality Control Level + Material Quality + HR Performance Quality) / 1000* "Performed Activities Controlled")* (1+Work Complexity))*(MAX(0,(60-Time)/((60

Table 4. State and flow variables

State variables	**Equations**
HR Provided Percentage so far	Supplying HR Shortage-HR reduction
HR Total Cost	HR Monthly Cost
Facilities Cost	Facilities Monthly Cost
Total Planned Activities so far	Activity Plan
Enforcement Effect	Enforcement
Total Material Used in Rework	Material Usage in Rework
Performed Activities - Not Controlled	Reworking Rejected Activities + Performance Rate-Work Release-Error Detection
Performed Activities – Controlled	Work Release-Error Detection in Controlled Activities
Rework	Error Detection in Controlled Activities + Error Detection-Reworking Rejected Activities
Material Provided	Supplying Material Shortage-Material Shortage

8. Numerical results and analysis

In this section, the research case study is considered. This deals with the formulation of simulation models and then tests and verifies the validity of the model and the results have been provided.

8-1- Formulating simulation model

All parameters need to be defined for the model implementation of date collected from constructing refinery project. There are 117 variables in the model, resulting in 117 mathematical relations to define. Since this article is not able to provide all these relations. The overall result of these relations will be explained. The risk values in the model are considered in two ways. The first method is to apply the amount of risk directly that the expected risk is substituted in the model and this risk with regard to the expected impact was model. The second method uses statistical distribution function in the risk modeling. Using two methods are reasoned to introduce different ways in entering the risk and also demonstrate the ability of the chosen approach in dealing with both of these methods. In explaining some relations, specifying an exact mathematical relation is not possible. Faced with such problems, the software VenSim allows the user to define optional function for the relation. Using of collection of data that defined in an interview by the specialist and expert of the subject, an approximate function is defined as a point; this function is used as the relation between two variables. All relations would be define and explained using the concepts, and the parameters have included in the model.

8-2- Testing and authentication model

In this section to test the model, the data collected of the 15 months of actual project was compared with simulation corresponding values during the same period. Because of the limited information that can be collected, we compared diagram of activities finished over the 15-month project with the same amount i.e. Performed Activities - Controlled, the results are shown in figure 7.

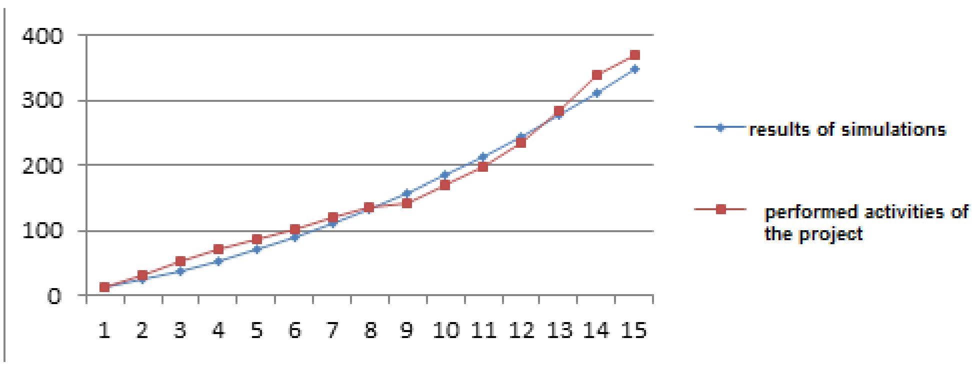

Fig 8. Simulation results against actual results

Pearson correlation test was performed on the data and the results are as follows.

Table 3. Pearson correlations at significance level of 0.01 (2-tailed)

		VAR00001	VAR00002
VAR00001	Pearson Correlation	1	.992(**)
	Sig. (2-tailed)		.000
	N	15	15
VAR00002	Pearson Correlation	.992(**)	1
	Sig. (2-tailed)	.000	
	N	15	15

As can be seen, there is a very high correlation between the data. As a result, we can ensure that the network has been created can well predict reality and its outputs can be trusted as good extent as possible.

8-3- Model solutions

There are 3 variables human resource, facilities and materials that are compared with 3 criteria, including comparison of actual values with planned values, buffer values and buffer in percent.

A. Human Resource (HR)

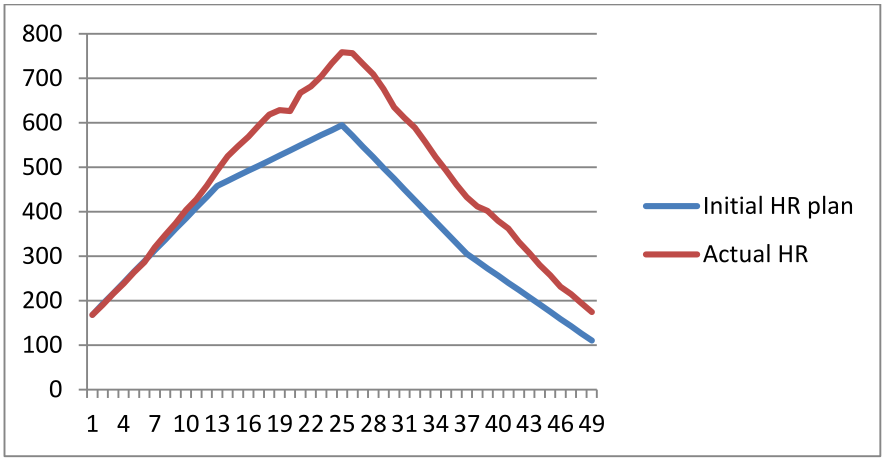

Fig 9. Needed HR compared with planned value

As figure 9 shows, the planned amount of HR is denoted with the blue line and the value predicted by the model, with a red line. At first, the predicted value is slightly less than the planned, but in the rest, the difference becomes greater. Figure 6 shows the difference.

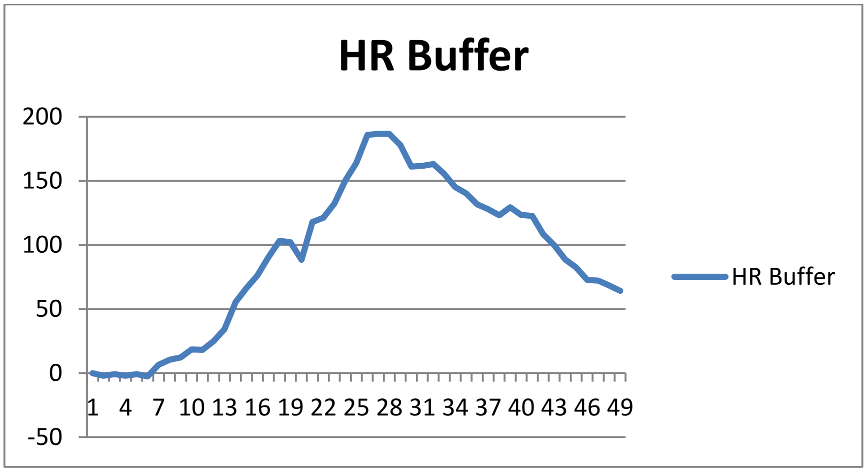

Fig 10. Buffer of HR

The above graph indicates that at any time during the project how much HR will be reduced or added. The graph below is in percent.

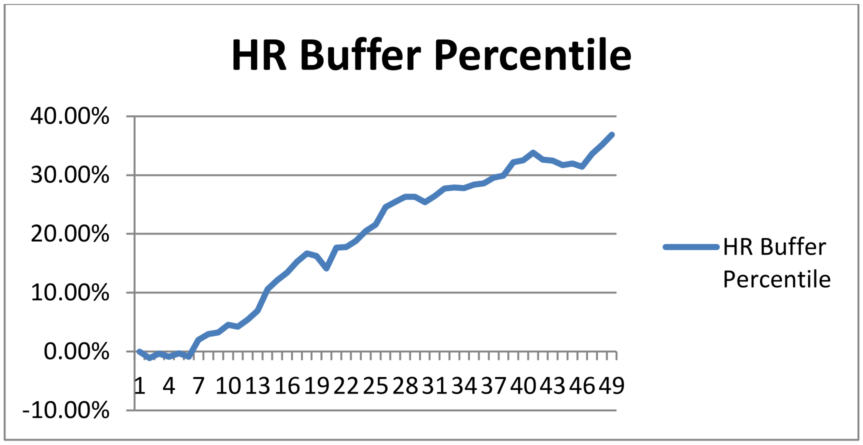

Fig 11. HR buffer in percent

As seen in figure 10, unlike the previous one, this shows an increasing trend from the beginning to the end of the project. In fact, declining buffer did not show a better functional status. But also reduction of HR required at the end of the project reduced the expected staffing levels, while the percentage of compliance of the program with the anticipated gets reduced continuously over time.

B. Facilities

Figure 11, it is related to the initial application of facilities (blue line) and the value predicted by the model (red line). As seen, the pattern of predicted facilities follows the early plan by the model.

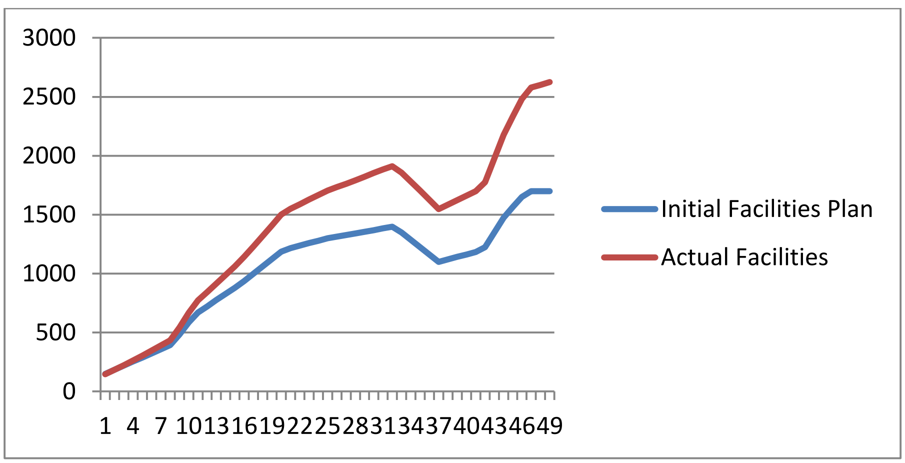

Fig 12. Required facilities compared with the planned

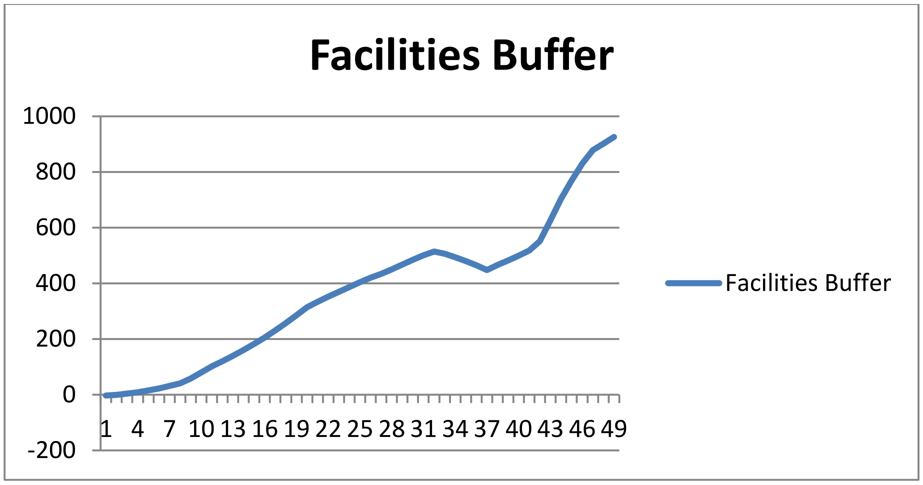

Fig 13. Facilities buffer

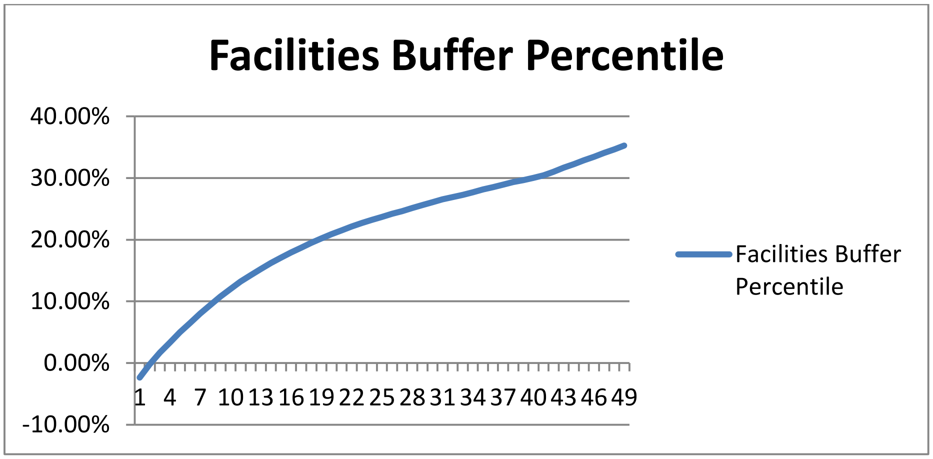

Fig 14. Facilities buffer in percent

The remarkable thing about the facilities, the buffer required (figure 13) also follows the pattern of initial application of facilities. The percentage of compliance of initial application with the anticipated is shown in figure 10, first it is under further slope increased and then its slope gets balanced. However, this slope is slightly proportional one to the trend of buffer value.

C. Materials

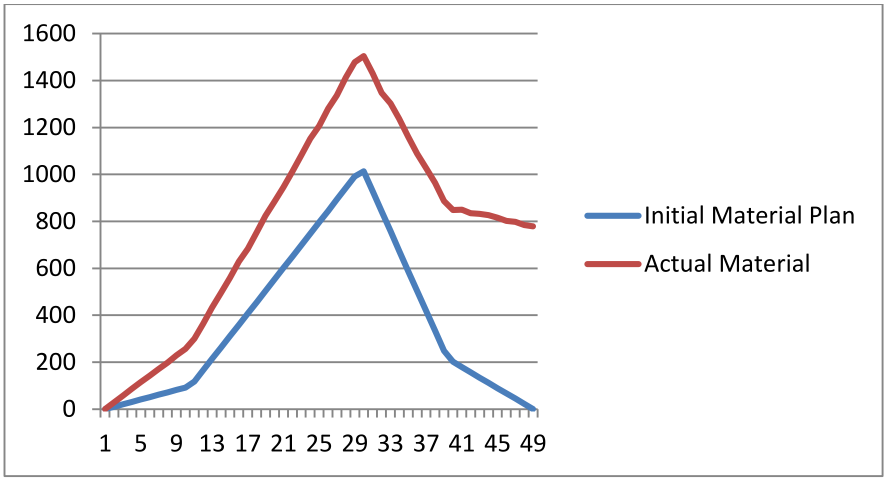

Fig 15. The needed materials compared with the planned

This follows the initial plan trend under expected situation, as seen in next one, the amount of materials bugger gets raised over the time.

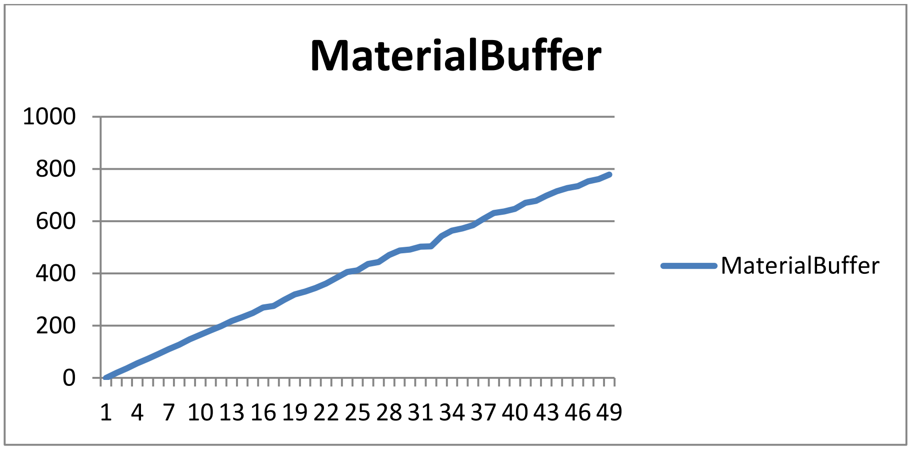

Fig 16. Material buffer

Unlike other resources, the value of the material buffer increases linearly and don't follow the initial plan. This is related to the discussion on the elimination of the materials (figure 15).

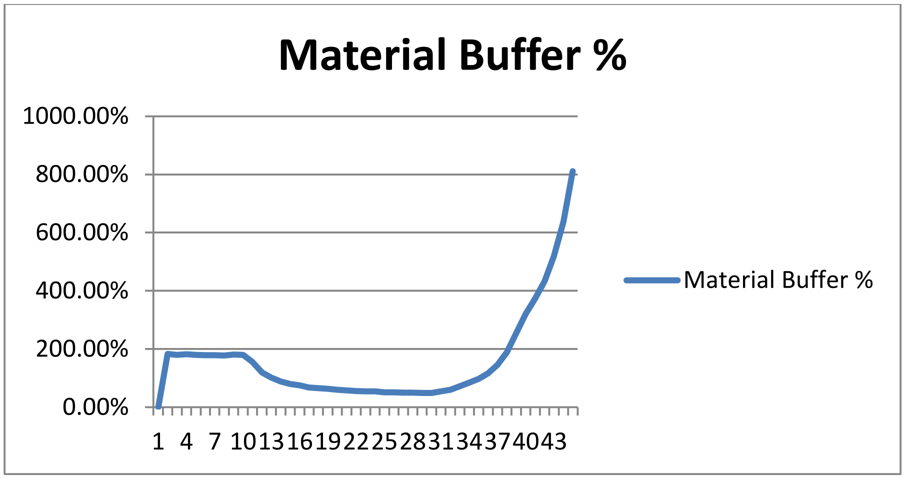

Fig 17. Material buffer in percent

Figure 13 shows the percentage of difference between the predicted value and the planned. During the first few months, this amount is increasing. Then improving mechanisms operate to improve the situation. Finally, due to a sharp increase in this percentage, the initial plan tends towards zero that makes the denominator extremely small, and this percentage increases exponentially.

9- Sensitivity analysis

In this section we will review and discuss the parameters of the model under different conditions. The software VenSim, a tool called SyntheSim in Model menu provides the opportunity for the user by changing any parameters (the fixed variables and the variables defined as (Look up)) to observe the effect of this change on model. In other words, this means that after the slightest change in any parameter, the model is again simulated and the results immediately are show. In the rest of this section, the model's sensitivity to the existing risks in the model is discussed. There 6 risks, including: HR Budget Risk, Material Budget Risk, Facilities Budget Risk, External Enforcement Risk, Tech Risk, and Work Complexity.

A. The effect of the change in the HR budget risk on 7 sub-systems was drawn as follows. The following figures show the results of the model with these values.

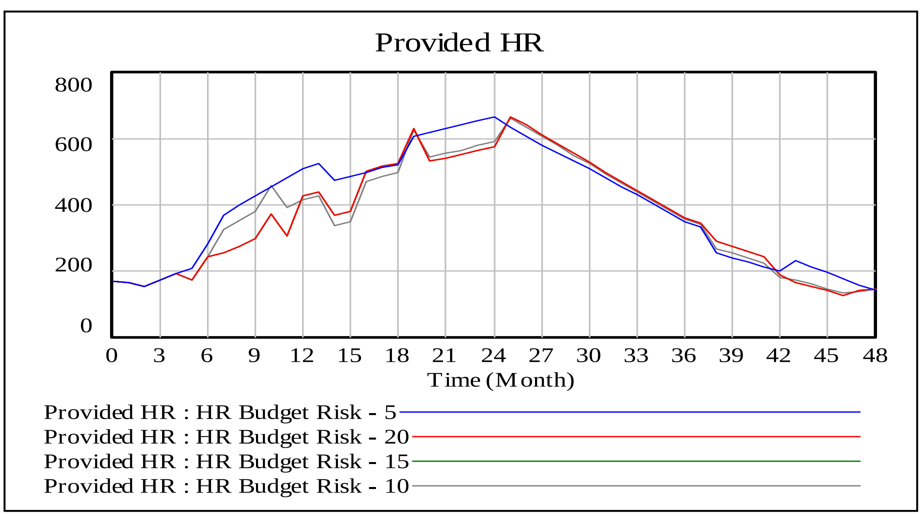

Fig 18. Provided HR to changing HR budget risk

As an important point on the same projects it can be concluded that in the case of high-risky human resources budget in a project, it requires that this be controlled early in the project by the management team and executed that the adverse effects caused by this risk to get reduced on the projects.

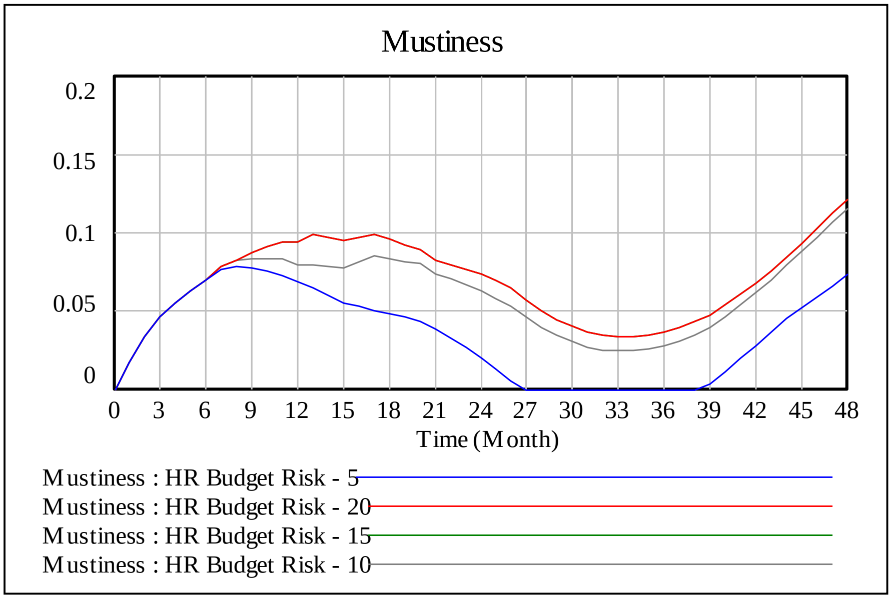

Fig 19. Muteness in project to changing HR budget risk

Increased HR budget risk has a significant impact on the muteness and then maintaining a low risk HR budget will be very useful in timely project, also that the management and executive teams should be recommended that if low HR budget risk, they pay special attention to maintaining low, because if it increases slightly, the muteness will have a significant change. In contrast, if the risk is high, it is recommended that the management team spend more energy and resources to other factors improving the status of the projects.

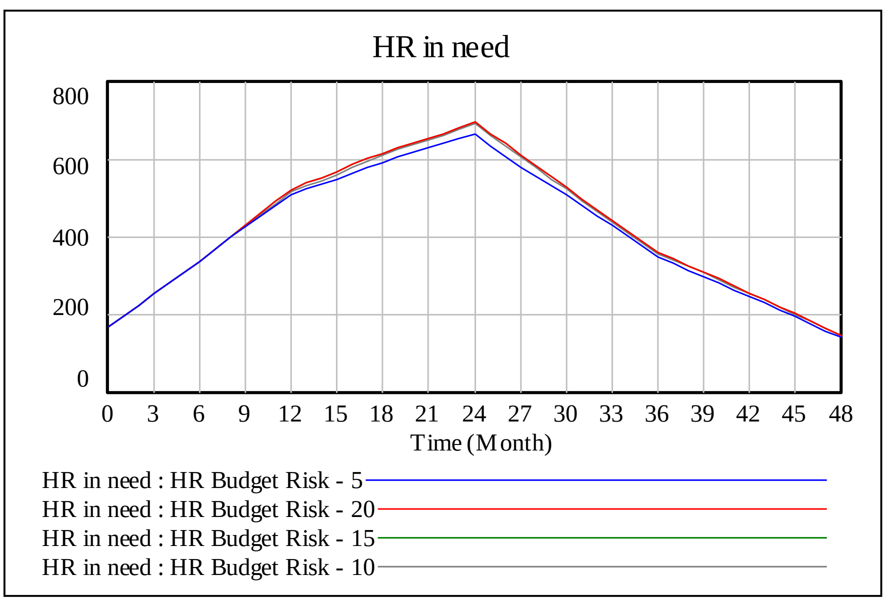

Fig 20. HR in need to changing HR budget risk

As can be seen, the risk increasing over time increases the amount of HR required. This is due to the muteness of the project and the created pressure to accelerate the project.

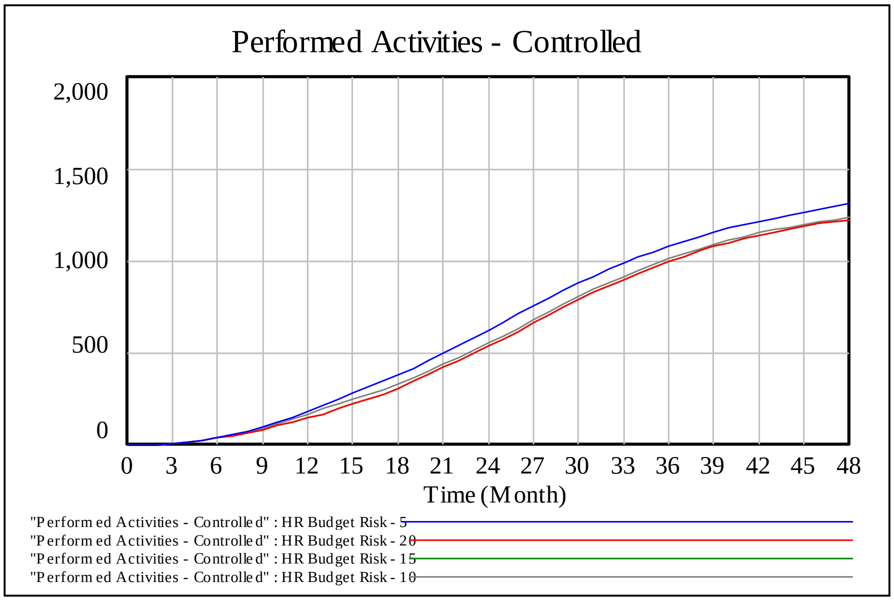

Fig 21. Performed-controlled activities to changing HR budget risk

Low-risk HR budget eventually leads to do work faster; and more controlled and performed activities over time are seen in higher levels of the risk.

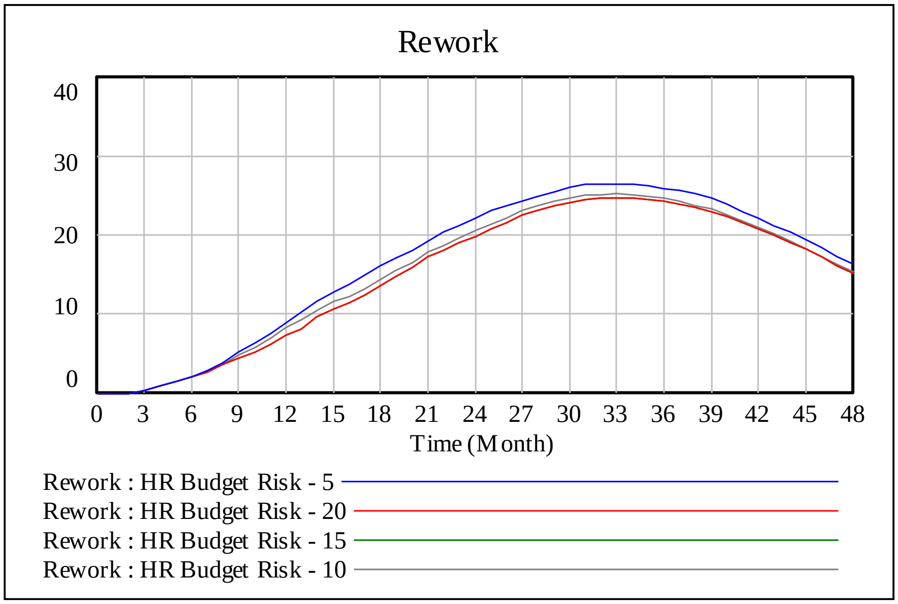

Fig 22. Rework to changing HR budget risk

The lower levels the risk, the greater the amount of work needs to be performed again. Also higher sensitivity is observed at low levels of risk.

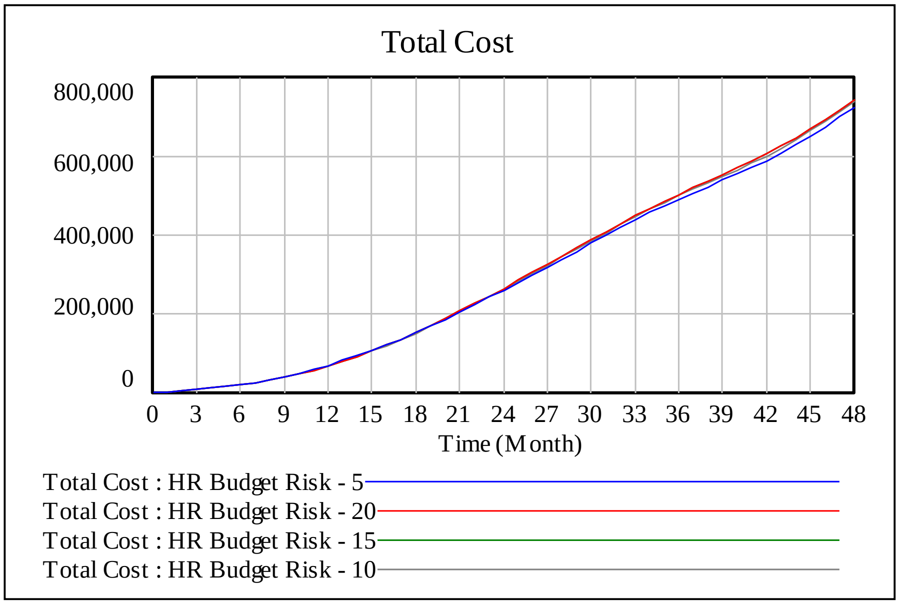

Fig 23. The total cost to changing HR budget risk

The lower level the risk, the lower the total cost of HR budget observed. Failure to provide HR budget being reduced staffing and as a result, operating costs of the project thus reduce staffing. But due to the muteness of the project and other risk factors affecting the cost of the project, contrary to what at first may be perceived, it increases the total cost of the project.

B. Material Budget Risk

This section examines the impact of changes in materials budget risk on the model.

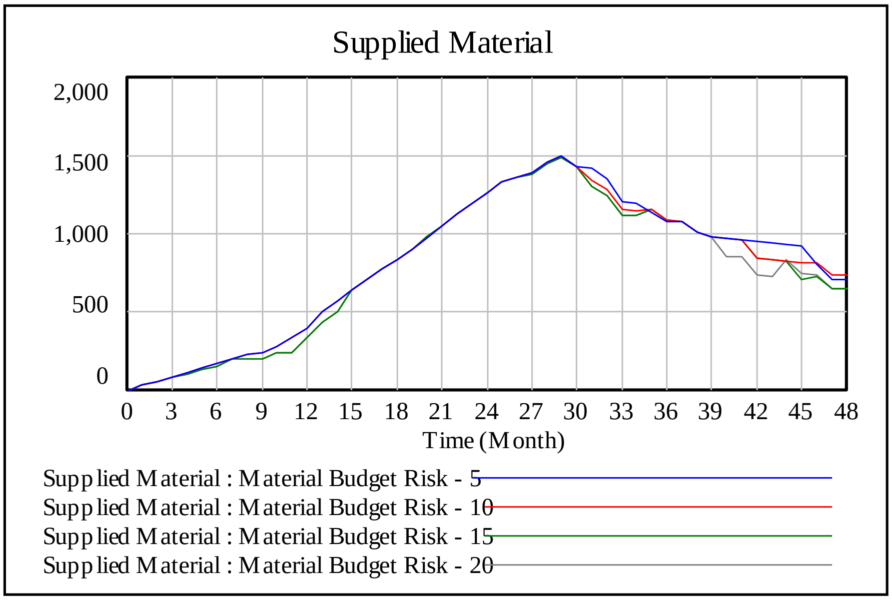

Fig 24. Supplied materials to the materials budget risk

Figure 24 shows the volume of materials supplied of different level of materials budget risk. As shown, the impact of this risk on the supplied materials is less than on the human resources. As a result, it is suggested that the management at the end of project have paid greater attention to funding material budget. It is due to the primary suppliers of materials at the beginning of the project.

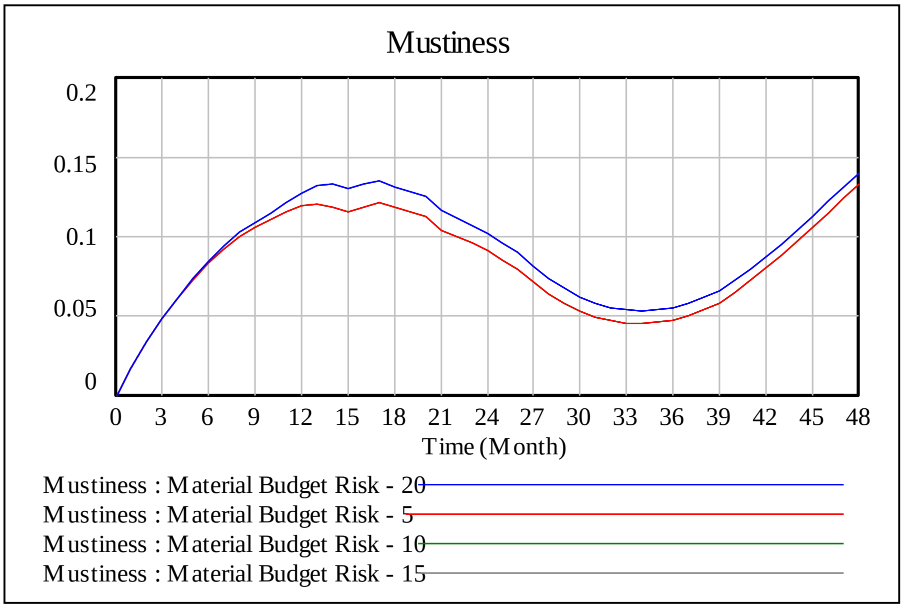

Fig 25. The muteness of project to the material budget risk

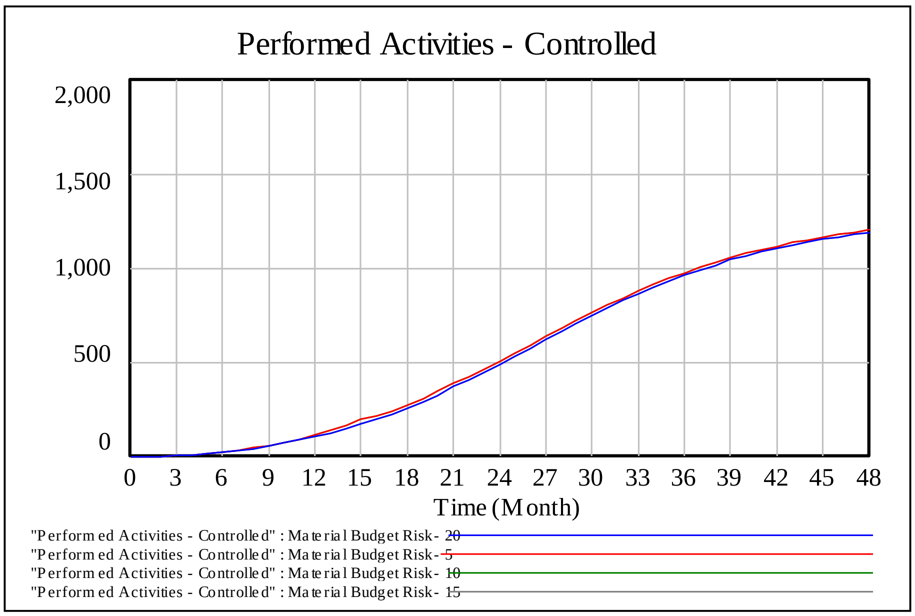

Fig 26. Performed and controlled activities to the material budget risk

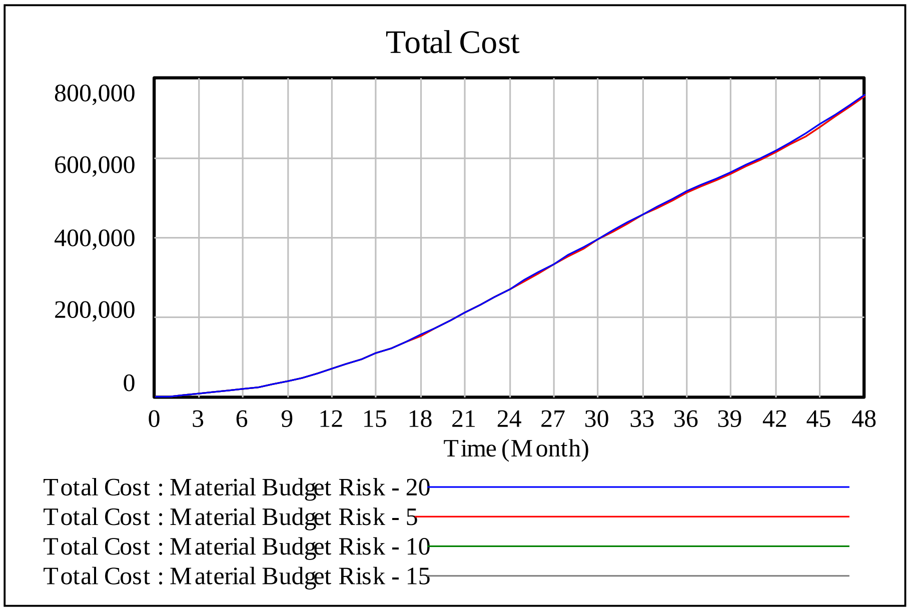

Fig 27. The total cost to the material budget risk

It has no significant impact on the variables except muteness of project. As a result of the conditions defined for the project, the material budget risk will not be sensitive matter and it is controlled up to 20%. This is again the result of the primary suppliers of materials at the beginning of the project.

C. Facilities Budget Risk

This section examines the impact of changes in facilities budget risk on the model.

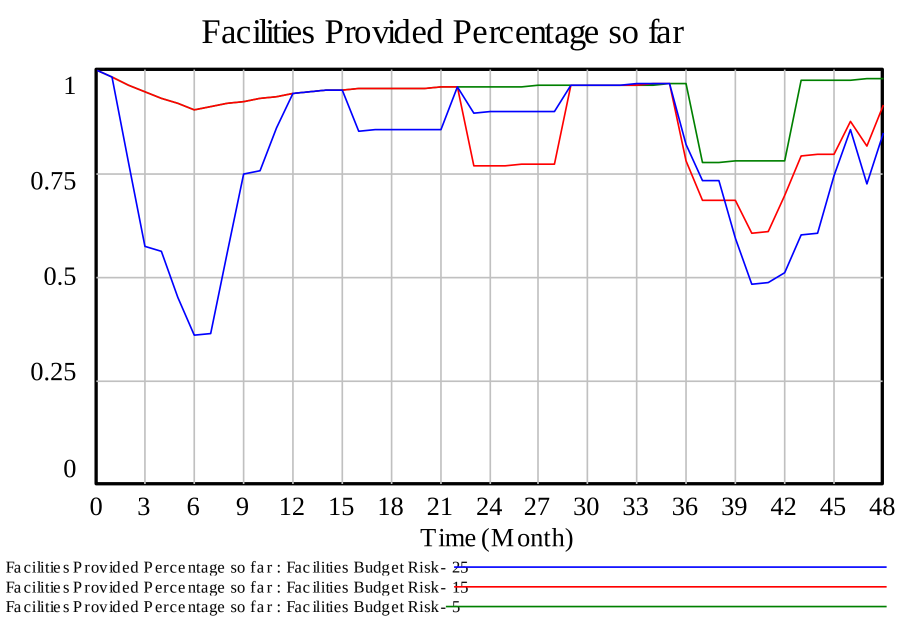

Fig 28. Percentage of supplying facilities so far to the facilities budget risk

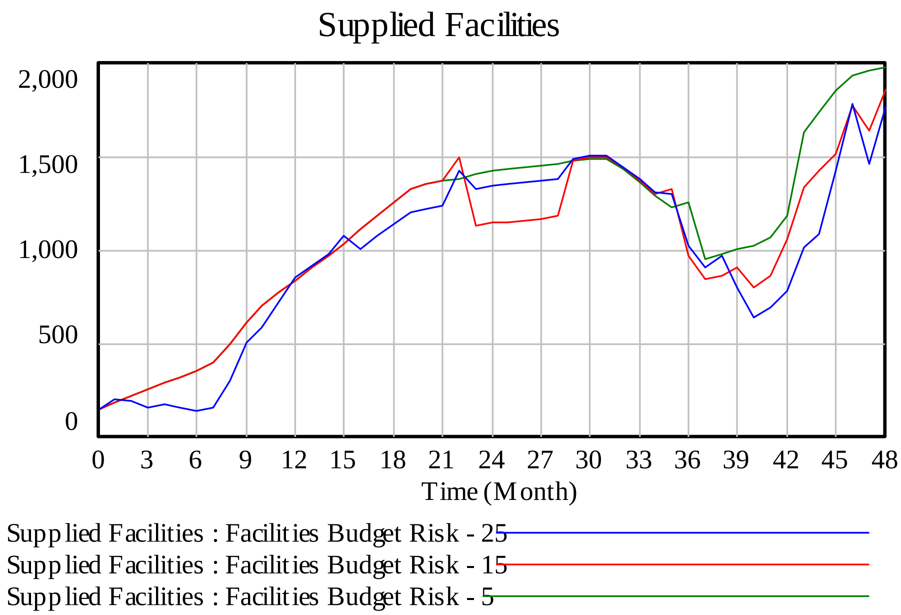

Fig 29. Supplied facilities to the facilities budget risk

There is a significant point in this Fig. While supplying facilities percentage has been further reduced at the beginning of the end of the project (Fig Supplied Facilities Percentage so far), the effect on Supplied Facilities can be more found at the end of the project. This is definitely due to reduced reliability of the facilities at the end of the project. As a result, the project sensitivity to risk in the facilities budget will be higher and need for greater control at the end of the project.

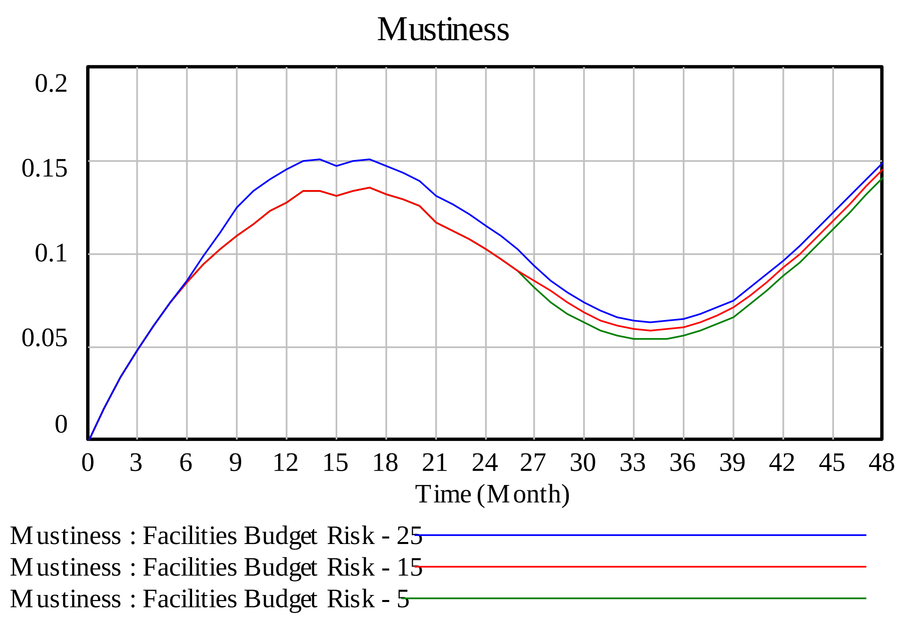

Fig 30. Muteness of the project to the facilities budget risk

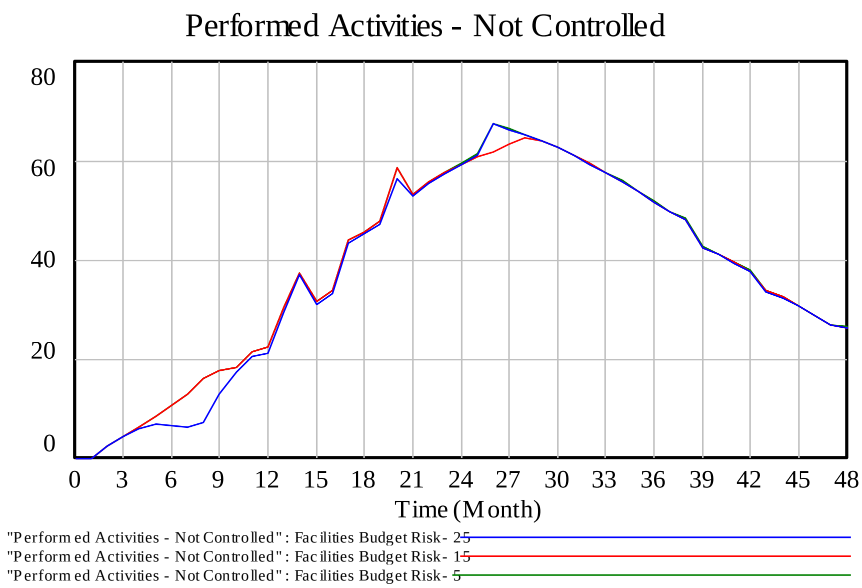

Fig 31. Performed and uncontrolled activities to the facilities budget risk

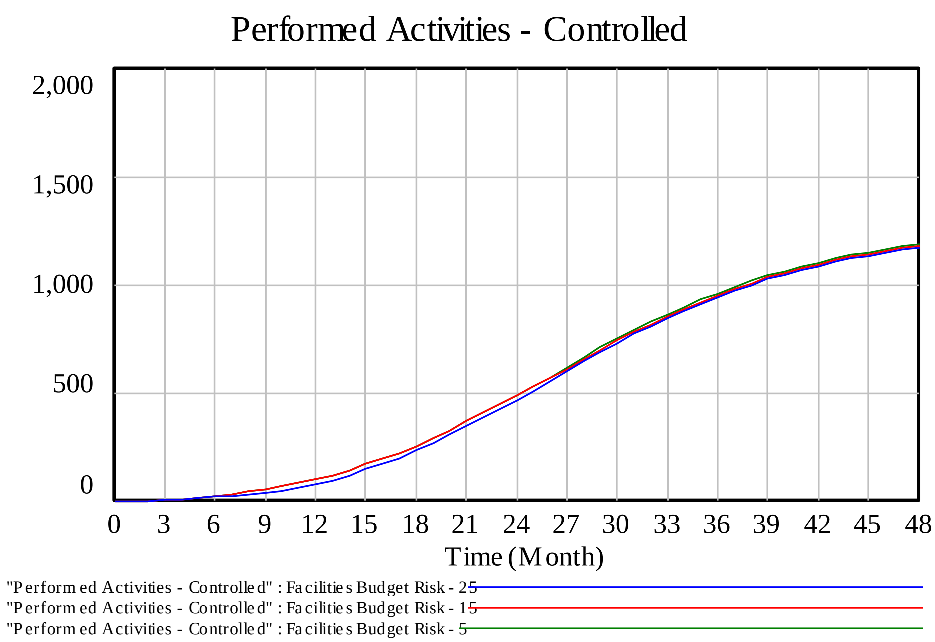

Fig 32. Performed and controlled activities to the facilities budget risk

Notably, there is a considerably point in performed and uncontrolled activities. As stated at the beginning and end of the project, the level of supplied facilities significantly reduced, under effect of the facilities budget risk. But only at the beginning of the project, this will affect the performed and uncontrolled activities. This is due to two other sources. According to the project activities and resources required at different levels, this variable is more sensitized to the facilities at the beginning and less, at the end.

D. External Enforcement Risk

The external enforcement risk is considered in the model.

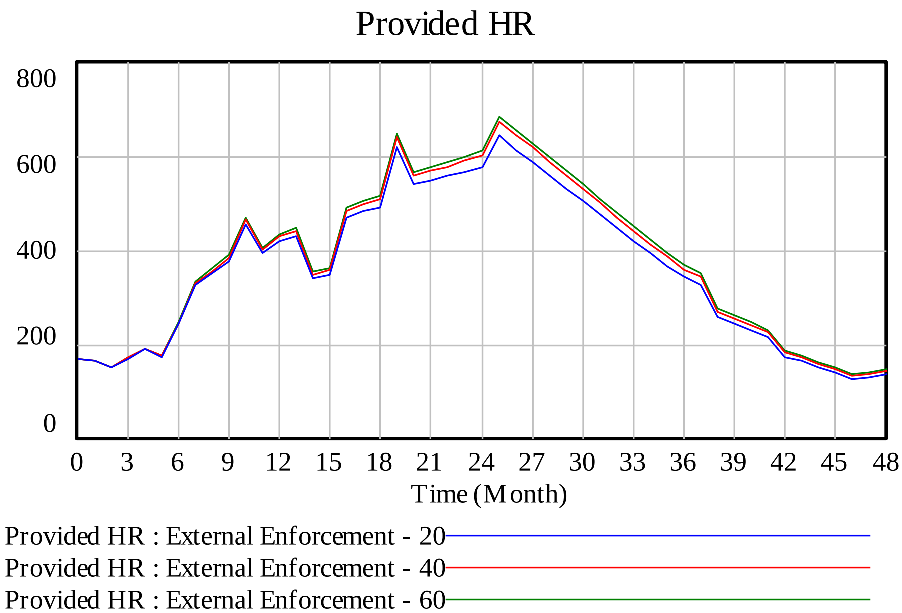

Fig 33. Supplied HR to the of external enforcement risk to accelerate the project

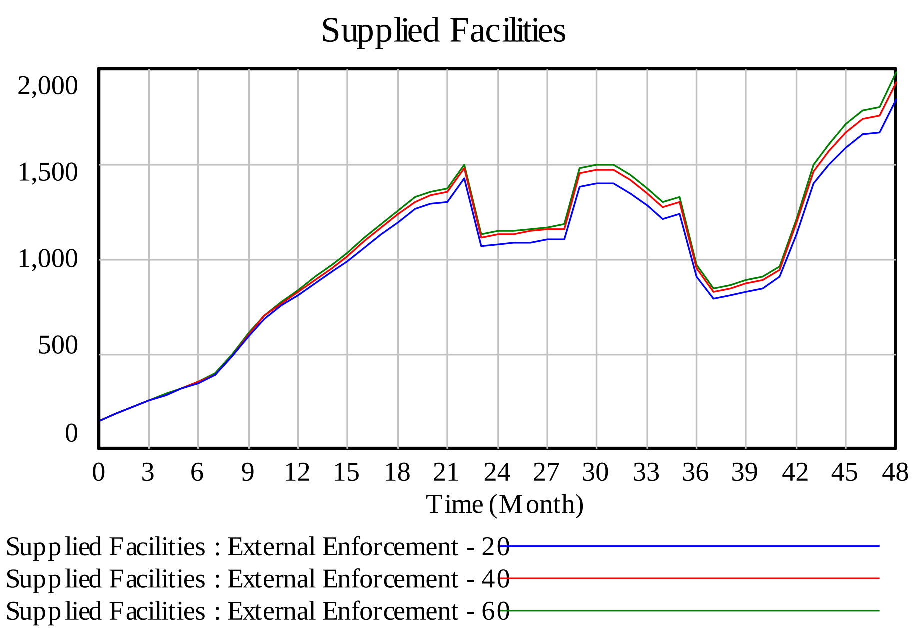

Fig 34. Supplied facilities to the external enforcement risk to accelerate the project

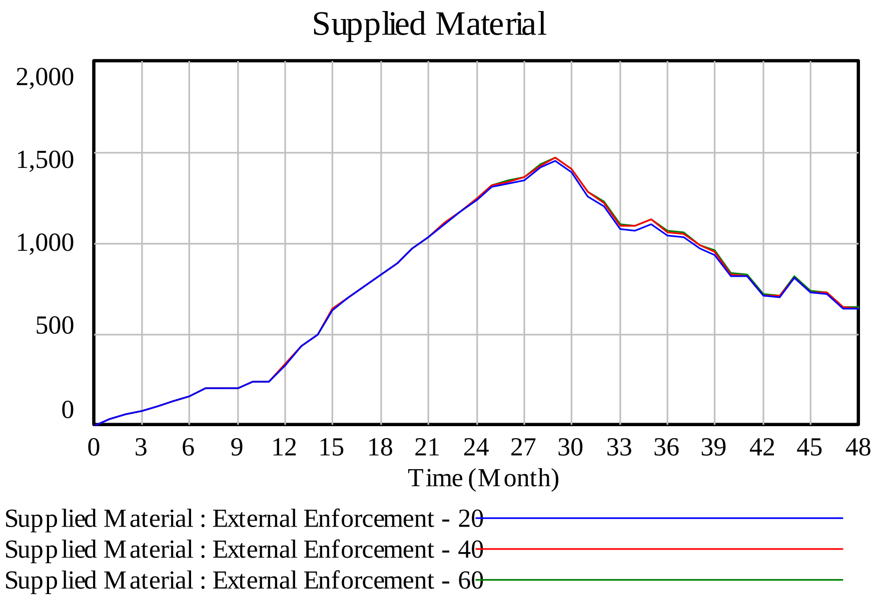

Fig 35. Supplied materials to the external enforcement risk to accelerate the project

Noted that, according to these figures, when the risk increases of 20% to 40%, we can see significantly increase in the amount of resources needed. But when 40% to 60% increased risk, it increases much smaller than 20 to 40% one. As a result, it can be concluded that keeping down the risk in a project can be very beneficial.

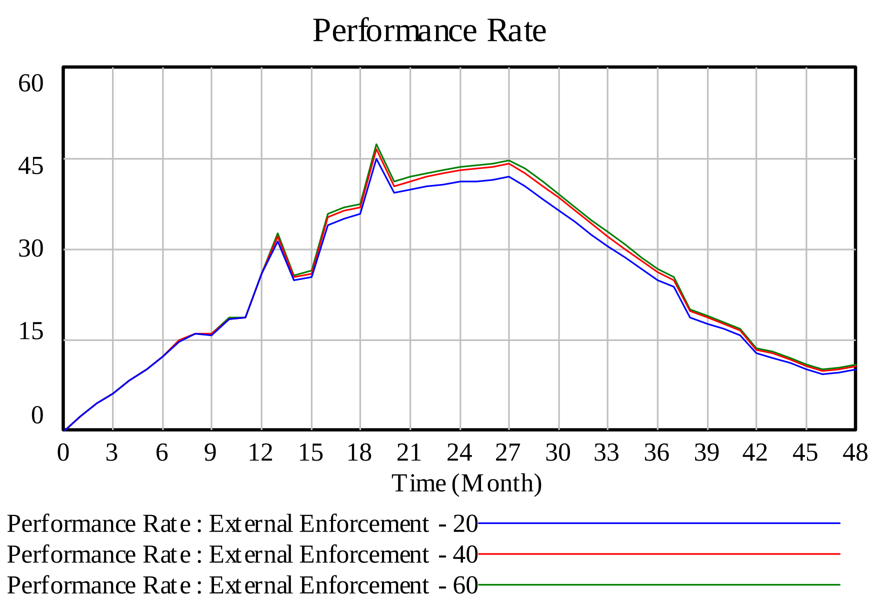

Fig 36. Rates of performed activities to the risk of external enforcement to accelerate the project

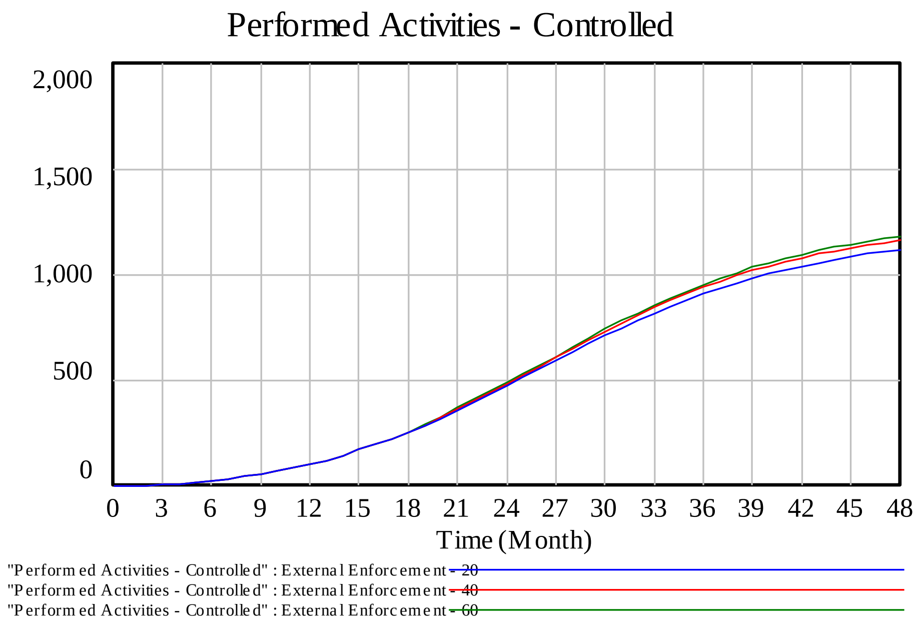

Fig 37. Performed and controlled activities to the risk of external enforcement to accelerate the project

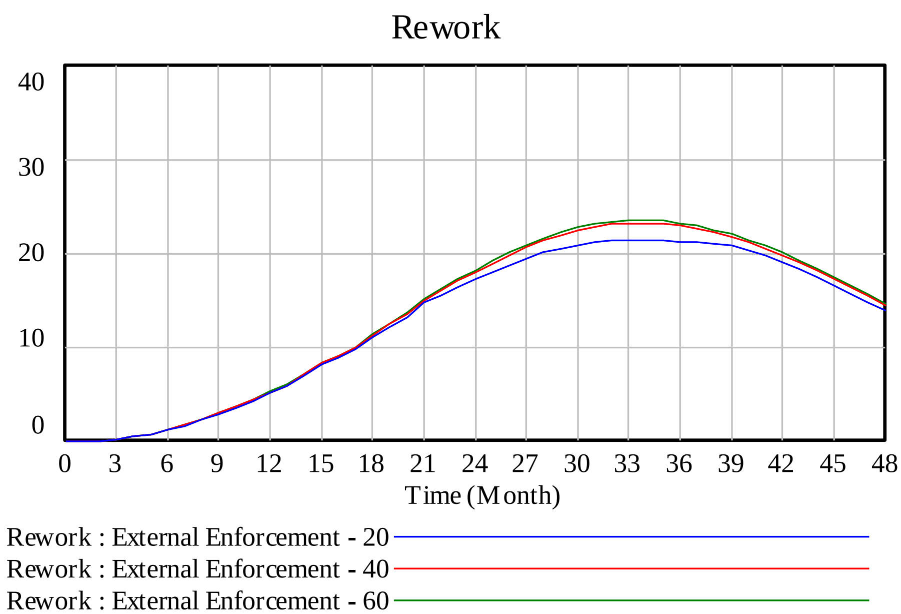

Fig 38. Rework to the risk of external pressure to accelerate project rework

As expected with an increased risk of accelerating the project, activities were carried out faster and they get more performed at a certain time and discharged. The sensitivity of the rework goes up at lower risks and the greater the risk, the lower, the sensitivity is.

E. Tech Risk

In this section we analyze the model sensitivity to risk technology problems. The results of the model with the values obtained as follows.

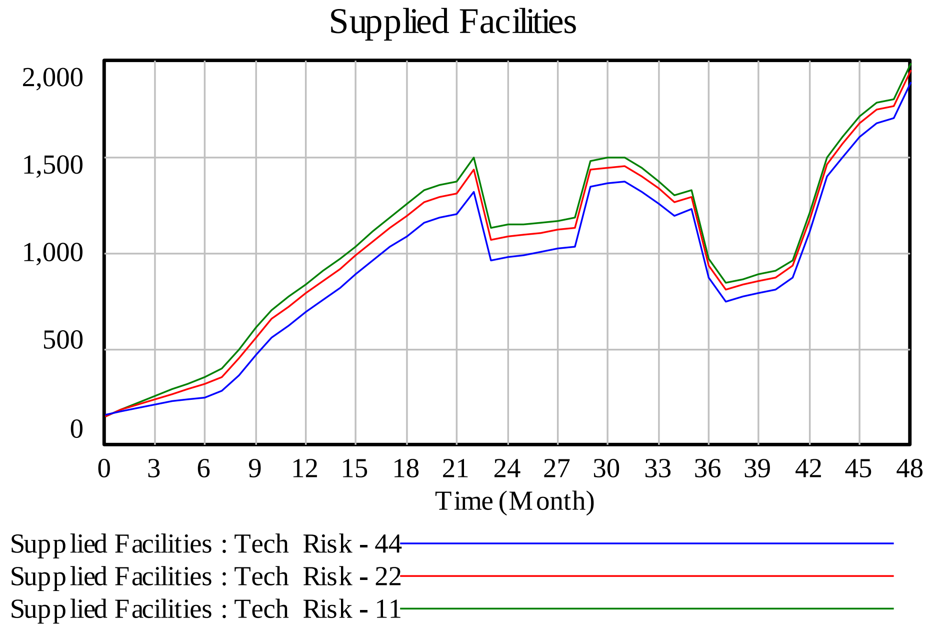

Fig 39. Supplied facilities to the risk of technology problems

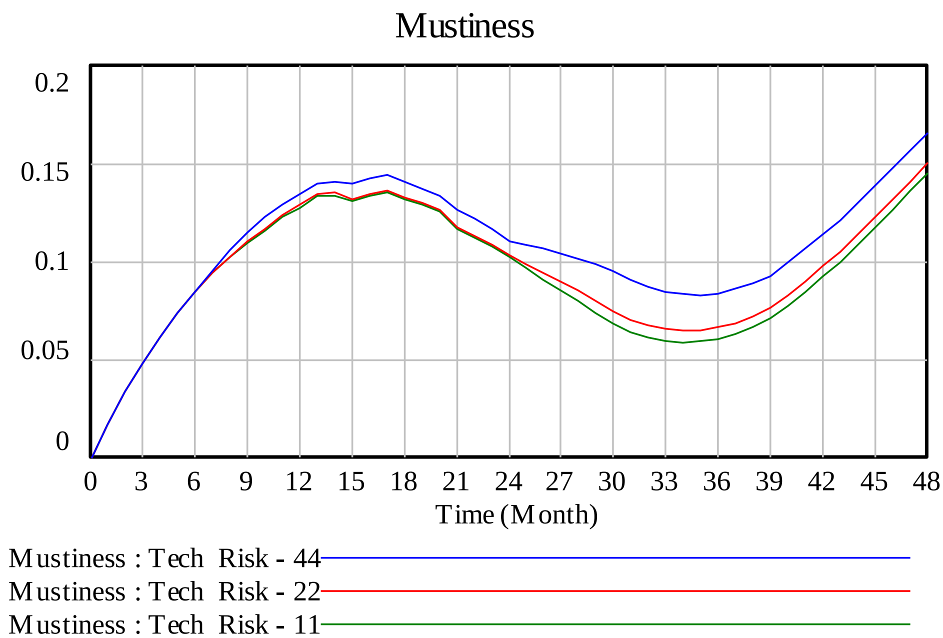

Fig 40. Muteness of project to the risk of technology problems

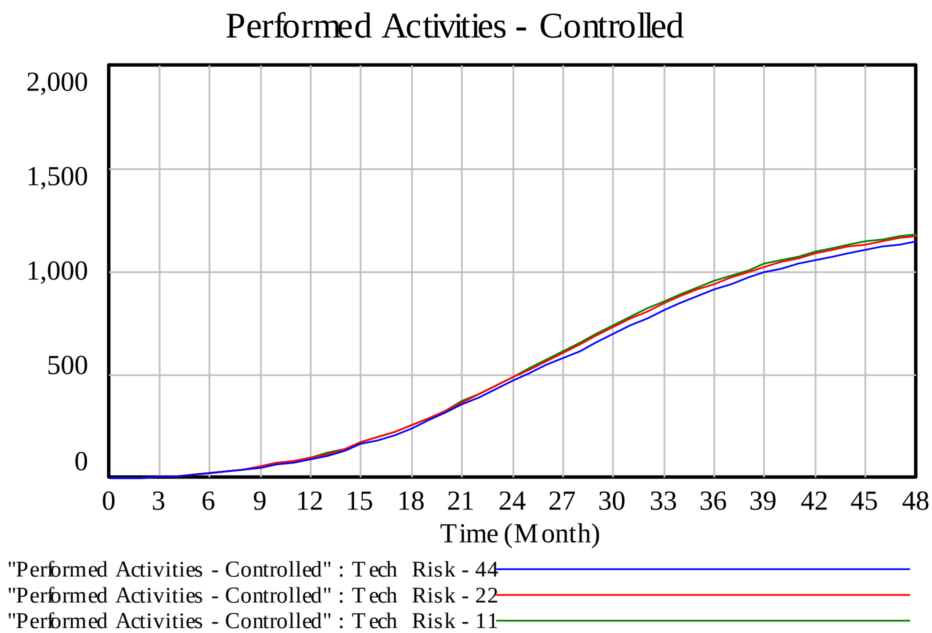

Fig 41. Performed and controlled activities to the risk of technology problems

According to these 3 diagrams, facilities reduction and increased risk are linearly related together. It is expected the higher the tech-problems risk, the lower the volumes of activities to be performed and diagrams also confirm this.

F. Work Complexity risk

The work complexity risk is taken into consideration. The results of the model are as follows.

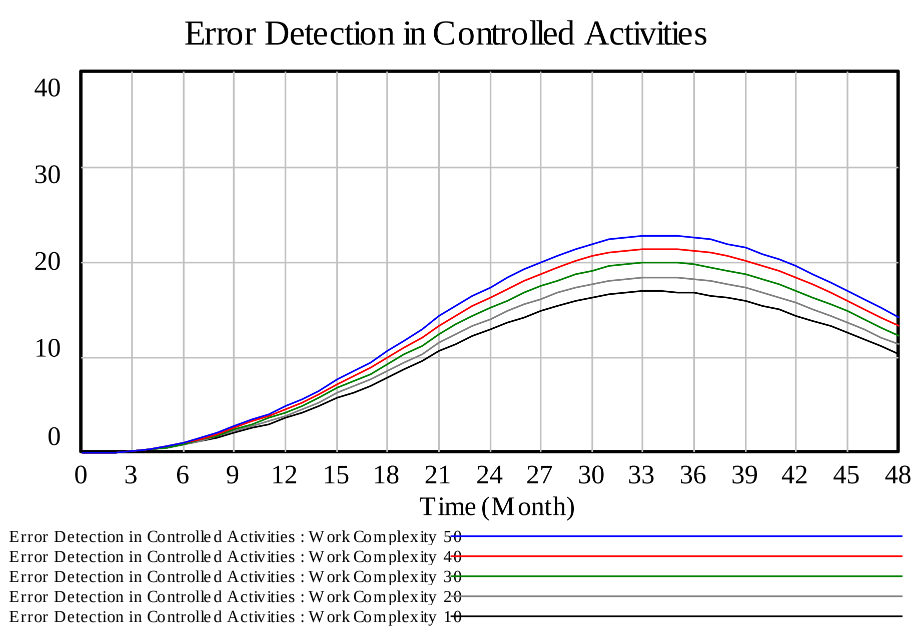

Fig 42. Errors found in controlled activities to the work complexity risk

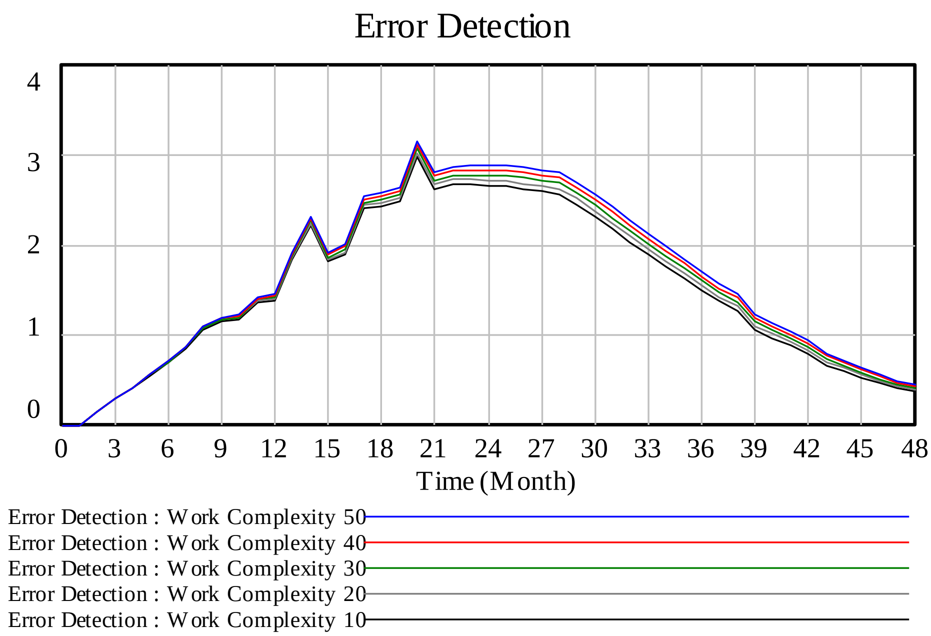

Fig 43. Error detection to the work complexity risk

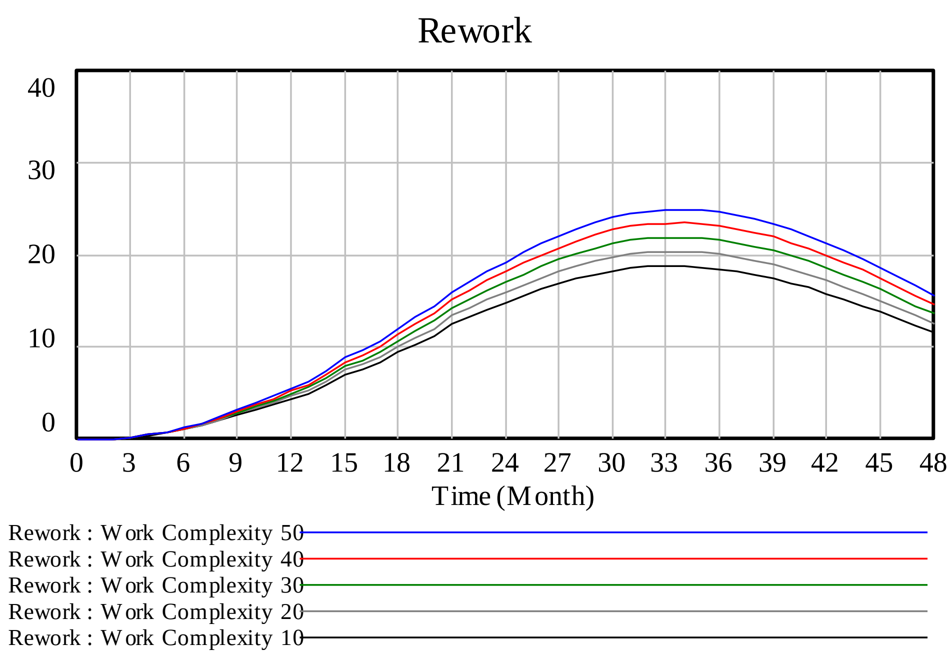

Fig 44. Rework to the work complexity risk

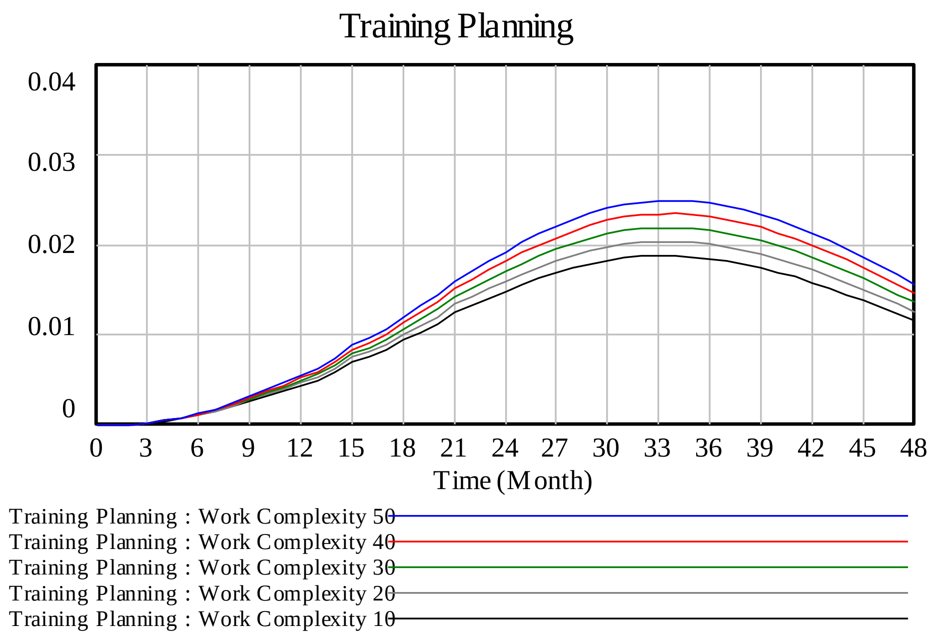

Fig 45. Education planning to the work complexity risk

There are projects with complexity, the management must pay attention to curriculum and make the executive team ready to rework again.

10- Discussion and conclusion

In this paper, risk management of refinery projects using systems thinking approach were discussed and evaluated. As a first step, all variables affecting the project and its objectives are identified and risks involved in the issue after interviewing with experts and managers of real project were given. To model and solve problems and evaluate the effects of risk on how to implement the project, a dynamic systems approach was used. After identifying the variables and risks involved, the sub-system diagram was introduced. Sub-system diagram shows overall system and all and essential dynamics and indicates how the variables affect each other generally and what the significant feedbacks are. There are 7 sub-systems:

- ✓ HR,
- ✓ Facilities,
- ✓ Materials,
- ✓ Training,
- ✓ Cost,
- ✓ Rework and
- ✓ Performed activities.

The state and flow model was developed. To employ the state and flow model, all relations between all variables would be defined mathematically. Using software VenSim, this model to a real problem about a construction project has been implemented at a refinery in south of the country and the results were obtained.

The results of the model indicate that:

(1) The initial resources planning are not commensurate with the planned activities. This happened because the initial planning of resources is done just based on specific activities which is planned, while any risk is not involved in the planning. As a result, the actual amount of resources needed much more than initial planning them, the model suggests this difference well and provides good insight for managers that to consider the different levels of various risks, the effect of all and final result on the resources become seen on the model and their initial plan is reformed.
(2) And also it provides a buffer from each of the sources and if needed and happened any of risks defined, the muteness of the project is prevented.
(3) Finally, risk sensitivity analysis has been included in the model. These risks include:
    - The HR budget risk,
    - Facilities budget risk,
    - Materials budget risk,
    - Work complexity risk,
    - Technology problems risk and
    - External enforcement risk of accelerating the project.

As is clear from the results and diagrams:

- <u>There has been more effective HR budget risk at the beginning of the project, while the risk of materials and facilities more effective at the end of the project.</u>
- <u>These will provide valuable guidelines to the management, this means that the management in the first half of the project should focus their power to control and improve the situation of the HR, in contrast, in the second half of the project, more aware of the materials and facilities.</u>
- <u>Such an approach will enable the management to prevent the muteness of project to a large extent.</u>

Finally, it can be concluded that the proposed approach is easily used in any refinery construction project. Because according to the managers and experts' comments under study, the risks and variables are contained in all of the refinery's construction projects. As a result, only entering the inputs and using the simplest data existing in all projects (such as initial activities planning, planned resource, etc.) the model has been implemented and will show the impacts of risks.

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