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SYSTEM DYNAMIC MODELING OF PROJECT RISKS

The Case of Telecommunication Projects

By

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Supervisor

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LIST OF ABBREVITIONS

SD	System Dynamic
CLD	Causal Loop Diagram
PSTN	Public Switched Telephone Network
ICT	Information and Communication Technology
IMF	International Monetary Fund
IP	Internet Protocol
VoIP	Voice over Internet Protocol
WoM	Word of Mouth
NUMBER	Normalized Unit Modeling By Elemantary Relationships

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ACKNOWLEDGEMENTS

As we all know, this part generally consists of typical sentences, but I don't want to present a typical structure. In order to save this from being typical and monotonous, I want to start with telling an incident I have faced with a few days ago.

A few days ago, while my dear colleague Levent, who I would thank to for his collaboration and supports during my study, and I were sitting at the school cafeteria drinking our coffees, a lady approached to us and ask whether we could fill out a survey for her project, and we took the survey to fill out. If I had received that survey before my graduate study, probably I would have filled that without looking at content of it al least for the curiosity. This time everything happened quite the contrary. We looked at the survey and tried to analyze the content and style, and we figured out some of the mistakes in the survey.

I am telling you all these because what made us to be able to criticize that survey was the knowledge we got during our program, knowledge we were thought by our instructor for last two years. Beyond having this information, being able share made, being respected because of the knowledge was precious and beyond description. I really couldn't find the word to describe how prideful and happy I was that time.

The first we said to her was about the length of the survey. We told her that due to fact that people have a *limited information processing capability*, the length of the survey would lead people to consider it with bias.

We learned that from Dr. M.Atilla ÖNER, who is my thesis advisor. I want to thank him for all the information he let us learn until now, and for the information, I am sure he will teach in the future. I am also grateful for his advices, endless patience, his intimacy, and his immeasurable help.

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I especially want to thank my wife who always supported me during the program, and my family, and my wife's family.

Finally I want to thank my sponsor that gave me such a marvelous chance, Turkish General Command of Gendarmerie

And I am dedicating my thesis to my lovely daughters Ayça and Ece. I wish them all the happiness in the world, better education opportunities and success all over their lives.

ABSTRACT

Risk, defined as exposure to the possibility of economic or financial loss or gains, physical damage, or injury, or delay as a consequence of the uncertainty associated with pursuing a cause of action, is by nature subjective. The fast changing environmental conditions, information technology, and the complexity of the projects increase risk threat and make project management more susceptible to risks. This sensitiveness is also at its highest level in telecommunication projects, because there are various technologies and scientific techniques used in telecommunication projects increasing the uncertainty and complexity.

Project risk dynamics are difficult to understand and control. Therefore managing project risks requires an approach supported by special tools and techniques. System dynamic (SD) modeling is a tool that covers a wide range of project management needs, by addressing the system issues that influence and often dominate the project outcome.

With SD modeling approach we will be able to see all things as a whole. SD modeling also will enable us to build formal computer simulation of complex project risk dynamics, so we can identify and analyze probable risks within the project and respond to them. In the thesis project, we attempt to classify all project risks within the framework of PSO (People-System-Organization) concept. Five risk sectors are defined.

1. Social Risk
2. Economic Risk
3. Technical Risk
4. Political Risk
5. Ecological Risk

Political and Ecological risk sectors are excluded and the first three sectors are defined as endogenous in the model. In Stock and Flow Map these three sectors are determined as main stocks. Modeling these three risk sectors stock and flow diagrams 46 risk variables are used. There are three main stocks and seven sub-stocks in the model. Moving from causal map to computer simulation we used the approach called NUMBER (Normalized Unit Modeling by Elementary Relationships), which enable us to limit the variable's values between 0 and 1. We needed to use this approach because we did not have the real data.

After forming the equations we simulated the model with time bound which is assumed to be 60 months. Simulation results show that all main risk sectors increase in the initial times of the project. Then if all thins go well the risk levels begin to decrease but never zero. Economic Risk shows the highest level about 0.6 at the time 18 in the base model. The highest levels of the other two main risk factors are about 0.3 at a determined time.

Near the base model we defined an alternative model to which a new variable called Hiring New Staff is added. After simulating the alternative model it was observed that to introduce new personnel to an ongoing project increases risks levels and project cost, decreases productivity, quality and leads to a poor team relationship.

The model can be simulated with different policies and designs. It enables us to see various situations of risk factors and other variables affecting risks. In this way, irrelevant risks can be eliminated, preventing unnecessary mitigating efforts. At the end of this study we are able to have a complete picture of telecommunication project risk dynamics with the help of an SD model computer simulation. This may help us in seeing risk behaviors during project time and formulating responses to risks for mitigating their impacts on telecommunication projects.

ÖZET

Potansiyel olarak her zaman varolan ve meydana geldiğinde olumlu veya olumsuz yönde etki yapma olasılığı bulunan her türlü ekonomik ve finanssal kayıp ve kazançlar, fiziksel zararlar veya gecikmeler olarak tanımlayabileceğimiz risk doğanın vazgeçilmez bir unsurudur. Hızla değişen çevre şartları, bilgi teknolojisi çağının etkin kullanımı ve projelerin kompleks hal alması risk tehlikesini arttırmakta ve proje yönetim kademelerini uyarmaktadır. Bu hassasiyet telekomünikasyon projelerinde belirsizliği ve kompleksliliği arttıran birçok değişik teknolojiler ve bilimsel teknik detaylar olduğundan hat safhadadır
Projelerdeki risk dinamikleri anlaşılması ve kontrol edilmesi zor olgulardır. Bu nedenle proje risk yönetimi özel araç ve tekniklerle desteklenen bir yaklaşım gerektirir. Sistem Dinamik Modelleme (SD) bu gereksinimi karşılayabilme ve uygun alternatifler sunabilme özelliği nedeniyle proje yönetiminde etkin bir rol oynayacaktır. SD modelleme yaklaşımı ile projeyi bir bütün halinde görme imkanına sahip olmaktayız. Ayrıca SD modelleme bize kompleks proje risk dinamiklerinin bilgisayar ortamında simülasyonunu sağlayacak ve değişik senaryolar üreterek proje risklerini tanımlama ,analiz etme ve risklere cevap verme süreçlerinde karar mekanizmalarına yol gösterecektir.
Tezimizde risklerin sınıflandırılması İnsan-Sistem-Organizasyon (İSO) konsepti çatısı altında yapılmaktadır. Beş risk sektörü belirlenmiştir.

5. Sosyal Risk
6. Ekonomik Risk
7. Teknik Risk
8. Politik Risk
9. Ekolojik Risk

Politik ve Ekolojik risk modelden çıkarılmış diğer ilk üç sektör modelde esas alınmıştır. Modelde stok ve akış diyagramı oluşturulurken 46 tane risk değişkeni kullanıldı. Model üç ana stok ve yedi yan stok içermektedir. İlk olarak temel bir yapı oluşturuldu ve alternatif senaryolar ile farklı simülasyonlar elde edildi. Modeli bilgisayarda simule edebilmek için denklem yazılımlarında NUMBER olarak bilinen bir yaklaşım kullanıldı. Bu bize değerleri 0 ve 1 aralığında gösteren grafikler elde etmemizi sağladı. Bu metodu kullanmamızın diğer önemli bir nedeni de gerçek data kullanılmadan modelin simule edilmesi idi.
Denklemler kurulduktan sonra model 60 aylık bir zaman çerçevesinde simule edildi. Sonuçta tüm risk faktörlerinin proje zamanı içerisinde ilk zamanlarda arttığını ve planlanan doğrultuda projenin devam etmesiyle risklerde düşüş olduğunu fakat hiçbir zaman sıfır olmadığını gördük. En yüksek risk seviyesi yaklaşık 0.6 ile ekonomik riskte 18 nci ayda meydana geldi. Diğer risk faktörlerinin en yüksek seviyeleri 0.3 civarında gerçekleşti.
Ana modelimizin yanı sıra alternatif bir model daha oluşturduk. Burada farklı olan teknik riske önlem olarak ek personel alımı yapmaktı. Model simule edildikten sonra görüldü ki devam eden bir proje esnasında ek personel alımı yapmak tüm risk faktörlerini arttırmakla beraber proje harcamalarını arttırıyor, en önemlisi de kaliteyi ve üretkenliği düşürüyor personel ilişkilerini zayıflatıyor.
Model değişik senaryo ve dizaynlarla defalarca simule edilebilir. Bu esneklik bize ger beslemeleri risklerin ve riskleri etkileyen değişkenlerin çeşitli durumlarını görmemizi sağlar. Sterman' ında belirttiği gibi zihni muhakemelerimiz çoğu zaman sistemimizin dinamiklerini belirleyen algılayamaz.
Bu çalışma sonunda SD modelleme yardımı ile telekomünikasyon projelerindeki risk dinamiklerinin komple bir resmine sahip olma imkanımız doğacaktır. Bu durum aynı tip projelerdeki risklerin meydana getireceği etkileri en aza indirmek için risklere uygun ve etkin cevabı verme sürecinde karar verme mekanizmalarına fayda sağlayacaktır

1. INTRODUCTION

We are living in a complex world and, faced with this complexity in our everyday lives – whether at work, at home or in business. Complexity defined by Baccarni (1996) as "consisting of many varied interrelated parts", also occurs in projects.

A "project" is a number of connected activities that are planned to happen during a set period of time, with a definite target. There are a few fundamental points that identify a project and differentiate it from "normal", everyday work. (The Scout Association 2000)

1. Projects are about change – not accidental and random, but deliberate and planned, and as such are a major contributor to survival and growth.
2. Projects are "one-time efforts" – the project that you manage will only exist for a short time span.
3. Projects have defined and limited times spans, and are also bounded by the other key features of cost and performance.
4. Projects have a defined target – if the project reaches this point, it is deemed successful.

The fast changing environment and the complexity of projects increase risk exposure. Chapman and Cooper (1983) define risk as exposure to the possibility of economic or financial loss or gains, physical damage, or injury, or delay as a consequence of the uncertainty associated with pursuing a cause of action. According to them risk is by nature subjective.

Chapman and Ward (1997) define project risk as: *"The implications of the existence of significant uncertainty about the level of project performance achievable."*

In everyday life risk is usually considered as some kind of an uncertain event that has negative consequences. However, as Pitkänen (1999) states, in some instances risks can also be considered as positive events. In these cases they are called opportunities. In fact risk analysis covers both the negative and the positive side of uncertainties.

In project environments the project managers should understand the persistent nature of risk. There are always risks concerned in every decision to be made. However, these risks can be affected by proper risk management. Being aware of the risks gives the decision maker the possibilities to make some corrective actions during the project if needed.

According to Pitkänen (1999) project risk management improves project performance by identifying, analyzing and controlling project risks.

Rodrigues (2001) claims that project risk dynamics are difficult to understand and control, and not all types of tools and techniques are appropriate to address their systemic nature. Human mind is not able cover this complex dynamics. Our mental model is inadequate to solve problems existing in projects. Rodrigues (2001) also emphasizes that managing project risk dynamics requires a different approach, based on a systemic and holistic perspective, capable of capturing feedback and of quantifying the subjective factors where relevant.

Complex projects are highly non-linear feedback systems and have proven extremely difficult to manage successfully using traditional tools alone. System dynamics (SD) models have demonstrated their ability to improve significantly the quality and performance of management on complex projects. In projects, risks take place within a complex web of numerous interconnected causes and effects, which generate closed chains of feedback. Risk dynamics are generated by the various feedback loops that take place within the project.

Computer models are also explicit and their assumptions are open to all for review. What is the most important is that they can be simulated under controlled conditions, allowing analysts to conduct experiments, which are not feasible or ethical in the real systems.

SD modeling is a tool that covers a wide range of project management needs, by addressing the system issues that influence and often dominate the project outcome. With SD modeling approach we will be able to see all things as a whole. SD modeling also will enable us to build formal computer simulation of complex project risk dynamics, so we can identify and analyze probable risks within the project and respond to them

In the thesis author represents a case study – SD Modeling of Telecommunication Project Risks. There are various technologies and scientific techniques used in telecommunication projects increasing the uncertainty and complexity. Risk dynamics are at highest level in such projects. Readers will be able to see the importance of SD Modeling usage with this case study where mental models are not adequate to understand and solve complex risk dynamics. Computer simulations enable us to overcome many of the limitations of mental models.

The use of SD Modeling approach helps us see the risk dynamics in Telecommunication Projects as a whole and this may help the project risk management identify, assess and mitigate the risk.

1.1. Description of Research

The thesis represents the use of SD modeling approach in Project Risk Management. It focuses on the Telecommunication Risks. This study will guide project risk management teams through identifying, assessing and responding to project risks.

1.1.1. Title

The title of thesis study is ***"System Dynamics Modeling of Project Risks – The Case of Telecommunication Projects"***

1.1.2. The Goal

The goal of this study is to propose a system dynamics model for understanding and managing risks in telecommunication projects.

Model will enable us to have a complete picture of telecommunication project risk dynamics. This may help us in formulating responses to risks for mitigating their impacts on telecommunication projects.

1.1.3. The Scope

In this study, the research will be focused on the SD Model of the telecommunication project risks. With alternative scenarios we will able to see the effects of risk dynamics on the projects so that we might determine the most important and influential risk dynamics sector or sectors. This capability will allow us to take measures for those risk sector(s).

With SD modeling approach we have the ability to see the complete picture of project areas in which uncertainties, complexities and risk dynamics occur. System thinking methodology will light the way, which project owners, politicians, lawmakers, civil sectors, and people go on.

1.1.4. The Structure

In Chapter 2, SD Modeling in project management, Telecommunication projects and risk in projects are discussed. In Chapter 3 the model is created, and simulations are defined. In Chapter 4 simulation results are given and discussed. In Chapter 5 conclusions are given.

1.2. Methodology

The dynamic feedback relations, which are presented more qualitatively in earlier studies, are modeled explicitly using System Dynamics Methodology within this study.

There are many variables and interactions between these variables in international relation theory. System Dynamics seems the most appropriate methodology to be used.

1.2.1. System Dynamic Modeling

System dynamics is an academic discipline created in the 1960s by Dr. Jay W.Forrester Chief of the Massachusetts Institute of Technology. System dynamics was originally rooted in the management and engineering sciences but has gradually developed into a tool useful in the analysis of social, economic, physical, chemical, biological, and ecological systems.

In the field of system dynamics, a system is defined as a collection of elements that continually interact over time to form a unified whole. The underlying relationships and connections between the components of a system are called the structure of the system. One familiar example of a system is an ecosystem. The structure of an ecosystem is defined by the interactions between animal populations, birth and death rates, quantities of food, and other variables specific to a particular ecosystem. The structure of the ecosystem includes the variables important in influencing the system. The term dynamics refers to change over time. If something is dynamic, it is constantly changing. A dynamic system is therefore a system in which the variables interact to stimulate changes over time. System dynamics is a methodology used to understand how systems change over time.

The way in which the elements or variables composing a system vary over time is referred to as the behavior of the system. In the ecosystem example, the behavior is described by the dynamics of population growth and decline. The behavior is due to the influences of food supply, predators, and environment, which are all elements of the system.

Roberts (1978) states that system dynamics is the application of feedback control systems principles and techniques to managerial, organizational and socioeconomic problems. For managerial usage, system dynamics advocates seek to integrate the several functional areas of an organization into a conceptual and meaningful whole and to provide an organized and quantitative basis for designing more effective organization policy.

1.2.2. Research methods

The research methods explained below are used for data collection, and analysis in this study.

1.2.2.1. Literature review

There are many books, papers, conference notes, and dissertations about project risks, project risk management and SD Modeling Approach. Literature review is the second chapter of this thesis.

1.2.2.2. Internet Survey

Search is conducted to obtain data about project risks, telecom projects and SD modeling studies through most common search engines such as Altavista, Yahoo, Excite Web Crawler etc., electronic libraries such as. The discussions which are mostly related to this thesis topic are explained Chapter 2.

1.2.3. Software

Vensim 4.1 has been used for system dynamic modeling and simulation. Vensim is a visual modeling tool that allows the analysts to conceptualize, document, simulate, analyze and optimize models of dynamic systems. Vensim provides a simple and flexible way of building simulation odes from causal loop or stock and flow diagrams. In addition Vensim has the ability to do sensitivity analysis. This can be very helpful in understanding the behavioral boundaries of a model and testing the robustness of model-based policies.

2. LITERATURE REVIEW

2.1. System Dynamic Modeling in Project Management

The business environment has changed dramatically during the end of the 20th century creating new challenges for firms in most industries. It has become more global, and dynamic making it difficult for firms to respond adequately to the shifting needs of markets and customers. In this context, the development of new products is becoming increasingly central to any strategy for achieving high levels of profitability, market share and, in the long run, gaining a significant leverage of competitive advantage

Project management improvement has become more crucial as companies are facing new challenges to carry out innovation projects. In response to the business environment pressures cited earlier, most firms have re-engineered their project management paradigms from a sequential functional process to a concurrent cross-functional one.

According to Lebcir (2002), "*Projects involving high innovativeness, different interacting new technologies, many interrelated parts and sub-systems, a high fraction of newly designed parts, and directed to a poorly understood market are obviously more difficult to manage and carry high levels of risks.*" Non-familiarity with customer needs and requirements, product and process technologies, coupled with a lack of information on how to proceed with development work, diminish developers' capability and confidence in executing the project work. One project manager reported in Tatikonda and Rosenthal (2000) describes this situation with "*Of course, we know what the big pieces are, but the problem is that we don't know what the small tasks are until we get there in the project, and oftentimes, these small tasks turn out to be big tasks*".

There are many difficulties in projects when errors are made, such as delays, cost overruns. These difficulties create poor profitability, loss of market share. At this point Sterman (1992) emphasizes the usefulness of formal models (computer models) against mental models. Mental models are not explicit; others do not easily examine them. And the most important is the limited human mind.

Simon (1957) states that the capacity of the human mind for formulating and solving complex problem is very small compared with the size of the problem whose solution is required for objectively rational behavior in the real world or even for a reasonable approximation to such objective rationality.

According to Sterman (2000) "*no mental model can adequately assess the impact of externally imposed changes or allocate responsibility for delay and disruption.*"

Computer models are also explicit and their assumptions are open to all for review. What is the most important is that they can be simulated under controlled conditions, allowing analysts to conduct experiments, which are not feasible or ethical in the real systems.

Wolstenholme (1990) emphasizes system dynamics as a method for modeling and analyzing the behavior of complex social systems, particularly in an industrial context to examine various social, economic and environmental systems, where a holistic view is important and feedback loops are critical to understanding the interrelationships. Rodrigues and Bowers (1996) state that the SD approach has attracted particular attention in the last quarter of the 20th century, since computer software has become readily available to help communicate the key dynamics of systems to the managers responsible. To emphasize their opinion they suggest Figure 2.1, which illustrates the main features of an influence diagram, the core of the system dynamics model.

According to Chapman (1998), "*System dynamics is seen as an approach to modeling projects which emphasizes the interrelationships and concentrates on the whole project.*" The motivation to apply system dynamics proposed by Rodrigues and Bowers (1996) would appear common and are adopted here:

1. a concern to consider the whole project rather than a sum of the individual elements
2. the need to examine major non-linear aspects typically described by balancing or reinforcing feedback loops,
3. a need for a flexible project model which offers a laboratory for experiments with management's options,
4. the failure of traditional analytic tools to solve all project management problems and the desire to experiment with something new.

Harris (2000) lists features of system dynamics that make it especially useful for certain problems:

1. System dynamics can model the effect of information feedback on the future direction of the model. For example, if the cycle time in a production process becomes excessive, management would typically intervene to make changes, while many process simulations would simply report that cycle time was continuing to grow. System dynamics handles this easily.

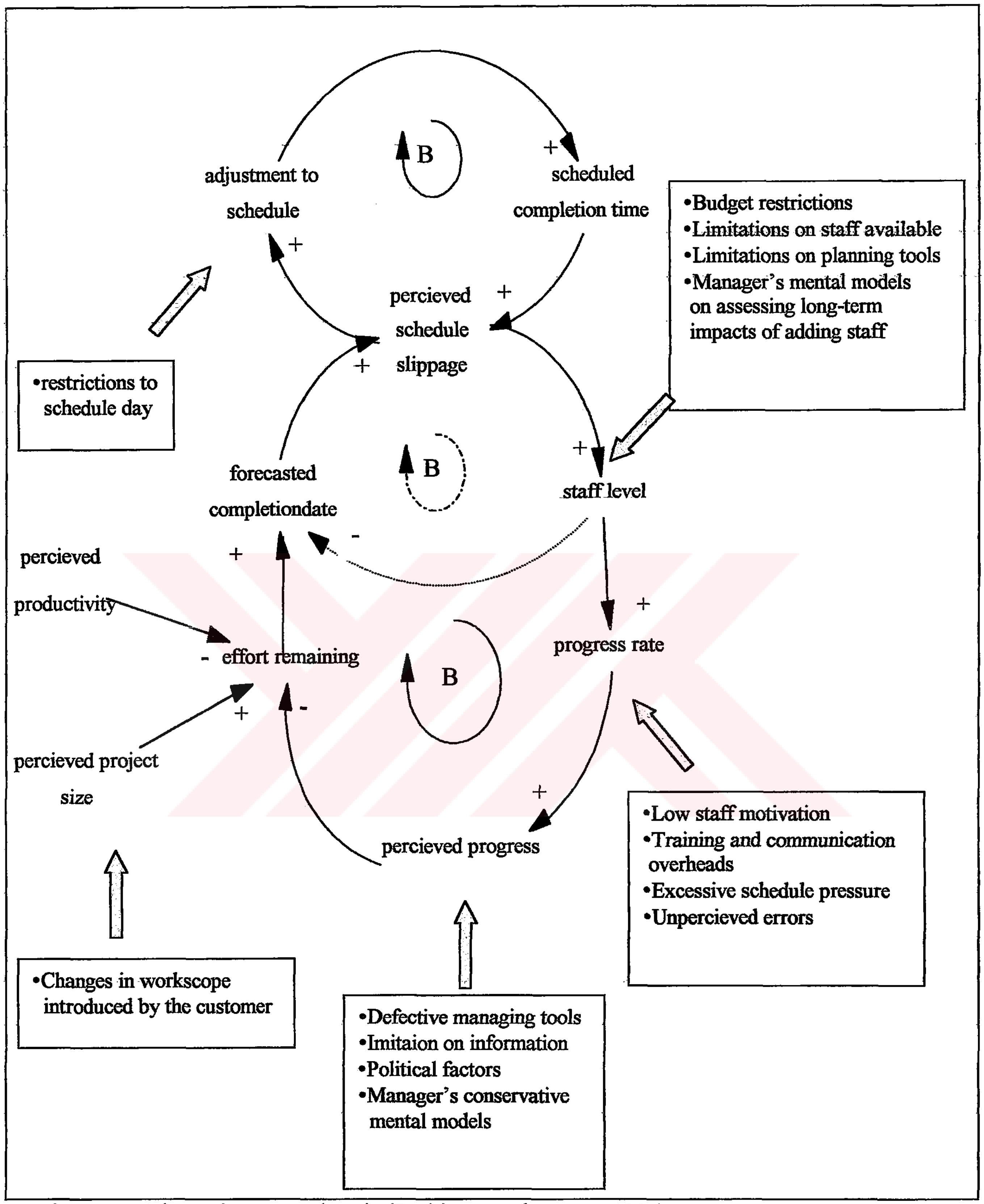


Figure 2.1. The project control cycle (Rodrigues and Bowers 1996)

2. To facilitate the use of information feedback, system dynamics carefully separates information accumulated about the state of the system and information fed back from that state to control the evolution of future states.

Sterman (2000) emphasizes the importance of SD modeling in project management suggesting that project management is intrinsically dynamic. Processes such as hiring and training unfold over time. There are multiple time delays in carrying out programs, in discovering and correcting errors, and in responding to unexpected changes in project scope or specifications. Such dynamic elements mean that the short run response of a system to a perturbation may differ from the long run response. Of all the formal modeling techniques, system dynamics has the most highly evolved guidelines for the proper representation, analysis, and explanation of the dynamics of complex technical and managerial systems.

Pugh (1993) defines the power of the system dynamics approach as its ability to incorporate the more subjective factors, which can have an important influence on the whole project. Factors such as changes in work scope; quality, productivity and motivation may be included and represented explicitly within causal feedback loops. He claims that, "*the system dynamics model offers a language, using symbols and the concepts of feedback loops, to express these factors in a rigorous though qualitative manner and also the opportunity to incorporate simple, quantitative approximations of their effects.*" A system dynamics model does not provide a breakdown of the project cost or duration but it can explicitly include the indirect causes that are often responsible for overrun and overspend. A project network analysis can contain approximations of the effects of these underlying influences, either by use of simple models of the durations of activities, including factors such as productivity or by employing more sophisticated network facilities.

Rodrigues (2001) defines System Dynamics modeling as a very complete technique and tool that, covers a wide range of project management needs, by addressing the systemic issues that influence and often dominate the project outcome. Its feedback and endogenous perspective of problems is very powerful, widening the range for devising effective management solutions. Rodrigues (2001) also states that, "*SD modeling is an appropriate approach to manage and model project risk dynamics, to which most of the traditional modeling techniques are inappropriate.*" SD has therefore a strong potential to provide a number of distinctive benefits to the overall project management process.

2.2. Telecommunication Projects

During the last part of the 20th century the telecommunications industry has gone through a major shift from regulated, monopolistic business towards a fully de-regulated, market driven and extremely highly competitive business. New technological breakthroughs like Voice-over-IP are becoming a commodity, and often a true threat to the industry. This process leads telecommunication operators to launch new service products (later products) in totally new environment. This new environment requires fast reacting business intelligence, continuous responses to competitor's movements, seamless co-operation between telecommunications providers marketing and other functions as well as fast, error free way to produce both innovative totally new products and also innovative incremental development of existing products. (Real Time Systems, Inc. 2001)

Telecom companies should benefit from new technological innovation to maintain and develop its position in market or else it will be a threat to them. Sedehi and Vaccaro (1998), emphasize a new technological innovation called VoIP, which will become a menace to Telecommunication Operators if there are no efficient management *strategic decisions* in transforming *VoIP* from a menace to a new business opportunity.

Sedehi and Vaccaro (1998) claim that telecom companies should integrate VoIP into their operational arena. They focus on a model supporting that strategic decision classifying the user sector given in Figure 2.2. and suggest an SD model Causal loop indicating the dynamics of the policy. Figure 2.3. shows dynamics of integration of VoIP with PSTN.

2.2.1. Technology Diffusion

New technologies are competitive factors for telecom companies. To increase their market share companies should use sophisticated new technologies in their projects.

Quaddus (1998), states that Information and Communication technologies (ICT) contribute to many advantages, the information from the data collection indicates critical problems confronting the business such as rapid obsolescence of adopted technologies, selection of inappropriate technologies, low productive usage of those adopted, lack of capable employees.

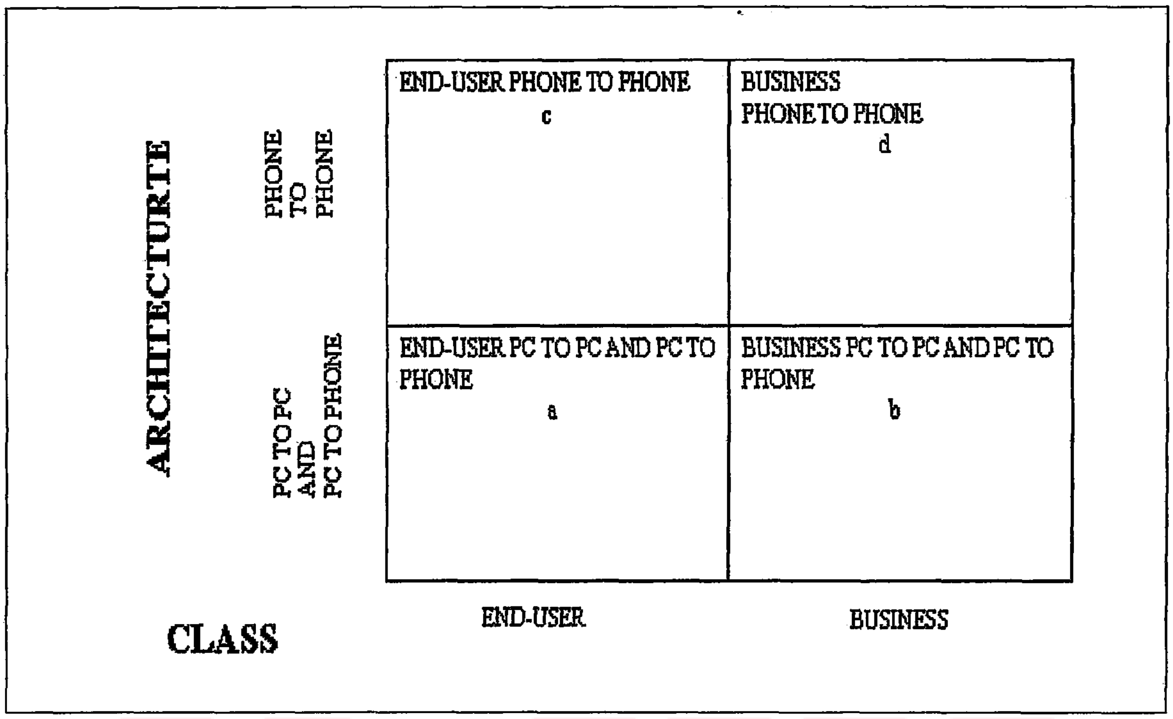


Figure 2.2. VoIP User Matrix (Sedehi and Vaccaro 1998)

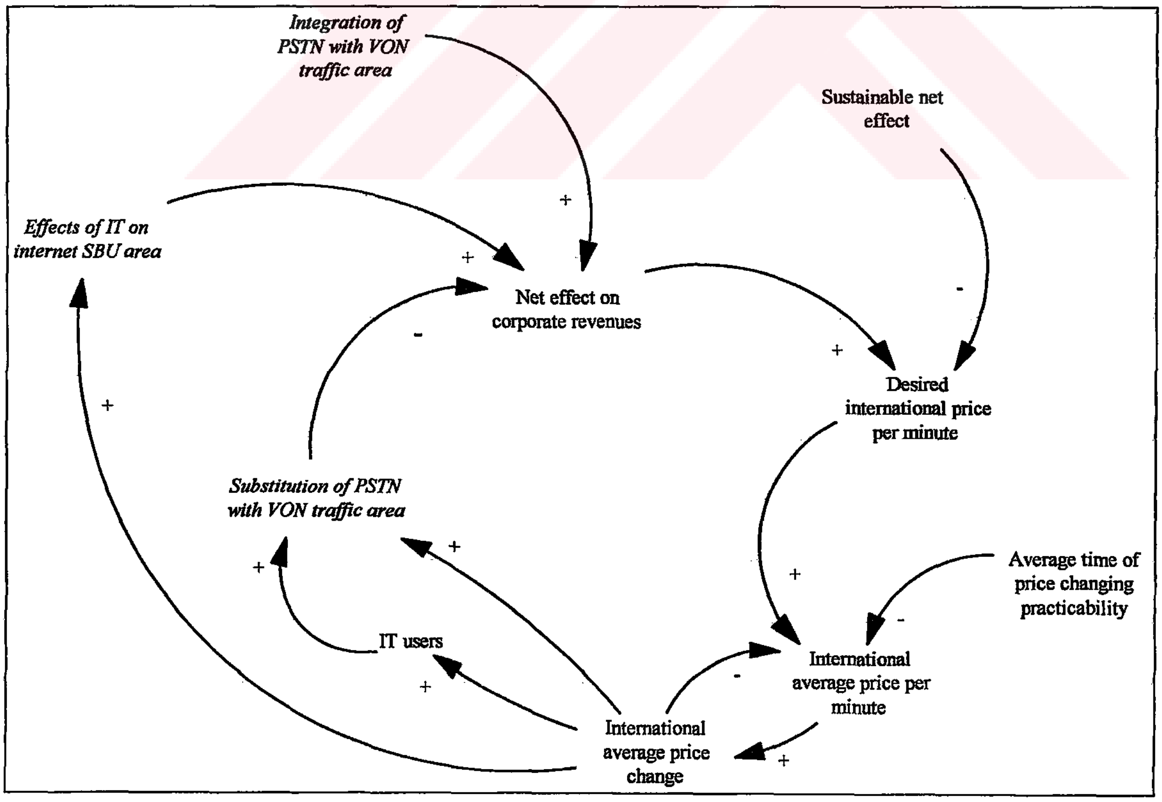


Figure 2.3. The dynamics of integration VoIP with PSTN (Sedehi and Vaccaro 1998)

2.2.1.1. Impact of "training support" on technology diffusion

Madu (1989) states that training is considered as a vital policy to provide knowledge, reduce levels of resistance, create skilled human resources and increase managerial potential because innovation can be succeed only if end users have a full understanding of the technology.

According to Quaddus (1996), technology diffusion changes positively with the level of training support. When technology is diffused, it creates learning environments that convince more end users to attend training and more trained staff and active staff further enhance diffusion rate.

Quaddus (1998) emphasizes the hypotheses regarding training support as;

1. Training support increases the rate of technology diffusion.
2. Training support increases relative advantages.
3. Training support increases sales.

2.2.1.2. Impact of "backlog of problems" on technology diffusion

Quaddus (1998) states that solving work problems and reducing uncertainty in problem solving are two main reasons for adopting information technology. However, whenever technology is diffused, a backlog of unsolved problems associated with technology itself and organizational aspects of adopters is created. According to Rogers (1983) and Seed (1990), if an organization fails to solve a backlog of problems, it may create one kind of uncertainty in the minds of adopters leading to demoting further adoption and simultaneously promoting existing adopters to abandon technology use.

According to Quaddus (1998), given a backlog of problems factor, the suggested risks are:

1. A backlog of problems decreases the rate of technology diffusion.
2. A backlog of problem decreases relative advantages.
3. A backlog of problem decreases sales.

2.2.1.3. Impact of "market potential" on technology diffusion

Dos Santos and Peffers (1995) say, "*Previous research indicates that early adoption of new IT applications leads to long-term competitive advantages (e.g. market share and income).*" However, Jirapinyo, (1997) has an opposite statement that "*an organization may hesitate to become involved in, or to postpone full implementation of a particular technology because of an obscure actual demand or market potential of a product deriving from technology use.*"

According to Maier, (1996) and Milling, (1996) market potential is physically reduced by sales in a period and increased by a flow coming from new potential customers and customers who repurchase due to product obsolescence. Maier, (1995) states that in a dynamic environment, short product life cycles, and a sharp decline in prices and time to market also affect market potential. In effect, although technology can be successfully diffused, economic gains are limited by the market potential.

Quaddus (1998) has the idea that "*Despite successful diffusion market potential inhibits sales.*"

2.2.1.4. Investment in new technology

Cooper and Zmud (1990) state that, "*Generally, a more costly technology is less likely to be adopted but once it is adopted, the large investment may highly motivate diffusion.*"

According to Quaddus (1998), "*It is important that an organization has to determine a balance between desired investment in new technology and economic returns from such investment.*"

2.2.1.5. Harvesting "economic gains" from "investment in new technology"

Applegate (1992) states that technological investment requires an adaptation and learning process to combine environment, organization, team, task and technology. Once the misalignments of these factors are corrected and end users eventually adopted, economic returns then will turn out fruitfully.

According to Quaddus (1998), technologies have to be substantially invested together with minimum sufficient usage then advantages from the technology can be harvested." His hypothesis relating to this research question is. Economic gains can be obtained after a new technology has been substantially invested." Figure 2.4. shows the influence of ICT on social and economic areas.

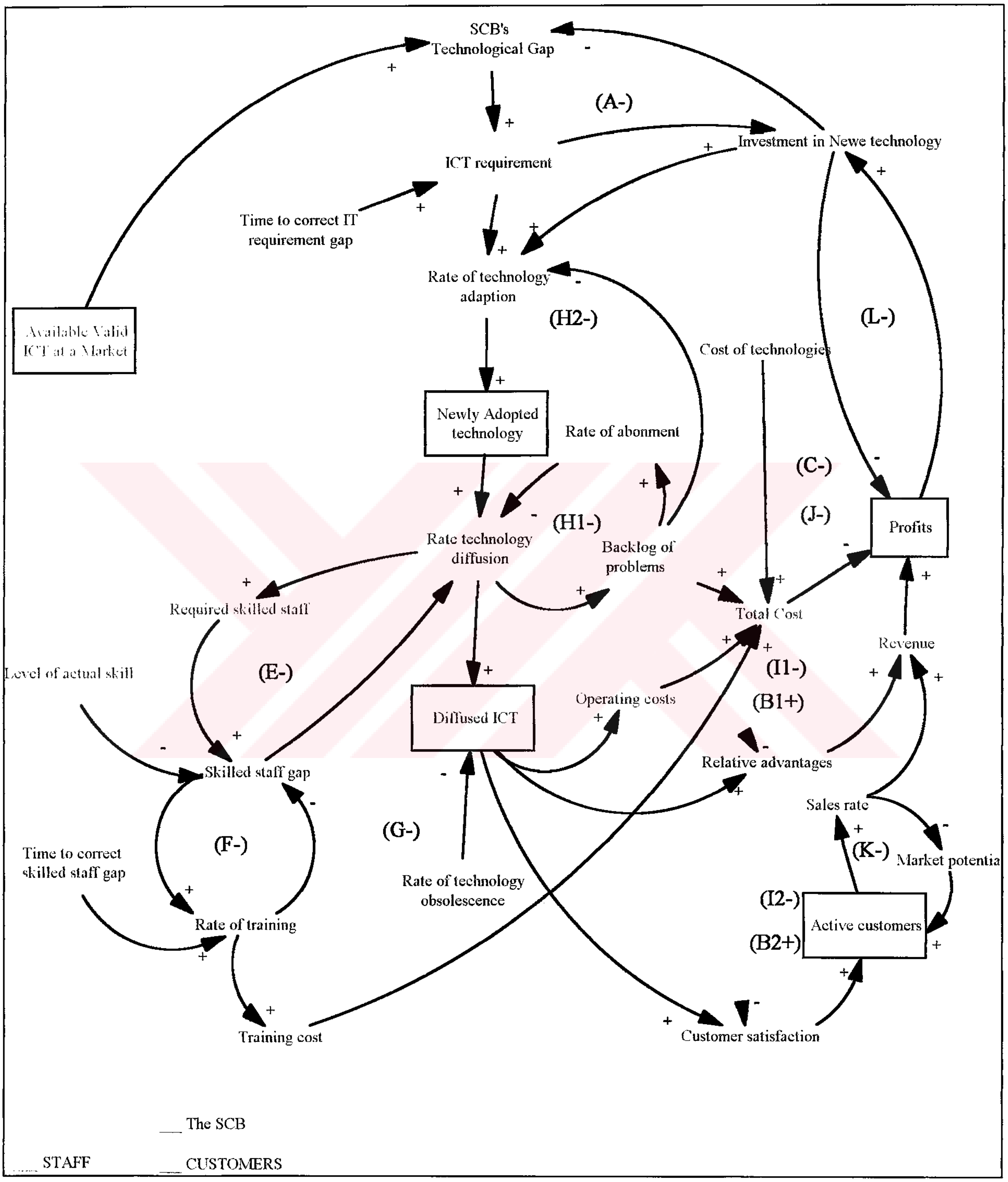


Figure 2.4. The influence diagram of the information and communication technology (ICT) model (Quaddus 1998)

There are positive and negative feedback loops in causal loop diagram. Table 2.1 explains these feedback loops.

Table 2.1. Feedback Loops in Causal Loop Diagram (Quaddos 1998)

Negative Feedback loop A	Requirements in information and communication technologies (ICT) are inspired by the gap between available valid ICT on the market and a level of investment in new technology.
Positive feedback loop B1 and B2	Customer satisfaction is the vital factor for generating active customers, which leads to accelerating sales rates and profits.
Negative feedback loop C	Massive expenditure (e.g. costs of technology and operational costs) is accommodated throughout the processes of adopting and diffusing new technology. Certainly, the costs reduce prospective profits.
Negative feedback loop E and F	New technology usage requires an increase in both the number of skilled staff and levels of skill of actual staff. Failing to upgrade levels of skilled staff widens the gap between the actual skilled staff and those required. Therefore, providing training is necessary to fill the gap.
Negative feedback loop G	Fulfilling quality and quantity of skilled staff via training results in increasing costs and subsequently decreasing profits. Once technology is integrated in work performances and services, a backlog of problems begins to accumulate. If end users or customers are annoyed or disappointed, they will abandon that technology use
Negative feedback loop H1 and H2	Once technology is integrated in work performances and services, a backlog of problems begins to accumulate. If end users or customers are annoyed or disappointed, they will abandon that technology use.
Negative feedback loop I1 and I2	A backlog of problems exerts negative impacts on both relative advantages and customer satisfaction. These impacts may completely or partially effect the positive gains from previous feedback loops (Loop B1 and B2).
Negative feedback loop J	Apart from costs of technology and operating costs, disparate costs (e.g. training costs, maintenance costs and costs from backlog of problems) continue to accumulate with the diffusing process.
Negative feedback loop K	The numbers of customer cannot be increased beyond market potential.
Negative feedback loop L	The balance between technological investment and profits must be found in order to arrive at the desirable level of technological expenditure because excessive investment can reduce the profits

2.2.2. Telecommunication Market

The Telecommunications industry is changing rapidly. New actors are entering the market and having their own influence on the sector as a whole. The consumer is getting used to perceive high quality for less money. It is necessary for a telecommunications company to have insight in the dynamics and growth patterns of these developments and in the effects of certain strategies of the company. According to Smits (2000), the questions that companies face are:

1. How will the market develop in the next 5 years?
2. What is the long-term effect of regulating the market?
3. Which competitors are serious threats for your company?
4. Which strategies will be successful?

Smits (2000) discusses these questions in the case of KPN, a telecommunication company in Netherlands and states the model given in Figure 2.5. describing the global scheme of the dynamics. The model exists of 10 building blocks (ext. environment, volume retail market, etc.). Each building block is giving it results to several other blocks.

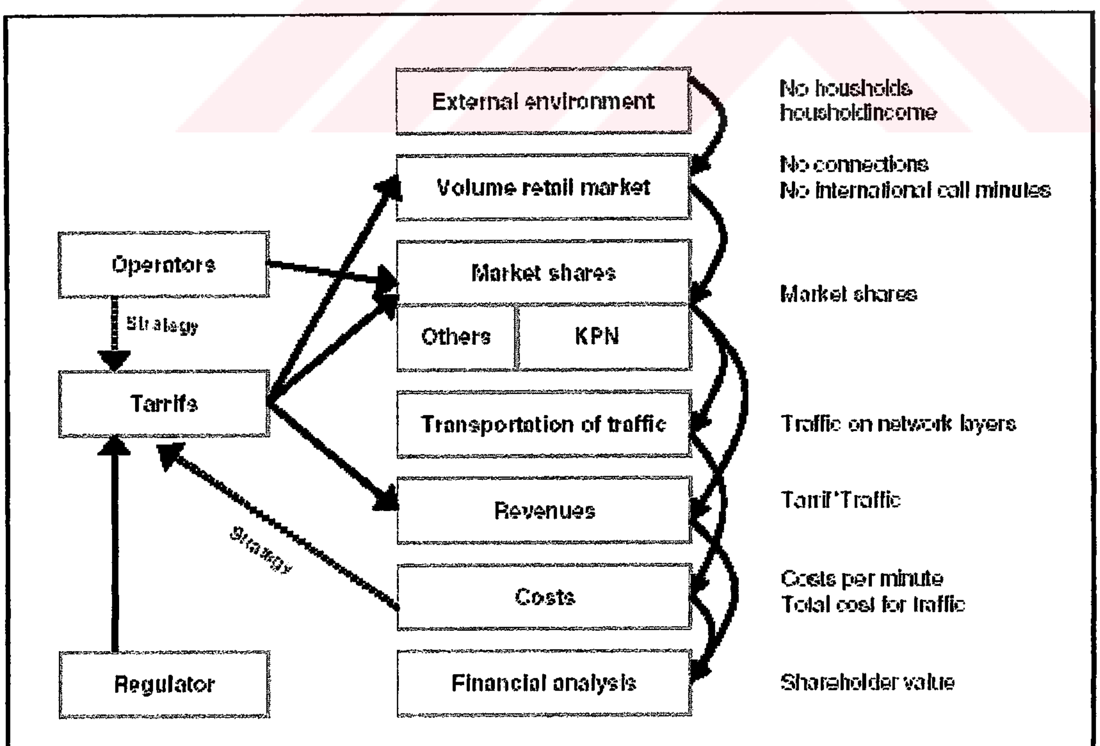


Figure 2.5. Global dynamics of the StratTel model (Smits 2000)

2.2.2.1. Market Opportunities for Telecommunications

Brady et al. (1999) state that, "*competition now comes from a range of network and service providers. It is therefore important for telecom operators to be able to model possible threats and opportunities and so plan their market strategies.*"

In particular, the telecom operator needs to understand the delicate balance between the costs incurred by the customer, the demand for services and churn. However, it can be difficult to holistically appreciate how the changes to one market sector would affect another.

One of the biggest threats for telco operators today is the churn of customers however; the opportunities to change are easier than ever. The biggest hurdle for customers to face is often their own lassitude.

In today's fast moving market place, all companies need to maintain a strong competitive edge. This is irrespective of the types of products, (or services), they provide. To achieve this, their products should be keenly priced with a low cost base, and the highest possible return on investment. As it is unlikely that all consumers will prove to be equally profitable, it is of prime importance to identify which sectors of the consumer market are most likely to purchase the goods or services. This enables effective targeting of marketing and the matching of company resources to customer demand to the time-of-day, or seasonal or show long-term trends over months or years, or be a combination of any of these time factors. By understanding these time-varying, dynamic customer characteristics, strategies can be put in place to enable the company to evolve and progress, whilst still maintaining its competitive advantage.

According to Matthews at all (1999), the dynamic effects belong to;

1. customer behavior
2. products and services launch
3. tariffing
4. costs of provision
5. revenue
6. profit.

Matthews et al (1999), illustrate these dynamics with an SD model given in Figure 2.6. They focus on the fact that the prospect of these enormous new revenues must not be allowed to blinker the vision of strategic business planners. Planners must understand the risks as well as the opportunities. Furthermore, the complex interacting requirements of their multi-dimensioned resources and the multi-faceted customer market must be understood.

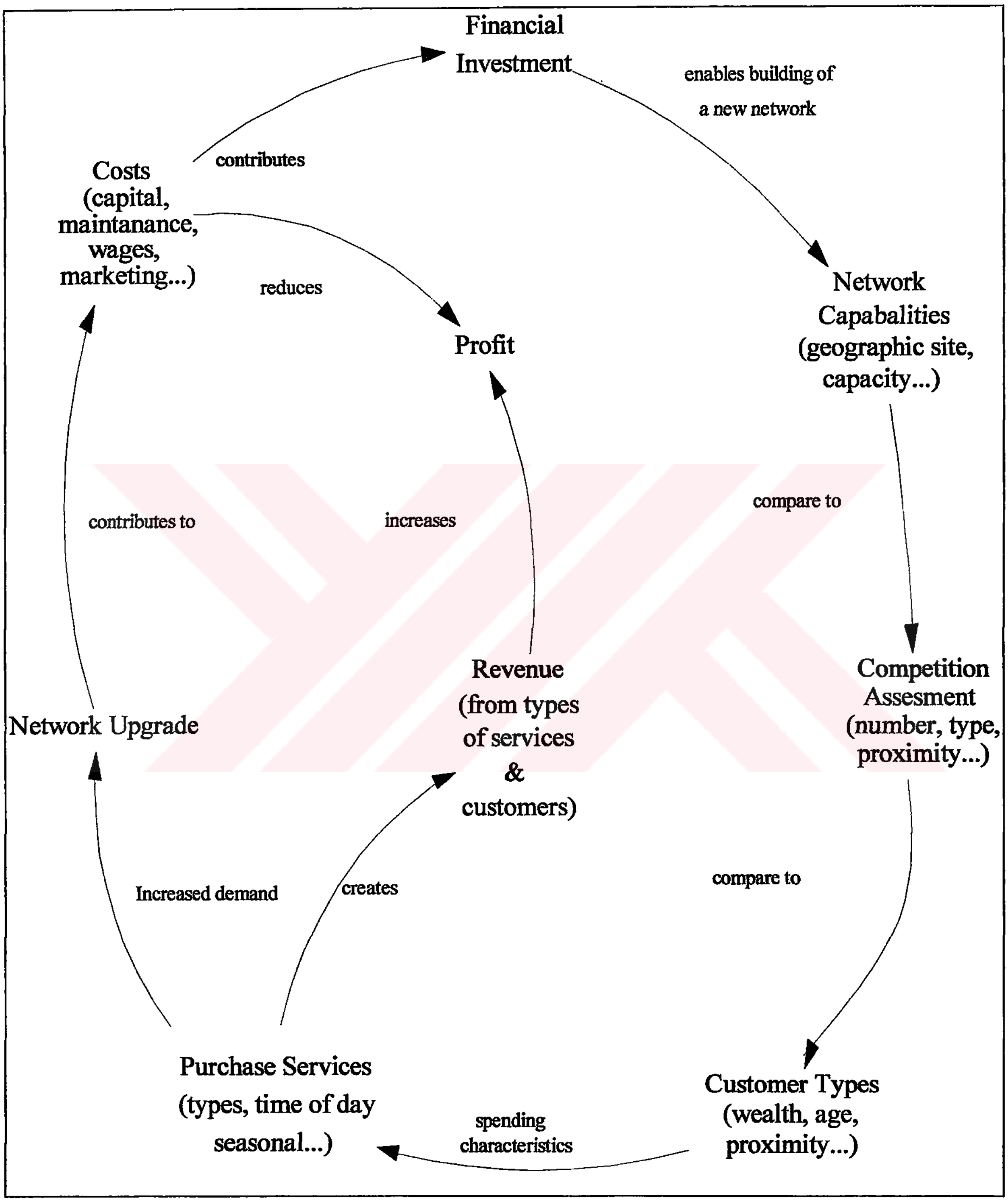


Figure 2.6. Flow Diagram for the Telecommunications Problem Space (Matthews et al. 1999)

From their own and other's investigations, Remenyi et al (1991) reported the following findings:

1. IT is not linked to overall productivity increases.
2. 70% of firms report that their IT systems were not returning the company investment.
3. IT overheads are consistently larger than anticipated.
4. 31% of firms surveyed report a successful introduction of IT.
5. 20% of IT spend is wasted.
6. 30%-40% of IS project realize no net benefit whatsoever.
7. 90% of firms did not have a systematic evaluation process.
8. 24% of firms surveyed report an above average return on capital from their IT.

Kennedy (1999) suggests an SD Model representing the dynamics of IT investment given in Figure 2.7.

2.2.2.2.Telecommunication Investment in Rural Areas

Information and Communications Technology has a vital role in connecting the rural community to outside world for exchange of information, a basic necessity for economic development. Rural entrepreneurs, artisans, traders, agriculturists and citizens can reap the benefits of national and global markets through the help of this modern tool. Without modern telecommunication systems rural communities will remain isolated and they will not be sharing the dramatic opportunities of growth new technologies could offer.

On the other hand ICT can provide an unprecedented opportunity to meet vital developmental goals such as poverty alleviation, basic and education. This enabling environment can help bridge the , more aptly called the digital divide and bring every one to the global economy. Traditional industry and business of a country or an area can attain global competitiveness fully exploiting the benefits of globalization. Effective use of ICT can demolish geographical boundaries and can bring rural communities closer to global economic systems and be of meaningful help to the under privileged.

According to Mathew (1999), investment in rural telecommunications is necessary for the following reasons.

1. Telecommunication resources can help diversify rural economics, open regional and global markets and create economic opportunities.

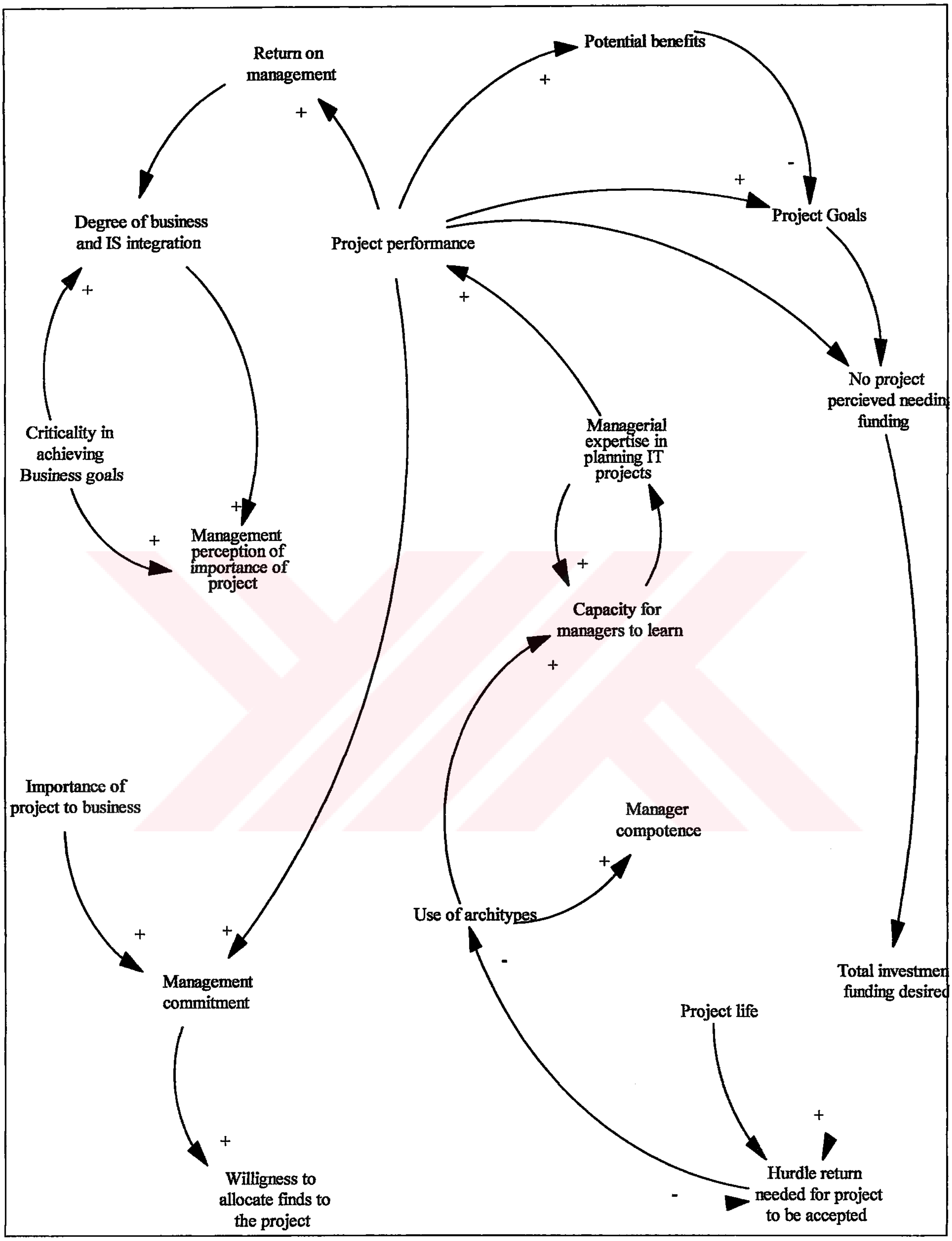


Figure 2.7. High Level Dynamic Hypothesis of IS/ IT investments (Kennedy, 1999)

2. Telecommunications can help diversify rural economics, more efficient and competitive.
3. Telecommunications resources can help reduce the impact of vanishing or seasonal jobs.
4. Telecommunications-based industries are typically cleaner and safer - for their workers, the community, and the environment.
5. Telecommunications resources can leverage a rural area's best features into competitive advantages in the challenge to attract new business.
6. Telecommunications resources can improve the career prospects or rural youth.
7. Telecommunication resources help build a more informed citizenry and more efficient and responsive local governments.
8. Investment in rural telecommunications assets has a significant ripple effect.
9. Cyberspace needs the influence and perspective of rural participants.
10. Telecommunications can improve the quality of rural life

He also emphasize the following risk factors possible to occur:

1. Telecom Technologies are high volatile.
2. Bringing Internet to rural communities means importing urban skills and urban expertise along with urban problems. This may result in rural anti-technology, back-to-basics backlash.
3. Intentions of unsuspecting rural communities and the not so altruistic objectives of powerful telecom multinational companies can be at cross-purposes.

All the advantages and probable risks could be illustrated with SD modeling approach. Figure 2.8. shows causal loop diagram of the role of ICT in rural economic and social development.

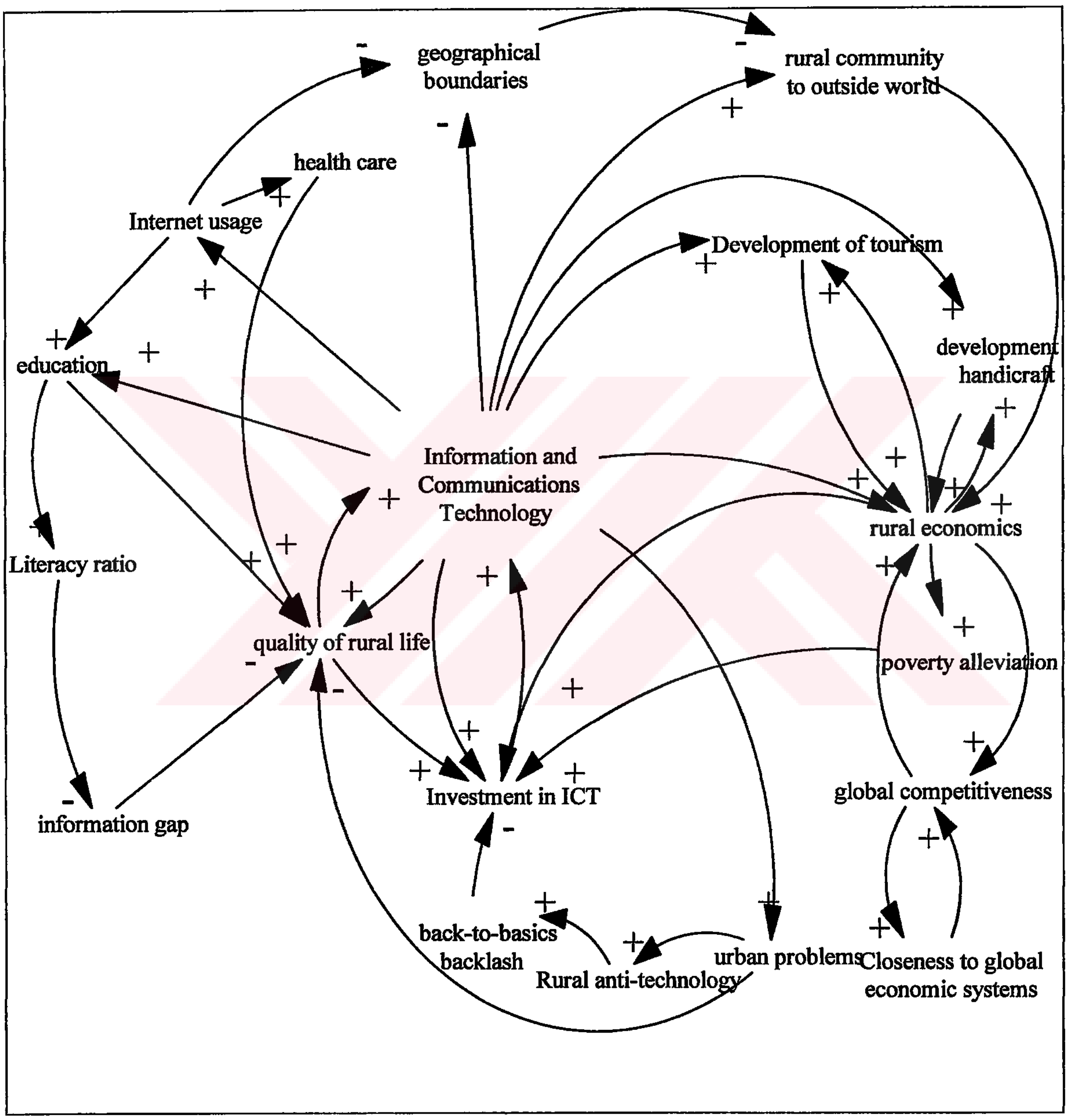


Figure 2.8. CLD of Role of ICT Investment in Rural Areas (drawn from Mathew, 1999)

2.3. Project Risks

2.3.1. Definition of Risk

The concept of risk can be defined in numerous ways. Singleton and Hovden (1987) present the following six definitions:

1. Risk is the probability of a loss.
2. Risk is the size of the possible loss.
3. Risk is a function, mostly the product of probability and size of loss.
4. Risk is equal to the variance of the probability distribution of all possible consequences of a risky course of action.
5. Risk is the semivariance of the distribution of all consequences, taken over negative consequences only, and with respect to some adopted reference value.
6. Risk is a weighted linear combination of the variance of and the expected value of the distribution of all possible consequences.

Hamilton (1988) states *" 'Risk' means the danger that a random event will affect negatively the possibility of attaining the desired goal."*

Willcock and Margetts (1994) define risk as *"exposure to such consequences as failure to obtain some or all of the anticipated benefits due to implementation problems and/or failure to complete the project on schedule, within budget, with adequate performance or in accordance with some measure of project success"*.

Monga (2001) suggests that risk addresses the problems associated with technical, cost, and scheduling aspects of designing, testing, manufacturing, operating and supporting, and disposing of processes, systems and equipment. Risks affect the ability to successfully achieve cost, schedule, and technical performance objectives. Potential sources of risk include new processes like designs, operational requirements, immature or emerging technologies, new performance requirements, and political or organizational changes.

2.3.2. Risk in Project

"Project uncertainty" occurs whenever there is a gap between " the amount of information required performing the task and the amount of information already possessed by the organization"(Galbraith, 1977).

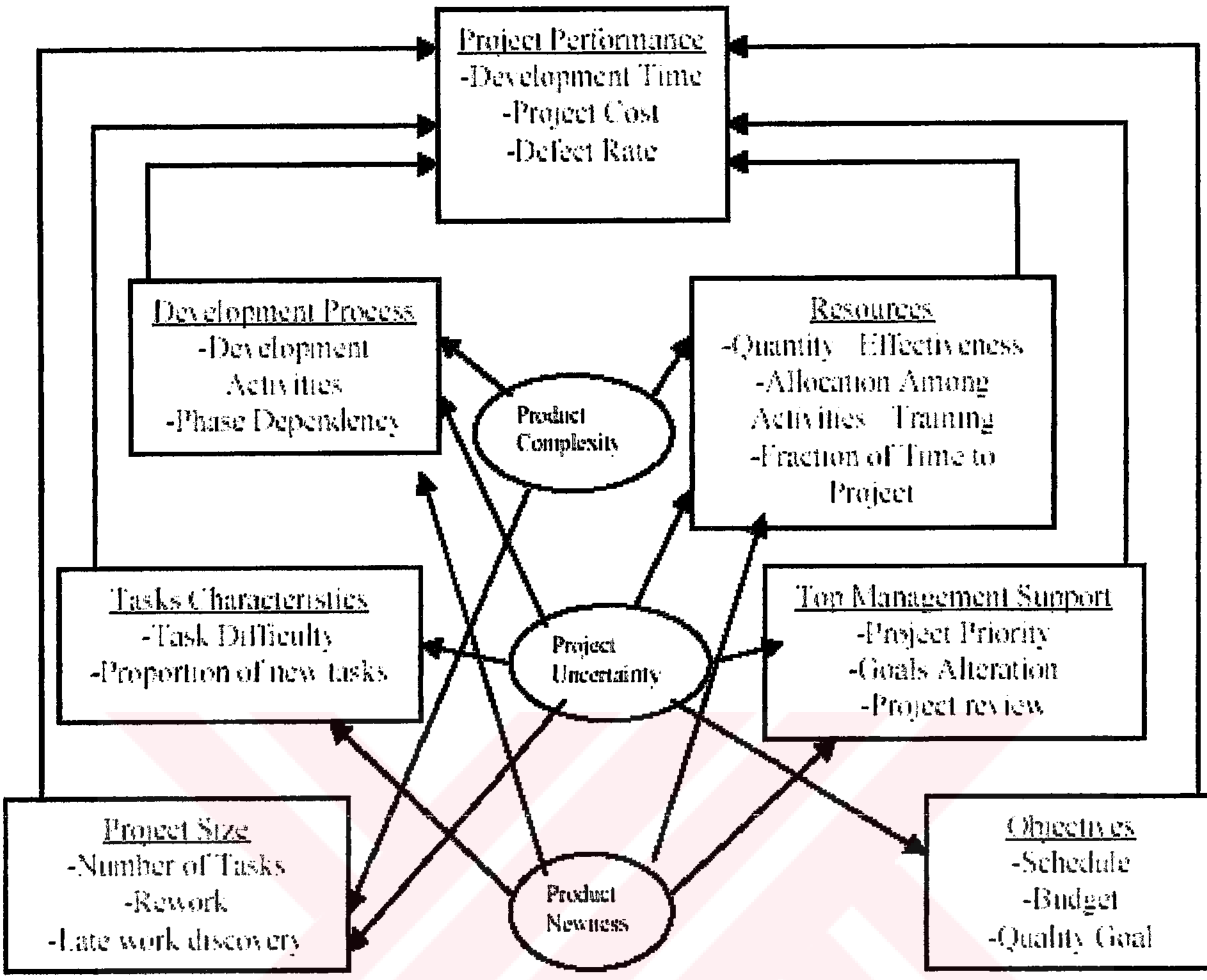


Figure 2.9. Generic Structure for project phase (Lebcir, 2002)

Lebcir (2000) states that in projects there are always uncertainties. These uncertainties affect each phase of project. Figure 2.9. shows phases of the development project represented by the generic structure. In this structure, project performance in each phase is affected by the interaction of development process structure, project resources, project tasks characteristics, project size, project objectives, and the level of top management support. Development process simulates the different activities involved in the project. Resources simulate the hiring and training of personnel. Tasks characteristics simulate the effects of task difficulty and the fraction of new tasks in the project. Project size simulates the effects of changes to initial phase scope, the effects of rework. Top management support simulates the effects of senior management involvement in project objective alteration. Objectives simulate the level of initial goals and how they are changed in response to project conditions.

The risk level in many projects is routinely underestimated, often due to human and organizational behavioral issues that are difficult to identify let alone solve (Conrow and

Shishido, 1995). For example, time-scales for implementation may exclude altogether the behavioral processes of managing change. A further problem area is the failure to allocate sufficient funds to train the people who will use the information system and make it work. According to Strassman (1985), a comprehensive assessment of expenses for training, for gaining user acceptance, for organizational learning and for ongoing support should be carried out long before acquiring any technology. He reminds us that technical choices should be determined by people costs rather than technology costs.

Willcocks and Margetts (1994) reinforce a more holistic approach to project risk management when they state "*Risk must be interpreted operationally as not just inherent in certain structural features of the environment or of a project, but also arising as a result of distinctive human and organizational practices and patterns of belief and action*"

2.3.3. Types of Risk

There are many risk types. In the thesis risk is classified under five headings called Social Risk, Economic Risk, Technical Risk, Political Risk and Ecological Risk.

2.3.3.1.Social Risk

According to Bienhous (2003) social systems are constituted by a set of commonly accepted or forced set of rules. These determine the system boundaries and the degrees of freedom of its elements:

3. individuals
4. groups
5. organizations.

The determinants can change – planned and put into action by man or caused by environmental upheaval or technical breakthroughs. Social systems tend to be constellations and forms of organization and interaction that are most efficient; at least in the mid-term having run through phases of adaptation. Change often means a loss of influence of established authorities. However, suppression of such development requires effort and as history shows, in the final analysis, not successful: serfdom, slavery, and totalitarian systems have largely disappeared. This dynamic structure of social systems affects many projects in business. One of the most serious changes in social system is change in customer requirements.

According to Sterman (1992), a change in customer specifications for a subsystem and subsequent issue of engineering change order may require the hiring and training of ıditional engineers, which in turn diverts skilled engineers from design to work training. Trainees may generate more errors, increasing network. Engineers changes render other, previously completed drawing obsolete and may also make some construction work already begun obsolete. Purchase orders already issued may have to be revised; some subcontracted components in process must be reworked.

Additional design and construction work must now be done without firm knowledge of how related components will interact, leading to still more work. Additional hiring can lead to congestion at the construction site, lowering productivity, increasing errors, and possibility leading to safety incidents. As these effects accumulate, the project management team has less and less time to oversee other aspects of the program, so quality and timeliness can suffer in areas previously doing well. Customer relations can deteriorate, and meetings, reviews, and customer oversight can grow increasingly burdensome.

Sterman (1992) suggests that, " *so changes (customer requirements) result in slow progress, reduced productivity, high cost.*" He also emphasizes that if the changes are large enough, the ripple effects create schedule compression and increase the degree of concurrency in design, resulting in excessive overtime, fatigue, increased errors, reduced quality, and strains on the project management team. Figure 2.10. shows the causal loop diagram of the changes in project.

2.3.3.2.Economic Risk

Knight (1921) defined financial risk as risk or situations in which the randomness facing a firm can be expressed in terms of specific, numerical probabilities. These probabilities may be objective or subjective, but they must be quantifiable. Because they can be quantified, they can be managed.

Atkinson (1998) and Mok et al. (1997) allude that financial risk incorporates technical, human, and managerial as well as environmental failures. Both building and environmental risk cause financial risk impacts in budget prediction. Diekmann (1997) states that the new business requirements on global corporate world demands financial attention to cater for social responsibilities that generate financial risks.

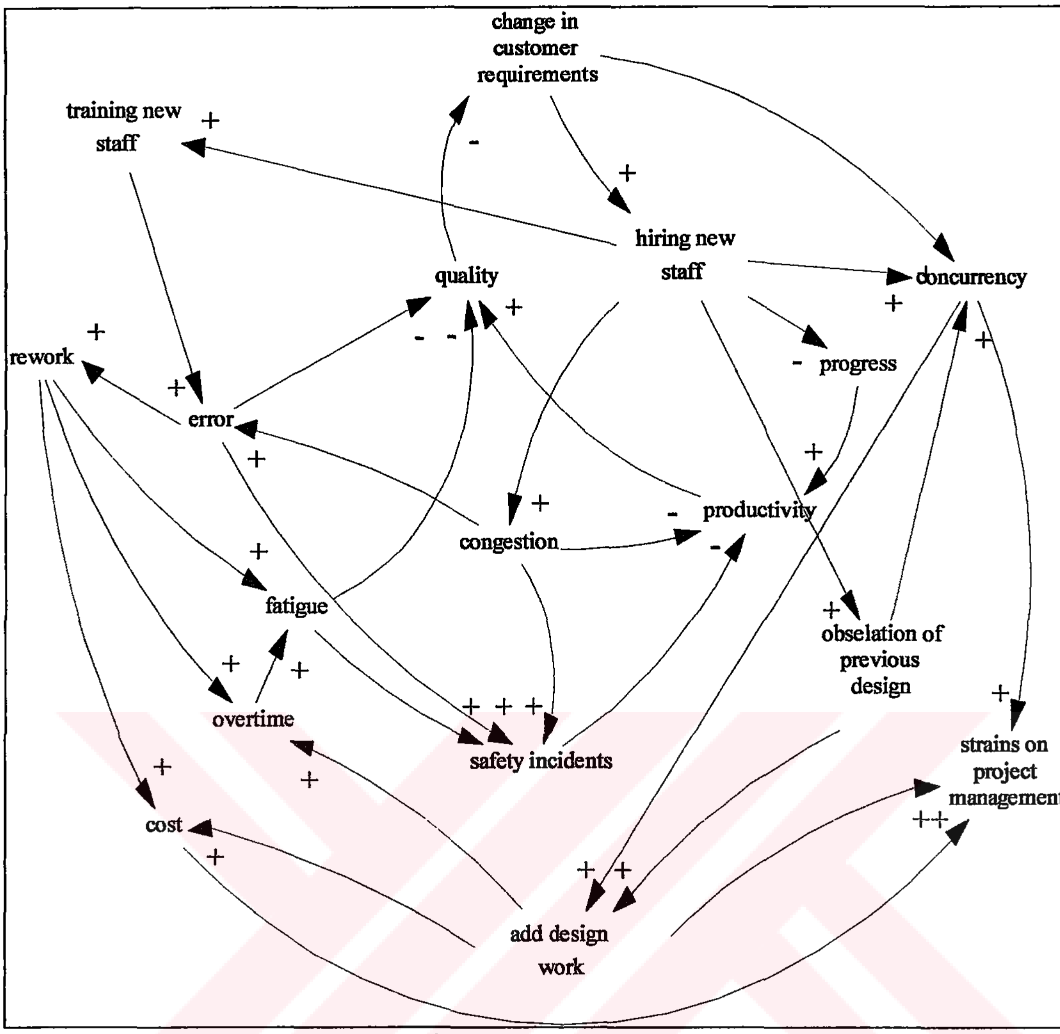


Figure 2.10. Customer Requirement Change (Drawn from Sterman 1992)

2.3.3.3.Technical Risk

Technological uncertainty relates to the uncertainty about the best technologies to be used in the product and/or process, and the degree of familiarity of the team with the technologies involved in the project (Swink 2000, Tatikonda and Rosenthal 2000 a,b,)

As pointed out by Branscomb et al (2000), the elements of technical risk are not easily characterized, since real technical risk involves a forecast of how science will be successful when real people conduct experimentation, interpret results, and apply them in real situations. The elements of technical risk are chaotic, in that they are dependent on people and environment, as well as the laws of science. Elements of technical risk are not independent of one another. Actions to understand and mitigate risk are interrelated through the laws of science, patterns of rational processes, and the personalities of people involved. Risk can be characterized as a probability of success, but it is always improbability given a set of premises, an expected environment, and a pattern of response with a correlated expectation of success.

There are several types of technical risks, such as wrong technology selection, equipment and material risk, engineering and design change, hardware or software failure, knowledge deficiency, change in technical staff etc…

Chapman (1998), states that the loss of key project personnel is highly disruptive to communication and the absence of recognition and allowance for this eventuality results in a significant under-estimation of uncertainty, which may increase technical risk.

As stated by Adlington et al. (1994), " *people issues, can often have as great an impact on an outcome as technical issues. The absence of such'soft' factors in risk analysis can result in a gross under-estimation of overall uncertainty.*"

Abdel-Hamid (1989), describes that the desire to maintain the indicated personnel level changes dynamically over the life of a project. He gives the example that towards the end of a project there is considerable reluctance to bring in new people even when the project is behind programme. This is because it takes just too much time and effort (relative to the time remaining) to acquaint new people with the mechanics of the project, integrate them into the project team and train them in the project procedures. Where there has been a loss of staff and the completion date has been set by the client as a fixed objective and made immovable, the following situations suggested by Abdel-Hamid (1989), may arise:

1. No additional staff is taken on and the remaining designers are required to increase their workload leading to an increase in the effort remaining and programme pressure.
2. The incoming design team members go through an orientation phase which erodes the programme increasing the effort remaining and programme pressure
3. The existing experienced designers loose productive time increasing programme pressure

When new staff is introduced to an ongoing project they have to go through a learning curve to become familiar with the project details. The work rate of new team members takes time to reach the level of the departed and existing team members. In addition the work rate of the existing team members reduces during the time they devote to assisting the new team members become 'acclimatised' to the project. As a consequence not only will project productivity fall as a result of the incoming team member needing to learn about the project before he can become fully productive but also because existing members lose productive time when answering queries or explaining previous decision making steps. As stated by Chapman (1998), also project information is so voluminous and complex it cannot be passed in totality from one individual to the next even if the incoming team member has the luxury.

Chapman (1998), suggests a model to understand how the change of a key team member impacts on a construction project, (see Figure 2.11.)

2.3.3.4.Environmental /Ecological Risk

Global environmental risks are becoming increasingly important as the world is globalizing and as the accumulation of local human interventions in nature are becoming measurable on global scales and start to threaten stable development pathways for human societies and natural ecosystems. Obersteiner (2001) states that as globalization of commercial and political markets, overpopulation, new technological opportunities, and large scale environmental threats raise levels of uncertainty and rewrite definitions of sustainability and risks, the basic strategic choice of the global community has morphed into a more complex and high-stakes dilemma. Wrong strategic bets, whether intentional or unintentional, of the global community carry an increasingly higher risk than ever before.

Hart (1999) states that environmental risks abound everywhere that humans make things. As our planet grows smaller, our populations larger, and our technologies more ferociously in need of energy sources, communicating about environmental risk has become increasingly necessary and increasingly difficult.

2.3.3.5.Political Risk

In its most simple definition, political risk refers to the possibility that political decisions, conditions, or events in a country will affect the business climate in such a way that investors will lose money or not make as much money as they expected when the investment was made.

Political risk occurs in many situations such as; changing scope, changes in government policy, changes in state laws/regulations, weak judicial system, foreign government interference etc.

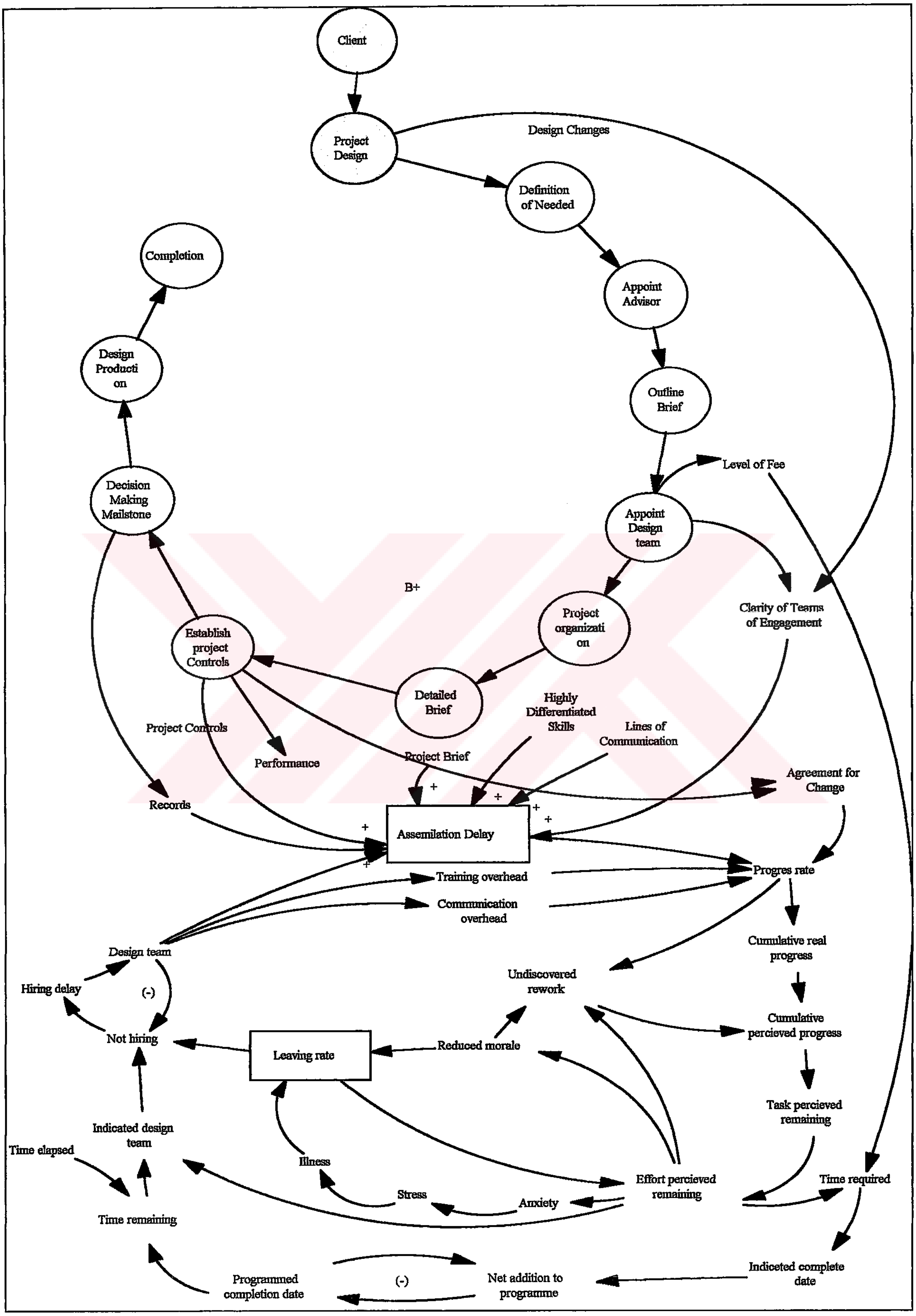


Figure2.11. Model of the design process illustrating the negative impact of a change of staff (Chapman 1998)

One of the most important types of political risk is defined by Simon (1982) as the risk for a government turnover and the effects such an event could have on a company. A number of variables can influence an irregular turnover in government. Many authors claim that the main influencing factor is the type of political system, but other examples are ethnic/ religious conflicts, foreign government intervention and economic stress.

Kennedy (1988) states that, *"Political risk can be defined as the risk of a strategic, financial or personnel loss for a firm because of such nonmarket factors as macroeconomic and social policies, or events related to political instability."*

Lindeberg and Mörndal (2002) make the common division of political risk into macro-risks and micro-risks. Macro-risks are also referred to as country risks and include all events that are likely to have an effect on foreign investments in general. The micro approach is a response to the simplified assumption that the degree of political risk exposure is the same for all firms in a country. The micro approach also indicates the need for company managers to pay attention to changes in industry specific conditions and not only radical changes in government. According to Kobrin (1982), most politically generated contingencies present micro and not macro risks.

Williams (2000) states that uncontrolled change can have an important effect on large design and development projects. Such effects are systemic and so are difficult to quantify. According to him one particular source of change that can have a major effect is changes to safety regulations.

The safety regime forms an essential part of the specification of a product to be developed. Changes to this regime during the period of development, after the specification has been agreed and design work started, necessitates a change to the specification and subsequent re-design and re-work. Furthermore, since the changes cause systemic effects, these effects can be very difficult to quantify and indeed often appear to give rise to over-runs and over-spends much greater than expected.

Design changes resulting from changes to safety regulations clearly are an important example of such external change. Williams (1995) describes the effects of design changes on the progress of a project in detail. His description can be summarised as follow;

1. Additional requirements or additions to the scope of work are demanded during the course of the project (thus not envisaged or planned for); these not only increase the

time required to carry out the design work but also might have cross-impacts on other parts of the system;

2. If safety concerns or other design changes are being considered, there will normally be delays- often extensive delays- to the approval process; and while individual delays can be measured and sometimes their implications assessed, the cumulative impact of a number of delays is very difficult to assess.

These primary effects cause a number of secondary effects:

1. The changes are systemic (within the product), so often a number of project elements must be redesigned simultaneously.
2. Most such changes increase complexity, producing increasing cross-relations between parallel activities developing cross-related parts of the product; this implies increasing difficulty in providing a system freeze, since changes in one component will increasingly cross-impact other components, creating a ripple effect across the system.
3. Additionally, or alternatively, this re-design causes disruption to the design schedule, which often means that system elements are being designed without having full specifications of necessary interface.

A simple Influence Diagram suggested by Williams (2000), could be drawn, as shown in Figure 2.12.

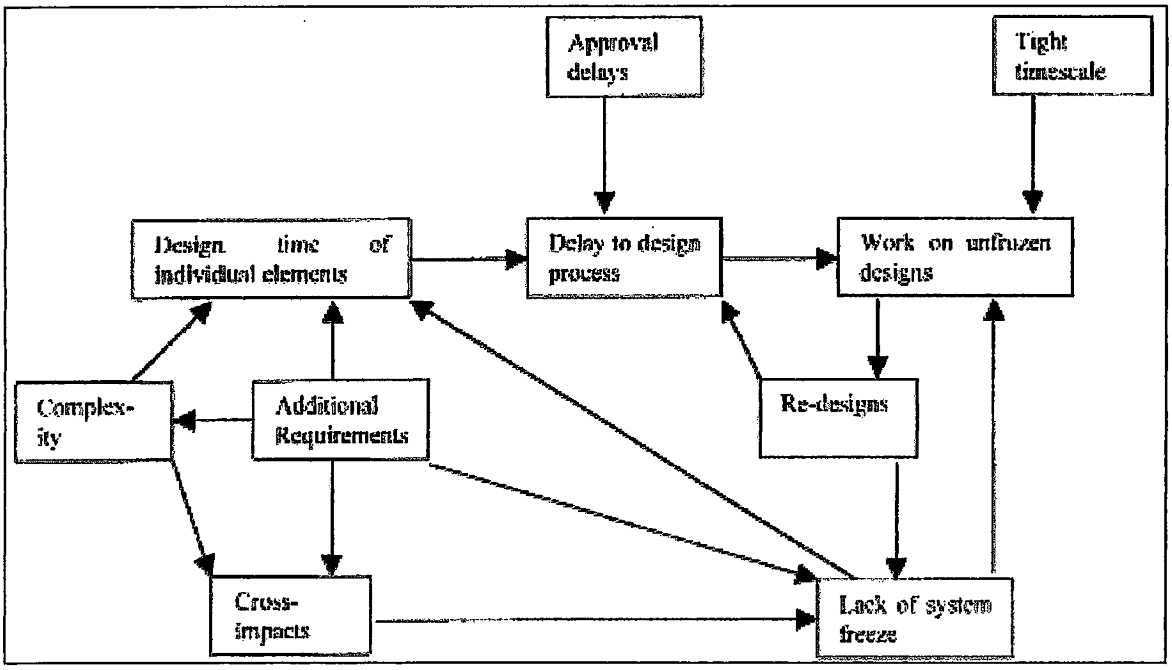


Figure 2.12. Initial influence diagram. (Williams 2000)

Changes to safety regulations can have significant effects on a design-and-manufacture project. This risk must be considered at the start of the project, and contractual liability for the risk established at the start. Such changes cause systemic effects which are difficult to quantify, and, because of their systemic nature, are much bigger than intuition would suggest.

2.3.4. Risk Management

Risk Management is the systematic process of identifying, analyzing, and responding to project risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives.

Wideman (1992) defines Project Risk Management, as *"Project Risk Management is the art and science of identifying, assessing, and responding to project risk throughout the life of a project and in the best interests of its objectives"*

Baker (1998) states that risks are involved in every phase of the projects' life cycle, and thus continuous management of them is needed to ensure the best possible outcome of risk management. In the best companies risk management is a routine task that is carried out in all of these stages. The risk management life cycle is visualized in Figure 2.13.

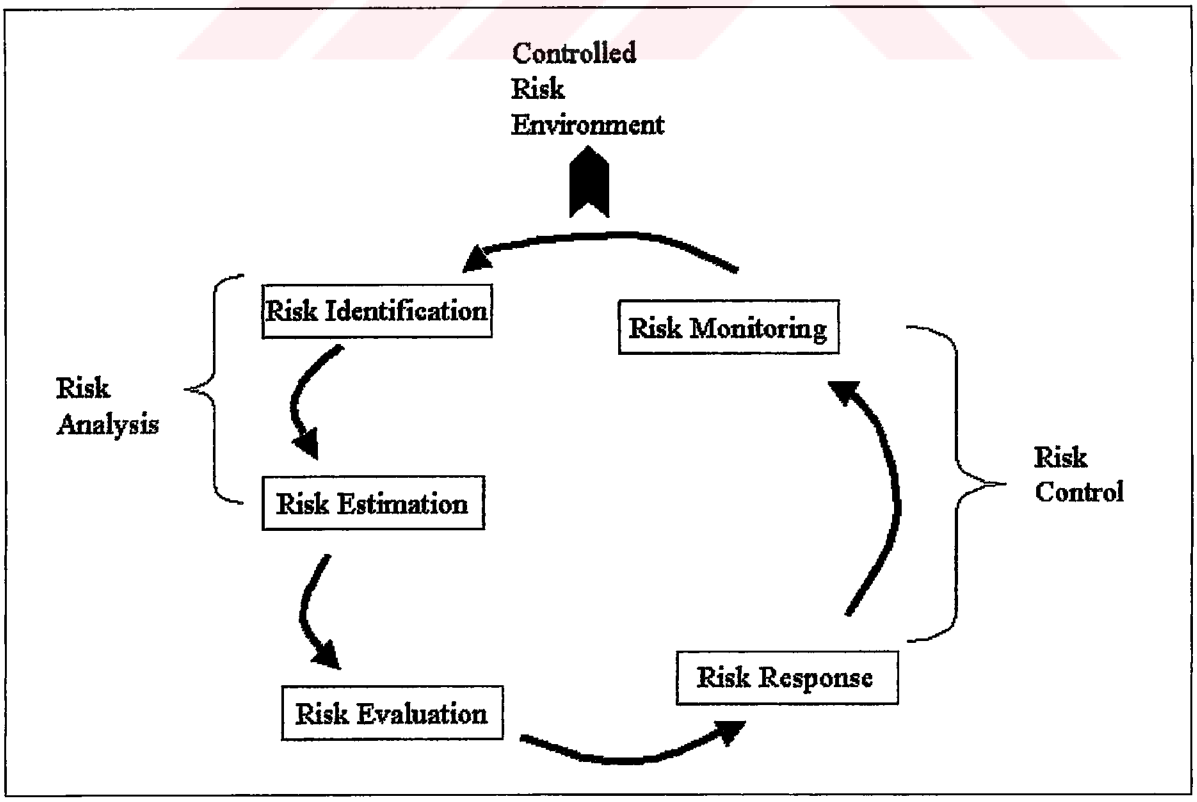


Figure 2.13. Risk management Life Cycle (Baker et al. 1998)

In project environments the project managers should understand the persistent nature of risk. There are always risks concerned in every decision to be made. However, these risks can be affected by proper risk management. Being aware of the risks gives the decision maker the possibilities to make some corrective actions during the project if needed.

The objective of the project risk management process is not to remove all the project risks (Singleton and Hovden, 1987). At this point Frame (1994) states "*The risks stay always with the project team as long as the project is running. Moreover, project risks are often even more difficult to handle than in other forms of activities due to the unique nature of projects.*" The job of risk management is to recognize risks and reduce the effect they have on the projects' performances.

According to Hamilton (1988) "*Risk management is a multidiscipline involving the identification and valuation of risks as well as controlling and financing any risk which is threatening life and property.*"

Pitkänen (1999) states that project risk management means improving project performance by identifying, analyzing and controlling project risks. We will expand this expression adding a few processes which are as important as the three stated by Pitkänen (1999).

Risk Management involves major processes. These processes interact with each other and with the processes in the other knowledge areas. Each process generally occurs at lest one project. Some characteristics of risk management quoted from PMBOK (2000) are explained below.

2.3.4.1. Risk Management Planning

Risk Management Planning is the process of deciding how to approach and plan the risk management activities for a project. It is important to plan for the risk management processes that follow to ensure that the level, type, and visibility of risk management are commensurate with both the risk and importance of the project to the orgnization.

2.3.4.2.Risk Identification

Risk identification involves determining which risks might affect the project and documenting characteristics.

Risk identification is an iterative process. The first iteration may be performed by a part of a project team, or by the risk management team. The entire project team and primary stakeholders may make a second iteration. To achieve an unbiased analysis, person who is not involved in the project may perform the final iteration.

2.3.4.3.Qualitative Risk Analysis

Qualitative risk analysis is the process of assessing the impact and likelihood of identified risk. This process prioritizes risk according their potential effcet on project objectives. Qualitative risk analysis is one way to determine the importance of adressing specific risk and guiding risk responses.

An evaluation of the quality of the available information also helps modify the assesment of the risk. Qualitative risk analysis requires that the probability and consequences of the risk be evaluated using established qualitative-analysis methods and tools.

2.3.4.4.Quantitative Risk Analysis

The quantitative risk analysis process aims to analyze numerically the probability of each risk and its consequence on project objectives, as well as the extend of overall project risk. This process uses techniques such as Monte Carlo simulation and decision analysis to:

1. Determine the probability of achieving a specific project objective
2. Quantify the risk exposure for the project, and determine the size of cost and schedule contingency reserves that may be needed.
3. Identify risks requiring the most attention by quantifying their relative contribution to project risk.
4. Identify realistic and achievable cost, schedule, or scope changes.

Quantitative risk analysis generally fallows qualitative risk analysis. The qualitative and quantitative risk analysis processes can be used separately or together. Considerations of time and budget availability and the need for qualitative or quantitative statements about risk and impacts will determine which method(s) to use.

2.3.4.5.Risk Response Planning

Risk response planning is the process of developing options and determining actions to enhance opportunities and reduce threats to the project's objectives. It includes the identification and assignment of individuals of parties to take responsibility for each agreed risk response. This process ensures that identified risks are properly addressed. The effectiveness of response planning will directly determine whether risk increases or decreases for the project.

Risk response planning must be appropriate to the severity of the risk, cost effective in meeting the challenge, timely to be successful, realistic within the project context, agreed upon by all parties involved, and owned by a responsible person.

2.3.4.6.Risk Monitoring and Control

Risk monitoring and control is the process of keeping track of the identified risks, monitoring residuals risks and identifying new risks, ensuring the execution of risk plans, and evaluating their effectiveness in reducing risk. Risk monitoring and control records risk metrics that are associated with implementing contingency plans. Risk monitoring and control is an ongoing process for the life of the project. The risk change as the project matures, new risk develops, or anticipated risks disappear.

Good risk monitoring and control processes provide information that assists with making effective decision in advance of the risk's occuring. Communication to all project stakeholders is needed to assess periodically the acceptability of the level of risk on the project.

Risk control may involve choosing alternative strategies, implementing a contingency plan, taking corrective action, or replanning the project. The risk response owner should report periodically to the project manager and the risk team leader on the effectiveness of the plan, any unanticipated effects, and any mid-course correction needed to mitigate the risk.

2.3.5. Use of SD model in Risk Management

Adjusting the level of structuring for the risk management activity is crucial for the practical implementation of the risk management process. A SD project model can be used to analyze this problem. An example of the use of a SD model for this purpose can be found in Rodrigues (2001).

2.3.5.1. Risk Identification with SD Model

A SD project model can support risk identification in two ways: at the qualitative level, through the analysis of influence diagrams, risks that result from feedback forces can be identified; at the quantitative level, intangible project status information (e.g. undiscovered rework) and assumptions in the project plan can be uncovered (e.g. required productivity).

Rodrigues (2001) suggests an influence diagram in which risks can be identified as events that result from,

1. Balancing loops that limit a desired growth or decay (e.g. the lack of available resources leads to a balancing loop that limits the potential growth of work accomplishment);
2. Reinforcing loops that lead to undesired growth or decay (e.g. schedule pressure leads to Quality Assurance (QA) cuts, which in turn lead to more rework and delays, thereby reinforcing schedule pressure; see "R+" loop L3 in Figure 2.14.)
3. External factors that exacerbate any of these two types of feedback loops (e.g. training delays exacerbate the following reinforcing loop: "the more you hire in the later stages, the worst the slippage due to training overheads.").

SD simulation models allow the project manager to check whether and how certain feedback loops previously identified, as "risk generators" will affect the project. In this way, irrelevant risks can be eliminated, preventing unnecessary mitigating efforts. Secondly, the calibration of the SD model uncovers important quantitative information about the project status and past, which typically is not measured because of its intangible and subjective nature. In this way, it forces planning assumptions to made explicit and thereby identifying potential risks.

2.3.5.2. Qualitative Risk Analysis with SD Model

Influence diagrams can help to assess risk probability and impacts through feedback loop analysis. Given a specific risk, it is possible to identify in the diagram which feedback loops favor or counter the occurrence of the risk. Each feedback loop can be seen as a dynamic force that pushes the project outcome towards (or away) from the risk occurrence. The likelihood and the impact of each risk can be qualitatively inferred from this feedback loop analysis.

A SD simulation model can be used to identify the specific scenarios in which a risk would occur (i.e. likelihood). Regarding impact, with simple models and preliminary calibrations, quantitative estimates can be taken as qualitative indications of the order of magnitude of the risk impacts.

2.3.5.3. Quantitative Risk Analysis with SD Model

In quantifying risks, a SD project model provides two additional benefits over traditional models: first, it delivers a wide range of estimates, and secondly these estimates reflect the full impacts of risk occurrence, including both direct and indirect effects.

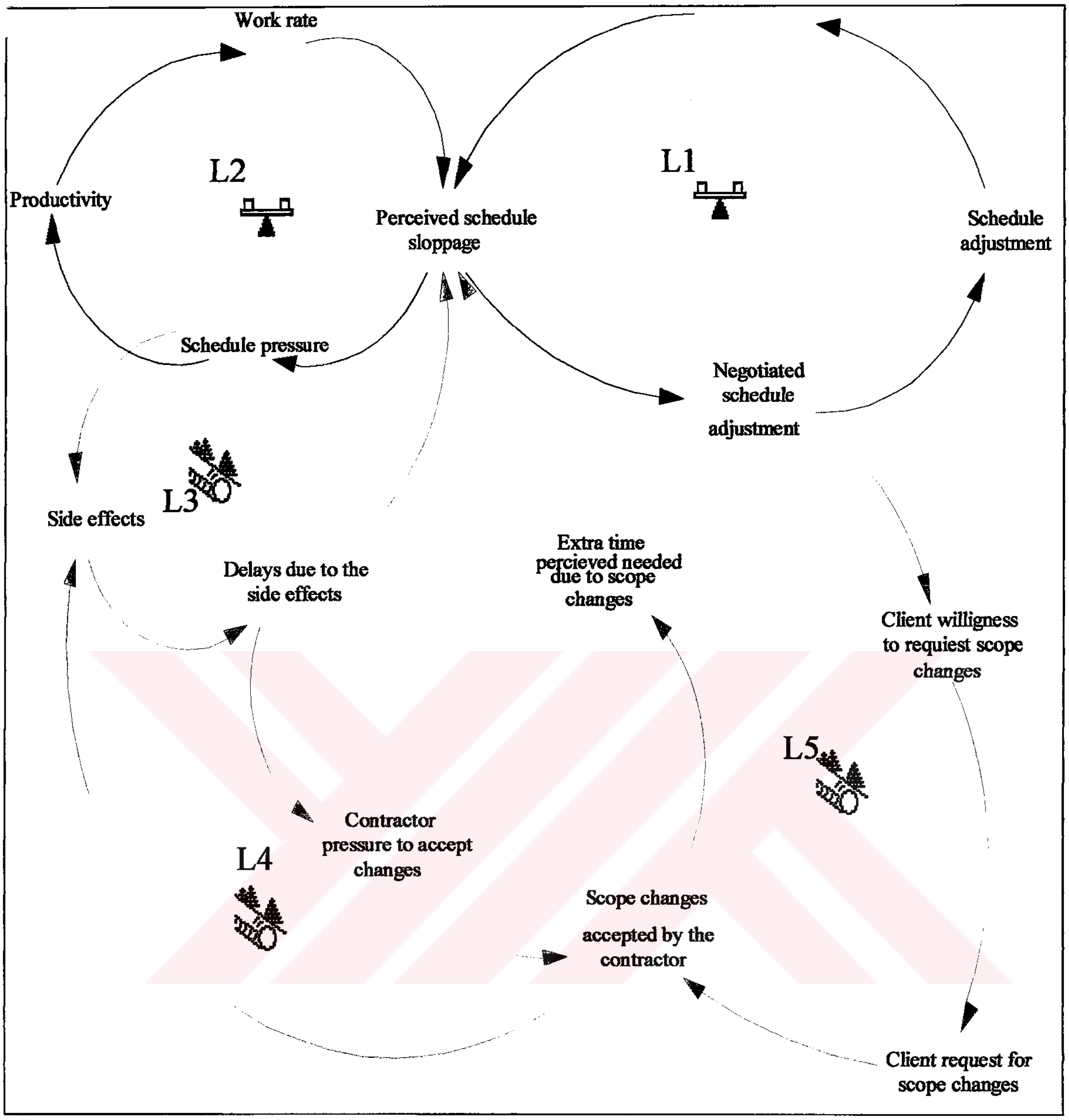


Figure 2.14.Example of a project feedback structure focused on scope changes (Rodrigues 2001)

Quantifying the impact of a risk consists in calibrating the model for a scenario where the risk occurs (e.g. scope changes), and then simulate the project. One can virtually analyze the impact of the risk occurrence in any project variable, by comparing the produced behavior pattern with the one obtained when a risk-absent scenario is simulated. The feedback nature of the SD model ensures that both direct and indirect impacts of risks are quantified – ultimately, when a risk occurs it will affect *everything* in the project, and the SD model captures the full impacts.

A SD project model generally includes variables related to the various project objectives (cost, time, quality, and scope). One can therefore assess the risk impacts on all dimensions of the project objectives. The SD model also allows for scenarios combining several risks to be simulated, and the project's sensitivity to certain risks as well as to their intensity (e.g. what is the critical productivity level below which problems will escalate?).

2.3.5.4. Risk Response Planning with SD Model

Influence diagrams and SD simulation models are very powerful tools to support the development of effective risk responses. According to Rodrigues they provide three main distinctive benefits:

1. Support the definition and testing of complex risk-response scenarios.
2. Provide the feedback perspective for the identification of response opportunities,
3. They are very effective in diagnosing and better understanding the multi-factor causes of risks; these causes can be traced-back the through the chains of cause-and effect, with counter-intuitive solutions often being identified. Influence diagrams provide the complementary feedback perspective.

A SD simulation model provides a powerful test-bed, wherein, at low cost and in a safe environment, various risk-responses can be developed, their effectiveness can be tested for the full impacts, and can be improved prior to implementation.

2.3.5.5. Risk Monitoring and Control with SD Model

A SD project model can be used as an effective tool for risk monitoring and control. The model can be used to identify early signs of risk emergence, which otherwise would remain unperceived until problems would aggravate. The implementation of risks responses can also be monitored and their effectiveness can be evaluated.

Risk occurrence can be monitored by analyzing the project behavioral aspects of concern. A SD model has the ability to produce many of these patterns, which in the real world are not quantified due to their intangible and subjective nature (the amount of undetected defects flowing throughout the development life-cycle is a typical example). The SD model provides a wide range of additional risk triggers, thereby enhancing the effectiveness of monitoring risk occurrence.

The implementation of a risk response can be characterized by changes in the project behavior. These changes can be monitored in the model, to check whether the responses are being implemented as planned. The effectiveness of the risk response (i.e. the expected impacts) can be monitored in the same way. When deviations occur, the SD model can be used to diagnose why the results are not as expected.

2.3.6. Risk Relationships

Chapman (1999) states that "efficient management of building projects demands clear effective communication and if risk analysis and management is to be used as a tool to assist the management of projects, then it must itself be clearly communicated and understood." According to Chapman (1999) commonly risks mutually affect, magnify or diminish each other. This kind of mutual influence among risks on a project is defined as the risk relationship.

Figure 2.15. shows that a risk may have multiple causes and be correlated to other risks. Risks occurring in series, describes the situation where one risk event generates another risk event in a continuous sequential action. In other words, risk event B is dependent on the occurrence of risk A. If risk A occurs, then risk B occurs directly as a result of A. If risk A does not occur, then risk B definitely does not occur.

Risks occurring in parallel, describes the situation where several risk events occur at the same time. Where three risk events have been identified, which will occur at the same time and have an impact on the same programme activity; then it is the risk, which will have the largest negative effect that is considered in any probabilistic analysis. For example, where the risks of changes in legislation, late Client changes to brief and design rework to realign design to cost plan have been identified against a programme activity called ``production information" and the risk of design rework to realign design to cost plan is assessed as having the highest probability and impact, then it is this dominant risk which is incorporated into any assessment of the risks in combination on the programme would not be greater than the impact then it is this dominant risk which is incorporated into any assessment of the risks in combination.

Chapman (1998) emphasizes that identification of risks requires an understanding of the characteristics of the process and how its main components must be maintained in balance. Identification requires an understanding of the sources of risk and General Systems Theory is put forward as a way of structuring those sources. In addition, it is proposed that risks have distinctive characteristics and that their interrelationship can be described in terms of whether they are in series or parallel.

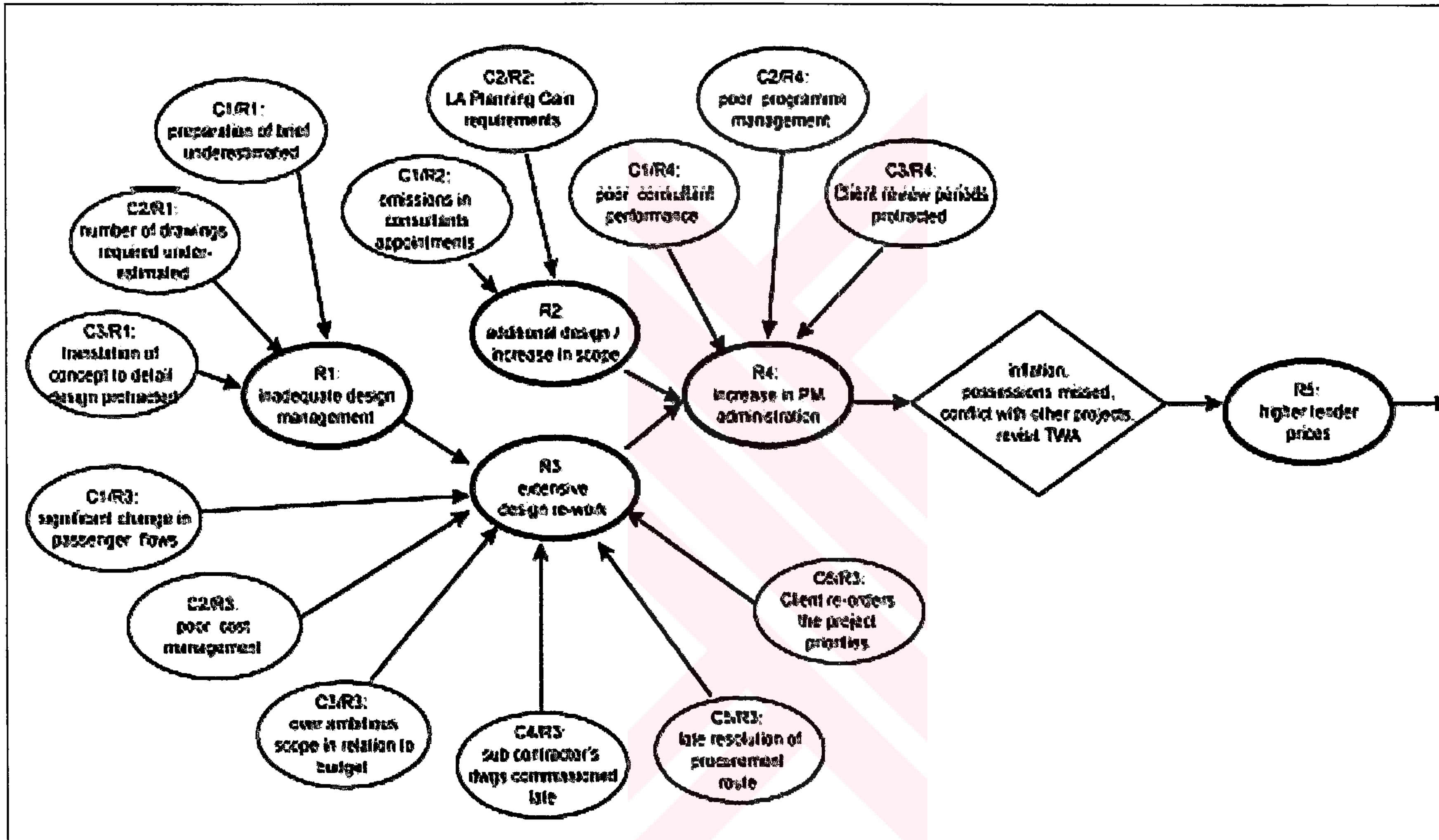


Figure 2.15. Risk relationships. (Chapman 1999)

3. PROPOSED MODEL

3.1.Mental Maps versus Causal Loops

According to Sterman (2000), our mental models often fail to include the critical feedbacks determining the dynamics of our system. In system dynamics several diagramming tools are used to capture the structure of the system, including causal loop diagrams and stock and flow maps.

Causal loop diagrams are wonderfully useful in many situations. They are well suited to represent interdependencies and feedback processes. They are used effectively at the start of a modeling project to capture mental models.

Sterman (2000) states that eliciting and mapping the participants' mental models, while necessary, is far from sufficient. The temporal and spatial boundaries of our mental models tend to be too narrow. They are dynamically deficient, omitting feedbacks, time delays, accumulations, and nonlinearities. The great virtue of many protocols and tools for elicitation is their ability to improve our models encouraging people to identify the elements of dynamic complexity normally absent from mental models. However, most problem structuring methods yield qualitative models showing causal relationship but omitting the parameters, functional forms, external inputs, and initial conditions needed to fully specify and test the model. Regardless of the form of the model or technique used, the result of the elicitation and mapping process is never more than a set of causal attributions, initial hypotheses about the structure of a system, which must then be tested.

According to Simon (1957), the capacity of the human mind to formulating and solving complex problem is very small compared with the size of the problem whose solution is required for objectively rational behavior in the real world or even for a reasonable approximation to such objective rationality.

3.1.1. Mental Map

The concept of "mental models" has been vitally important to the field of system dynamics since its inception. Information about the structure and relationships in dynamic systems gleaned from mental models, for example, are what allow system dynamic computer models to be constructed in the absence of written and numerical data (Forrester, 1961).

Among the most commonly reported shortcomings of mental models of dynamic systems are the following:

1. Mental models are typically vastly oversimplified. While all models must simplify reality in order to be useful, mental models are often so simple that they omit information that is crucial for understanding the dynamics of systems.
2. Mental models can only rarely be mentally simulated accurately, primarily because even relatively simple dynamic models outstrip the mind's ability to calculate or infer their consequences.
3. Mental models are typically "sloppy" or "messy." For example, their causal pathways often have gaps or omissions and sometimes lead to dead ends; signs of relationships between variables are often ambiguous; and variables are rarely described quantitatively. This lack of completeness and coherence acts as a further hindrance to mental simulation.

3.1.2. Causal Loops

According to Monga (2001), causal loops are immensely helpful in eliciting and capturing the mental models of the decision-makers in a qualitative fashion. Interviews and conversations with people who are a part of the system are important sources of quantitative as well as qualitative data required in modeling. Views and information from people involved at different levels of the system are elicited, and from these, the modeler is able to form a causal structure of the system.

The problem with causal-loop diagrams is that they make no distinction between information links and rate-to-level links (sometimes called "conserved flows").

Sterman (2000), claims that causal loop diagrams are excellent for:

1. quickly capturing your hypotheses about the cause of dynamics
2. eliciting and capturing the mental models of individuals or teams
3. communicating the important feedbacks you believe are responsible for a problem"

Monga (2001), states that causal loops are used effectively at the start of a modeling project to capture mental models. However, one of the most important limitations of the causal diagrams is their inability to capture the stock and flow structure of systems.

3.2. Direct Conversion of Causal Maps into SD Model

3.2.1. The Need for Conversion

In the discipline of system dynamics, causal maps have been used mainly as a bridge between system insights and system modeling. According to Coyle (1998) the value of a causal map in its own right is rapidly gaining ground. The causal map can be built with less time and efforts than a simulation model and it can give important insights and understanding that clients demand. On the other hand, cognitive map has been used widely to represent mind maps of decision-makers without using computer simulation. However, the causal map and cognitive map have fundamental limits in understanding behavioral implications. Even the use of fuzzy cognitive maps has limits in simulation (Kardaras and Karakostas 1999)

Kim (2000) states that to build a system dynamics model from a causal or cognitive map, two kinds of task are required. First, one must add some operational structure. Second, lots of quantification should be introduced into the original map. Since these two kinds of task require too much burden, simulation of them are usually given up. However, there often come some situations that one cannot avoid the simulation of the causal or cognitive map. Sometimes system insights can be found only after one sees the dynamic behavior of the causal and cognitive map. When this situation occurs, one has to collect additional data and information to build a system dynamics model. But, more often than not, it is difficult to collect enough data. Usually additional data and complication of the map to make a simulation drives away the original insights.

According to Sterman (2000) "*causal loop diagrams suffer from a number of limitations and can easily be amused. One of the most important limitations of causal loop diagram is their inability to capture the stock and flow structure of the system.*" Also he states, " *causal diagrams can never be comprehensive (and you shouldn't try: modeling is the art of simplification.) They are also never final, but always provisional.*"

3.2.2. Normalized Unit Modeling By Elementary Relationships (NUMBER)

A method is needed for directly converting causal maps and cognitive maps. Kim (2000) suggests a method called 'NUMBER' indicating "Normalized Unit Modeling By Elementary Relationships". The method of the NUMBER has three steps for converting a causal map into a SD model. First, several variables in the causal map are chosen as level (stock) variables according to their role in the map. Second, all variables are normalized between 0 and 1. That is why this method is called as "Normalized Unit Modeling". Thus this method normalizes units of all variables between 0 and 1. In the third and last step, variables are connected by elementary relationships that are designed to constrain the value of variables between 0 and 1. Especially, level variables are connected with automatically introduced rate variables by predefined relationships. Thus this method is called as "normalized unit modeling by elementary relationships (NUMBER)".

NUMBER is consisted of two important assumptions. The first assumption is that the value of all variables can be expressed between 0 and 1. This does not mean that all variables should remain between 0 and 1. Some variables like gap and distance can have minus value. But even the minus value must be remained between 0 and -1. This constraint will allow variables in the acceptable ranges and prohibit them from affecting other variables by extreme degree. One has to notice that addition, subtraction, and division might lead variables to exceed this constraint. But multiplication will preserve variables within this range. With this constraint, there are some safe operations for calculation.

Table 3.1. lists typical example of the safe operations. For example, if there is an opposite relationship between two variables A and B, one can represent it as "A=a*(1-B)" instead of "A=a/B". Even though this safe formula cannot cover all kinds of causal relationships, they will provide safe ground to quantify abstract conceptual variables. If one cannot represent some causal relationships, one can use graph function.

Table 3.1. Safe operation that will satisfy the constraint of 0 and 1. (Kim 2000)

Safe formula	Meanings
A=1-B	B affects A disproportionately
A=0+B	B affects A proportionally
A=0.5+B/5	B affects A proportionally beyond 0.5
A=(B+C)/2	B and C affects A proportionally
A=(B-C)/2	B affects A proportionally and C affects A disproportionately
A=B*C	B and C increase A
A=B*(1-C)	B increases A but C decreases A
A=(1-B)*(1-C)	B and C decrease A

In addition to this safe formula, an elementary relationship between level variable and rate also introduced in NUMBER. Since the value of level variable is accumulated during the simulation, it will easily move out of the boundary. This elementary relationship is introduced to keep the level variable within the boundary between 0 and 1.

level variable=INTEG (increasing rate-decreasing rate)

increasing rate=(1-level variable)*changing ratio

decreasing rate=(level variable)*changing ratio

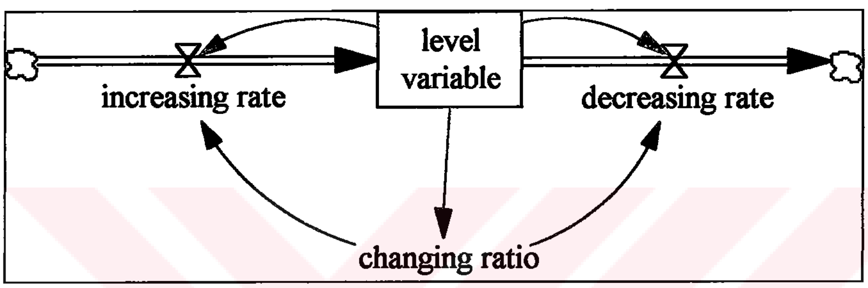


Figure 3.1. Elementary relationship between level and rate variables (Kim 2000)

Figure 3.1. shows equations that will preserve value of the level variable between 0 and 1. In order to ensure this, increasing rate is defined to converge towards zero as the value of the level variable comes near 1. This can be done by multiplying (1- level variable) to the equation of the rate variable. On the other hand, we defined the decreasing rate to converge toward zero as the value of the level variable goes to zero. This can be done by multiplying the level variable to the equation of the decreasing variable. Thus the value of the level variable stops increasing as it comes to 1 and it stops decreasing as it moves to 0. In this way, the level variable remains in the boundary of 0 and 1.

NUMBER is a technical guideline for performing abstract simulation. As discussed above NUMBER consists of two important rules:

1. Constraining unit of variables between 0 and 1
2. Elementary relationship for level variables that will automatically enforce the value of the level variable within the boundary.

With NUMBER, one can convert causal map and cognitive map directly into system dynamics model by introducing only some rate variables to make the elementary relationships for level variables. In order to experiment the usefulness of NUMBER, it is applied to several causal maps of systems archetype and cognitive map of policy maker.

3.2.3. Applying NUMBER to Causal Maps in System Archetype

Lane and Smart (1996) state that "*Causal maps for system archetype are famous for their simple structure and rich insights. But they cannot show any behavioral implication and thus do not allow any behavioral experimentation.*" Causal maps of system archetype are rich in structural implication but poor in behavioral insights. NUMBER can provide this missing link between structure and dynamic behavior. See Appendix B for archetype examples.

3.3. The Model

The modeling process used for the development of the model followed the steps and guidelines presented by Sterman (2000).

3.3.1. Problem Articulation

According to Sterman (2000), the most important step in modeling is the problem articulation. The identification of a clear purpose is very critical. Models are effective when designed for a small problem or part of the system rather than the whole system itself. Identification of a clear purpose based on a problem in the system helps in making decisions about the framing of the model, i.e., what it should include and what should be left out.

3.3.1.1.The Problem

The business environment has changed dramatically creating new challenges for firms in most industries. It has become more global, turbulent, and dynamic making it difficult for firms to respond adequately to the shifting needs of markets and customers. In this context, the development of new technologies is becoming increasingly central to any strategy for achieving high levels of profitability, market share and, in the long run, gaining a significant leverage of competitive advantage. (Lebcir 2000)

As Smits (1999) states the telecommunications industry is changing rapidly. New actors are entering the market and having their own influence on the sector as a whole. The consumer is getting used to perceive high quality for less money. It is necessary for a telecommunications company to have insight in the dynamics and growth patterns of these developments and in the effects of certain strategies of the company.

Fast changing environment and dynamic structure of telecommunication area increase risk factors in projects. Project management teams should manage these risks factors to avoid from their effects on projects by assessing and mitigating. Risk management is always crucial in telecommunication projects. Rodrigues (2001) suggests that the traditional tools and techniques used in risk management process are not designed to address the increasingly systemic nature of risk uncertainty in modern projects. The growing uncertainty in modern projects most organisations fall short from implementing effectively structured frameworks. There are certain types of risks that are not handled properly by the traditional tools and techniques proposed. Managing project risk dynamics requires a different approach, based on a systemic and holistic perspective, capable of capturing feedback and of quantifying the subjective factors where relevant. System Dynamics is a simulation modeling approach aimed at analyzing the systemic behavior of complex social systems, like projects.

In this thesis the author has defined risks in telecommunication projects in 5 categories.

1. Social risk
2. Economic risk
3. Technical risk
4. Political risk
5. Ecological and Environmental risk

Table 3.2. shows risk classification in telecommunication projects. The risk classification table is formed within the framework of PSO (People-System-Organization) concept. Components of categories were derived from the literature.

Table 3.2. Risk Classification

	PEOPLE	SYSTEM	ORGANIZATION
SOCIAL	1. User involvement 2. Capability of Supervisors 3. Project management skills 4. Control 5. Capability of Contractors 6. Capability of consultants 7. Capability of Vendors 8. Staff commitment 9. Project management commitment 10. Change in customer requirement 11. Fatigue in staff personnel 12. Word of Mouth 13. Contact Rate 14. Customer Abandonment Time	1. Failure to manage end-user expectations 2. Appropriate experience of the user represantitatives 3. Overtime 4. Schedule Pressure 5. Rework 6. Quality 7. Productivity 8. Process Improvement	1. Advertisement campaign 2. Team relationship 3. No change Management Process 4. Managing 5. Safety incidents 6. Congestion in staff 7. Inward orientation and burdensome internal regulations
ECONOMIC	1. Labor cost 2. Purchasing power	1. Fund risk 2. Inflation risk 3. Production cost 4. Training Cost 5. Rework Cost 6. Market Share 7. Interest rates 8. Unit price 9. Investment for new projects 10. Profit	1. Macroeconomic stability 2. Improper market estimation 3. IMF policies 4. Hegemony of foreign companies
POLITICAL	1. Commitment of people in government 2. Provocative comments of politicians in opposite parties 3. Nationwide strikes/ boycotts 4. Foreign government interference	1. Changing scope / objectives 2. Changes in government policy (policy volatility)	1. Changes in State Laws 2. Weak judicial system 3. IMF policies 4. Progress in privatization
ECOLOGICAL	1. Demonstrations of social groups such as Green Peace 2. Damages of people where the systems are located	1. Act of God 2. Ecological equilibrium 3. Land Acquisition	1. Environmental Clearence
TECHNICAL	1. Knowledge deficiency 2. Productivity of technical personnel 3. Actual Skilled Staff	1. Wrong technology selection 2. Equipment and material Risk 3. Engineering and design change 4. Hardware or software failure 5. Testing 6. Delay in R&D process 7. Theft of hardware or software 8. Diffused ICT 9. ICT Requirement 10. Technology Gap 11. Available Technology 12. Technology Adoption 13. Technology Obsolescence Time	1. Organizational structure in technological staff 2. Implementation Methodology Selection 3. Definition of roles and responsibilities 4. Planning 5. Overly Optimistic Schedules 6. Training 7. Change in technical staff

3.3.1.2.Key Variables

1. Social Risk

Social Risk is a risk factor in all projects affecting processes and whole project. Social Risk should be considered from point of the view of two factors called customer and staff including management. Staff takes place in all processes of projects. Customer factor is taken into account after product sales. Quality and productivity are also important factors affecting social risk in projects.

2. Economic Risk

Economic Risk is a risk factor in all projects affecting processes and whole project. Uncertainties about economic events such as revenue, project total cost, sales, macroeconomic stability, interest rate, inflation create economic risk in projects. The future of firms mostly depends on economic situation. If risk in economic sector gets worst its effect would be greatly harmful to firm.

3. Technical Risk

Technical Risk is a risk factor in all projects affecting processes and whole project. Technological uncertainty relates to the uncertainty about the best technologies to be used in the product and/or process, and the degree of familiarity of the team with the technologies involved in the project.

4. Political Risk

Political risk can be defined as the risk of a strategic, financial, or personnel loss for a firm because of such nonmarket factors as macroeconomic and social policies, or events related to political instability. (Kennedy, 1988)

5. Ecological Risk

It can be described as Act of Got. For example weather conditions are very important factors causing time delays during projects. The most important risk is assumed to be earthquake.

3.3.1.3. Reference Modes

System dynamics modelers seek to characterize the problem dynamically, that is, as a pattern of behavior, unfolding over time, which shows how the problem arose and how it may evolve in the future. Reference Modes are a set of graphs and other descriptive data showing the development of the problem over time (Sterman, 2000). These graphs assist the decision makers and the modelers to break free from the narrow event-oriented perspective to a broader holistic perspective and to events that are removed in time and space.

3.3.1.4.Time Horizon

This is a very important feature in any problem characterization. Most conventional approaches focus on studying the problem and the system over a short time horizon. This is mainly due to our event-oriented outlook. We need to realize that the problem might have originated a long time back, and also that actions taken now may cause effects that are far displaced in time and space. Therefore, selecting an adequately long time horizon is very important. Author defines the time horizon of telecommunication project risks as 60 months.

3.3.2. Formulating Dynamic Hypotheses

This is the next step in modeling in which a working theory is developed to explain the problem at hand. Since the theory should account for the dynamics of the behavior of the system based on the underlying feedbacks and interactions between its different components, it is called a dynamic hypothesis. The role of the modeler is to elicit the views of the decision-makers that can affect the problem in the system, and to develop hypotheses to explain the problem.

3.3.2.1.Endogenous Explanation

System Dynamics seeks endogenous explanations for phenomena rather than exogenous ones. Explanations based on exogenous entities/variables are not of much interest as they articulate dynamics of endogenous variables in terms of other variables whose behavior is assumed (Sterman, 2000). Exogenous variables are "outside" the system and therefore they are not affected dynamically by interactions and feedbacks among the variables/entities within the system. An explanation of the system behavior in terms of these exogenous variables cannot capture the dynamics of the system. There should be very few exogenous variables in the model of the system under study. A broad boundary should be determined for the system as opposed to a narrow limiting boundary.

The following hypotheses are proposed.

1. There are two major factors including social risk; customers and project personnel. Commitment is important in project management. A lack of commitment of staff

personnel or management might cause delays in project, which results in cost overruns. Project management team should estimate customer requirements properly because change in customer requirements entails rework in project, which can cause hiring new staff and concurrency in development phase.

Customer satisfaction about the previous products and services of the company is crucial reference for potential customers. If there is no satisfaction about company at the market, new products and services could be under the risk of not being sold. Product and service quality is important factor effecting customer satisfaction. Namely the more quality, the more customer satisfaction.

2. Economic risks are crucial obstacles in telecommunication projects. If there are cost overruns or shortage in fund in a project, project can result in failure. The economic stability of the country is also an effective factor on projects. High inflation rates and high interest rates can interrupt projects. They can also increase labor costs which cause an increase in product unit cost. This lead to an ineffective competitive strategy in market. Also market share is as critical as the other economical risks. If a product has no share in market the turn of investment will be negative which leads to a financial crisis in the company. This crisis hinders new investments and the company could go bankrupt.

3. If technical capacity of staff personnel is not adequate, failures in software hand hardware are mostly probable. These failures requires rework which leads to cost overruns and time delays. Change in technical staff during a project is detrimental to project because training will be inevitable. Training leads to schedule pressure in projects, which results in cost overruns. If project management selects improper technology in development phase and implements wrong techniques while proceeding with project there could be a necessity of design changes, reworks and additional time. These necessities cause cost overruns, and delays.

3.3.2.2. Mapping

System dynamics includes a variety of tools to help with communicating the boundary of the model and represents its causal structure. These include subsystem diagram, model boundary diagrams, causal loop diagrams, and stock and flow maps (Sterman 2000)

3.3.2.2.1. Subsystem Diagram

A subsystem diagram shows the overall architecture of a model. Each major subsystem is shown along with the flows of material, money, goods, informations, and so on coupling the subsystems to one another. Subsystem diagrams convey information on the boundary and level of aggregation in the model (Sterman 2000). Figure 3.2. shows subsystem diagram of the model.

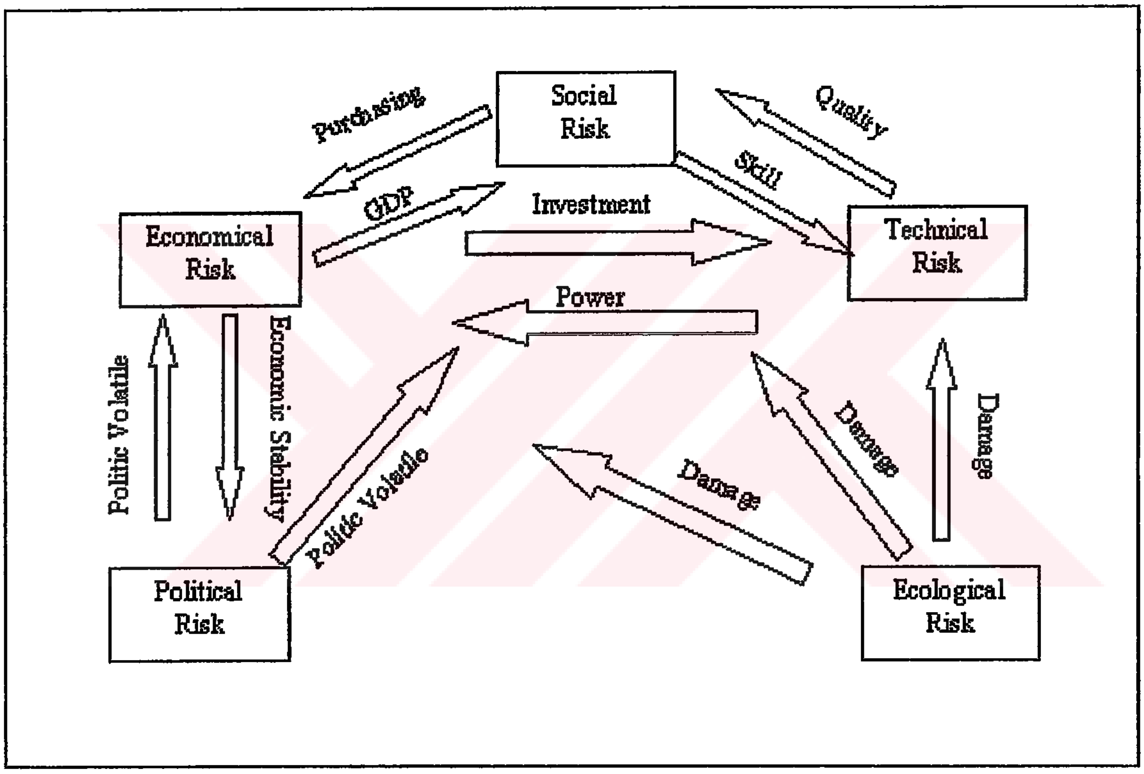


Figure 3.2. Subsystem Diagram of project risks

3.3.2.2.2. Model Boundary Diagram

The author presents model boundary diagram in two stages. In the first stage the five risk sector is classified as endogenous, exogenous and excluded, and a model boundary diagram is formed. Social, technical and economic risks are determined as endogenous variables in the model. Table 3.3. shows the model boundary diagram of risk sectors.

Table 3.3. Model Boundary Diagram of Risks

Endogenous	**Exogenous**	**Excluded**
Economic Risk **Social Risk** **Technical Risk**	**Political Risk**	**Ecological Risk**

Thereafter these three sectors are studied individually. Three model boundary diagrams are formed. Table 3.4., 3.5 and 3.6. show model boundary diagrams of three risk sectors.

Table 3.4.Model Boundary Diagram of Social Risk

Endogenous	**Exogenous**	**Excluded**
1. Staff commitment	1. Contact Rate	1. User involvement
2. Project management commitment	2. Customer Abandonment Time	2. Appropriate experience of the user representatives
3. Customer requirements		3. Effective management skills
4. Team relationship		4. Control
5. Safety incidents		5. Managing
6. Fatigue in staff personnel		6. No change management process
7. Inward orientation and burdensome internal regulations		7. Capability of supervisors
8. Overtime		8. Capability of contractors
9. Schedule Pressure		9. Capability of consultants
10. Rework		10. Capability of vendors
11. Quality		11. Failure to manage end-user expectations
12. Productivity		12. Advertising campaign
13. Process Improvement		13. Congestion in staff
14. Word of Mouth		

Table 3.5. Model Boundary Diagram of Economic Risk

Endogenous	Exogenous	Excluded
1. Market Share 2. Labor cost 3. Unit price 4. Rework Cost 5. Training Cost 6. Fund risk 7. Production cost 8. Macroeconomic stability 9. Investment for new projects 10. Profit 11. Revenue 12. Sales 13. Saving Measures	1. IMF policies 2. Inflation Risk 3. Interest rates 4. GDP Growth	5. Hegemony of foreign companies 6. Purchasing Power

Table 3.6. Model Boundary Diagram of Technical Risk

Endogenous	Exogenous	Excluded
1. Engineering and design change 2. Hardware or software failure 3. Delay in R&D process 4. Productivity of technical personnel 5. Equipment and material risk 6. Diffused ICT 7. Technology Gap 8. Technology Adoption 9. Staff Training 10. ICT Requirement	1. Available Technology 2. Actual Skilled Staff 3. Technology Obsolescence Time	1. Optimistic schedules 2. Definition of roles and responsibilities 3. Testing 4. Planning 5. Change in technical staff 6. Theft of hardware or software 7. Implementation methodology selection 8. Wrong technology selection 9. Knowledge deficiency of staff personnel 10. Improper organizational structure in technical staff

3.3.2.2.3. Causal Loop Diagram

The feedback structure of complex systems is qualitatively mapped using causal loop diagrams. (see Appendix A.2.3 for a discussion of causal loop diagrams)

It may help the user to look at the Causal Loop Diagram because it gives the general structure based on causalities and feedback loops. The interpretation of these loops and their combined complexity can be recognized easily by this way. It may help separate the loops to two groups, namely Reinforcing and Balancing Loops. The red arrows show the Balancing Loops and the green ones show the reinforcing loops.

In terms of risk types, the author forms three causal loop diagrams. These are;

1. Social Risk Sector Causal Loop Diagram
2. Economic Risk Sector Causal Loop Diagram
3. Technical Risk Sector Causal Loop Diagram

3.3.2.2.3.1. Social Risk Causal Loop Diagram

The main causal loops identified for the Social Risk Factors (depicted by Figure 3.3.) are as follows:

In projects there are many factors increasing Social Risk. Active Customer increases social Risk, **Fatigue in project staff** and **Combined Effect**. In other words, if **Active Customer** increases Social Risk is affected by this increase and it is increased too. It can be explained also by other way. If there are more and more customers there will be more and more problems about products and services. These problems would create social dissatisfaction. Also as **Combined Effect** increases Social Risk is increased. . In other terms, if there is something going wrong in the project then this would affect the other risk factors too. There is one important factor called **Fatigue in project staff** increasing Social Risk. The more Fatigue in staff personnel the more Social Risk in project. (Loops R1, R5, B7).

Social Risk is affected by **Customer Satisfaction, Management Commitment** and **Staff Commitment**. (Loops B2, B3, B4). These three factors create a balance in model. **Customer Satisfaction** might be described as external factor which is an important factor firms seek for. As **Customer Satisfaction** increases there would be less complaint about services and product so that Social Risk would be decreased. In projects there are two important factors, **Management Commitment** and **Staff Commitment**. They might be described as internal factors for firms. If there were no commitment to work and to firm there would be no success. If firms can realize this commitment Social Risk will be decreased from the point of the view of internal side.

Active Customers of the company have an important task. They could affect other people who are potential customers for company. The term "Word of Mouth" explains this event. If **Word of Mouth Rate** increases **Active Customers** increase too. Also the more **Active Customers** the more **Word of Mouth Rate**. (Loop R6)

Quality is the first aim for firms. There is a **Quality Balance** which is the ratio of current **Quality** with the **Desired Quality**. If **Quality** goes to one, which firms seek for, **Customer Satisfaction** will be increased. If **Customer Satisfaction** increases Social Risk decreases. (Loop B1)

Productivity is an important thing increasing **Management Commitment** and **Staff Commitment**. The more **Productivity** the more **Management Commitment** and the more **Staff Commitment**. (Loops R2, R3).

In projects many **Safety Incidents** occur. These safety incidents are detrimental to firms and should be eliminated. If more **Safety Incidents** take place **Management Commitment** decrease and Management team takes severe measures by regulations which would decrease **Staff Commitment**. (Loops B5, B6).

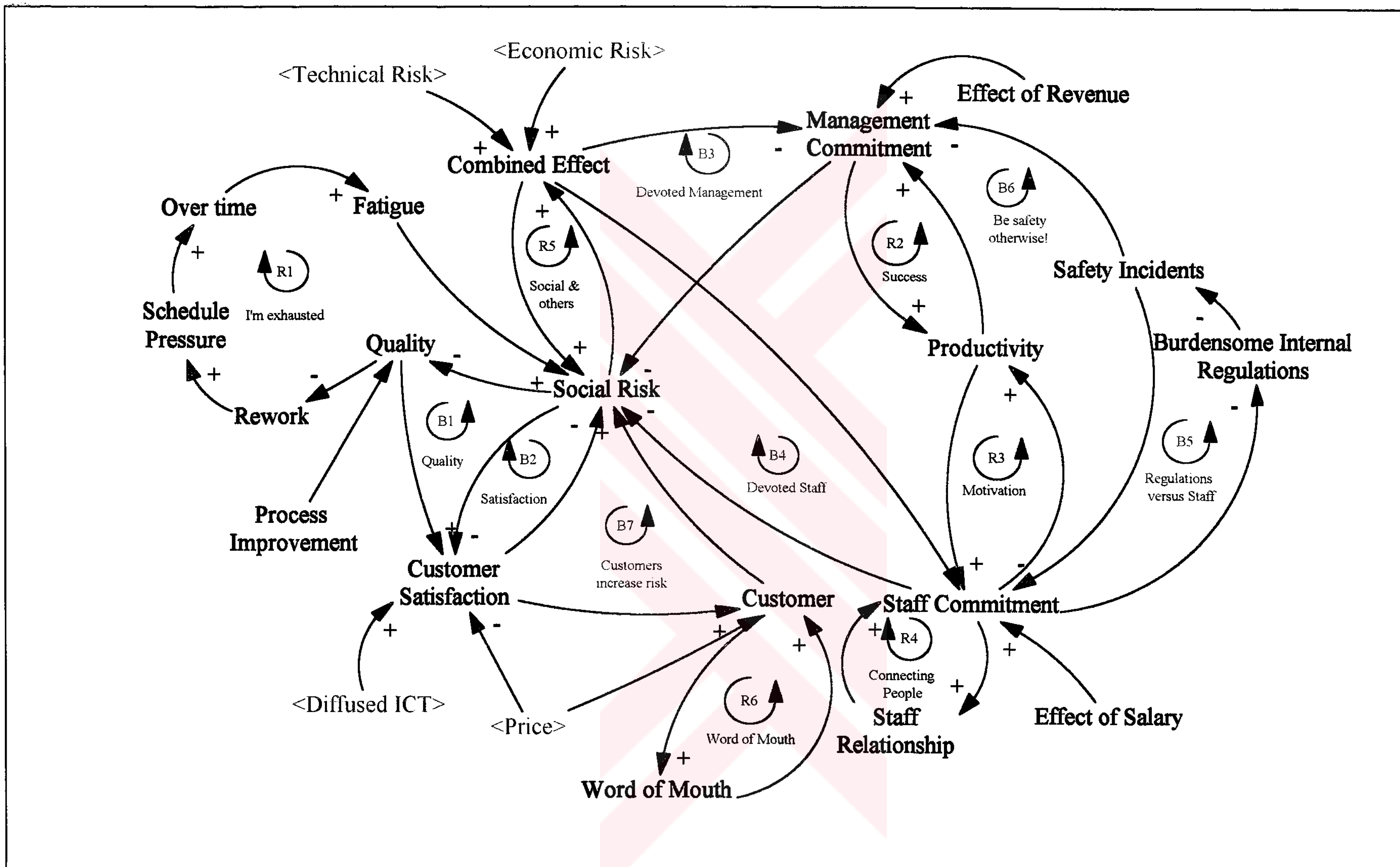


Figure 3.3. Social Risk Causal loop Diagram

3.3.2.2.3.2. Economic Risk Causal Loop Diagram

The main causal loops identified for the Economic Risk Factors (depicted by Figure 3.4.) are as follows:

If **Combined Effect** increases, **Economic Risk** is increased. In other terms, if there were something going wrong in the project then this would affect the other risks, too. (Loop R7)

There is one factor decreasing **Economic Risk**. This factor is called **Investment in New Technology**. In the model it is assumed that Investment factor is associated with **Profit**. If **Profit** increases it leads to an increase in **Investment in New Technology** implying a decrease in Economic Risk. (Loops B8)

A balancing behavior occurs between **Profit** and **Project Total Cost**. If **Revenue** increases it leads to an increase in **Profit**. As **Profit** increases company would have opportunity to make more spending for its needs increasing **Project Total Cost**. This increase in **Project Total Cost** leads to a decrease in **Profit**. Because there will be more spending from **Revenue** to **Project Total Cost**. (Loop B9).

There is one more balancing behavior in model. It comes into existence between **Project Total Cost** and **Saving Measures**. Saving Measures are necessary for company to curb **Project Total Cost** of the company. If **Project Total Cost** increase it causes an increase in **Saving Measures**. This increase could restrain the increase of **Project Total Cost**. In other words the more **Saving Measures** the less **Project Total Cost**. (Loop B10).

Another balancing loop occurs between **Macroeconomic Stability** and **Inflation**. If **Inflation** increases it leads to an increase in **Interest Rate** which causes a decrease in **Macroeconomic Stability**. Also an increase in **Macroeconomic Stability** affects **Inflation** in opposite direction. (Loop B11)

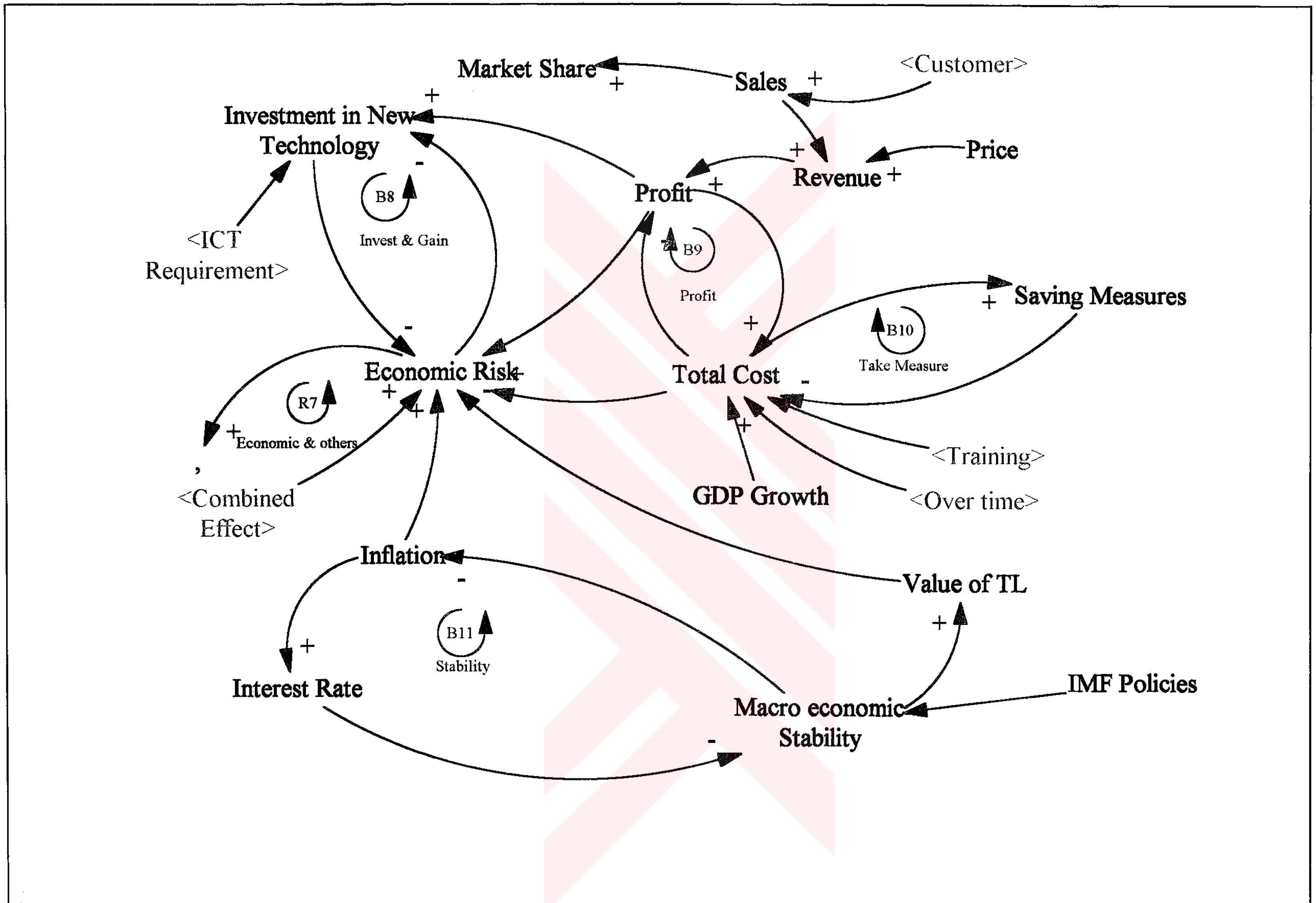


Figure 3.4. Economic Risk Causal Loop Diagram

3.3.2.2.3.3.Technical Risk Causal Loop Diagram

The main causal loops identified for the Technical Risk Factors (depicted by Figure 3.5.) are as follows:

Delay in R&D Process is an important factor increasing Technical Risk. Some reasons cause **Delay in R&D Process**. Those are **Software Failure**, **Hardware Failure** and **Engineering and Design Change**. An increase in those factors drives up **Delay in R&D Process** implying an increase in Technical Risk. (Loops R8, R9, R10)

Material and Equipment Risk is assumed an important factor increasing Technical Risk. That is to say if **Material and Equipment Risk** increases it leads to an increase in Technical Risk. (Loop R11)

Combined Effect affects Technical Risk in the same way as it does in other Sectors. Namely if **Combined Effect** increases Technical Risk increases too. (Loop R12)

Technical Risk could be decreased by two factors. These factors are called **Rate of Training** and **Diffused ICT**. If project staff is trained there will be more skilled personnel. An increase in skilled staff associated with the increase in training leads to a decrease in Technical Risk. (Loop B12)

The second factor is **Diffused ICT**. If company adopts technologies at market it could be compete more effectively. That is to say the more diffused technology the more decrease in Technical Risk. (Loop B13)

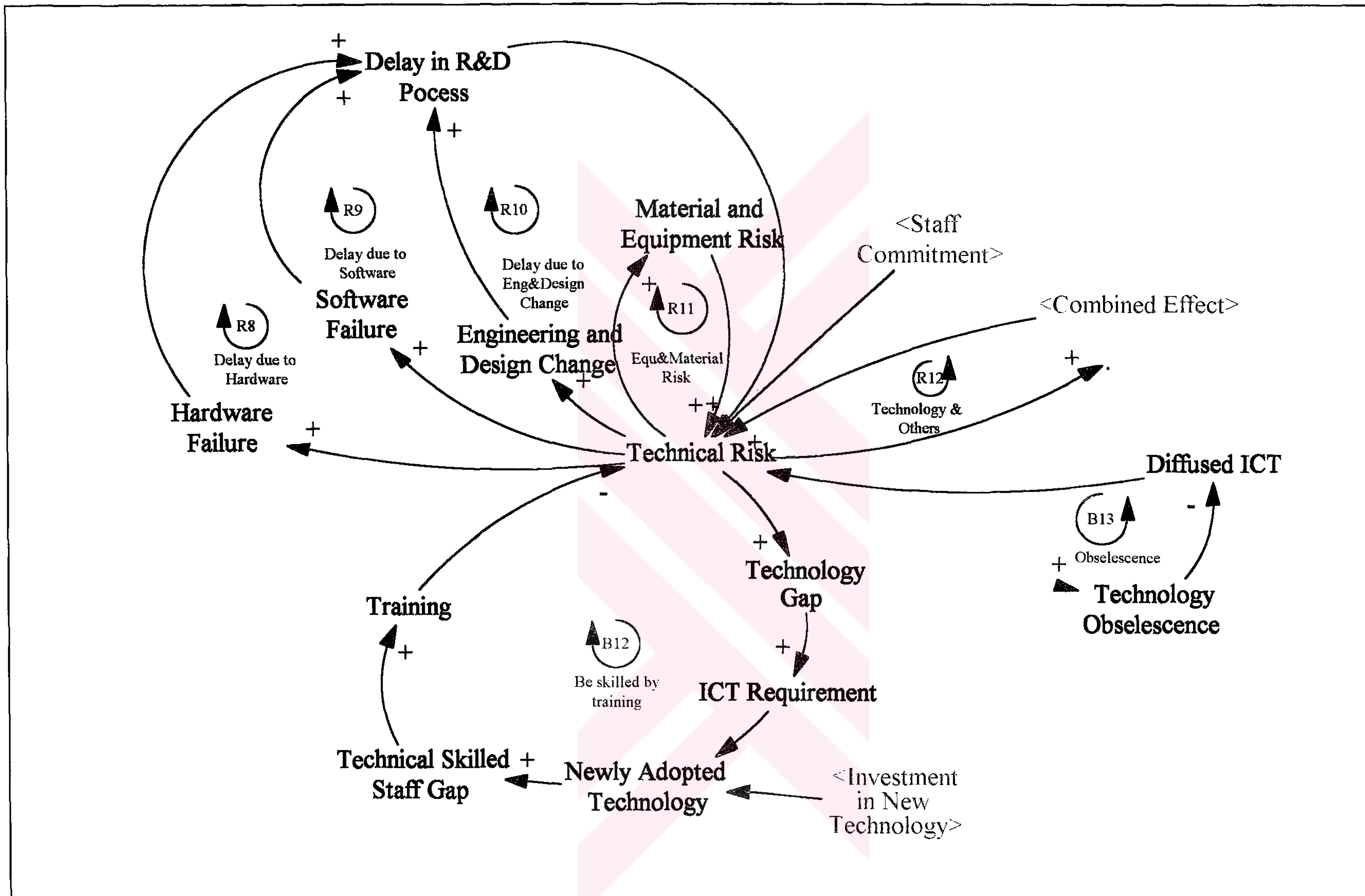


Figure 3.5. Technical Risk Causal Loop Diagram

3.3.2.2.4. Stock and Flow Maps

As Sterman [2000] suggests, the snapshot test is used for the selection of the stocks. The idea behind is freezing the time and deciding if the variable makes sense at that time. If it has a value, it is probably a stock. The main stocks after this analysis are as follows:

1. Social Risk
2. Economic Risk
3. Technical Risk

In addition to main stocks there are several sub-stocks. These are as follows:

1. Management Commitment
2. Staff Commitment
5. Active Customers
6. Quality Level
7. Project Total Cost
8. Newly Adopted Technology
9. Diffused ICT

3.3.2.2.4.1.Social Risk Sector

The stock of **Social Risk** has two flows namely, **Social Risk Increasing** and **Social Risk Decreasing**. There are three factors controlling Social Risk Increasing. **Fatigue in Project Staff** is depends on the physical and psychological condition of the project personnel. Commitment rate of the personnel an important factor on fatigue. **Rework** rate has also an important impact on Fatigue. If there are more rework there will be more Fatigue.

Active Customers rate is an important effect on **Social Risk Increasing**. The **Active Customers** is a sub stock in the model. **Customer Inflow** which is controlled by **Market Share**, **Effect of Price** and **Word of Mouth Ratio**; and **Customer Outflow** which is controlled by **Technology Obsolescence** and **abandonment fra**, are two flows of Active Customers. It is assumed that if there are more customers purchasing new services and products there could be complaints about them. If customer rate increases there will be an increase in dissatisfaction and complaints. In the model it is assumed that the negative effect of **Active Customers** reflects to Social Risk Increasing at rate of 10 %.

Combined Effect is another reason affecting **Social Risk Increasing**. **Combined Effect** is obtained with the mean value of the three main risk sectors, which is calculated with dividing

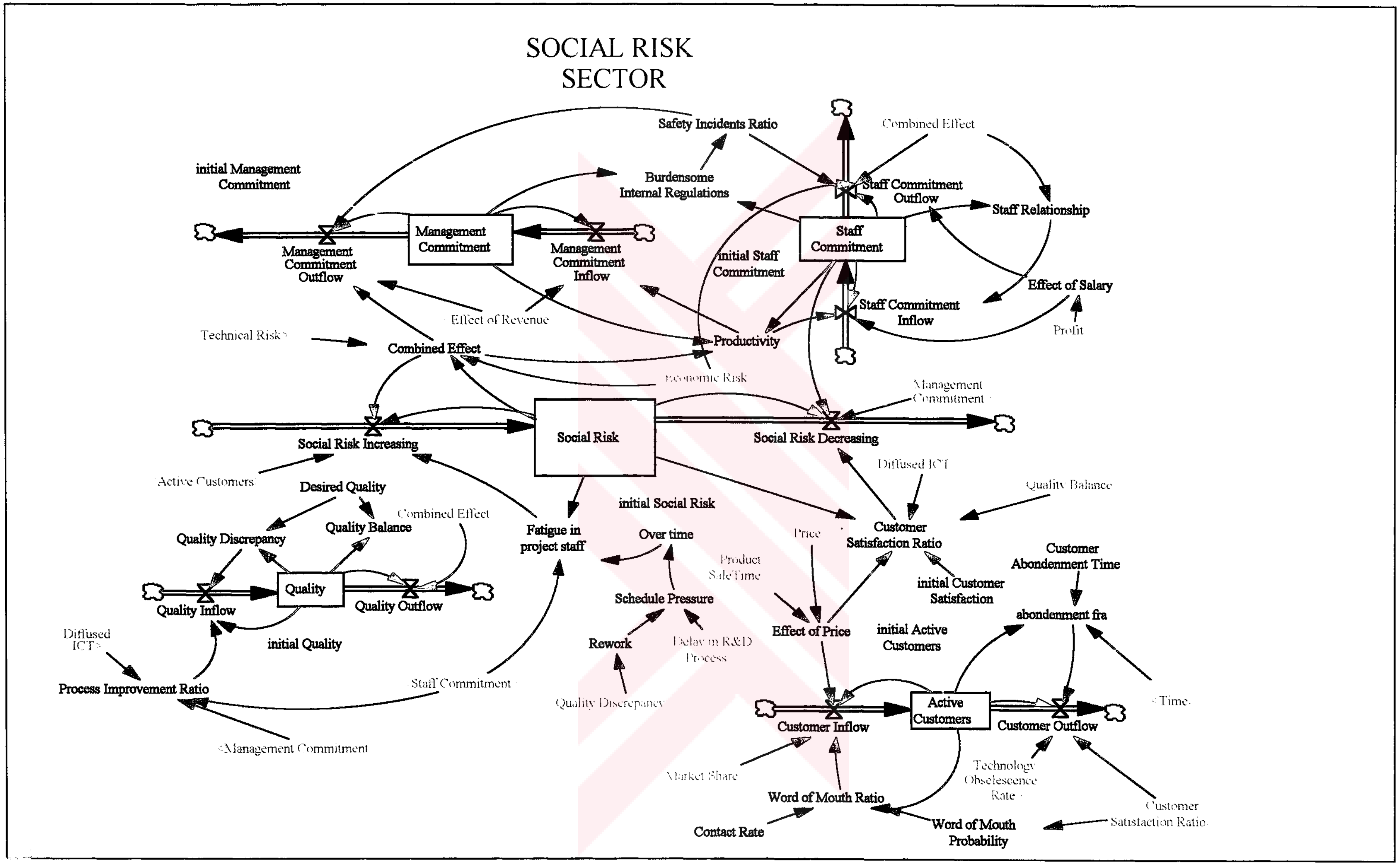


Figure 3.6. Social Risk Sector Stock and Flow Diagram

the sum of three factors by three. Its effect reflects to all main risk factors because if something is going wrong then it will affect the others too.

Three factors control **Social Risk Decreasing.** One of them is **Customer Satisfaction Ratio**. It indicates that how is the satisfaction rate of the customers about the firm and its products and how will it be with time about the company's new services and products. **Effect of Price** and **Quality Balance** strongly affect **Customer Satisfaction Ratio. Effect of Price** is related to the value of Price in opposite direction. If Price increases **Effect of Price** decreases, conversely if Price decreases **Effect of Price** increases. **Quality Balance** is obtained with the division of **Desired** and actual **Quality**. If actual Quality increases **Quality Balance** will increase and its effect on **Customer Satisfaction** increases too.

Other two factors controlling **Social Risk Decreasing** are **Management Commitment** and **Staff Commitment**. They are sub stocks in the model. Management Commitment has an initial value with **0.8** which expected to be a high commitment rate for the firm. Staff Commitment initial value is 0.6 which is a moderate value. **Staff Commitment Inflow** is controlled by **Staff Relationship**, **Effect of Salary** and **Productivity**. Management Commitment Inflow is controlled by **Effect of Revenue** and **Productivity**. Economic situation of personnel is an important factor which is given in the model as **Effect of Revenue** and **Effect of Salary**. If their salaries are adequate and their economic conditions are well they will be strongly committed. Because if a worker is satisfied with its job and is strongly committed to its firm work conditions don't affect him seriously.

Combined Effect and **Safety Incidents Ratio** control both **Management Commitment Outflow** and **Staff Commitment Outflow**. **Safety Incidents Ratio** depends on **Burdensome Internal Regulations, which** is related to both **Management** and **Staff Commitment** disproportionately.

Social Risk Sector has more different variables. They will be discussed below with their equations.

Social Risk= INTEG (+Social Risk Increasing-Social Risk Decreasing,+ initial Social Risk)

It is mainly social risk level of the projects. Social Risk is a risk factor in all projects affecting processes and whole project.

Social Risk Increasing= (1-Social Risk)*0.2*(Fatigue in project staff + (Active Customers*0.1) + Combined Effect)/3

It is the inflow of social risk, which determines the increase of Social Risk. In the equation an interesting variable is realized, (1-Social Risk). It might be so explained that an elementary relationship between level variable and rate variables is used. Since the value of level variable is accumulated during the simulation, it will easily move out of the boundary. This elementary relationship is introduced to keep the level variable within the boundary between 0 and 1. (see section 3.2.2.) There is also a constant 0.2 which indicates that the effect of Social Risk on its increase is about 20 %.

Social Risk Decreasing=Social Risk*(Customer Satisfaction Ratio+Staff Commitment +Management Commitment)/3*0.1

It is the outflow of Social Risk, which determines the decrease of Social Risk. The elementary relationship is also used in Social Risk Decreasing equation to keep the stock within the boundary between 0 and 1. 0.1 indicates that in model it is assumed that Social Risk has an impact on its outflow about 10 %.

initial Social Risk= 0.1

Initial value is 0.1 or 10 %. Because it is assumed that in all projects there is always initial social risk and it is expected about 10 %.

Staff Commitment= INTEG (Staff Commitment Inflow-Staff Commitment Outflow,+ initial Staff Commitment)

It is commitment level of project staff. It shows how the project workers believ and trust their firm and support their projects.

Staff Commitment Inflow=IF THEN ELSE (Effect of Salary>0, (1-Staff Commitment) * 0.05*DELAY1 ((Productivity+Staff Relationship + Effect of Salary) /3, 6), DELAY1 (Staff Relationship *(1-Staff Commitment) *0.05,6))

It is the inflow of Staff Commitment. In the equation DELAY1 function is realized. It is used to indicate that it takes 6 months to see the effect of factors controlling Staff Commitment Inflow. Elementary relationship is used to keep level between 0 and 1. There is a constant 0.05 indicating that there is an effect of Social Risk about 5 % on its inflow.

Staff Commitment Outflow= (Staff Commitment*0.03)*DELAY1 ((Safety Incidents Ratio+ Combined Effect+IF THEN ELSE (Effect of Salary > 0,0.01, (Economic Risk*2))) /3,6)

It is the outflow of Staff Commitment. It is assumed that it takes 6 months to see the effect of variables controlling the outflow. If Effect of Salary grosser than zero in other words if firm gets profit and its reflection to salary is felt there will be very little effect of salary as negative. But if there is no profit it will reflect to salary and Effect of Salary will be zero. Under this condition there occurs a strongly negative effect given with the assumption that twofold effect of Economic Risk to be seen on the outflow.

initial Staff Commitment= 0.6

It shows that staff personnel have a commitment to company with rate 0.6 in the beginning of the project.

Effect of Salary= Profit

It is assumed that if profit increases it contributes to staff salaries and it affects staff commitment.

Management Commitment= INTEG (Management Commitment Inflow-Management Commitment Outflow,+ initial Management Commitment)

It is commitment level of management. It shows how the management team believ and trust their personnel and support their projects.

Management Commitment Inflow= (1-Management Commitment) *0.2* (DELAY1I (Productivity +IF THEN ELSE(Effect of Revenue<0 , 0, Effect of Revenue)/2,3,0))

It is the inflow of Management Commitment. It takes 3 months to see effect of factors controlling the outflow. Elementary relationship is used because of the pre mentioned reason. (see section 3.2.2.) The constant 0.2 is used to indicate that there is a 20 % effect of the stock on its inflow.

Management Commitment Outflow= (Management Commitment*0.1)*((Combined Effect + Safety Incidents Ratio + IF THEN ELSE(Effect of Revenue> 0, 0, (ABS (Effect of Revenue*2))))/3)

It is the outflow of Management Commitment. Elementary relationship is used to keep the stock level between 0 and 1. There is a constant 0.1 which explains that there is a 10 % effect of the value of the stock on its outflow.

initial Management Commitment= 0.8

It shows that Management team at the company have a strong commitment to company with a rate of 0.8 in the beginning of the project.

Effect of Revenue= Revenue-TotalCost

It indicates the effect of revenue on management commitment.

Active Customers= INTEG (Customer Inflow-Customer Outflow,+ initial Active Customers)

It shows the customer level. It is a sub stock in the model.

initial Active Customers=0.5

There is an initial Customer rate purchasing company old products and services.

Customer Inflow= (1-Active Customers)*0.2*DELAY1 (((Market Share*0.1)+Word of Mouth Ratio +Effect of Price)/3,3)

It is the inflow of Active Customers. DELAY1 function is used to indicate that it takes 3 months to see the effect of the variables controlling the inflow. Elementary relationship is also used due to pre mentioned reason. (see section 3.2.2.) The constant 0.2 claims that there is an effect of the stock on its inflow about 20 % of its rate.

Customer Outflow= Active Customers*0.1*DELAY1((abandonment fra+ Technology Obsolescence Rate + (1-Customer Satisfaction Ratio))/3,3)

It is the outflow of Active Customers. The constant 0.1 indicates that there is an effect of the stock on its outflow about 10 % of its rate. DELAY1 function is used to indicate that it takes 3 months to see the effect of the variables controlling the outflow. Elementary relationship is also used due to pre mentioned reason.

Abandonment fra= IF THEN ELSE(Time<Customer Abandonment Time,Active Customers*0.1,Active Customers*0.5)

It is the fraction showing the abandonment rate of customers from the services or products. It is assumed that until Customer Abandonment Time abandonment fra is calculated with the assumption that 10 % of the customers leave the products and services because of some reasons. After this time fraction constant is calculated with the assumption that 50 % of the active customers begin to leave the company's services and products.

Customer Abandonment Time=42

It is assumed that customers begin to leave the company's products and services after 42 months.

Quality= INTEG (Quality Inflow-Quality Outflow,+ initial Quality)

It is the aggregate product quality of the company. It is a sub stock in the model.

Quality Inflow= (1-Quality)*DELAY1((Process Improvement Ratio*0.7)+(Quality Discrepancy*0.3),6)*0.1

It is the inflow of Quality. It takes 6 months to see the effect of the variables controlling the inflow. Elementary relationship is also used due to pre mentioned reason. (see section 3.2.2.). The constant 0.1 is given in the equation to indicate that the stock affects its inflow proportionally with a rate of 10 %. It is assumed that Process Improvement Ratio has a grosser effect than Quality Discrepancy. To show this assumption Process Improvement Ratio is multiplied with 0.7 and Quality Discrepancy is multiplied with 0.3.

Quality Outflow= Quality*Combined Effect*0.05

It is the outflow of Quality. Elementary relationship is also used due to pre mentioned reason. Quality has a 10 % effect on its outflow. To keep the stock level between 0 and 1 elementary relationship is also used.

initial Quality= 0.6

It is accepted that company old products and services have a quality with the rate of 0.6.

Quality Balance= Quality/Desired Quality

It is the ratio showing how good or bad the company is according to the desired level. Quality Balance is obtained with the division of Desired and actual Quality. This would later affect the Customer Satisfaction Ratio.

Quality Discrepancy= Desired Quality-Quality

It is the discrepancy between the Actual Average Product Quality and Desired Quality required by the company. It would later affect the Rework rate.

Desired Quality=1

It is the desired quality that the company seeks for its products.

Combined Effect= (Economical Risk+Social Risk+Technical Risk)/3

It is the effect that distributes the effect of all risk ratios to the others. If something goes wrong, this bad thing would be felt everywhere.

Economic Risk=INTEG (Economical Risk Inflow-Economical Risk Outflow, + initial Economic Risk)

It is mainly economical risk level of the projects. Economical Risk is a risk factor in all projects affecting processes and whole project. It will be later discussed in Economic Risk Sector.

Technical Risk= INTEG (Technical Risk Inflow-Technical Risk Outflow, +initial Technical Risk)

It is mainly technical risk level of the projects. Technical Risk is a risk factor in all projects affecting processes and whole project. It will be later discussed in technical Risk Sector.

Effect of Price = 1-Price

It is the effect of Price on Customer Satisfaction. If price get higher its effect gets lesser. Conversely if price gets closer to zero its effect will be grosser than former.

Price=0.6

It is the price of services and products of company.

Delay in R&D Process= (Time to correct Engineering and Design Change+Time to Correct Hardware Failure+Time to correct Software Failure)/3

It shows the total delay time in R&D process consisting of delays in correction times.

Customer Satisfaction Ratio=(((Diffused ICT+Quality Balance)/2)*1)-(((Social Risk* 0.2) +Effect of Price on Cus Sat Ratio\)/2)

It indicates the customer satisfaction situation about company products and services.

Diffused ICT= INTEG (Technology Diffusion Rate-Technology Obsolescence Rate,0)

Diffused ICT is the level of new technology in company being integrated in work performances and services

Fatigue in project staff= (1-Staff Commitment)*(Over time+Social Risk+1)/2

It shows the project staff fatigue in projects.

Burdensome Internal Regulations= (1-Management Commitment)* (1-Staff Commitment)

It results from Management Commitment situation as a reaction to project staff. The situation of Staff Commitment affects the variable disproportionately.

Over time=Schedule Pressure

It is the extra time in working to come to end by the due date.

Process Improvement Ratio= (Staff Commitment*0.6)+(Management Commitment* 0.3) +(Diffused ICT*0.1)

It is the ratio of process improvement increasing Quality in company.

Productivity= (Management Commitment*Staff Commitment*(1-Combined Effect))

It shows the productivity rate in company.

Rework=IF THEN ELSE (Quality Discrepancy>0.3,RANDOM UNIFORM(0.5, 1 , 0.25) ,RANDOM UNIFORM (0.1,0.5 ,0.25))

It indicates that if there is a discrepancy in quality it must be decreased by rework. Rework is calculated with random function. It is assumed that if Quality Discrepancy is grosser than 0.3 there will be a Rework rate between 0.5 and 1. Otherwise the rate of Rework decreases and its value varying at random between 0.1 and 0.5.

Safety Incidents Ratio=DELAY1((1-Burdensome Internal Regulations) ,2)*0.1

It shows that how frequently there occur safety incidents in projects.

Schedule Pressure=Delay in R&D Process*Rework

It is the pressure determining the schedule.

Staff Relationship= Staff Commitment*(1-Combined Effect)

It shows that how the relations are among project staff.

Technology Obsolescence Rate= IF THEN ELSE(Time<Technology Obsolescence Time, Diffused ICT*Technical Risk*0.01, DELAY1 (Diffused ICT* Technical Risk*0.5, 1+Time))

It is the rate at which the technologies become obsolete. It is discussed in Technical Risk sector in detail.

Word of Mouth Ratio= Active Customers*Contact Rate*Word of Mouth Probability

Word-of-Mouth effect for Potentials affected by Customers to become Customers

Word of Mouth Probability= Customer Satisfaction Ratio*0.5

It is the probability showing that the ending result of a contact between a Potential and Customer is again a new Customer.

Contact Rate= 0.4

It is the rate of contacts that a customer can make with potentials.

Customer Satisfaction Ratio= IF THEN ELSE(Effect of Price>0, initial Customer Satisfaction+DELAY1(Effect of Price*Diffused ICT* Quality Balance* (1-Social Risk), 3), initial Customer Satisfaction-Social Risk)

It indicates that whether customers are satisfied with company's products or not.

initial Customer Satisfaction= 0.6

It indicates that customers have been satisfied with company's old products and services at the rate of 0.6.

3.3.2.2.4.2.Economic Risk Sector

The stock of **Ecoconomic Risk** has two flows namely, **Economic Risk Inflow** and **Economic Risk Outflow**. **Economic Risk Inflow** is controlled by **Project Total Cost, Inflation Ratio, Combined Effect** and **Effect of Profit on Economic Risk Inflow**.

Project Total Cost covers all spendings of the company. It has an inflow called **Total Cost Inflow**, which is controlled by **Labor Spending, Production Spending, Overhead Spending, Rework Cost, Training Cost** and **Saving Measures**. The first five variables bring to stock a reinforcing feedback, whereas **Saving Measures** behaves as negative feedback decreasing the increase in **Project Total Cost**. There is a **initial Total Cost**. It indicates that the average cost of the company will be at the rate of 0.3 during project time. It is assumed that there will be cost overruns related to unexpected reasons. Labor, Production and Overhead Spendings stated above are not the whole cost. They are cost overruns about themselves. The rate of the cost overruns should be determined in relation with **GDP Growth** rate and **Profit. Rework Cost** and **Training Cost** occur when there is a rework or training. Their values are not defined at the start and not included in **initial Total Cost**.

Inflation Ratio increases Economic Risk. It is controlled by **Interest Rate** and **Macro economic Stability**. If **Interest Rate** increases **Inflation Ratio** increases too. Conversely if **Macro economic stability** increases **Inflation Ratio** behaves decreasingly. **Interest Rate** is a constant value, 0.2. It is assumed that there is a 20 % currency Interest Rate in the country

When there is no **Profit** its effect on Economic Risk will be reinforcing. In the model this effect is given as **Effect of Profit on Economic Risk Inflow**.

Combined Effect has the same impact with the same challenges as it shows in Social Risk Sector.

Economic Risk Outflow is controlled by **Macro economic Stability, Value of TL, Delayed Effect of Investment** and **Effect of Profit on Economic Risk Outflow. Macro economic Stability** is assumed to be associated with **Interest Rate** and **Dependence rate on IMF**. There is a random distribution of **IMF Policies** between 0.3 and 1. It is assumed that if IMF intervenes in our Policy and economy frequently, its value is 1. If there is a little intervene from IMF its value is assumed to be 0.3.
Value of TL is controlled by **Inflation Ratio** and **Macro economic Stability**. If **Inflation Ratio** is at a higher value, the **Value of TL** will be lower. When **Macro economic Stability** is in a good situation its reflection will be in positive direction and will increase **Value of TL.**

There are two more serious variables called **Revenue** and **Profit. Profit** is calculated by subtracting **Project Total Cost** from **Revenue. Profit** has an effect on many stocks and variables in the model. **Economic Risk** is one of them. If there occurs **Profit** after **Sales** Economic Risk goes to lower value related to variable called **Effect of Profit on Economic Risk Outflow**. If there is no **Profit** Economic Risk goes to a higher value related to variable called **Effect of Profit on Economic Risk Inflow**. On the other hand **Profit** leads to an increase in **Project Total Cost**, which has an effect on **Economic Risk Inflow**. It is assumed that there could be cost overruns in project. These cost overruns would be limited by Profit rate. If **Profit** goes to a high value the firm will be able to make more extra spendings. For example there could be an increase in **Labor Spending** or there could be a decrease related to poor Profit.

Economic Risk Sector has more different variables. They will be discussed below with their equations.
Investment has an important impact on the outflow of the stock. It reflects to the outflow with a delay time called **Investment Delay Time** due to it is assumed that if there is a new investment its reflection will be felt after a delayed time.

Economic Risk=INTEG (Economic Risk Inflow-Economic Risk Outflow, + initial Economic Risk)
It is mainly economical risk level of the projects. Economical Risk is a risk factor in all projects affecting processes and whole project.

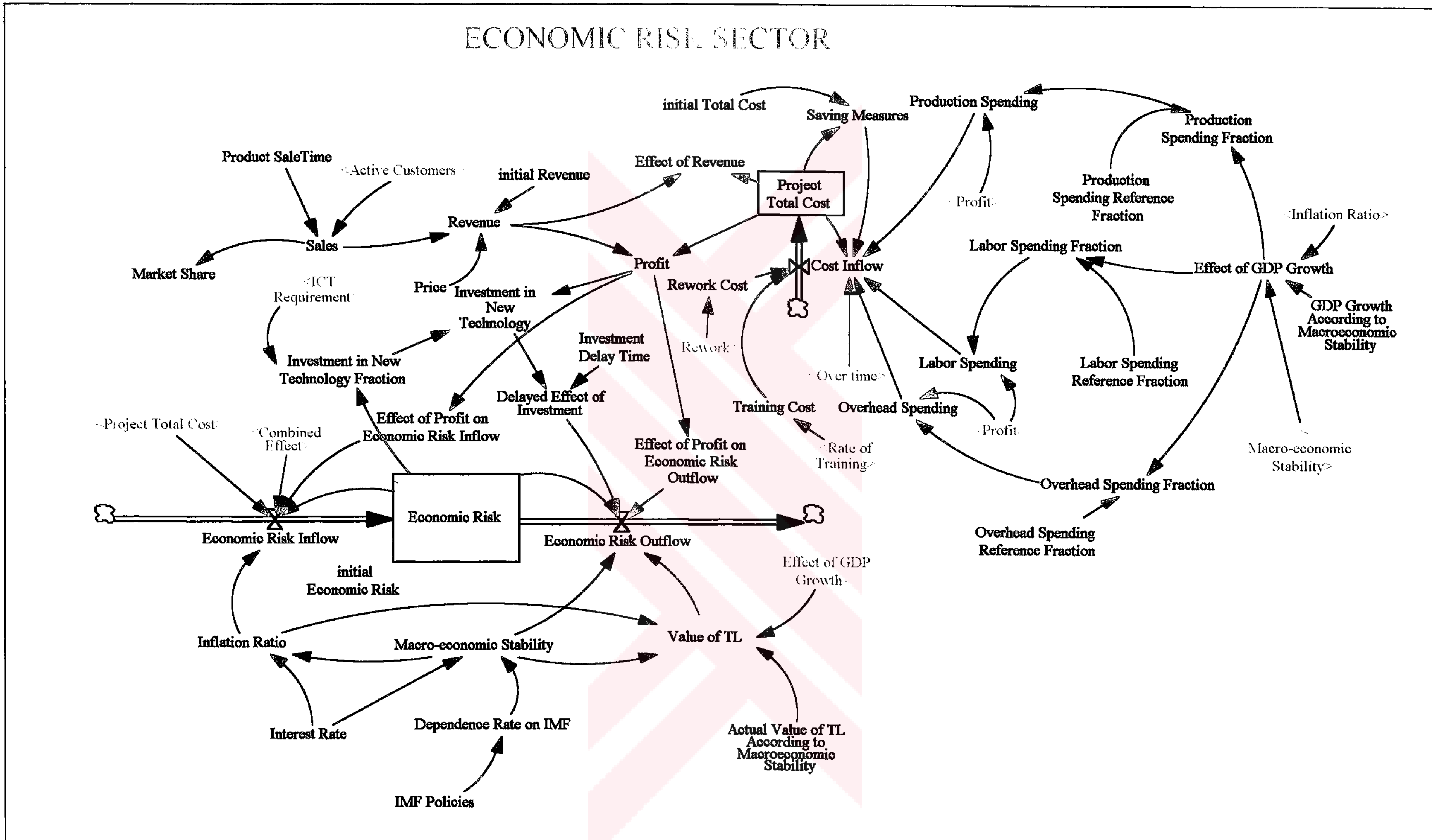


Figure 3.7. Economic Risk Sector Stock and Flow Diagram

Economic Risk Inflow= (1-Economic Risk)*DELAY1(((IF THEN ELSE(Project Total Cost>=initial Total Cost+(initial Total Cost*0.2), Project Total Cost*0.2, Project Total Cost *0.01) * 0.1) +(IF THEN ELSE (Inflation Ratio<=0.275,(Inflation Ratio*0.1*0.4),SQRT (Inflation Ratio*0.1)*0.4)+(Effect of Profit on Economic Risk Inflow*0.4)+(Combined Effect * 0.1))) ,3) *0.2

It is the inflow of Economical Risk. Elementary relationship is used to keep the stock rate between 0 and 1. It is assumed that it takes 3 months to see the effect of variables controlling the inflow. It is given in the equation with DELAY1 function.

There is a SQRT function, which is used to increase the effect of Inflation Ratio. The fact that SQRT function decreases the value of a variable is here not valid due to the values of variables are smaller than 1. It creates a different situation. For example SQRT (16) is equal to 4. 16 is grosser than 4. On the other hand SQRT(0.16) is equal to 0.4 and 0.16 is smaller than 0.4. This interesting mathematical calculation helps us strengthen the effect of the variable.

In the inflow equation there is a constant 0.2. It indicates that the stock contributes 20% effect to inflow. Project Total Cost effect is given differently. If there is an increase grosser than 20 % of initial Total Cost in Project Total Cost, its effect on inflow is grosser than that if it is smaller than 20%.

Economic Risk Outflow=Economic Risk*((Effect of Profit on Economic Risk Outflow*0.5)+(Value of TL*0.1)+("Macro-economic Stability"*0.1)+(Delayed Effect of Investment*0.3))*0.1

It is the outflow of Economic Risk. Elementary Relationship takes place in the equation due to pre mentioned reason. (see section 3.2.2.). It is clearly understand from the equation that the most dominant effect belongs to Effect of Profit on Economic Risk. The constant 0.1 indicates that stock has a 10% impact on its outflow

initial Economic Risk= 0.1

Initial value is 0.1 or 10 %. Because it is assumed that in all projects there is always economic risk at first and it is accepted as 10%.

Project Total Cost= INTEG (Cost Inflow,initial Total Cost)

It shows the level of all spendings in project.

initial Total Cost= 0.3

It is assumed that in the beginning there is a Project Total Cost level 0.3. This value is expected to occur in general situations. It includes Labor, Production and Overhead Spendings.

Cost Inflow= (1- Project Total Cost)* 0.05* (Labor Spending+Over time+Overhead Spending + Production Spending+Training Cost-Saving Measures+Rework Cost)/6

It is the inflow of Project Total Cost.

Training Cost= DELAY1(Rate of Training,6)

It is the cost of training, which is necessary for staff to be skilled.

Value of TL=Actual Value of TL According to Macroeconomic Stability("Macro-economic Stability")+((Effect of GDP Growth*0.1)+(1-Inflation Ratio)*0.1)/2

It shows currency value.

Actual Value of TL According to Macroeconomic Stability= ([(0,0.2)-(1,1)], (0,0.5), (0.07,0.33), (0.17,0.3), (0.25,0.36), (0.28,0.45), (0.33,0.5), (0.4,0.48), (0.5,0.58), (0.63,0.55), (0.7,0.5), (0.75,0.55), (0.8,0.565789), (0.9,0.53), (0.9,0.4), (1,0.35)

It determines Value of TL associated with Macroeconomic Stability.

Macro-economic Stability= DELAY1(((1-Dependence Rate on IMF)+(1-Interest Rate))/2,6)

It is the stability of economy.

GDP Growth According Macroeconomic Stability=([(0,0.4)-(1,1)], (0.005,0.6), (0.045,0.65), (0.15,0.5), (0.3,0.6), (0.35,0.6), (0.3,0.75), (0.45,0.786842), (0.587156,0.784211), (0.65,0.7), (0.7,0.6), (0.75,0.6), (0.9,0.7), (0.95,0.9), (1,0.9))

It shows GDP growth rate associated with Macroeconomic Stability.

Effect of GDP Growth=GDP Growth According to Macroeconomic Stability (Macro-economic Stability)+((1-Inflation Ratio)*0.1)

It shows how GDP Growth affects Macroeconomic stability.

Investment in New Technology=0.2+(DELAY1(Investment in New Technology Fraction * Profit,3))

It is the investment of company in new technologies, which is necessary for feature of company. It is assumed that there is an initial investment rate 0.2. Company tries to realize this rate under any condition.

Investment in New Technology Fraction=IF THEN ELSE(Economic Risk>0.4, 0 , ICT Requirement)

It is the fraction determining Investment rate.

Delayed Effect of Investment= DELAY1(Investment in New Technology,Investment Delay Time)

It shows the effect of investment on the company with a delay.

Investment Delay Time=24

It determines the delay of investment.

Dependence Rate on IMF=IF THEN ELSE(IMF Policies<=0.5,IMF Policies*0.4 ,IMF Policies*0.8)

It is the rate determining the dependency of the country to IMF.

Product Sale Time=18

It is assumed that company will be able to sell its new service or product after 18 months.

Profit=IF THEN ELSE(Project Total Cost>=Revenue, 0 , Revenue- Project Total Cost)

It is the profit company gets from services and product sales after paying Project Total Cost.

Effect of Profit on Economic Risk Inflow= IF THEN ELSE(Profit>0, 0, (1-Profit)*0.5)

It shows that if there is no Profit there will be an increase in Economic Risk.

Effect of Profit on Economic Risk Outflow=IF THEN ELSE(Profit<=0,0,SQRT (Profit))

It shows that Profit affects Economic Risk in the same direction. There is a SQRT function, which is used to increase the effect of Profit. The fact that SQRT function decreases the value of a variable is here not valid due to the values of variables are smaller than 1. It creates a different situation. For example SQRT (16) is equal to 4. 16 is grosser than 4. On the other hand SQRT(0.16) is equal to 0.4 and 0.16 is smaller than 0.4. This interesting mathematical calculation helps us strengthen the effect of the variable.

IMF Policies= RANDOM NORMAL(0.3, 1 , 0.6, 0.1 ,10)

It shows IMF policies in the country. There is a random distribution of IMF Policies between 0.3 and 1. It is assumed that if IMF intervenes in our Policy and economy frequently, its value is 1. If there is a little intervention by IMF its value is assumed to be 0.3.

Inflation Ratio= DELAY1(((1-"Macro-economic Stability")+Interest Rate)/2,3)

It is the ratio of Inflation in the country. It is controlled by Interest Rate and Macro economic Stability with a delayed effect of 3 months.

Interest Rate=0.2

It shows interest rate in the country.

Labor Spending= Labor Spending Fraction*Profit*0.5

It shows Labor Spending cost overrun during the project.

Labor Spending Fraction= Effect of GDP Growth*Labor Spending Reference Fraction

It is the fraction determining Labor Spending associated with Profit.

Labor Spending Reference Fraction=0.3

It is the reference fraction determining the labor spending fraction associated with GDP Growth.

Overhead Spending= Overhead Spending Fraction*Profit*0.5

It is a cost overrun for company to be spent on overheads such as rent, electricity etc. affecting Project Total Cost

Overhead Spending Fraction= Effect of GDP Growth*Overhead Spending Reference Fraction

It is the fraction determining Overhead Spending associated with Profit.

Overhead Spending Reference Fraction=0.2

It is the reference fraction determining the overhead spending fraction associated with GDP Growth.

Production Spending= Production Spending Fraction*Profit*0.5

It is a cost overrun for company to be spent for production affecting Project Total Cost

Production Spending Fraction= Effect of GDP Growth*Production Spending Reference Fraction

It is the fraction determining Production Spending associated with Profit.

Production Spending Reference Fraction=0.5

It determines the production-spending fraction associated with GDP Growth.

Rate of Training= (Technical Skilled Staff Gap+IF THEN ELSE(Technical Risk>0.2, Technical Risk , Technical Risk*0.2))/2

It is the training rate to be realized reducing the gap in skill compared with the necessary skill.

Revenue= IF THEN ELSE((Price*Sales)+initial Revenue<=1,(Price*Sales)+initial Revenue,(Price*Sales)+initial Revenue-((Price*Sales)+initial Revenue-1))

It is the revenue of company to be gained from the services and product sales.

Initial Revenue=0.3

It is assumed that in the beginning there is a revenue rate 0.3. It is necessary to respond to initial Total Cost.

Sales= STEP(Active Customers, Product SaleTime)

It shows sale rate

Market Share= 0.2+DELAY1(Sales*0.2,6)

It shows that how the company has share in market. 0.2 indicates that the firm has a share in market before the new project with a rate of 0.2.

Saving Measures= IF THEN ELSE(Project Total Cost<=initial Total Cost+0.05, Project Total Cost*0.01, Project Total Cost*0.3)

It indicates the saving measures in company, which is necessary to reduce Project Total Cost.

3.3.2.2.4.3.Technical Risk Sector

Technical Risk sector has two flows namely, **Technical Risk Inflow** and **Technical Risk Outflow**. There are some variables controlling **Technical Risk Inflow**. The first one is **Delay in R&D Process**. It consists of the delays necessary for correct times to some probable technical risk factors such as **Hardware Failure Ratio, Software Failure Ratio,** and **Engineering and Design Change Rate.**

The second one is **Equipment and Material Risk Ratio,** which is a risk in project expected to occur dependently on Technical Risk rate. The third one is **Technology Gap**. It is assumed that if there are new technologies at market and the firm has not yet adopted them, the firm couldn't be able to compete in terms of technical capability. This assumption creates a risk called **Technology Gap.**

There is one more effect called **Combined Effect**. Its impact on technical Risk Inflow is similar to other impacts on Economic and Social Risks.

Technical Risk Outflow is controlled by **Quality**, **Staff Commitment**, **Effect of Training on Technical Risk** and **Diffused ICT**. Quality and Staff Commitment are discussed above in Social Risk sector.

Diffused ICT means the diffusion rate of **Newly Adopted Technology**. There occurs **ICT Requirement** due to the **Technology Gap**. The firm should adopt **Available Technology at Market** and diffuse this technology. **Newly Adopted Technology** requires skilled staff called **Required Technical Skilled Staff** which causes training if its level grosser than **Level of Actual Skill.**

Rate of Training shows this necessary training. It brings about a cost called **Training Cost** increasing **Project Total Cost.** On the other hand **Rate of Training** has an impact on **Technical Risk Inflow** called **Effect of training on Economic Risk Outflow.**

Technical Risk Sector has more different variables. They will be discussed below with their equations

Technical Risk= INTEG (Technical Risk Inflow-Technical Risk Outflow,+initial Technical Risk)

It is mainly technical risk level of the projects. Technical Risk is a risk factor in all projects affecting processes and whole project.

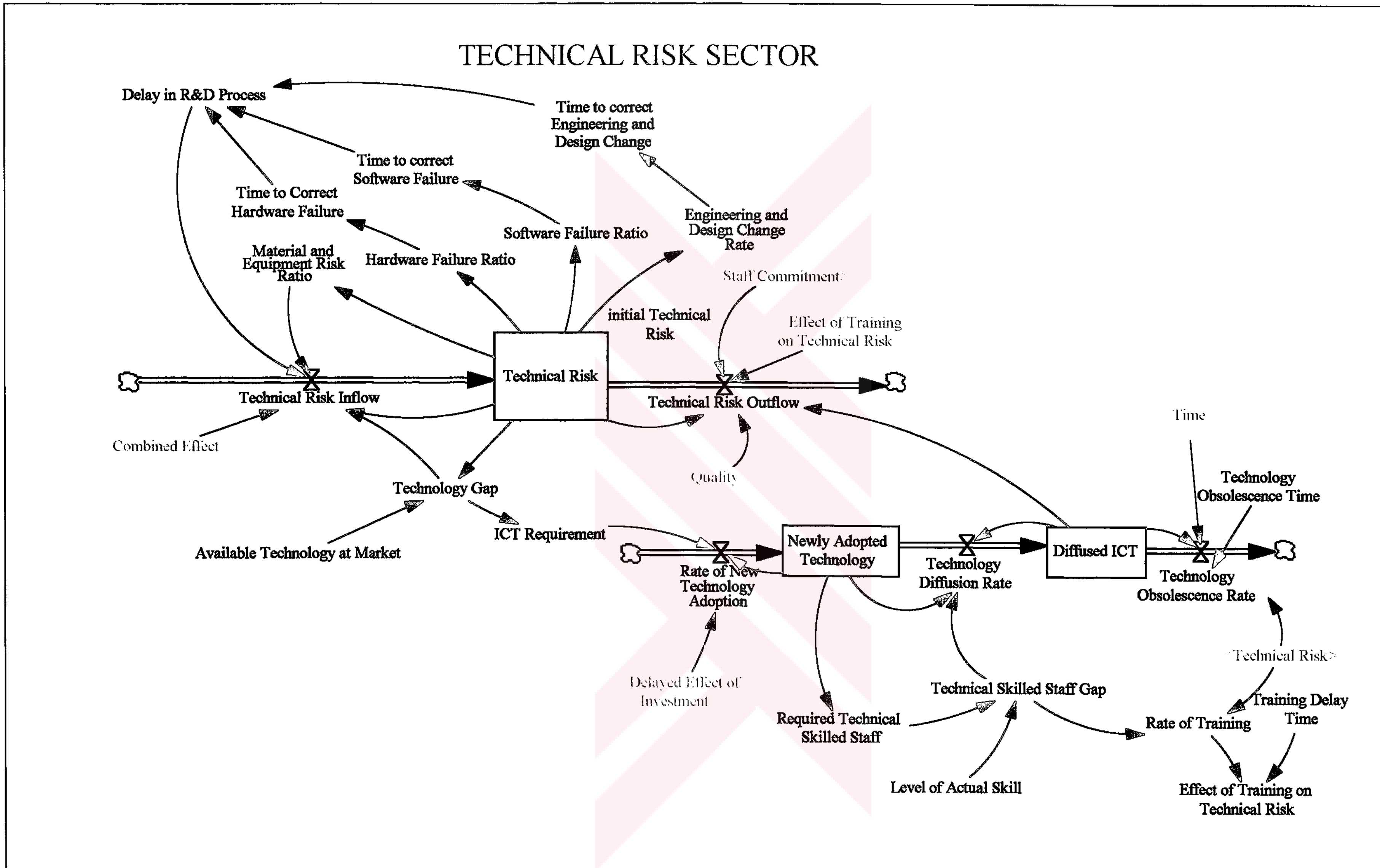


Figure 3.8. Technical Risk Sector Stock and Flow Diagram

initial Technical Risk=0.1

Initial value is 0.1 or 10 %. Because it is assumed that in all projects there is always technical risk at first and accepted as 10%.

Technical Risk Inflow= (1-Technical Risk)*0.5*(Delay in R&D Process +Material and Equipment Risk Ratio+ Technology Gap+Combined Effect)/4)

It is the inflow of Technical Risk. It is assumed that it takes 3 months to see effects of variables increasing the inflow. Elementary relationship is used due to the pre mentioned reasons. (see section 3.2.2.). There is a constant 0.5 which indicates that Technical Risk has 50 % impact on its inflow.

Technical Risk Outflow=Technical Risk*0.5* (Diffused ICT+ Staff Commitment + Effect of Training on Technical Risk+Quality)/4

It is the outflow of Technical Risk. There is a constant 0.5 which indicates that Technical Risk has 50 % impact on its outflow. Elementary relationship is used due to the pre mentioned reasons.

Newly Adopted Technology= INTEG (Rate of New Technology Adoption-Technology Diffusion Rate,0)

It shows the rate of adopted technology by the company.

Rate of New Technology Adoption= (1-Newly Adopted Technology)*(ICT Requirement+Delayed Effect of Investment)/2*0.2

It is the inflow of Newly Adopted Technology.

Technology Diffusion Rate= (1-Diffused ICT)*Newly Adopted Technology*(1-Technical Skilled Staff Gap)*0.1

It has two missions. The first one is the outflow of Newly Adopted Technology, the other is the inflow of Diffused ICT.

Technology Obsolescence Rate=IF THEN ELSE(Time<Technology Obsolescence Time, Diffused ICT*Technical Risk* 0.01 ,DELAY1(Diffused ICT*Technical Risk*0.5, 1+Time))

It is the outflow of Diffused ICT.

Technology Obselescence Time=36

It is time indicating technology obsolescence.

Technology Gap= ((Technical Risk*0.1)+Available Technology at Market)/2

It shows the technology gap of company compared to Available Technology at Market.

Available Technology at Market=0.5

It shows the new technologies at market.

Engineering and Design Change Rate=(1+Technical Risk)*0.1

It is the change rate of engineering and design resulting from internal or external reasons.

Time to correct Engineering and Design Change=DELAY1(Engineering and Design Change Rate, 9)

It is the time required to respond change necessity causing delay in R&D process.

Hardware Failure Ratio=(1+Technical Risk)*0.05

It is assumed that in products and services there could be hardware failure during projects.

Time to Correct Hardware Failure=DELAY1(Hardware Failure Ratio, 3)

It is the time required to respond hardware failure causing delay in R&D process.

Software Failure Ratio=(1+Technical Risk)*0.05

It is assumed that in products and services there could be software failure during projects.

Time to correct Software Failure=DELAY1(Software Failure Ratio, 6)

It is time required to respond software failure causing delay in R&D process of projects.

Material and Equipment Risk Ratio=(1+Technical Risk)*0.01

It shows the risk of material and equipment during projects.

Required Technical Skilled Staff=Newly Adopted Technology+0.2

It shows the need for technical skilled staff.

Technical Skilled Staff Gap= IF THEN ELSE(Level of Actual Skill>=Required Technical Skilled Staff, 0 , Required Technical Skilled Staff-Level of Actual Skill)

It is about that if actual skilled staff is not adequate there is a gap in skilled staff.

Level of Actual Skill=0.5

It is the level of actual skilled staff in company.

ICT Requirement=Technology Gap

It shows the requirement of company about Technology.

Training Delay Time=9

It shows delay time necessary for training.

4. TESTING AND VALIDATION

In testing of the model to see if it is an adequate representation of the reality, Barlas [1996] proposed a sequence of validation tests for formal validation. In this section, this sequence will be followed with the chosen and relevant tests for the model. As the model does not take raw and actual data into account, there is no attempt to replicate the history. All tests are concerned on the structure and sensitivity.

4.1.Direct Structure Test

These tests assess the validity of the model structure by direct comparison about real system structure. One will not be able to see a simulation, but rather structure and parameter confirmation with dimensional consistency.

In this part each equation is considered alone and evaluated with the current knowledge about it. This was in fact done with the stock and flow model building at the same time. Each equation was checked and evaluated if it reflects real life.

4.2.Extreme Conditions Test:

This test includes simulation through time by giving extreme values to the selected variable and comparing the model-generated behavior to the anticipated behavior of the real system under the same extreme condition. [Barlas, 1996].

4.2.1. initial Total Cost

initial Total Cost is set at 0, which is relatively a low value and at 1, which is relatively a high value. initial Total Cost is chosen to be very close to zero, which is 0.00001 in order to eliminate the divisibility, by zero error.

Expectedly, if initial Total Cost is 0 there will be a very low increase in Project Total Cost. This low Project Total Cost leads to a decrease in Economic Risk. Because the company doesn't have to make more spending at the start of the project. Namely Economic Risk gets closer to zero.

When initial Total Cost is 1, which is relatively a high value the firm, will be dramatically affected. Because its revenue doesn't meet cost spendings and its economic risk goes to its highest value. As seen from the Figure 4.1. Economic Risk is not 1 yet but it is assumed to be its highest value for long periods.

Other main stocks, Social and Technical Risk are affected by this extreme situation, too. When initial Total Cost is zero Social Risk shows at start an increasing behavior because of positive factors to Social Risk such as Fatigue in Project Staff, Combined Effect of main risk sectors etc. Thereafter the effect of initial Total Cost is felt strongly. There occurs a decrease in Social Risk. It is assumed that it goes to zero with a period of time.

If initial Total Cost is zero, the trend in Technical Risk is like the trend in Social Risk There is an increase at start but then trend goes down.

When initial Total Cost is one, its highest value, behaviors of risk factors are observed in increasing position. This increase in Social and Technical Risk is not as sharp as the increase in Economic Risk because effect of cost is felt strongly in Economic Risk. If initial Total Cost is one all revenue of the firm should be spend. If there is no cash money in the firm, it causes a high Economic Risk.

Figure 4.1 shows main stocks behaviors if the value of initial Total Cost is zero and if it is one.

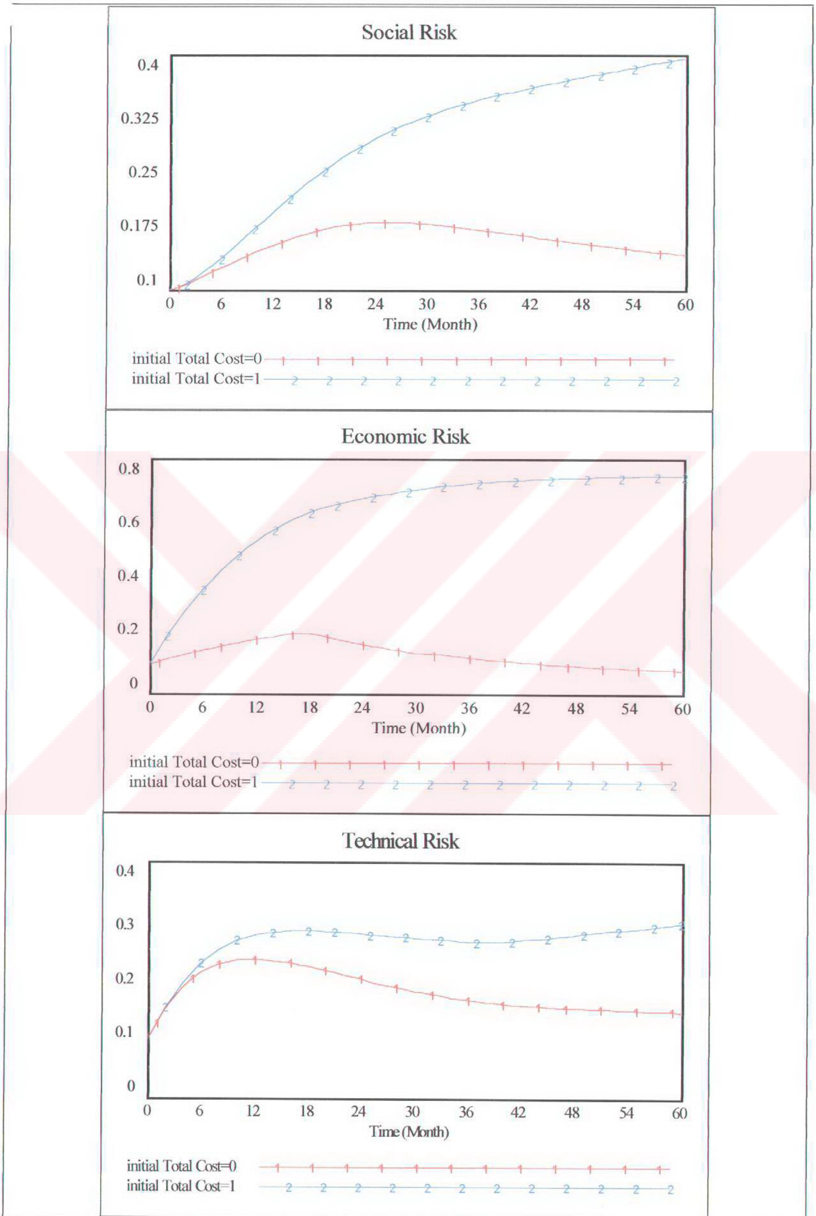


Figure 4.1. Main Stocks of the Model after Extreme Condition Test

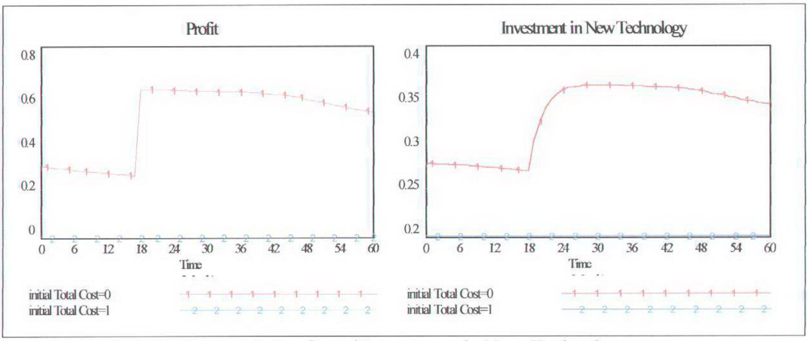


Figure 4.2. Profit and Investment in New Technology

When initial Total Cost is zero, the revenue of the firm doesn't have to be spent for Company outcomes. This situation affects directly the Profit. Profit behavior gets an increasing position. Related to profit company investment goes up, too.

Conversely if initial Total cost is one there is no Profit and no investment except for previous investment rate. Figure 4.2 shows Profit and Investment behaviors related to initial Total Cost with extreme condition test.

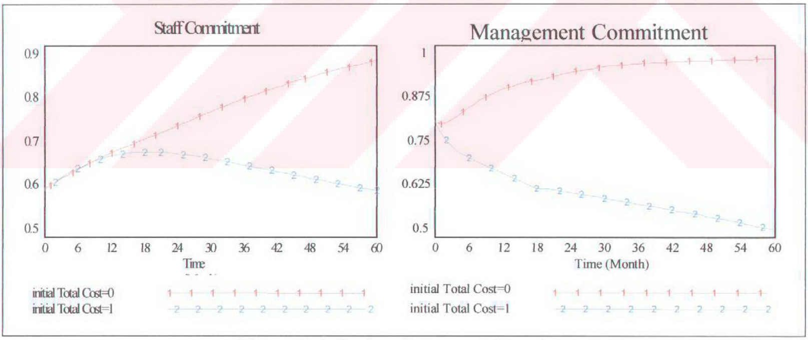


Figure 4.3. Project Personnel Situation

It is shown from the Figure 4.3. that initial Total Cost of the firm has an important effect on project personnel. If there is zero initial Total Cost in the beginning, there will be more Profit and less Economic Risk. This situation reflects to Project personnel commitments behaviors. They get increasing values with time.

When initial Total Cost is one, which is the highest value, personnel commitments behaviors become contrary to former. It results especially from economic factors. High economic risk leads to a decrease in Management and Staff Commitment. As shown from the Figure 4.3., in the initial times increases of commitment result from that at the start there is a high commitment to firm, and relationships between personnel are strong. This situation reflects to Staff Commitment again because of feedback structure of the system. Thereafter effect of Economic Risk is felt dramatically and Staff Commitment begins to decrease.

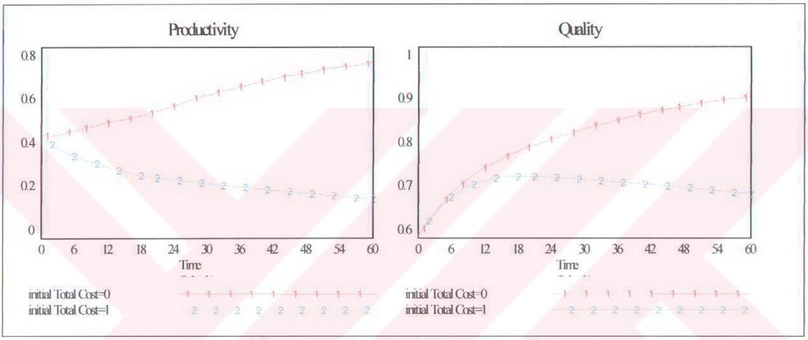


Figure 4.4. Productivity and Quality

As seen from the Figure 4.4. if initial Total Cost is zero Productivity and Quality go to higher values because Profit of the company leads to an increase in personnel commitments and this situation reflects to Productivity and Quality.

However, when initial Total Cost is one Productivity and Quality get closer to zero. They are affected from initial Total Cost in opposite direction. Because decreasing commitment affects Productivity and Quality.

Related to Quality, Customer Satisfaction is affected from this extreme condition test. If initial Total Cost is zero Quality and Productivity get closer to higher values and this situation reflects Customer Satisfaction and it goes to a high value. If initial Total Cost is one Customer Satisfaction behaves in the beginning increasingly but not the same as former. On both assumptions there is a decrease after a time in satisfaction rate. It results from other effects connected with Customer Satisfaction such as Technology Obsolescence, Abandonment from services and products of the firm etc.

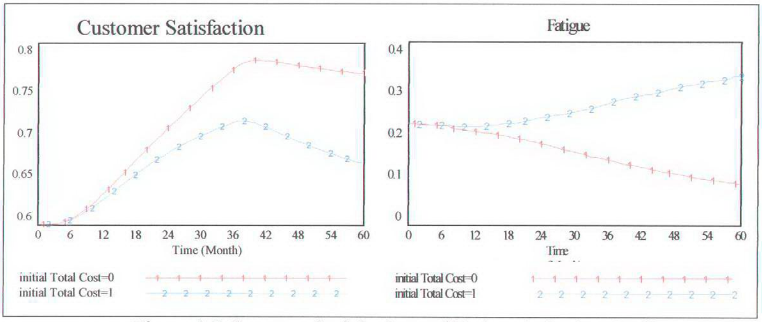


Figure 4.5 Customer Satisfaction and Fatigue in Project Staff

Extreme values of initial Total Cost affect also Fatigue rate of the project personnel. If there is no initial Total Cost, Fatigue goes to zero. When initial Total Cost is one Fatigue rate goes higher values with time. Because there is no Profit it reflects to personnel commitments and Quality. Decreasing quality entails increasing rework and this increasing rework rate creates more fatigue. As result Fatigue of project personnel goes to a high value. Figure 4.5. shows Customer Satisfaction and Fatigue behaviors.

4.2.2. Price

Price is set at 0, which is relatively a low value and at 1, which is relatively a high value. Price is chosen to be very close to zero, which is 0.00001 in order to eliminate the divisibility, by zero error.

When Price is zero Economic Risk gets closer to one, its highest value. It results from Revenue and Profit of the firm. There is a fact that a firm must get revenue from its products and services. Therefore firm must sell its products with an appropriate price. If there is zero price all things get wrong and the firm collapses.

If Price is one, which is the highest value, there is an increasing behavior of Economic Risk till Product Sale Time, and then Economic Risk gets closer to zero. But there is an interesting thing about Price's highest value. Although Price is at highest value all main risk factors don't go to zero. There is always a risk value. It results from other variables affecting main risk factors. For example in the Figure 4.7. it can be clearly observed that Active Customer rate decreases if Price is one. This situation reflects to Sales. Decrease in Sales leads to a decrease in Profit although Price is at highest value.

Social Risk is affected by Price with extreme values too. If Price is zero Social Risk gets a high value but not as sharply as Economic Risk. This increase results from project personnel commitments rates and Active Customer rate.

When price is one, there is a decreasing behavior of Social Risk. Its trend is like the trend of Economic Risk. Till a determined time Social Risk increases, thereafter a decrease begins and it gets closer to zero but never zero.

Behavior of Technical Risk is similar to Social Risk. When Price is zero it gets a high value. If Price is one till a time Technical Risk increases, thereafter a decreasing behavior begins but never goes to zero because of other variables affecting Technical Risk

Figure 4.6. shows main risk factors behaviors if Price is zero, which is the lowest value and if Price is one, which is the highest value.

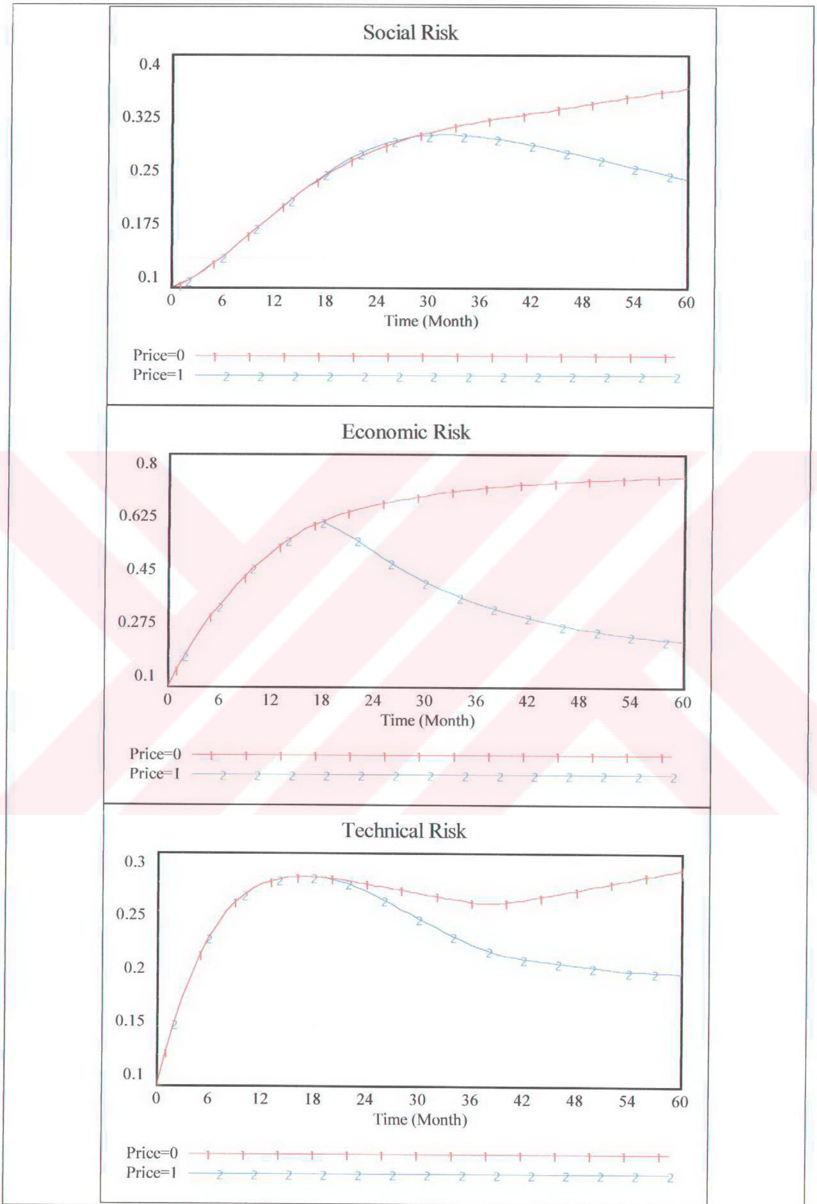


Figure 4.6. Main Stocks of the Model after Extreme Condition Test

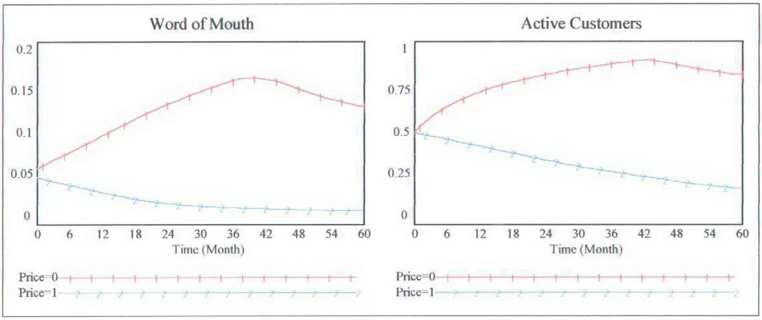


Figure 4.7. Customers Situation

Extreme values of Price have strong effects on other variables. Figure 4.7. shows that if Price is zero Active Customer rate gets closer to one. Because free products and services attract potential customers. But there is an interesting situation as seen from Figure 4.7. Active Customer rate begins to decrease after a time, although there is no price for products. It results from that after a determined time there occurs dissatisfaction with product because of technology and product obsolescence.

Zero Price affects Word of Mouth Ratio, too. It increases and gets closer to one. But the same behavior of Active Customer is observed at Word of Mouth ratio. After a time it begins to decrease although Price is zero.

When Price is one there is a decreasing behavior of Active Customer and Word of Mouth Ratio. Because high price creates antipathy against to company products and even old customers begin to leave.

From Figure 4.8 it is clearly understand that there is a relation between customers and sales. If Price is zero there is an increasing behavior of customers leading to an increase in Sales and Market Share. Goal seeking behavior is observed in Sales and Market Share, too. It results from decreasing behavior of Active Customers after a determined time.

Conversely when Price is at highest value, one, Sales and Market share get closer to zero related to Active Customers. It is realized that in the beginning there is a small increase in Sales and Market Share. It might result from old customer commitment to firm.

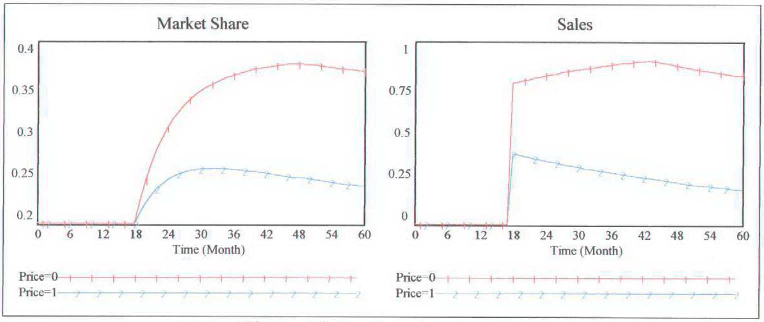


Figure 4.8. Market Share and Sales

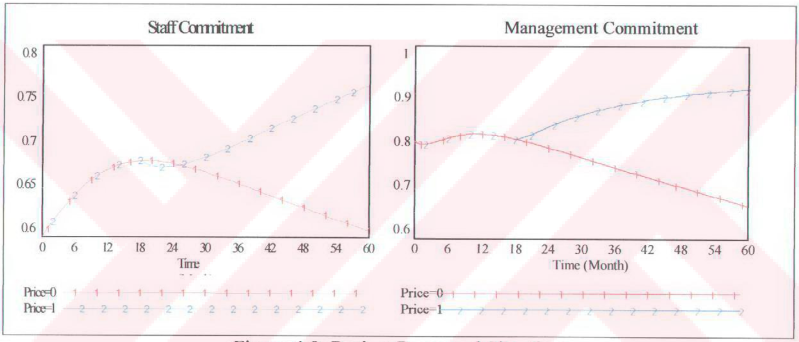


Figure 4.9. Project Personnel Situation

Management and Staff Commitment are affected by extreme values of Price, too. When Price is zero there occurs no Profit, but Economic Risk with a high value. This situation leads to uneasiness among project personnel. It reflects to commitments of personnel to their firm. In the beginning it is observed that there is an increase in Staff and Management Commitment. It results from that in all projects there occurs always a strong commitment to project. All personnel support their projects.

When Price is one, its effect on Revenue and Profit reflects to Management and staff commitment. They go up to high values closer to one. Figure 4.9. shows behaviors of Staff Commitment and Management Commitment during the project time with extreme values of Price.

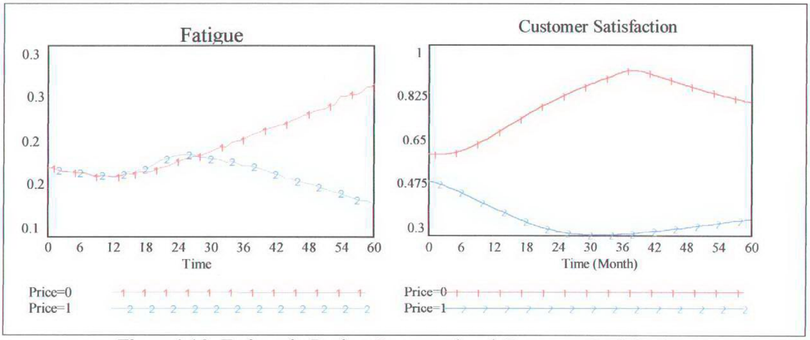


Figure4.10. Fatigue in Project Personnel and Customer Satisfaction

When Price is zero Fatigue in Project Staff goes to a higher value. Staff and Management Commitment and current Quality cause this situation. If price is one there is a decreasing behavior to zero in Fatigue. If there is zero Price Customers are expectedly very satisfied with the price and its behavior is to high values. When Price is one there is a decreasing Customer Satisfaction. Figure 4.10. shows of Fatigue and Customer Satisfaction Rate.

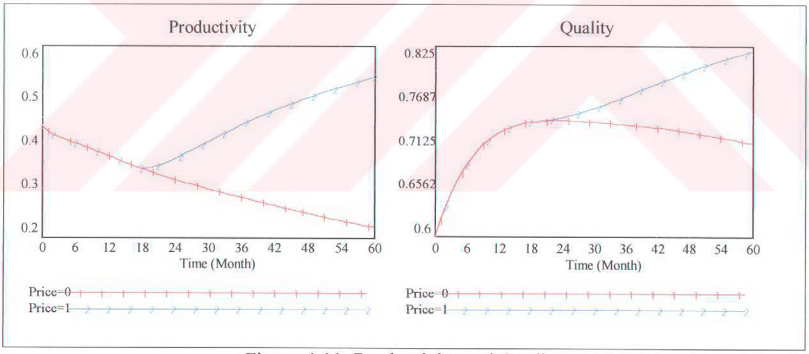


Figure 4.11. Productivity and Quality

When price is zero there is a decreasing commitment and it affects Productivity. It gets closer to zero. If Price is one productivity increases and goes to a higher value.In the beginning there is an increase in Quality but then zero Price leads to a decrease in Quality. When Price is one, Quality increases and gets closer to one. Figure 4.11. shows behaviors of Productivity and Quality with extreme values of Price.

4.2.3. Product Sale Time

The third extreme condition test is done with Product Sale Time. It is the time that when new products and services of the firm would be sold. Product Sale Time is set first at 0, which is relatively a low value and at 1, which is relatively a high value. Product Sale Time is chosen to be very close to zero, which is 1 in order to eliminate the divisibility, by zero error.

As seen from the Figure 4.12. when Product Sale Time is 1 Economic Risk get closer to zero. Because the company is able to get profit in the beginning. It can meet company outcomes and there is always cash money in the company.

Conversely, if Product Sale Time is 60, which is project completion time and the highest value, Economic Risk goes to a higher value closer to one. It is also so expressed that because the firm couldn't sell its products and services till project due time there will be no profit and firm will not be able to meet spendings. As a result the company collapses.

When Product Sale Time is 1, in the beginning there occurs an increase in Social Risk because of other variables increasing Social Risk. Thereafter it gets closer to zero. The effect of Product Sale Time is felt.

Social Risk gets a higher value if Product Sale Time is 60. It results from various effects. Decreasing Staff and Management Commitment, Customer Dissatisfaction are some reasons for this increase. But this increase is not as sharp as Economic Risk.

Technical Risk behavior is similar to behavior of Social Risk. When Price is 1, at start there is an increasingly goal seeking behavior in Technical Risk. Then trend of risk direction is down. It gets closer to zero but never zero, because there are other factors leading to Technical Risk such as software or hardware failure.

As Product Sale Time is 60, at its highest value, Technical Risk goes to a higher value. As observed in Social Risk, increase of Technical Risk is not as sharp as the increase of Economic Risk.

Figure 4.12. shows main risk factors behaviors with extreme condition test of Product Sale Time.

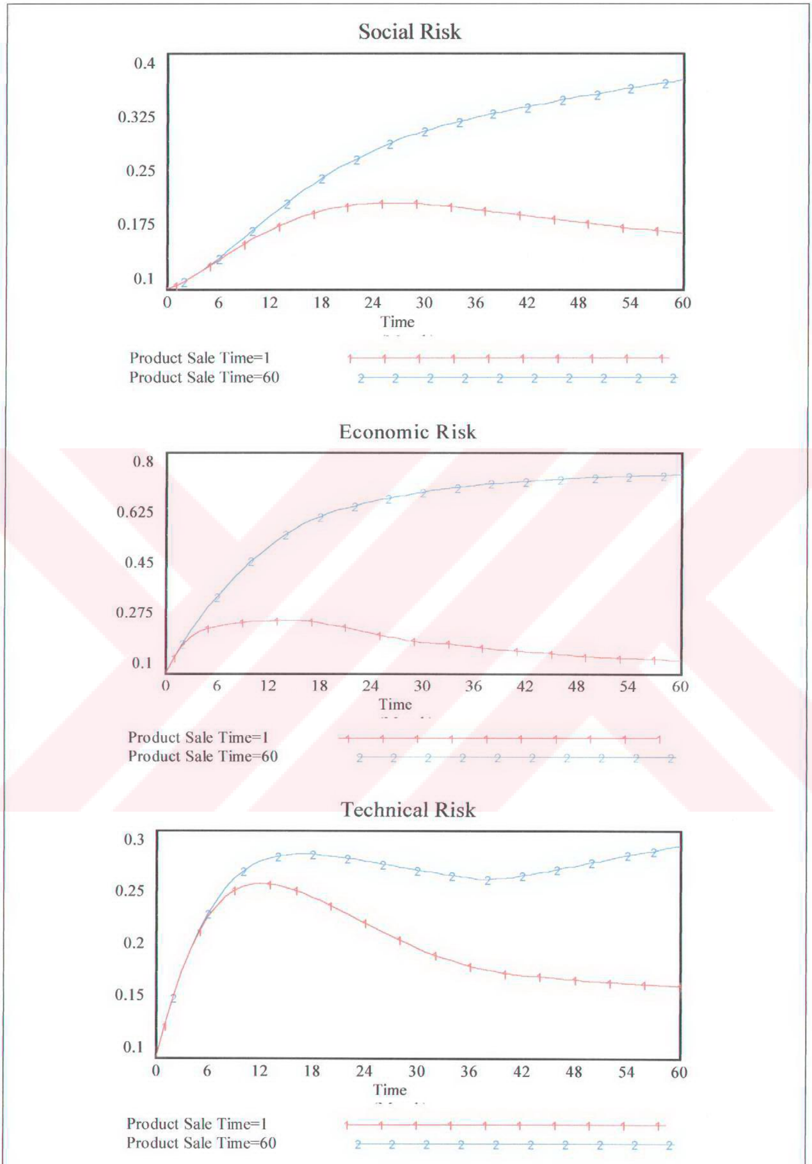


Figure 4.12. Main Stocks of the Model after Extreme Condition Test with Product Sale Time

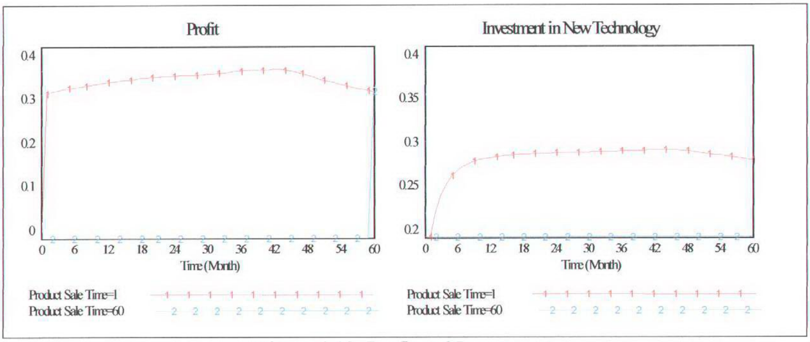


Figure 4.13. Profit and Investment

From the Figure 4.13. it is clearly understand that the most affected variable by extreme condition test of Product Sale Time in the model is Profit because profit depends on Product sale. When Product Sale Time is one there will be sales in the beginning. It brings about Revenue from sales at the start of the Project. Revenue leads to an increase in Profit.

If there is no sale, there will be no revenue consequently Profit is zero. In other words when Product Sale Time is 60, which is the highest value Profit, is zero during project time. Because project time takes 60 months.

When Product Sale Time is one, effect of Profit reflects to Investment rate. In other words if Product Sale Time is one there is an increasing behavior of Investment. This increasing trend becomes then a smooth value because of other factors affecting Investment.

There is no new Investment except for previous steady Investment in the firm, if Product Sale Time is 60 because there is no Sales and naturally no Profit. It is obviously known that without Profit there couldn't be Investment.

Extreme values of Product Sale Time affect Management and Staff Commitment. If Product Sales Time is one in the beginning of the project the company gain money from sales and gets more Profit. It reflects directly to personnel situation. Because their economic situations are in a better condition, Management and Staff Commitment go to higher values closer to one.

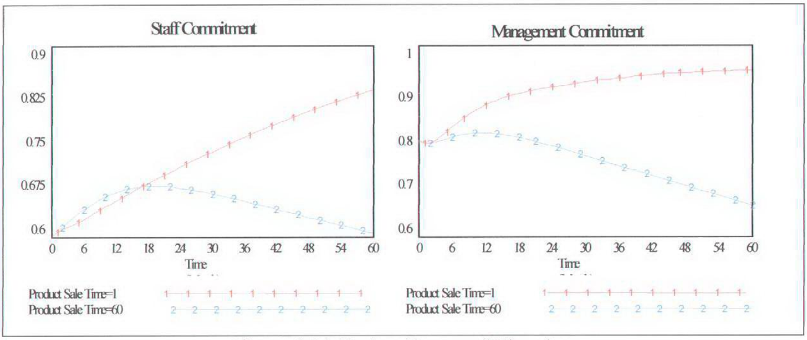


Figure 4.14. Project Personnel Situation

When Product Sale Time is 60 there occurs no Profit till project due time, but Economic Risk with a high value. This situation leads to uneasiness among project personnel. It reflects to commitments of personnel to their firm. In the beginning it is observed that there is an increase in Staff and Management Commitment. It results from that in all projects there occurs always a strong commitment to project. All personnel support their projects. Figure 4.14. shows Personnel Commitments Behaviors.

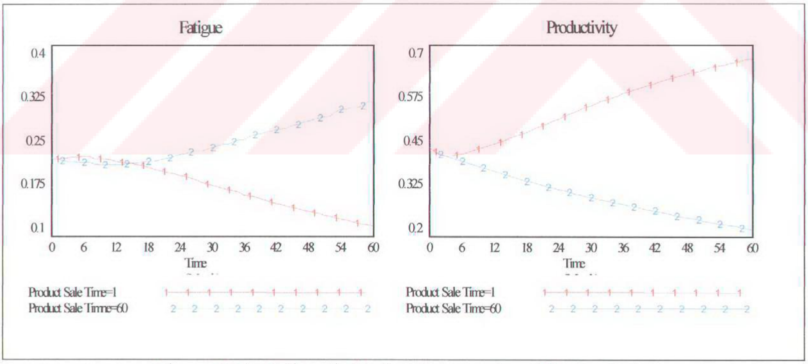


Figure 4.15. Fatigue in Project Personnel and Productivity

Fatigue in Project Staff gets closer to zero related to Personnel Commitment and quality of products and services, when Product sale Time is one. Conversely if Product Sale Time is 60 Fatigue rate goes to a higher value.

Productivity rate is affected by this extreme situation. Low value of Product Sale Time leads to an increasing behavior in productivity, it goes to a higher value. When Product Sale Time is 60 Productivity gets closer to zero. Figure 4.15. shows behaviors of Fatigue and Productivity of Project Personnel.

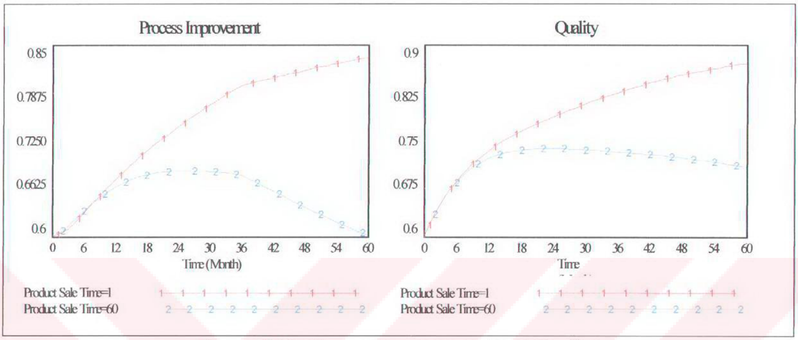


Figure 4.16. Process Improvement and Quality

When Product Sale Time is 1 Process Improvement goes to a high value closer to 1. It results from the increase in Management and Staff Commitment. Associated with Process Improvement, Quality of products and services behaves increasingly. It is not 1 yet but it is assumed to be at its highest value for a long period of time.

If Product Sale Time is 60 it is observed that there is a decrease in Process Improvement after a low increase resulting from initial high Management and Staff Commitment in the beginning of the project. After a determined time it gets closer to zero. The same trend is realized in the Quality behavior.

When Product Sale Time is 60 there is a low increase in the beginning because of similar reasons as in Process Improvement. Thereafter Quality goes down. Figure 4.16. shows behaviors of Process Improvement and Quality with Product Sale Time extreme condition test.

4.3. Sensitivity Test

This test consists of determining those parameters to which the model is highly sensitive, and asking if the real system would exhibit similar high sensitivity to the corresponding parameters. (Barlas,1996). As Sterman (2000) states all models are wrong. Therefore the robustness of conclusions to uncertainty in our assumptions should be tested. Sensitivity analysis asks whether our conclusions change in ways important to our assumptions are varied over the plausible range of uncertainty.

Sensitivity analysis is made with Monte Carlo Simulation. According to Sterman (2000) Monte Carlo simulations allow us to generate dynamic confidence intervals for the trajectories in our models. In Monte Carlo Analysis, a probability distribution is specified that characterizes the likely values of each parameter.

4.3.1. Available Technology at Market

There is always an uncertainty about technology. We are living in information technology era. Companies must use available technologies within their projects. But sometimes there can be some things going wrong. When a firm plans a project, there could be no appropriate technology. Conversely there can be a lot of new technologies, which are not yet widely used, and therefore an advantage for firms. The rate of available technology is very sensitive for projects, especially for technical projects such as telecommunication. The lower limit of Available Technology at Market is 0.1, whereas its upper limit is 1. Sensitivity simulation proves a variation ranging from 0.1 to 1 and effects of these values on other variables and stocks in the model.

Sensitivity of technology can be observed dramatically in risk factors. In the Figure 4.17. the confidence bounds for Technical Risk and Technology Gap are shown. Given the assumption there is a 50 % chance that Technical Risk will be between 0.24 and 0.32 in month 15 and a 95 % chance that Technical Risk will be between 0.2 and 0.35.

As for Technology Gap during the project time there occurs a steady behavior at all chance. For example the 95 % chance of technology Gap is approximately between values 0.08 and 0.5 during whole project time and a 50 % chance that Technology Gap approximately will be between 0.15 and 0.40.

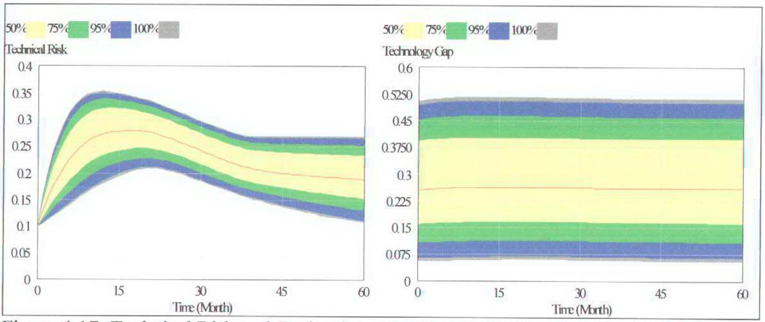


Figure 4.17. Technical Risk and Technology Gap Sensitivity Graphs with Available Technology at Market

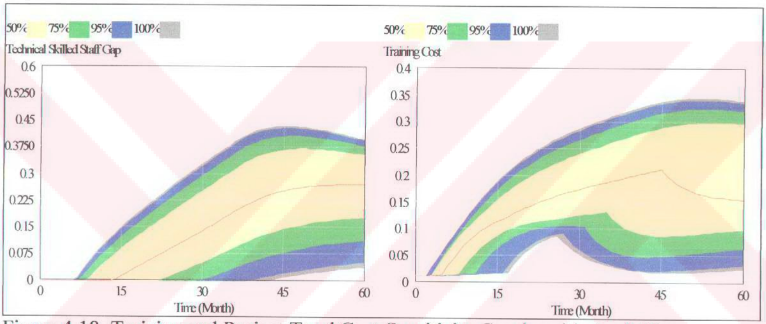


Figure 4.18. Training and Project Total Cost Sensitivity Graphs with Available Technology at Market

Figure 4.18. shows the confidence bounds of Technical Stilled Staff Gap and Training Cost. Technical skilled Staff Gap will be between zero and 0.08 in month 15 with a 50 % chance and with this 50% chance it will be between 0.15 and 0.35 in month 45. Training Cost confidence bounds are interesting. Although there is a 100 % chance that training Cost will be between 0.1 and 0.25 in month 25, the 100 % chance expands in month 45. Its confidence bounds are between 0.01 and 0.33.

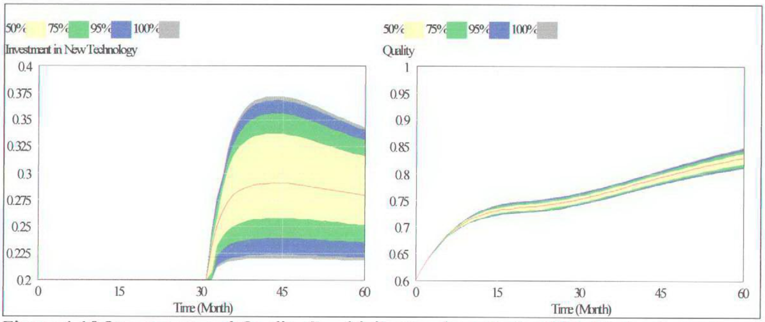


Figure 4.19.Investment and Quality Sensitivity Graphs with Available Technology at Market

From the Figure 4.19. it is observed that Investment rate never goes down or up till time 30. In month 45 there is a 75% chance that Investment in New Technology will be between 0.23 and 0.35.

Confidence bounds of Quality are very near to each other. For example there is a 50 % chance that quality will be between 0.745 and 0.76 and a 100 % chance that Quality will be between 0.74 and 0.765.

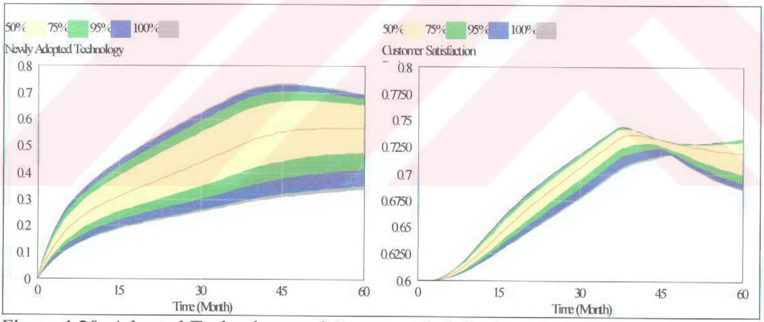


Figure 4.20. Adopted Technology and Customer Satisfaction Sensitivity Graphs with Available Technology at Market

Figure 4.20 shows the behavior of Newly Adopted Technology and Customer Satisfaction. If Available Technology changes between 0.1 and 1 there is a 95 % chance that Newly Adopted Technology will be between 0.3 and 0.6 in month 30. There is a 75 % chance that it will be between 0.4 and 0.7 in month 45. Confidence bounds of Customer Satisfaction behave rather narrowly in month 45. There is a 75 % chance that Customer Satisfaction will be between 0.72 and 0.73 and a %0 % chance that it will be between 0.725 and 0.73.

4.3.2. initial Staff and Management Commitment

Beginning a project there are two important factors affecting project risk in the same or opposite direction. Those factors are Commitment of Management and Staff to their projects. Commitment rate of company personnel has an uncertainty. It could be at its lowest value or at it highest value or between these values. To observe the sensitivity of initial Staff and Management Commitment they are assumed to be distributed between 0.1 and 1 and confidence bounds of main risk factors and other variables are formed.

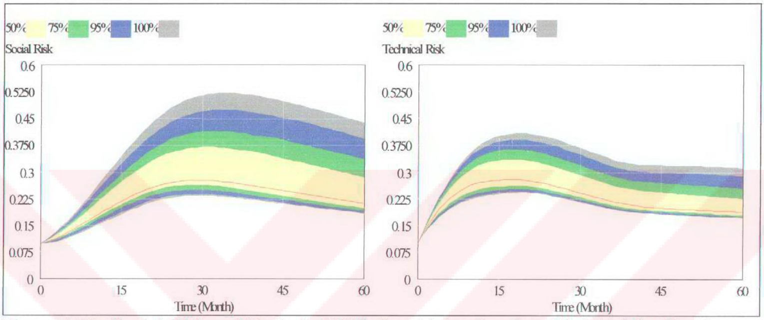


Figure 4.21. Social Risk and Technical Risk Sensitivity Graphs with initial Staff and Management Commitment

Figure 4.21. shows the confidence bounds of Social and Technical risks with the sensitivity analysis of initial Staff and Management Commitment. Given these assumptions there is a 100 % chance that Social Risk will be approximately between 0.22 and 0.52 in month 30 and in the same time a 50 % chance that it will be between 0.25 and 0.37.

Fatigue in Project Staff is very sensitive to initial Management and Staff Commitment. Because if there is poor commitment to project it brings about dissatisfaction and poor motivation leading to Fatigue in project works. From the Figure 4.22. it is observed that there is a 75 % chance that Fatigue will be between 0.1 and 0.7 in month 30 and with the same chance it will be 0.1 and 0.6 in month 45.

Customer Satisfaction confidence bounds are closer to each other in the initial times. With time confidence bounds expand. For example there is a 100% chance that Customer Satisfaction will be between 0.63 and 0.64 in month 15 but the same chance in month 45 is that Customer Satisfaction will be between 0.65 and 0.75.

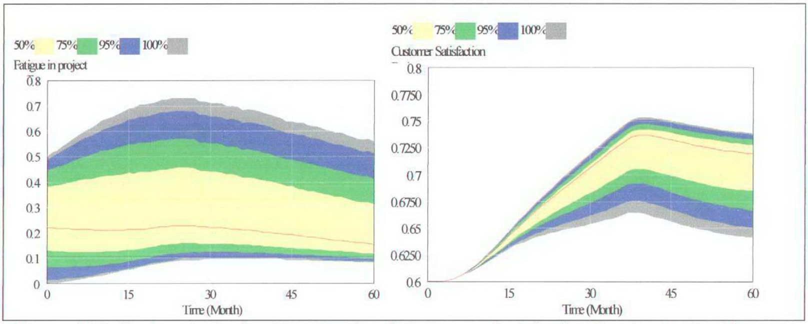


Figure 4.22. Fatigue in Project Personnel and Customer Satisfaction Sensitivity Graphs with initial Staff and Management Commitment

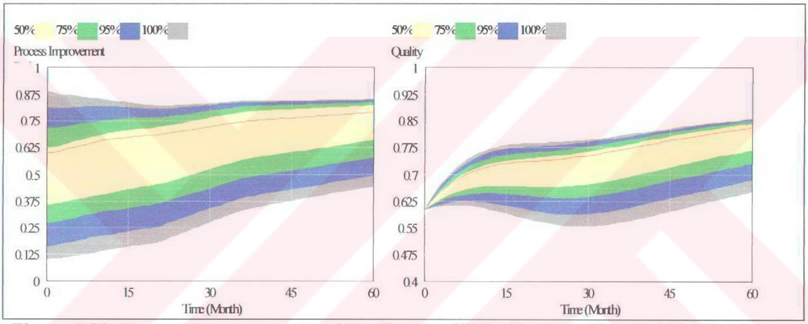


Figure 4.23. Process Improvement and Quality Sensitivity Graphs with initial Staff and Management Commitment

Process Improvement and quality are affected from this sensitivity. The confidence intervals of Process Improvement are wide during project time. Given assumptions of initial Management and Staff Commitment there is a 75 % chance that Process Improvement will be between approximately 0.35 and 0.80 in month 30 and a 50 % chance that process Improvement will be between 0.5 and 0.75.

As for Quality there is a 95 % chance that Quality will be 0.6 and 0.79 in time 30. The same chance in month 60 is that Quality will be between 0.7 and 0.85. In the same time the chance of being between 0.75 and 0.85 is 50 %. Figure 4.23. shows the confidence intervals of Process Improvement and Quality with the assumption of initial Staff and Management Commitment values.

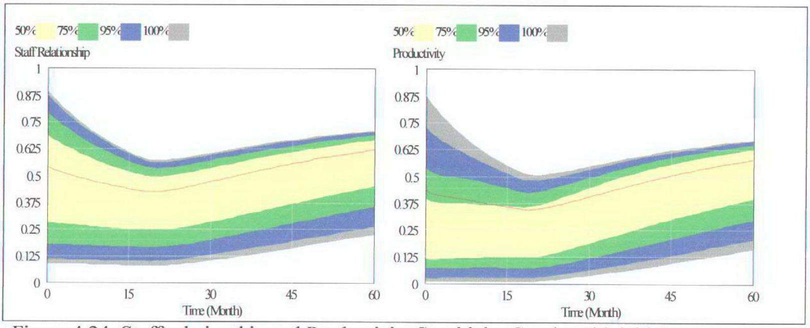


Figure 4.24. Staff relationship and Productivity Sensitivity Graphs with initial Staff and Management Commitment

Figure 4.24. shows that confidence bounds of Staff Relation Ship and Productivity are very wide. It results from that if initial staff and Management Commitment very low ore very high their reflections to staff Relationship and Productivity are dramatically felt. Given the assumptions of initial Staff and Management Commitment for example there is a 50 % chance that Staff Relationship will be between 0.25 and 0.5 in month 15 and a 100 % chance that it will be 0.12 and 0.62.

The confidence intervals of Productivity are wider than those of Staff Relationship. Because Productivity rate is affected both Staff and Management Commitment proportionally. There is a 75 % chance that Productivity will be between 0.05 and 0.55 in the beginning and the same chance in month 30 is that it will be between 0.12 and 0.5.

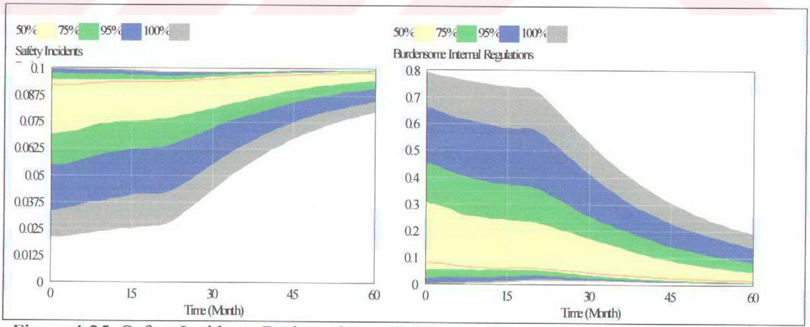


Figure 4.25. Safety Incidents Ratio and Regulations Sensitivity Graphs with initial Staff and Management Commitment

From the Figure 4.25. it is observed that Safety Incidents rate shows an interesting behavior with sensitivity analysis. In the initial times there are wide confidence intervals. Those intervals become narrow during the last times of project. For example there is a 100 % chance that Safety Incidents will be 0.02 and 0.1 at the start of the project. This same chance in the end of the project is also so that it will be between 0.08 and 0.1.

The confidence intervals of Regulations are wide at the start of Project, too. Because initial Staff and Management Commitment distribution between 0.1 and 1 affects strongly Regulations rate. With time Staff and Management Commitments confidence bounds become narrow. Related to this situation Regulations confidence bounds become narrow. This relation is acceptable between Staff and Management Commitment and Safety Incidents, too. There is a 95% chance that Regulations will be between 0.01 and 0.6 in month 15 and a 50 % chance that it will be between 0.05 and 0.25. In the end of the project there is a 95 % chance that Regulations will be between 0 and 0.15 and a 50 % chance that it will be between 0 and 0.05.

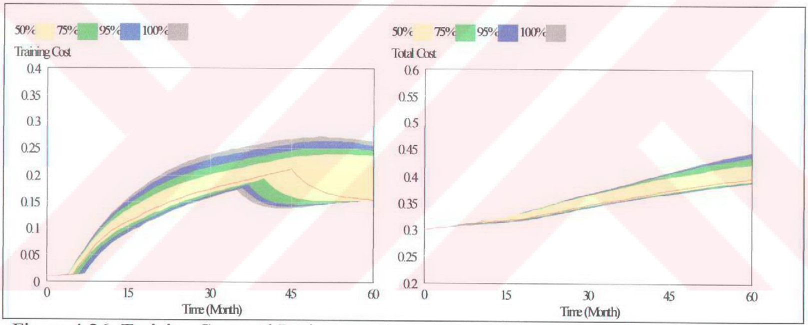


Figure 4.26. Training Cost and Project Total Cost Sensitivity Graphs with initial Staff and Management Commitment

Training Cost and Project Total Cost behaviors are given in Figure 4.26. There is a narrow interval of 50% chance in month 40 that Training Cost will be 0.2 and 0.225. Thereafter its interval widens. In month 50 there is a 50% chance that Training Cost will be between 0.15 and 0.25.

As for Project Total Cost the values of confidence bounds are nearly the same during project. For example there is a 50 % chance that Project Total Cost will be between 0.37 and 0.40 in month 45. In the same time there is a 75 % chance that it will be between 0.37 and 0.41.

4.3.3. Interest Rate

Interest Rate is an uncertain variable in the model. While it doesn't depend on any plan in project it can vary with time. Interest Rate is also out of control in all projects. The uncertainty of Interest Rate entails a sensitivity analysis to see how variables in the model are affected. Interest Rate is assumed to be distributed normally and independently between 0.1 and 1.

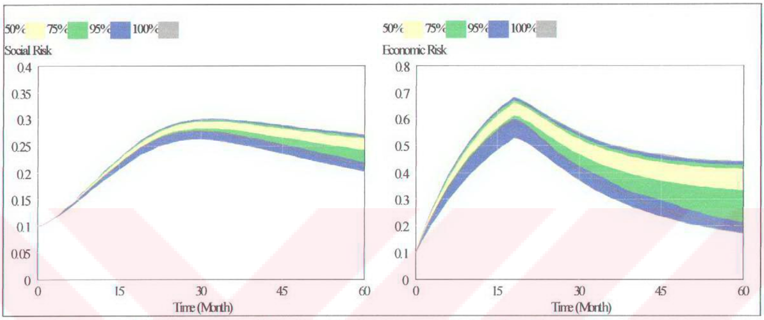


Figure 4.27. Social and Economic Risk Sensitivity Graphs with Interest Rate.

Given this assumption Figure 4.27. shows the confidence bounds of Social and Economic risk. The effect of Interest Rate sensitivity on Social Risk is not as strong as on Economic Risk. Its confidence intervals are also narrow. For example there is a 75 % chance that Social Risk will be between 0.25 and 0.29 in month 45 and a 95 % chance that it will be between 0.23 and 0.29.

The confidence intervals in Economic Risk are narrowly behaving till the middle of the project, but then they widen. Although, in month 15 there is a 95 % chance that Economic Risk will be between 0.5 and 0.6, in month 50 this 95 % chance is that Economic Risk will be between 0.2 and 0.45.

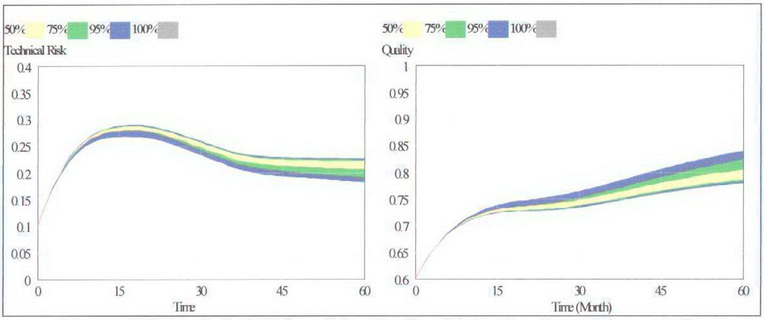


Figure 4.28. Technical Risk and Quality Sensitivity Graphs with Interest Rate.

From the Figure 4.28. it is understand that Technical Risk and Quality of product and services are not strongly affected from Interest Rate variation. From month 10 to month all confidence bounds are approximately between 0.25 and 0.30. From month 30 to due time of the project they are between 0.20 and 0.25. It indicates that there is approximately 20% deviation of Technical Risk if Interest Rate uncertainty is varies between lowest and highest values. There is a similarity between Technical risk and Quality confidence bounds. Quality confidence intervals are narrow too. For example there are 75 % and 50 % chances that Quality will be between 0.74 and 0.75 in month 30.

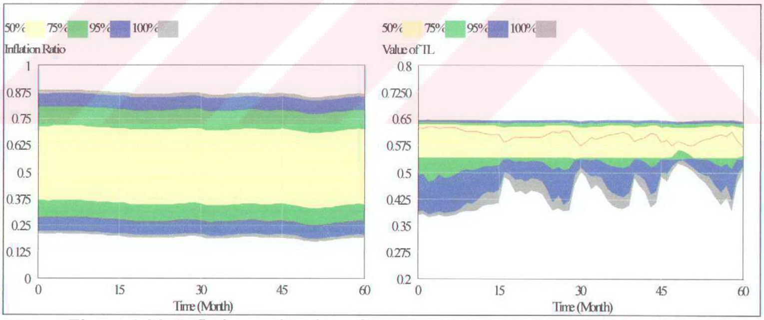


Figure 4.29. Inflation and Value of TL Sensitivity Graphs with Interest Rate.

Figure 4.29 shows that the most affected variable from the sensitivity analysis of Interest Rate is Inflation. All chances are almost steady during the project time. For example there is a 95 chance that in the beginning Inflation Ratio will be between 0.2 and 0.8. The same chance is similar to values in the beginning in month 60. They will be between 0.2 and 0.8.

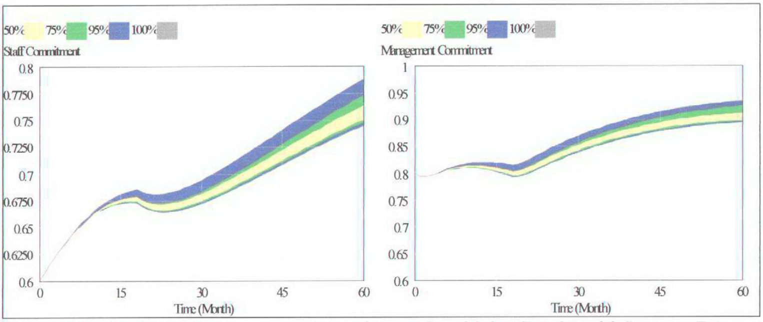


Figure 4.30. Staff and Management Commitment Sensitivity Graphs with Interest Rate.

Staff and Management Commitments are affected from the sensitivity analysis of Interest Rate but not strongly. Figure 4.30. shows confidence bounds of Staff and Management Commitment.

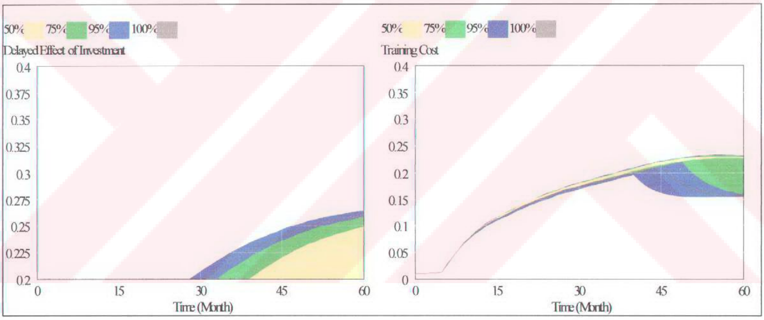


Figure 4.31. Effect of Investment and Training Cost Sensitivity Graphs with Interest Rate

Delayed effect of Investment is constant at value 0.2 till month 30. Thereafter confidence bounds are observed. The confidence bounds of Training Cost narrowly behave till month 40. After month 40 confidence bounds widens. For example there is a 95 % chance that Training Cost is between 0.15 and 0.22 in month 45. But there is a narrow 50% chance that it will be between 0.21 and 0.22 in the same time.

4.3.4. Other Constant Variables

In this section some constant variables are assumed to be tested together with sensitivity. Table 4.1. shows minimum and maximum values of the variables used in sensitivity test.

Table 4.1. Value Table of Constant Variables for Sensitivity Test

	Minimum Value	Maximum Value	Base Value
Product Sale Time	6	60	18
Technology Obsolescence Time	6	60	48
initial Active Customer	0.2	0.9	0.5
Level of Actual Skill	0.1	0.8	0.5
Contact Rate	0.1	0.9	0.4
initial Quality	0.1	1	0.6

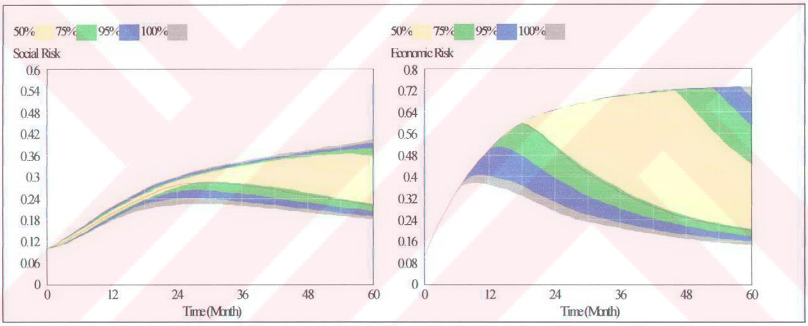


Figure 4.32. Social Risk and Economic Risk Sensitivity Graph with some Variables

Given these assumptions it is observed that Economic Risk shows the most sensitivity. As seen from the Figure 4.32. there is a 95 % chance that Social Risk will be between 0.24 and 0.32 in month 30 whereas the same chance in Economic risk is between 0.25 and 0.68 in the same time.

There are some grapes below showing the sensitivity levels of variables. From figures it can be clearly observed that variables have wide sensitivity boundaries because of the fact that in the sensitivity analysis many constant variables are used and their variations affect risk factors and other variables dramatically.

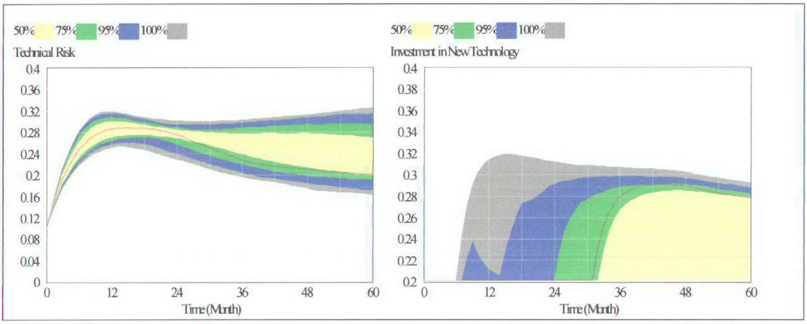


Figure 4.33. Technical Risk and Investment in New Technology Sensitivity Graph with some Variables

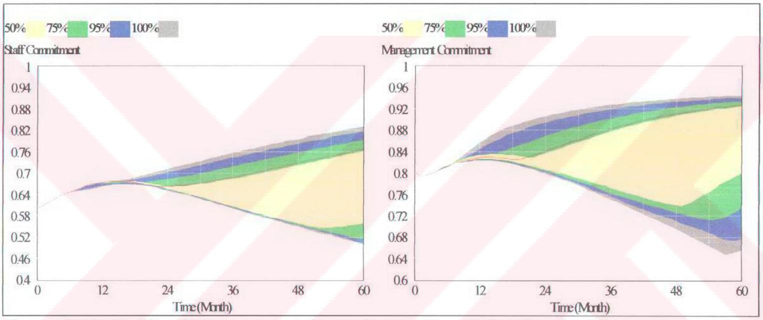


Figure 4.34. Staff and Management Commitment Sensitivity Graph with some Variables

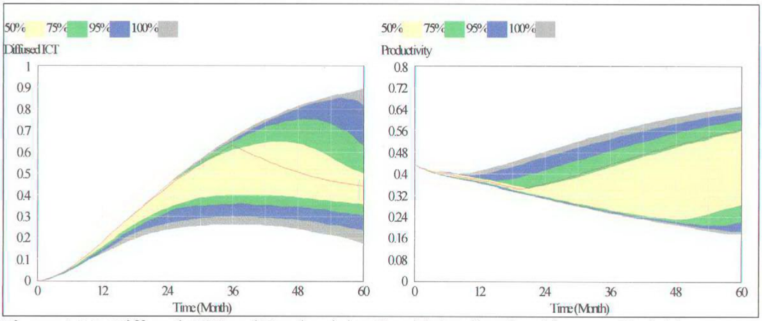


Figure 4.35. Diffused ICT and Productivity Sensitivity Graph with some Variables

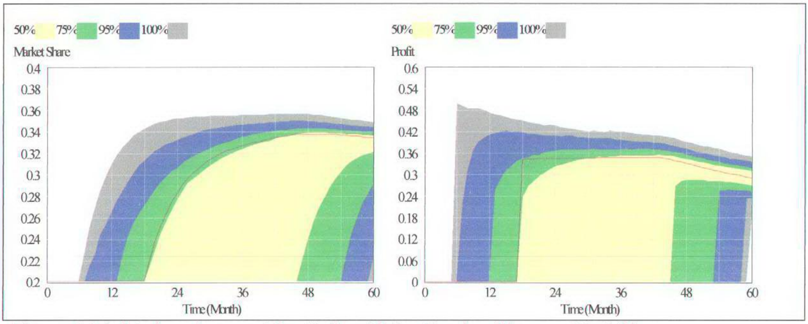


Figure 4.36. Market share and Profit Sensitivity Graph with some Variables

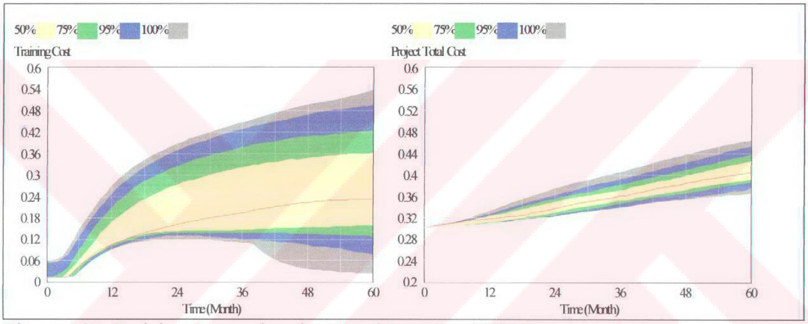


Figure 4.37. Training Cost and project Total Cost Sensitivity Graph with some Variables

5. SIMULATION RESULTS AND DISCUSSION

5.1.Base Run

Base Run constitutes our model assumptions. In the model there are initial risk values in the base run at the start of the project. All initial values of main risk sectors are 0.1. because it is assumed that when beginning a project there is always a initial risk probability with 10 %. Quality of the company old products and services is 0.6 in the beginning of the new project. Management team is greatly committed to the new project. Their commitment value is 0.8. Staff commitment is in the middle with value 0.6. The current Revenue of the firm is assumed to be 0.3.

New products and services will be sold after 18 months. The Price of new services and products is assumed to be 0.6. It is expected that a new technology, which the firm adopted, will be obsolete after 36 months. It reflects to Customer satisfaction and Customer Abandonment Time. Customer Abandonment Time is also assumed to be 42 months. In the beginning of the project the rate of Available Technology at market is 0.5.

In the beginning of the project the Interest rate is also assumed to be 0.3 closer to currency value. Active Customers of the firm are moderately satisfied with old products and services. Their satisfaction rate is 0.6. It is assumed that the firm plans to have a Project Total Cost with rate of 0.3, but during the new projects there could be extra spendings dependent on Profit and GDP Growth.

The constants of the model for Base Run are given in the Table 5.1.

5.1.1. Social Risk

Social Risk shows different characters of behavior throughout the simulation. It first increases like an Exponential Growth (see Appendix A.2.2.1) due to its net flow's almost linear increase till time 6. Then the Net Flow comes to a smooth valley between 6 and 10. This short smooth situation brings about a linear behavior in Social Risk between those times. After month 10 Net Flow starts to drop down which would a decreasing increase in Social Risk. There is a Goal Seeking behavior (see Appendix A.2.2.2) till time 30. After time 30 the Net Flow drop down under zero. It causes a collapse in Social Risk. Collapse is very close to a linear way after time 36. Because it can be observed from the Net Flow graph that after time 36 there is a smooth behavior in Net Flow till due time.

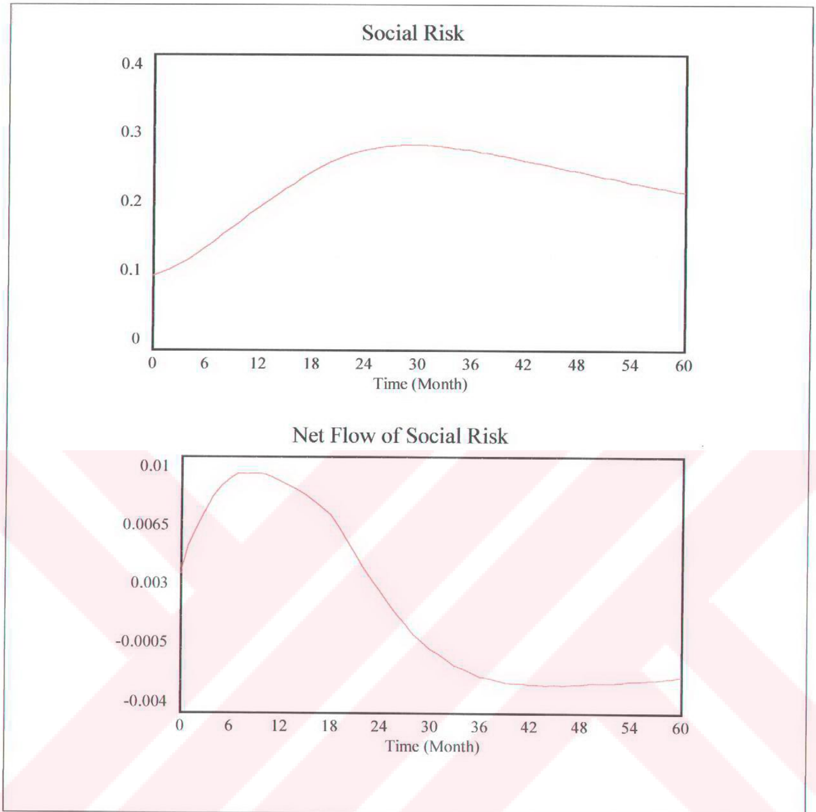


Figure 5.1. Social Risk and its net flow with Base Run

Table 5.1. Some Parameter Values for the Runs

VARIABLES	Base Run	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11
		Extreme Condition Test						**Sensitivity Test**			
initial Social Risk	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Initial Economic Risk	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
initial Technical Risk	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
initial Staff Commitment	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	Between Values 0.1-1	0.6	0.6
initial Management Commitment	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	Between Values 0.1-1	0.8	0.8
initial Customer Satisfaction	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
initial Quality	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	Between Values 0.1-1
Initial Revenue	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
initial Total Cost	0.3	0.00001	1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
initial Active Customers	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	Between Values 0.2-0.9
Price	0.6	0.6	0.6	0.00001	1	0.6	0.6	0.6	0.6	0.6	0.6
Investment Delay Time	24	24	24	24	24	24	24	24	24	24	24
Product Sale Time	18	18	18	18	18	1	60	18	18	18	Between Values 6-60
Technology Obsolescence Time	36	36	36	36	36	36	36	36	36	36	Between Values 6-60
Customer Abandonment Time	42	42	42	42	42	42	42	42	42	42	42
Contact Rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	Between Values 0.1-0.9
Available Technology at Market	0.5	0.5	0.5	0.5	0.5	0.5	0.5	Between values 0.1-1	0.5	0.5	0.5
Level of Actual Skill	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	Between Values 0.1-0.8
Interest Rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	Between values 0.1-1	0.2

5.1.2. Economic Risk

Economic Risk behavior is like an Overshoot and Collapse behavior (Sterman 2000). (see Appendix A.2.2.6). Till the time 18 there is a goal seeking behavior in Economic Risk. It results from the decrease in Net Flow. Net Flow decreases decreasingly till time 18 which would affect the stock with the goal seeking type of behavior. After time 18 there is no growth any more.

Because the Net Flow is under zero. It causes a decrease e in Economic Risk. It results from the effect of Profit. Because product sales begin after time 18. After time 30 there is a decreasingly drop in Economic Risk. Then there occurs an increase in Net Flow. It could be result from the increase in Project Total Cost. In the base model it is assumed that if the rate of Project Total Cost pasts over its initial rate with 10% its effect on Economic Risk will be increasingly felt.

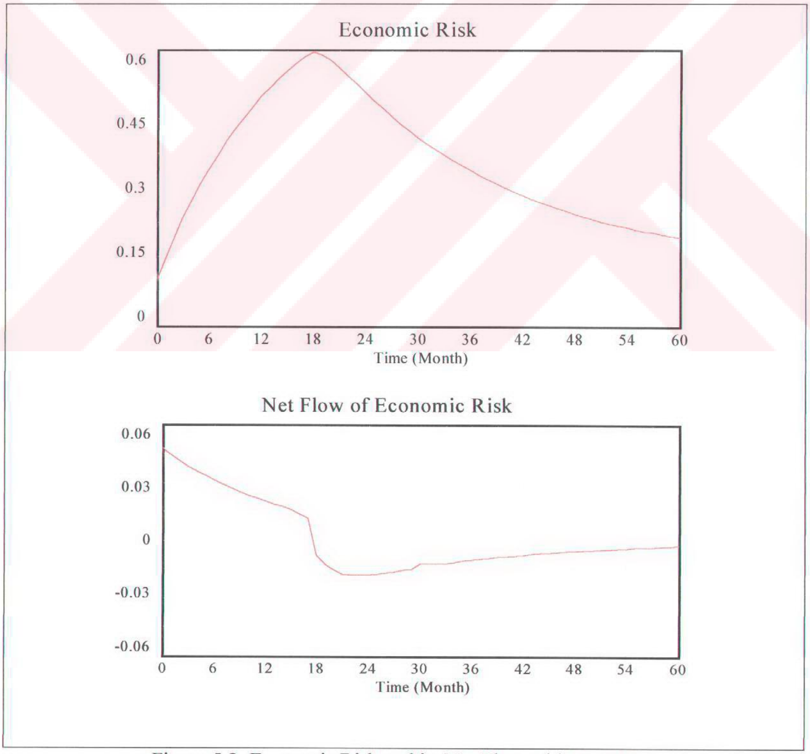


Figure 5.2. Economic Risk and its Net Flow with Base Run

5.1.3. Technical Risk

Technical Risk shows rather a distinct type of behavior. Until time 15 the Net Flow decreases decreasingly down to zero. During this time Technical Risk increases with a type of goal seeking behavior. Then from time 15 to 18 the Net Flow rate is stable at zero. It leads to a smooth behavior in Technical Risk. From the Figure 5.3. it is clearly observed that there is no growth or collapse between times 15 and 18. After this time a collapse begins because of the drop of the Net Flow under zero. It results from that the outflow of Technical Risk is grosser than the inflow. After time 48 the Net Flow is very closer to zero. It leads to very slow decrease in Technical Risk. Almost there is no collapse after this time. Its behavior is similar to a smooth behavior.

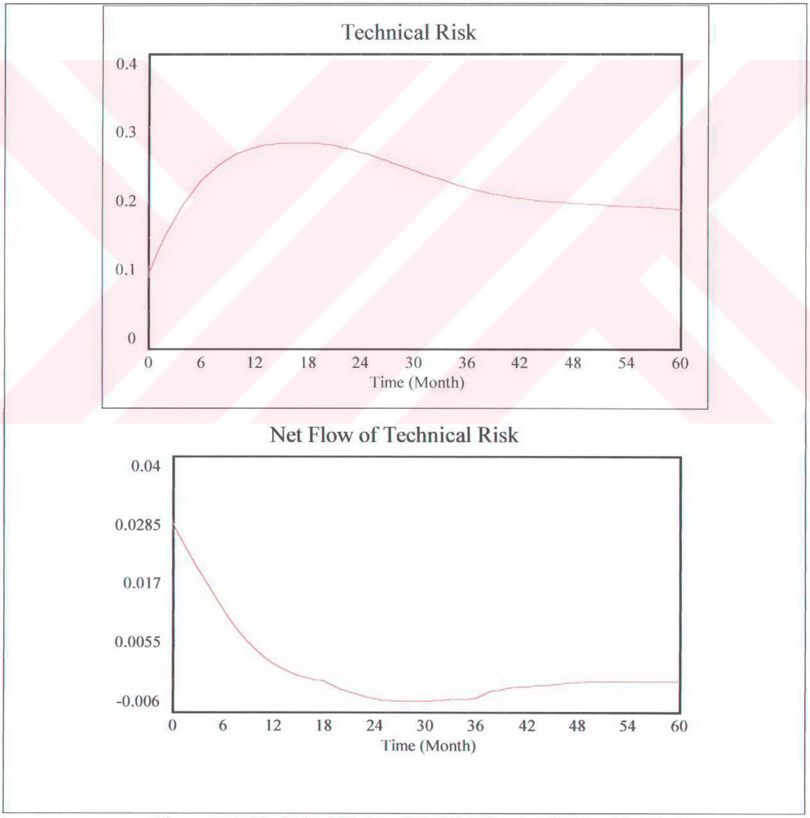


Figure 5.3. Technical Risk and its Net Flow with Base Run

5.1.4. Sub-Stocks of the Model

There are many sub stocks in the model. They are;

1. Staff Commitment
2. Management Commitment
3. Quality
4. Active Customers
5. Newly Adopted Technology
6. Diffused ICT
7. Project Total Cost

Figure 5.4. shows Staff and Management Commitment behaviors with Base Run. It is assumed that in the beginning of the new project there is a moderate commitment of staff with value 0.6. Till time 18 it increases decreasingly with a type of goal seeking behavior. Time 18 is a turning point for Staff Commitment. Decreasing Staff Commitment begins to increase after a short decrease. The decrease in Net Flow under zero causes to this short decrease. It would be resulted from the delay of reflection of Sales and Profit to personnel. After time 18 Net Flow begins to increase with linear behavior. It leads to at first an Exponential Growth (see Appendix A.2.2.1). Then after time 30 it is observed that there is a linear increasing behavior in Staff Commitment. It results from a smooth behavior in the Net Flow.

Initial Management Commitment is assumed to be 0.8, which is a high value. In the first three months Management Commitment decreases. It could result from that increasing values of main risk factors and delayed effect of productivity lead a decrease in Management Commitment. The minus value of Net Flow at start indicates this decreasing decrease. After time 3 there occurs a goal seeking behavior and Management Commitment increase decreasingly till time 12.

Then a decrease begins till time 18. Because Net Flow moves under zero with a decreasing trend. After time 18 an S-Shaped Growth is observed till time 24. It results from that after time 18 product sales begin and the firm gets revenue from new services and products. There is a delayed effect of revenue reflecting to Management Commitment. The linear increase in Net Flow verifies this behavior.

With time beside the revenue as positive effect other negative effects balance the behavior of Management Commitment and after time 24 a goal seeking behavior is observed.

Namely there is a decreasing increase in Management Commitment. Especially after time 42 there is a dominant effect of balancing variables on Staff Commitment increase. The effect of decrease in Active Customers after time 42 can lead to this behavior.

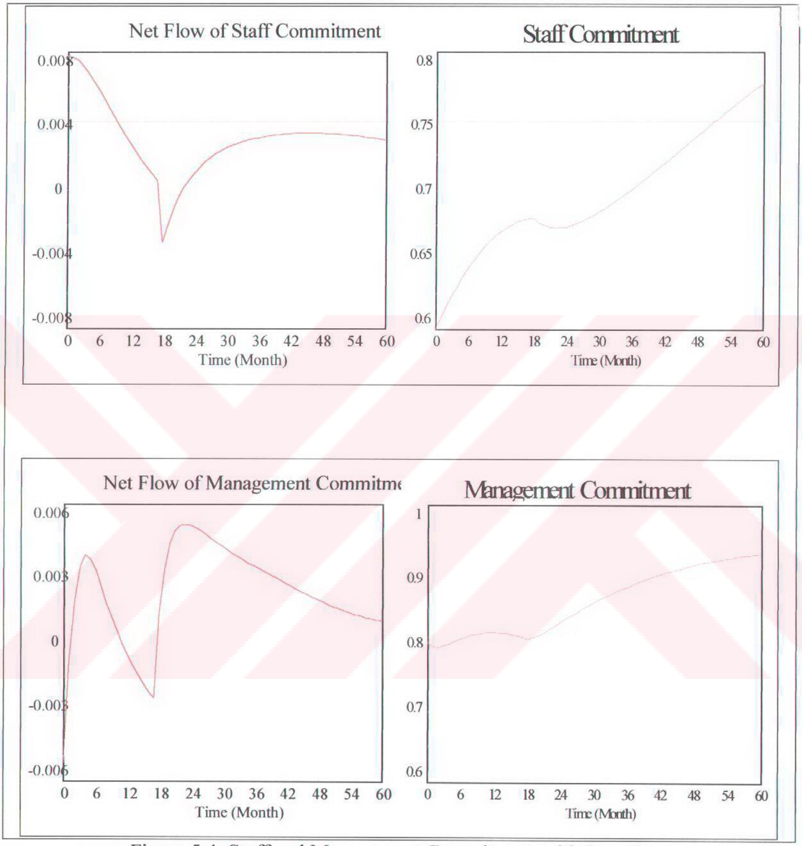


Figure 5.4. Staff and Management Commitment with Base Run

Quality shows an increasing trend with different characters throughout the simulation. It first increases decreasingly like a goal seeking behavior till time 18. Then due to its Net Flow increases Quality starts to increase. Between times 36 and 42 there is a flat behavior of Net Flow. Technology obsolescence could be an effect on this balance.

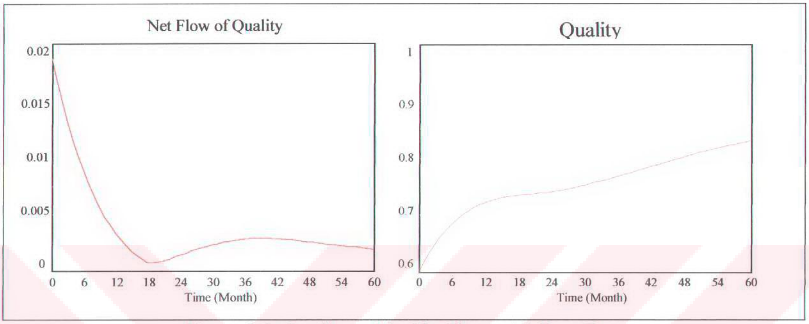


Figure 5.5. Quality and its Net Flow with Base Run

After time 42 there occurs a decrease in Net Flow. Because beside the Technology Obsolescence effect there occurs a decrease in Active Customer due to the Customer Abandonment rate in time 42 which causes a decrease in Profit consequently poor Personnel Commitments and its effect on Quality. Decrease in Net Flow causes again a goal seeking behavior in Quality but it cannot be clearly observed due to the small value of Net Flow. Figure 5.5 shows Quality and its Net Flow behaviors with time.

From the Figure 5.6. it is observed that Net Flow of Active Customers decreases decreasingly which leads to a goal seeking behavior in Active Customer. It goes on till time 42. Then Net Flow drops under zero, which means that the outflow of Active Cosutomer is grosser than its inflow.

It could be resulted from that in the model there is a customer abandonment fraction and it is assumed that after time 42 its effect will be strongly felt. It causes to a decreasing behavior in Active Customers and until the due time of the project this decrease goes on.

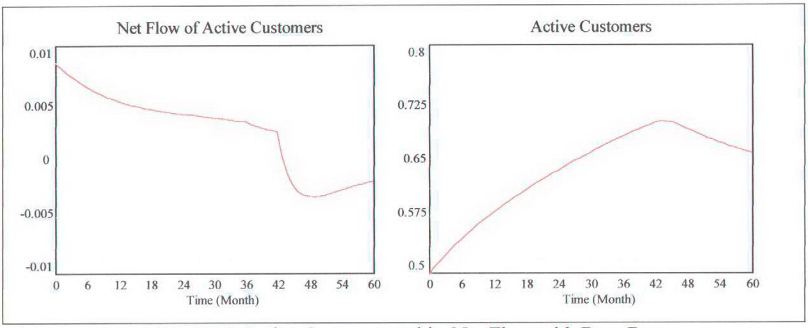


Figure 5.6. Active Customer and its Net Flow with Base Run

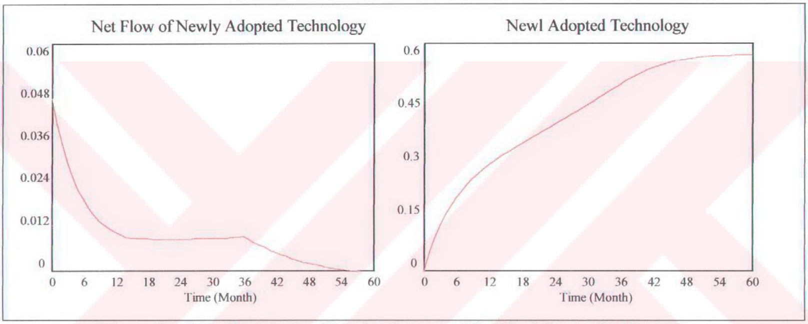


Figure 5.7 Newly Adopted Technology and its Net Flow with Base Run

Newly Adopted Technology shows rather a distinct type of behavior. It first increases decreasingly as a type of goal seeking behavior due to its Net Flow decrease till time 18. Between times 18 and 36 Net Flow gets a flat behavior, which leads to a linear increase in Newly Adopted Technology.

After time 36 Net Flow starts to decrease. Until time 54 Newly Adopted Technology stock increases decreasingly like a type of goal seeking behavior. Then its Net Flow gets zero, which means that there is no growth any more. Figure 5.7. shows the behaviors of Newly Adopted Technology and its Net Flow.

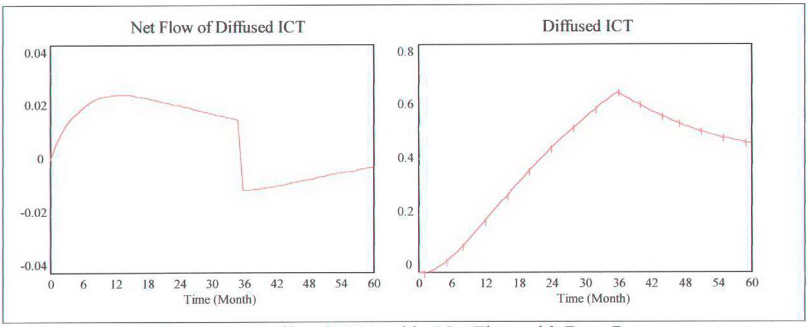


Figure 5.8. Diffused ICT and its Net Flow with Base Run

Diffused ICT shows an S-shaped growth until time 12 due to its Net Flow increases. Then there occurs a small decrease in Net Flow. But the reflection of this decrease is not felt clearly in Diffused ICT behavior. Diffused ICT increases very close to a linear way.

After time 36 there is a sharp collapse in Net Flow. It could be resulted from a negative feedback's strong domination over positive feedbacks. This negative feedback is Technology Obsolescence Time. After time 36 Diffused ICT starts to decrease decreasingly, because there is an increase in its Net Flow closer to zero. The behavior of Diffused ICT is similar to the type of Collapse and Overshoot behavior.

The initial Total Cost of the company is assumed to be 0.3. Initial Total Cost includes Labor, Production and Overhead spendings. It is also assumed that there could be overruns related to many effects, for example main risk factors, Profit, GDP Growth etc. Labor, Production and Overhead spending graphs show those overruns. Rework Cost and Training cost are assumed to occur during project time.

From the Figure 5.9. it is clearly observed that Project Total Cost increases continuously with a linear behavior. Its linearity increases after time 18. It could result from that after time 18 product sales begin, company gets profit and related to profit there could be cost overruns.

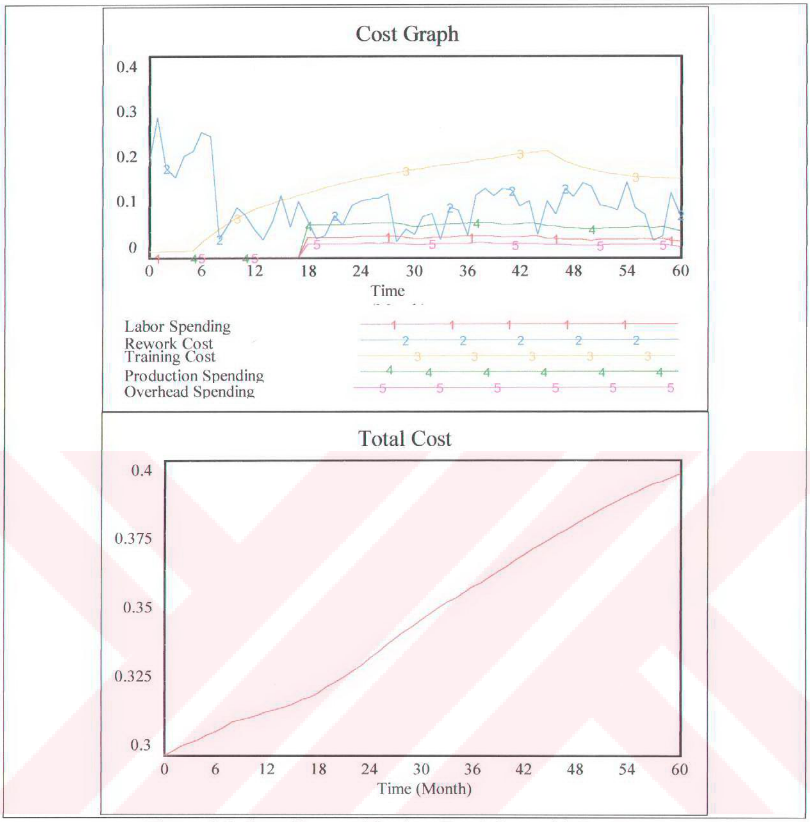


Figure 5.9. Spendings and Project Total Cost with Base Run

5.1.5. Other Variables in the Model

There are auxiliary variables in the model. Some of them are discussed in this section. Figure 5.10 shows Fatigue in Project Staff and Productivity. Fatigue rate has an average value 0.2 till time 24. Then the effect of Profit reflects to Management and Staff Commitment, which leads to a decrease in Fatigue. As for Productivity, in the initial time of the project productivity rate decreases. Decreasing Management and Staff Commitments are the major factor causing this situation. After time 18 there is an increase in Productivity until the due time.

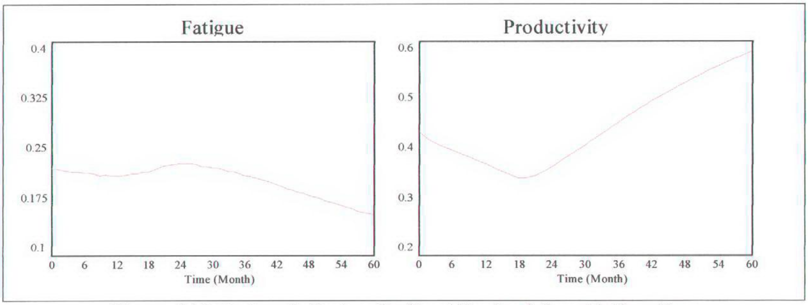


Figure 5.10. Fatigue in Project Staff and Productivity with Base Run

At start there is an initial Customer Satisfaction rate with 0.6. Customer Satisfaction increases with an S-Shaped Growth till time 36. Then it starts to decrease. Obsolescence in technology could trigger this decrease. Until time 18 the firm cannot widen its Market Share because it is assumed that new services and products are put on the market 18 months later. After time 18 there is an increase in Market Share. This increase lasts decreasingly till time 48. Then there occurs a decrease, there is no growth any more. Figure 5.11. shows Customer Satisfaction and Market Share behaviors.

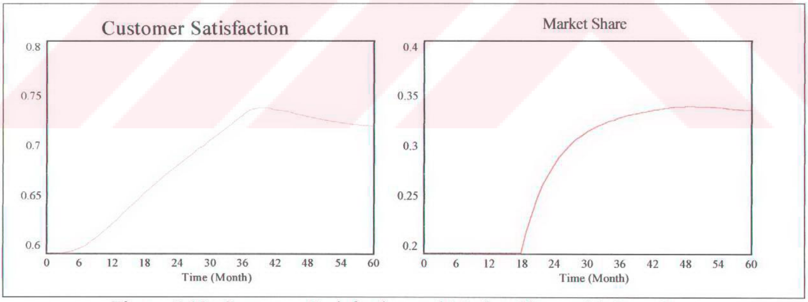


Figure 5.11. Customer Satisfaction and Market Share with Base Run

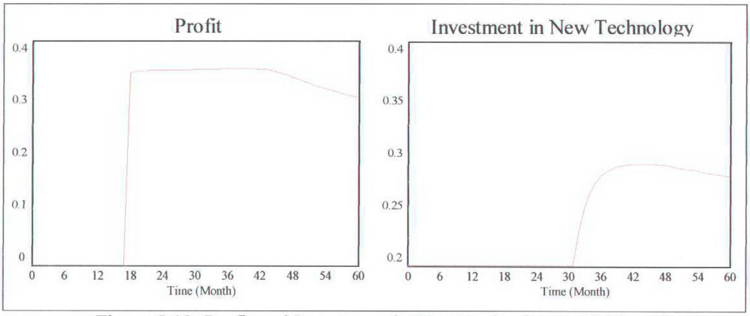


Figure 5.12. Profit and Investment in New Technology with Base Run

From the Figure 5.12. it is observed that until time 18 there is no new profit resulting from the Product Sale Time. Between times 18 and 42 there is a flat behavior. After time 42 Profit decreases related to Active Customers. It is assumed that Investment should be in New Technology at least 0.2 whatever condition is. From the Investment graph it is observed that there is no increase till time 30. Investment is assumed to be related to Profit but there is another factor affecting it conversely. This factor is Economic Risk. In the base Run of the model it was assumed that if Economic Risk is grosser than 0.4 there will be no increase in Investment. After time 30 Investment starts to increase till time 42.

The behaviors of Macroeconomic Stability and Value of TL show random distribution. Because in the model it is assumed that there is volatility in economy and its effect reflects to Macro economic stability and Value of TL. Figure 5.13. shows the random behaviors of Macroeconomic stability and Value of TL.

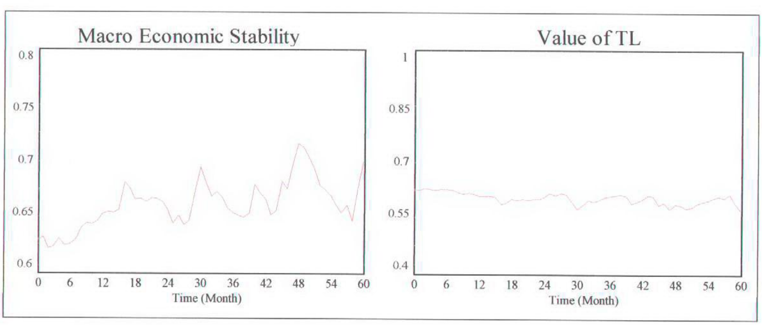


Figure 5.13. Macroeconomic Stability and Value of TL with Base Run

5.2.Alternative Model

In this section, we aim to design an alternative model. The departure point for the design of the alternative model is the decision for the Hiring New Staff. In the base model it was assumed that the risk of engineering and design change doesn't entail new staff hiring. However, in the alternative model against to the probability of engineering and design change a measure is assumed to be taken called Hiring New Staff Rate.

5.2.1. Alternative Model Assumptions

At first look the measure Hiring New Staff Rate could be seen as a good response for the risk of engineering and design change. Taking this measure project management teams could be able to take some advantages. For example the work to be done would be increased. Beside these advantages there would be some disadvantages. Additional staff hiring can lead to an increase in Technical Skilled Staff Gap, which entails more training. If training rate increases Training Cost increases proportionally causing an increase in Project Total Cost. This cost overrun would later increase Economic Risk level.

New staff would create poor relationship decreasing Staff Commitment. A decrease in Staff Commitment leads to a decrease in Management Commitment related to increase in Safety Incidents. Decrease in Staff and Management Commitment bring about a decrease in Productivity, which accelerates the decrease in Commitments of staff and management.

When there is poor commitment to project there will be an increase in Social Risk level. Quality is affected by this poor commitment, too. Because decrease in Staff and Management Commitment leads to a decrease in Process Improvement Ratio which causes a decrease in Quality. When there is a poor Quality there will be a decrease in Customer Satisfaction leading to a decrease in Active Customers, which decreases Market Share. If Market Share decreases Revenue and related to Revenue Profit will decrease which leads to a decrease in Investment in New Technology. Quality is also affected by this situation because decrease in Investment in New Technology causes a decrease in Newly Adopted Technology leading to a decrease in Diffused ICT, which is an impact on Quality.

System Thinking helps us mapping these assumptions. We are able to see all dynamics as a whole in the model. By simulating this model project management can see how the measure Hiring New Staff Rate affects project risks levels as seen from the Figure 5.14. To realize the differences additional variables and their relations are shown in red color.

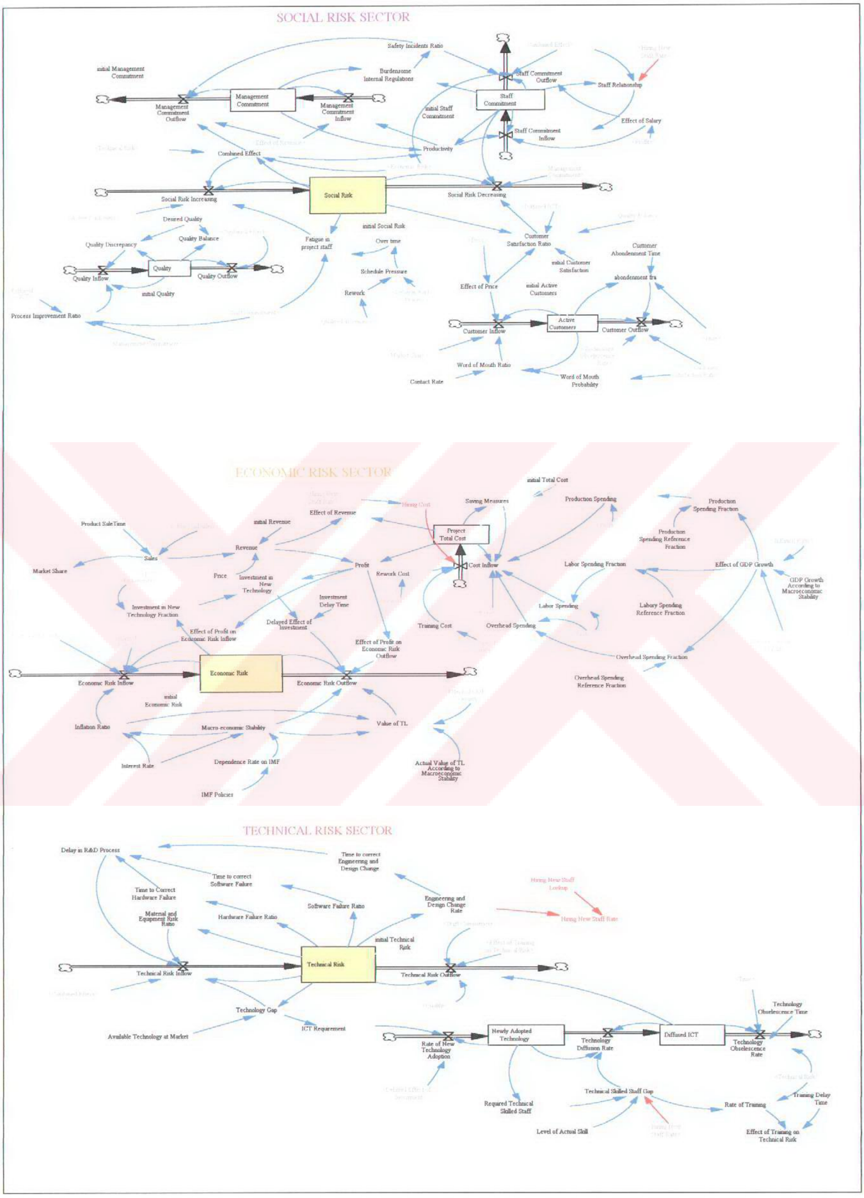


Figure 5.14. Alternative Model

5.2.2. Alternative Model Simulation Results

If Project Management team decides to hire additional staff for ongoing project there occurs an increase in Social Risk level. This increase goes on increasingly especially after the half time of the project. As seen from the Figure 5.15. at the end of the project there is approximately 10 % difference between two models.

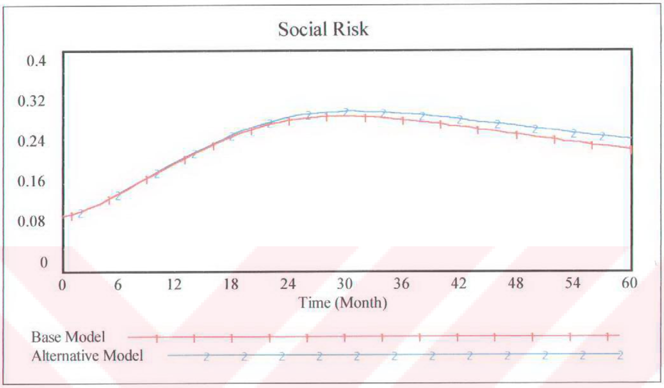


Figure 5.15. Social Risk with Alternative Model

The same trend in Social Risk is realized in Economic Risk level. Because of the increase in Project Total Cost resulting from Hiring Cost and the increase in Training Cost, Economic Risk level shows an increase in the Alternative Model. Figure 5.16 shows this behavior in Economic Risk.

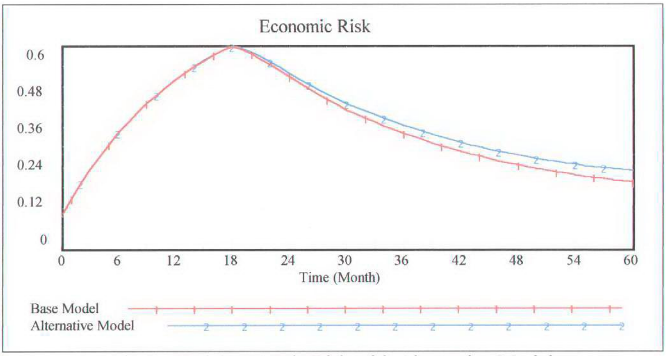


Figure 5.16. Economic Risk with Alternative Model

Figure 5.17. shows that the difference in Technical Risk level is not observed so much dramatically because the increasing Technical Skilled Staff Gap is compensated for by training. Therefore its effect on Technical Risk is not strongly felt. However, there is a small increase, which could be resulted, by the increase in Combined Effect.

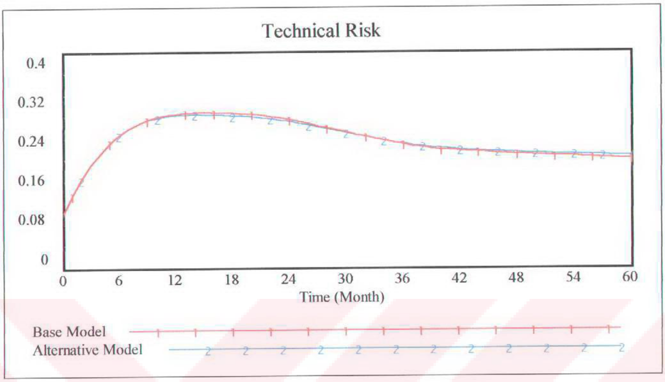


Figure 5.17. Technical Risk with Alternative Model

If there are new personnel in project team there could be communication problems between. These problems could damage relationships among people. Figure 5.18. shows that how the Staff Relationship is affected by this situation. There is approximately a 30 % difference between two models from point of the view of Staff Relationship. In the Alternative model it is obvious that when new staff are introduced to an ongoing project, there would occur a weakness in relationship among project personnel.

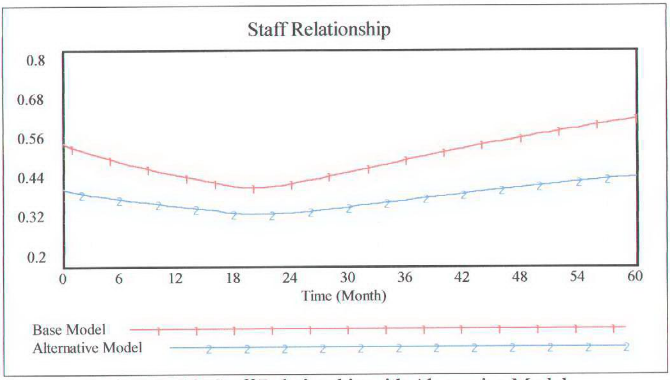


Figure 5.18. Staff Relationship with Alternative Model

Naturally, poor Staff Relationship affects Staff Commitment leading to a decrease. From the Figure 5.19. it is observed that additional staff hiring causes a decrease in Staff Commitment.

Figure 5.19. Staff Commitment with Alternative Model

Related to decrease in Staff Commitment a small decrease in Management Commitment is realized as seen from the Figure 5.20.

Figure 5.20. Management Commitment with Alternative Model

If Staff and Management Commitment decrease, Productivity decreases, too. Figure 5.21. shows this assumption.

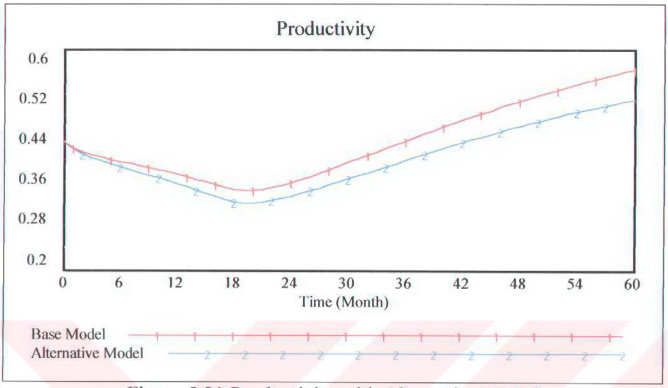


Figure 5.21 Productivity with Alternative Model

Although additional staff hiring leads to an increase in Technical skilled Staff Gap its effect on Quality is not strongly felt. It results from that when Staff and Management Commitment decrease Process Improvement Ratio would be affected by this situation. Figure 5.22. shows this decreasing behavior of Quality.

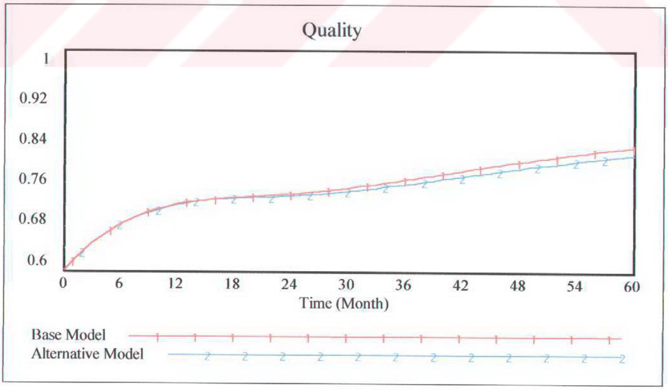


Figure 5.22. Quality with Alternative Model

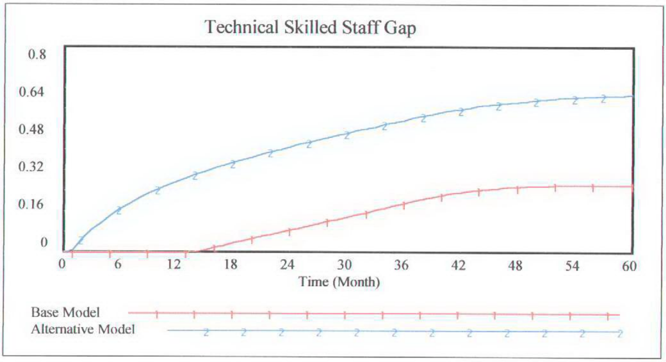


Figure 5.23. Technical Skilled Staff Gap with Alternative Model

In the base model until a determined time Level of Actual Skill is enough for the project. Thereafter the increase in Newly Adopted Technology entails more skill leading to an increase in Technical Skilled Staff Gap. As for Alternative Model it is obvious that if additional new personnel are hired, their technical capacity could be not enough for the project works which leads to an increase in Technical Skilled Staff Gap as seen from the Figure 5.23.

In both Base and Alternative model it is assumed that when there occurs a gap in technical skill it would be compensated for by training. Figure 5.24. shows that because there is an increase in Technical Skilled Staff Gap when new personnel are hired, Rate of Training increases, too.

Figure 5.24. Rate of Training with Alternative Model

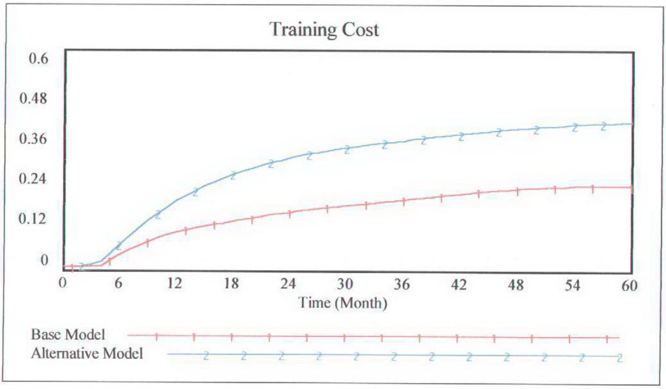


Figure 5.25. Training Cost with Alternative Model

The increase in Rate of Training leads to an increase in Training Cost. Figure 5.25. shows this increase obviously.

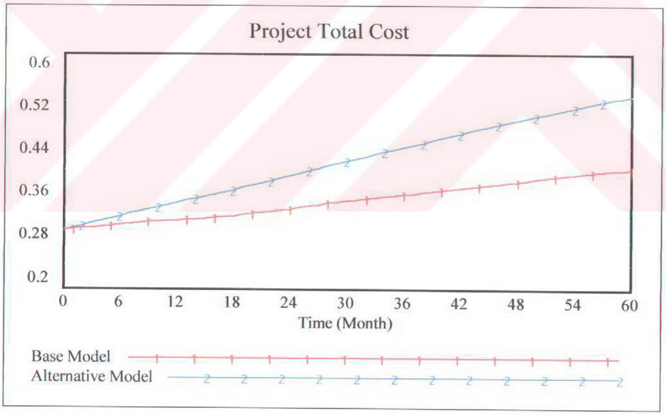


Figure 5.26. Project Total Cost with Alternative Model

Figure 5.26. shortly explains that if Training Cost increases Project Total Cost increases simultaneously, which would later lead to an increase in Economic Risk. Not only is resulted the increase in Project Total Cost from Training Cost also Hiring Cost contributes to this increase.

6. CONCLUSION

Risk is inevitable in all projects and has various interrelated types. The most important characteristic of the risks is their dynamic structure, which brings them continuity at every phase of the project. Risk threat never disappears during the project, and as a result its impact is felt at each step and each phase. In order to be well responded, risk must be well defined, well assessed, and well analyzed. Traditional methods are not sufficient in mitigation of the dynamic structure of risk. At that point, the use of SD Modeling is needed.

The aim of the study was to present how SD Modeling Method could be used as a learning tool in Project Risk Management. We classified the risk sectors under five headings.

1. Social Risk
2. Economic Risk
3. Technical Risk
4. Political Risk
5. Ecological Risk

In our model Political Risk and Ecological Risk were excluded, since it was assumed that those two risk factors behave out of control and information of project management. Maybe in later studies they could be included in the model. In our model, we tried to concentrate on the three other risk sectors.

The use of NUMBER (Normalized Unit Model by Elementary Relationship) was another challenge in our model. NUMBER enabled us to limit the values of risk or other variables between 0 and 1. We used NUMBER due to the fact that we didn't have real quantitative data and our model was assumed to be a learning tool. By using NUMBER approach, we could simulate without introducing our own assumptions. We were able to attribute wrong assumptions, if any, to the simulation and thus we were more neutral and critical to the assumption. In this way, we have maintained our honesty in simulating the unsimulable mental maps.

It was necessary to define the model boundary diagram to determine which risk had an impact on which risk, which sub-risk factors increased or decreased main risk sectors and how the variables in the model increased or decreased main risk sectors. In our model, it was assumed that not only were the variables resulting from company's internal issues, but also external factors took place in feedback loops. For example customer factor was an important effect. There could be a dilemma whether customer sector should be included. In our model, we assumed that customer factor should be considered as a variable affecting main risk factors, especially Social Risk. After product sale time there occurs an important feedback in the model.

When product attracts the attention of potential customers, the rate of customer level will begin to increase. It indicates another factor called customer satisfaction because of the fact that customers would be well satisfied with the product and their word of mouth would increase which brings more new customers. More customers indicate more problems and complaints about products, which have an impact on the increase of Social Risk.

Macroeconomic stability, value of TL, inflation and interest rate were included in our model. It was assumed that they were not a reciprocal relation with main risk factors, but they had important effects on them. For example, in our model interest rate was assumed to be %20 and its effects on Economic Risk were observed. If the interest rate were %100 what would happen? When we assumed its value as %100 and than simulated the model we would observe that Economic Risk gets a high value.

Although macroeconomic stability, value of TL, inflation and interest rate do have impact on the Economic Risk of a specific firm, Economic Risk of that particular firm does not have any impact on any of these parameters because these parameters cover the whole economic situation of the country, and even though macroeconomic stability was assumed to be en exogenous variable and didn't behave in a feedback loop with main risk factors, in future studies it can be used in a feedback loop. For example, if it is assumed that there are 1000 projects in the country and all are simulated with SD model, economic risks of projects will have an impact on macroeconomic stability.

In the base model it can be observed that the most important risk sector is Economic Risk. During the project's initial times a lot of uncertainties and delay of money turn to the firm increase the economic risk at higher values. In month 18, it is at its highest value with 0.6. After this time, it begins to decrease because the product begins to be sold and firm makes profit, and eventually, profit causes a decrease in economic risk.

The highest values of social risk and technical risk were about 0.3, which could be interpreted as low. They did not increase as sharp as economic risk because we assumed that the psychological and technical situations of project personnel were at higher levels at the beginning, and some measures were taken against these negativities increasing those risk sectors. For example, if there is a gap among technical staff, the rate of training increases.

An interesting event in our model was that the main risk factors never reached zero. During the project time there were always risks with a value. At the end of the project the risk values were about 0.2. In future studies researchers will seek for the ways to decrease the risk levels to their minimum values.

In our base model, we assumed that there was no need hiring additional staff for responding to engineering and design changes. In alternative model, a new scenario was created. The risk of engineering and design changes would be responded with additional new staff hiring, but there are many disadvantages of hiring near its advantages. For example, number of communication channels will increase as new people are added, and as a result formal and informal relationship among the staff will lessen, there will be more unskilled personnel who are required to be trained, people who has been working must spend time educating newcomers, thereby reducing the amount of time spent on productive development effort etc. After the determination of those boundaries, we defined their equations. At the end of the definitions, we simulated the model and observed that all main risk factors are increased if new staff is introduced to the ongoing project.

Hiring New Staff leaded to approximately 10 % difference between two models from the point of the view of Social Risk. In the base model the starting point of Economic Risk level was 0.1. During the project it reached its highest level with the value of 0.2816 in month 30, then its final value was 0.2203. Although the starting point of Economic Risk level in the alternative model was the same in the base model, in the middle of the project time its value was about 0.29 and 0.2384 in the end of the project.

Increase in Economic Risk level is grosser than the increase in Social Risk. While the value of Economic Risk was 0.2 in the end of the project, at the same time it was about 0.23, which was grosser about 15 %. The difference in Technical Risk level is not observed so much dramatically because the increasing Technical Skilled Staff Gap is compensated for by training. Therefore its effect on Technical Risk is not strongly felt. However, there is a small increase in Technical Risk, which could be resulted, by the increase in Combined Effect.

After comparing the two models we observed that new staff hiring brought about a lot of disadvantages and increased all main risk sectors. Many other variables can be added in the model and their impacts on main risk sectors or risks relations can be observed without spending money and time.

SD modeling provides project management with the opportunity of observing the risk behaviors and effects of variables on main risk factors as a whole. For instance, when we consider staff relationship, how can staff relationship have a role in increasing company profit? The answer is kept in the model simulation. If staff relationship is at a high level, the commitment of staff will increase because of the good relationship results in strong job satisfaction. Furthermore, if the optimum number of communication channels, which is directly related to the number of staff, is provided it will ease staff's job in terms of informal communication and relationship. Increasing commitment results in better productivity and quality that will cause increase in customer satisfaction, which in turn brings more active customers. As the number of customers increases, sales will also present an increasing trend, which will mean more profit for the firm. Project manager is able to observe all those sequences of events and results with SD model.

One of the most important characteristics of the study is that it may be the first in its field. By now, numbers of studies about project risk management are realized, but there is no pattern of the use of SD modeling in identifying, analyzing, responding and observing the risks in projects. We don't challenge that our model is correct because the most important reality in our study is that all models are wrong. Our aim was to define the model boundary and determine feedback loops with logical assumptions.

In our study, we did have some difficulties. The most important difficulty was that we did not have a pattern study about the use of SD model in project risk management. When creating the feedback loops we should have used real data especially main risk values.

To obtain valid results, real data should be used in the model. We suggested our model as a learning tool. We sought to establish the framework of risk management in projects with SD modeling. We claim that if our model is simulated after obtaining real data, there could be valid simulation results guiding project managers in their decisions. They would be able to see the project risk behaviors and feedbacks among them with time and they could easily decide whether to respond or not. It could also be understood that how would the results be after responding the risks.

In our model, some variables were assumed to be excluded and not used in feedback loops. Project managers may face many of these risk factors in their projects. In future studies, these risk factors could be used in model and their feedback loops could be determined.

Two main risk sectors Political Risk and Economic Risk were not included in our model. The reason for this situation was that we sought to concentrate on the risk sectors, which project managers were able to control. In future studies, other two main risk sectors could be included in the model and their relationships could be determined.

As we stated, this study is the first in Turkey, and will be a guide for further comprehensive studies. Using SD modeling method, project managers would be able to easily define, analyze, mitigate, respond and control the project risks. They will be able to make concrete and valid information estimation in their decision-making processes.

Although project management process does seem like a civil or economical concept, it absolutely associates with the military applications as well. The main aim of our model is to provide decision maker with proper risk information to minimize, monitor, and control the probable uncertainties in any project. Decision-making process is much more critical in military applications because the irrecoverable results of unidentified risks. Required decisions may range from a tiny project to a strategic project, which may impact the whole country. In military applications, there would always be a project leader who named as commander instead of project manager. Risks must also be well defined, well analyzed, and properly responded and controlled in military applications.

Using SD modeling method, the dynamic structure of risks will be well comprehended and investigated with the help of system thinking approach. Computer simulations will enable decision makers to overcome many of the limitations of mental models. The SD modeling approach will help decision makers apprehend the risk dynamics in projects as a whole, and this will ease their job in terms of identifying, assessing and mitigating the risks.

APPENDIX-A: BRIEF ACCOUNT OF SYSTEM DYNAMIC MODELING

A.1. System Thinking

"*System thinking is a mindset for understanding how things work. It is a perspective for going beyond events, to looking for patterns of behavior, to seeking underlying systemic interrelationships which are responsible for the patterns of behavior and the events.*" (Bellinger, 1998)

According to Aronson (1996), the approach of systems thinking is fundamentally different from that of traditional forms of analysis. Traditional analysis focuses on the separating the individual pieces of what is being studied; in fact, the word "analysis" actually comes from the root meaning "to break into constituent parts." System thinking focuses on how the thing being studied interacts with the other constituents of the system of which it is a part. This means that instead of isolating smaller parts of the system being studied, system thinking works by expanding its view to take into account larger numbers of interactions as an issue is being studied. This results in sometimes different conclusions than those generated by traditional forms of analysis, especially when what is being studied is dynamically complex or has a great deal of feedback from other sources.

According to Richmond (2001), system thinking offers "filtering thinking" skills. He also focuses on "10.000. meter thinking" and "causal loop thinking." Figure A.1. shows how the reality can be perceived thanks to system thinking approach.

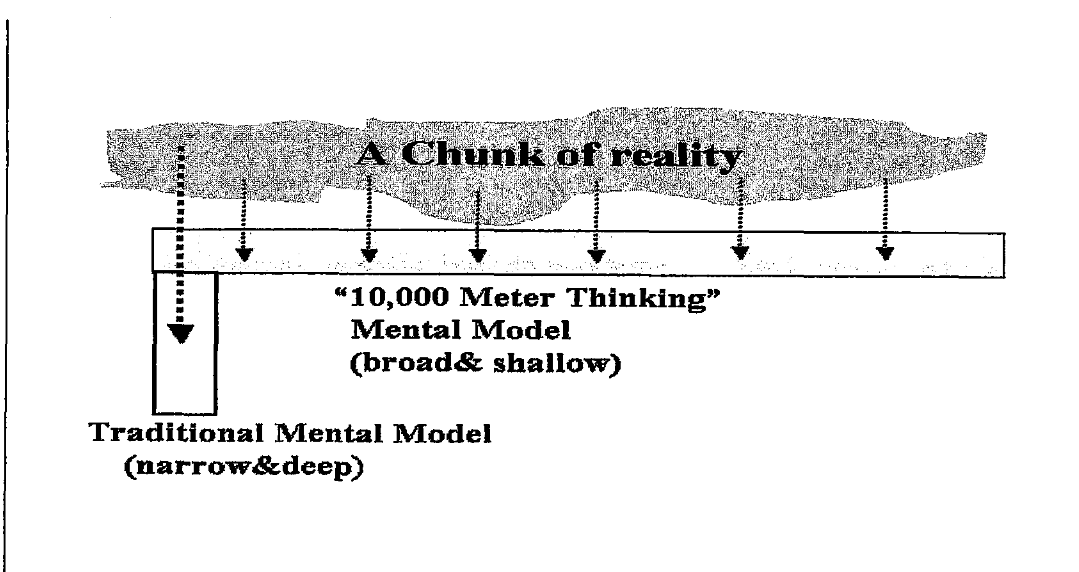


Figure A.1. The Content in a Traditional, versus a "10,000 Meter Thinking," Mental Model. (Richmond 2001)Systems thinking is a conceptual framework for problem solving that considers problems in their entirety. Problem-solving in this way involves pattern finding to enhance understanding of, and responsiveness to, the problem. Outcomes from systems thinking depend heavily on how a system is defined because systems thinking examines relationships between the various parts of the system. Rubenstein-Montano et al. (2001) state "*systems thinking is championed on the premise that there are emergent properties of systems that do not exist when systems are decoupled into smaller parts.*"

A.1.1. Thinking in Models

According to Glasersfeld (1995) thinking in models is inevitable. He emphasizes that we can only think according to our pictures and views of the world, which are necessarily models of the world itself. Systems thinking requires the consciousness of the fact that we deal with models of our reality and not with the reality itself.

System thinking requires the consciousness of the fact that we deal with models of our reality and not with the reality itself. Thinking in models also comprehends the ability of model building. Models have to be constructed, validated and developed further. The possibilities of model building and model analysis depend to a large degree on the tools available for describing the models. To choose an appropriate form of representation (e.g. causal loop diagram, stock-and-flow diagram, equations) is a crucial point of systems thinking.

The causal loop diagram allows qualitative modeling; the stock-and-flow diagram already gives key hints about the structure of the quantitative simulation model.

A.1.2. Closed Loop Thinking

If-then relations are basic building blocks of our mind and our understanding of things. A foundation of this kind of thinking is a strict distinction between cause and effect. In order to explain a phenomenon we have to find its (probably single) "cause". It is supposed that this cause does exist and that the effect always can be observed whenever the cause is valid. (Figure A.2.) Words and phrases like "because", "therefore", "if – then" denote such thinking concepts in everyday language. The mathematical analogon is the function-concept with one independent variable (="cause") and one dependent variable (="effect"). Accordingly the thinking in simple cause-effect relationships might be called functional or linear thinking - in contrast to closed loop thinking.

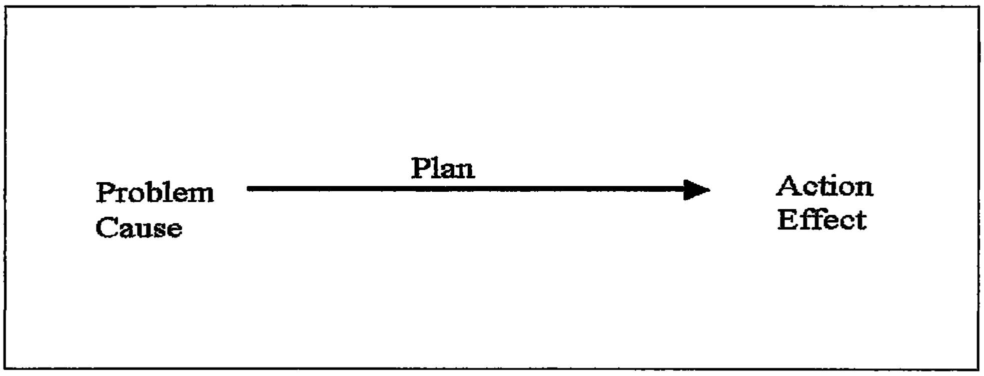


Figure A.2. Linear Thinking

System thinking marks an important shift from the more linear thinking to a new way of thinking which emphasis circular chains of cause and effect. (See Figure 2.3.) A proper understanding of feedback loops requires a dynamic perspective, in order to see how things emerge over time. In interrelated systems there are not only direct, but also indirect effects. This may lead to feedback loops. Feedback loops might be reinforcing (*positive*) or balancing (*negative*), in order to see how things emerge over time.

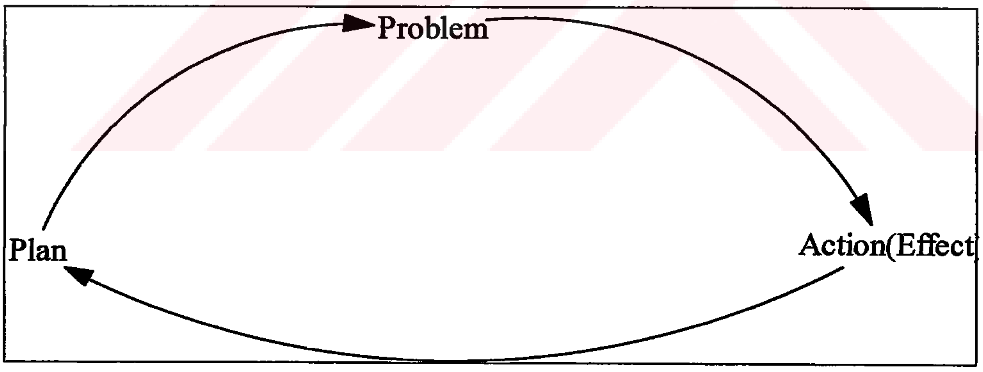


Figure A.3. Interrelated (non-linear) thinking

Interrelated thinking is a kind of thinking which takes into account indirect effects, networks of causes and effects, feedback loops and the development of such structures over time. Interrelated thinking also requires adequate representations: the causal loop diagram is the simplest and most versatile tool for denoting interrelated issues.

A.1.3. Dynamic Thinking

Systems have a certain behavior over time. Time delays and oscillations are typical features of systems, which cannot be observed without the time dimension. Even the simple task of keeping the temperature constant in a (simulated) cooling house is for many subjects a difficult task, because changes in the temperature would require some time before they became effective (Dörner 1989). Considering only the present state of the temperature as a guideline for adjustment might lead to serious overreaction, which might take even a rather inert system like a refrigerated warehouse out of control. Dynamic thinking also means foreseeing (possible) future developments. A mere retrospective view of past developments is insufficient for the practical steering of systems - or would you trust a car driver who makes exclusive use of the rear mirror in order to determine where to steer the car? Often simulation models are helpful or even necessary in order to foresee future developments - especially when reality emerges rather slowly.

A.1.4. Steering System

This brings the fourth core aspect of systems thinking: the practical steering of systems. System thinking also always has a pragmatic component: it deals not just with contemplating the system; it also is interested in system-oriented action. One of the most fundamental and most important questions of practical systems management is: *Which of the systems components are subject to direct change?* In a social system it is often impossible to change the behavior of others directly, one can only change one's own behavior. In an economic system the producer usually has no direct control over the market. Marketing activities are usually actions on the supply side in order to induce the desired reaction on the demand side.

A.2. System Dynamics

System Dynamics was developed during the 1950ies by Jay W. Forrester at MIT. Originally developed to solve complex management problems within industry, it turned out to be a general method that could be applied in many areas, from industrial management problems to global environmental problems, urban planning, energy planning etc.

Wolstenholme (1990), states, "*System Dynamics is concerned with creating models or representations of real world systems of all kinds and studying their dynamics. In particular, it is concerned with improving problematic system behavior.*" The purpose in applying System Dynamics is to facilitate understanding of the relationship between the behavior of the system over time and its underlying structure and strategies/policies/ decision rules.

Forrester (1999) emphasizes that System dynamics is a professional field dealing with the complexity of systems. System dynamics is the necessary foundation underlying effective thinking about systems. System dynamics deals with how things change through time, which covers most of what most people find important. He also states "*System dynamics involves interpreting real life systems into computer simulation models that allow one to see how the structure and decision making policies in a system create its behavior*."

A.2.1. Origins and Fundamental Notions of System Dynamics

System Dynamics is a policy modeling methodology based on the foundations of decision making, feedback mechanism analysis, and simulation. Decision making focuses on how actions are to be taken by decision-makers. Feedback deals with the way information generated provides insights into decision-making and effects decision-making in similar cases in the future. Simulation provides decision-makers with a tool to work in a virtual environment where they can view and analyze the effects of their decisions in the future, unlike in a real social system.

Monga (2001) states that a stark feature of modern times is continuous change. Changes in existing elements often encounter resistance from people themselves. The problems are often too complex and dynamic in nature, i.e., there are many factors and forces in play that we do not comprehend easily. Also, these factors and forces themselves are very dynamic in nature. System thinking is advocated by many "thinkers" who advocate holistic thinking and the conceptualization of "systems" wherein "everything is connected to everything else". Systems Dynamics is an approach whose main purpose is to understand and model complex and dynamic systems. It employs concepts of nonlinear dynamics and feedback control, concepts.

A.2.2. SD Behaviors

The feedback structure of a system generates its behavior. Sterman (2000) suggests six fundamental modes of behavior of dynamics observed in systems:

1. exponential growth,
2. goal seeking,
3. oscillation
4. S-shaped growth
5. S-shaped growth with overshoot
6. Overshoot and collapse

These modes of behavior are shown in Figure2.4.

A.2.2.1. Exponential Growth

Exponential Growth arises from positive or self-reinforcing feedback. The greater a quantity is, the greater is its net change (increase/decrease), and this is the feedback to the process that further augments the net change. Thus this is a self-reinforcing feedback and there is an exponential growth/decline.

A.2.2.2. Goal seeking behavior

Goal seeking behavior arises from negative or self-controlling feedback. Negative feedback loops tend to oppose any changes or deviations in the state of the system; they tend to restore equilibrium and hence are goal seeking. The rate of change diminishes as the goal is approached, such that there is a smooth attainment of the goal/equilibrium state of the system.

A.2.2.3. Oscillation

Oscillation *arises* due to negative feedback with significant time delays. Corrective action to restore an equilibrium state or to achieve the goal of the system continues even after the equilibrium has been reached due to time delays in identifying the effects of the actions on the system. Thus the goal is overshot. Corrective action taken again (negative feedback loop) leads to undershooting and hence oscillation. The principle that behavior is a result of the structure of the system enables a discovery of the system structure (its feedback loops, non-linear interactions) by observing the behavior of the system. Therefore, when the pattern of behavior is observed, conclusions can be drawn about the dominant feedback mechanisms acting in the system. Nonlinear interactions among the three major feedback structures give rise to other complex patterns of behavior of the systems (Sterman, 2000).

A.2.2.4. S-shaped growth

S-shaped growth arises when there is a positive feedback initially, and later negative feedback dominates, leading to attainment of equilibrium by the system.

A.2.2.5. S-shaped growth with overshoot

S-shaped growth with overshoot occurs when, after an initial exponential growth phase, negative feedback with time delays kicks in. In this case, the system oscillates around the equilibrium state.

A.2.2.6. Overshoot and collapse

Overshoot and collapse occurs as a result of the equilibrium state itself declining after the exponential growth phase has commenced, and negative feedback is triggered. Since the equilibrium declines, a second negative feedback gets activated, wherein the system approaches the new equilibrium state.

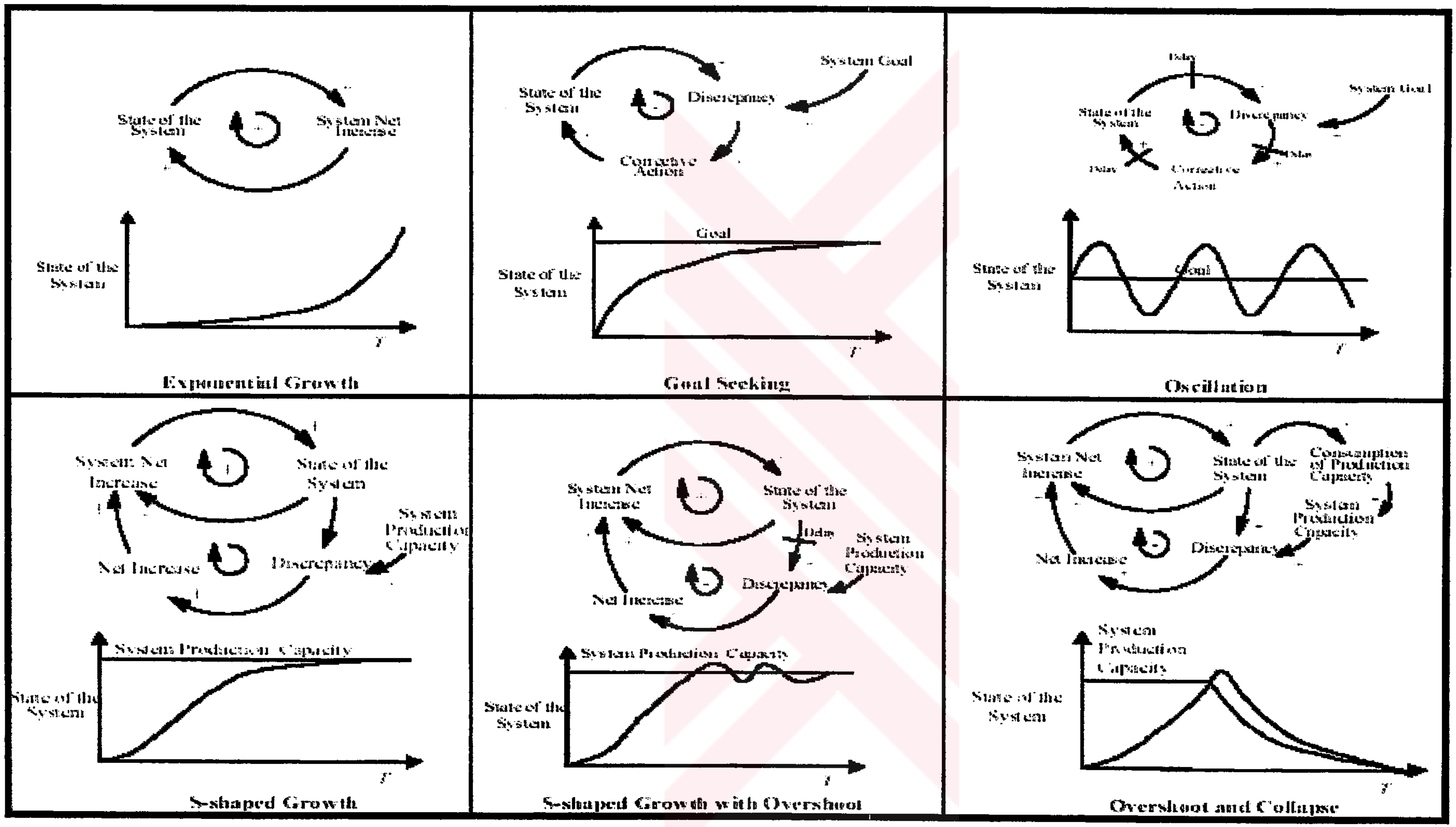


Figure A.4. System Dynamics Structures and their Behavior (Sterman, 2000)

A.2.3. Causal Loop Diagrams

Kirkwood (1998) states that causal loop diagram is the graphical notation for representing a system structure. It shows the relation among the elements of a system. This diagram presents relationships that are difficult to verbally describe because normal language presents linear cause and effect chains, while the diagram shows that in the actual system there are circular chains of cause and effect.

The feedback structure of complex systems is qualitatively mapped using causal diagrams. A Causal Loop Diagram (CLD) consists of variables connected by causal links, shown by arrows. Each link has a polarity. A positive (denoted by "+" on the arrow) link implies that if the cause increases (decreases), the effect increases (decreases) *above (below) what it would otherwise have been.* A negative (denoted by "-" on the arrow) link implies that if the cause increases (decreases), the effect decreases (increases) *below (above) what it would otherwise have been* (Sterman, 2000).

In the example in Figure A.5. an increase in the fractional birth rate means the birth rate will increase above what it would have been and a decrease in the fractional birth rate means the birth rate will fall below what it would have been. That is, if average fertility rises, the birth rate, given the population, will rise, if fertility falls, the number of births will fall (Positive link). On the other hand, an increase in the average lifetime of the population means the death rate will fall below what it would have been and a decrease in the average lifetime means the death rate will rise above what it would have been. That is, if life expectancy increases, the number of deaths will fall and if life expectancy falls, the death rate will rise (negative link).

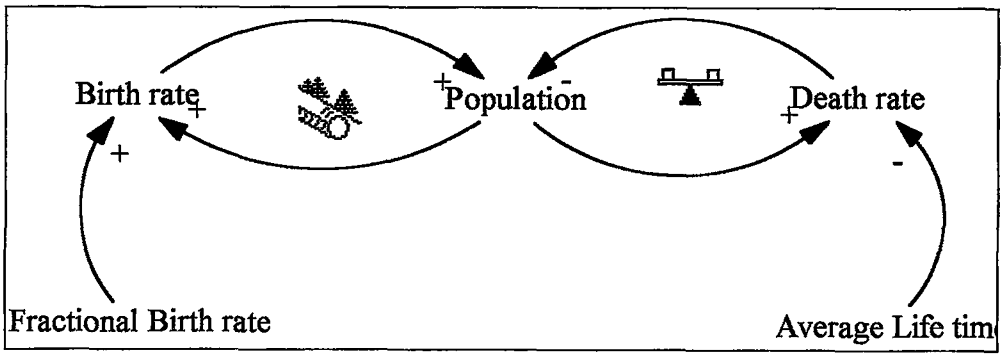


Figure A.5 Causal Loop diagram notation

Causal loops are immensely helpful in eliciting and capturing the mental models of the decision-makers in a qualitative fashion. Interviews and conversations with people who are a part of the system are important sources of quantitative as well as qualitative data required in modeling. Views and information from people involved at different levels of the system are elicited, and from these, the modeler is able to form a causal structure of the system.

A.2.4. Stocks and Flows

Causal loops are used effectively at the start of a modeling project to capture mental models. However, one of the most important limitations of the causal diagrams is their inability to capture the stock and flow structure of systems. Stocks and flows, along with feedback, are the two central concepts of dynamic systems theory. Stocks are accumulations as a result of a difference in input and output flow rates to a process/component in a system. Sterman (2000) states, "*stocks give the systems inertia and memory, based on which decisions and actions are taken. Stocks also create delays in a system and generate disequilibria.*"

All stock and flow structures are composed of stocks (represented by rectangles), inflows (represented by arrows pointing into the stock), outflows (represented by arrows pointing out from the stock), valves, and sources and sinks for flows (represented by clouds). (see Figure A.6.)

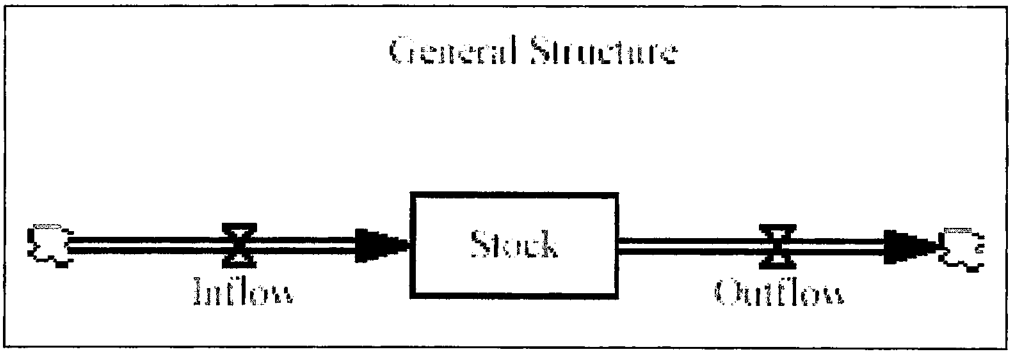


Figure A.6.General Structure of a Stock and Flow

A.2.4.1. Mathematical Representation of Stocks and Flows

Stock (t) = Stock (t_0) + [Inflow(t) – Outflow (t)] dt (Monga 2001)

Stocks are the state variables or integrals in the system. They accumulate (integrate) their inflows less their outflows. Flows are all those which are rates or derivatives. If a snapshot of a system was taken at any instant of time, what would be seen is the state of different processes or components of the system. These are the stocks in the systems. The inflows and outflows are what have been frozen and so cannot be identified. Stock and flow networks undoubtedly follow the laws of conservation of material. The contents of the stock and flow networks are conserved in the sense that items entering a stock remain there until they flow out.

A.2.4.2. Auxiliary variables

Auxiliary variables are often introduced in stock and flow structures to provide a better understanding. Auxiliary variables are neither stocks nor flows; they are functions of stocks and exogenous inputs. They are variables used for computational convenience. According to Monga (2001) the contribution of Stocks to Dynamics is multifold:

1. Stocks denote the state of a particular element in the system, and based on this information, decisions can be made or actions can be taken.
2. They provide the system with inertia and memory.
3. They induce delays in the system. A stock or accumulation occurs when the output lags the input to a process, and whenever this happens, delays occur.
4. Stocks decouple inflow from outflow. Inflows and outflows are controlled or decided upon by different people/resources in the system

A.2.5. Princible for successful use of System Dynamics

According to Sterman (2000) there are a number of principles for effective development and implementation of system dynamics models.

b) Develop a model to solve a particular problem, not to model the system

c) Modeling should be integrated into a project from the beginning

d) Be skeptical about the value of modeling and force the "why do we need it" discussion at the start of the project.

e) System dynamics does not stand alone. Use other tools and methods as appropriate.

f) Modeling works best as an iterative process of joint inquiry.

g) Avoid black box modeling.

h) Validation is a continuous process of testing and building confidence in the model.

i) Get a preliminary model working as soon as possible. Add detail only as necessary.

j) A broad model boundary is more important than a great deal of detail.

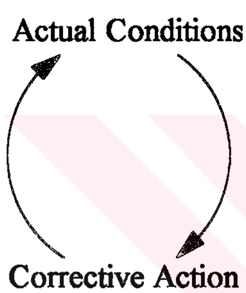
k) Use expert modelers, not voices.

l) Implementation does not end with a single project.

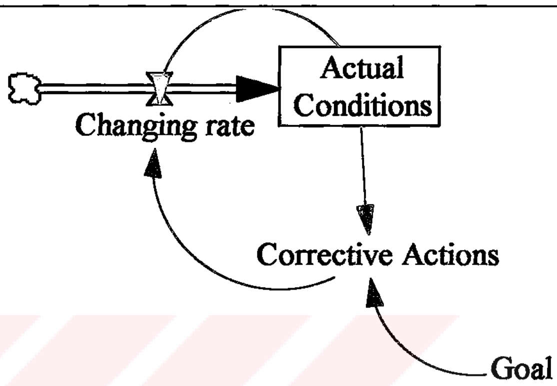
APPENDIX-B: APPLYING NUMBER TO CAUSAL MAPS INSYSTEM ARCHETYPE

B.1. Balancing-Process-with-Delay Archetype

FigureB.1. Shows the results of applying NUMBER to the archetype of "balancing process with delay".



Causal Map in the archetype



SD model converted with NUMBER

Equations:

Actual Condition= INTEG(+Changing Rate, 0.5)

Changing Rate= (1-Actual Condition)*DELAY1(Corrective Action, 5)

Corrective Action=Goal- Actual Action

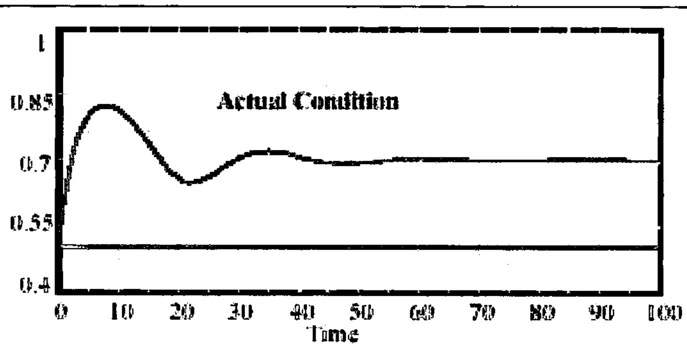
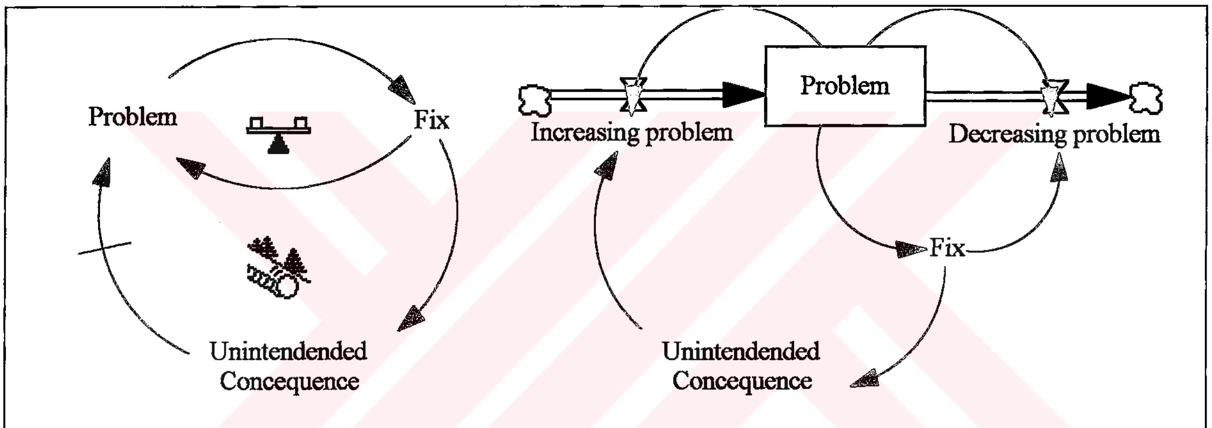


Figure B.1. Applying NUMBER to the archetype of balancing process with delay (Kim 2000)

While applying NUMBER to this archetype, "actual condition" is treated as level variable. Delay function can be used in the equation as with normal SD modeling. One can see that the concept of goal is necessary to produce any meaningful behavior. The 'Goal' variable must be included in the archetype to generate fluctuating behavior.

B.2. Fixes-that-Fail Archetype

Figure B.2. is the result of applying NUMBER to the archetype of "fixes that fail". In this archetype "problem" is represented as level variable. The two rate variables for increasing and decreasing problem is introduced automatically. SD model in Figure B.2. demonstrates that 'fix' and 'unintended consequence' are related to the rate variables. While 'fix' affects the rate variable of decreasing problem, 'unintended consequence' changes the value of "increasing problem" with some time delay. Time behavior of problem shows that the problem will reappear after a short-term reduction in the problem



Causal Map in the archetype

SD model converted with NUMBER

Equations:

Problem=INTEG(+increase problem-decrease problem, 0.5)
Decrease problem=Problem*fix
Fix=Problem*0.1
Increase problem=(1-Problem)*DELAY1(unintended consequence, 10, 0)
Unintended consequence=fix

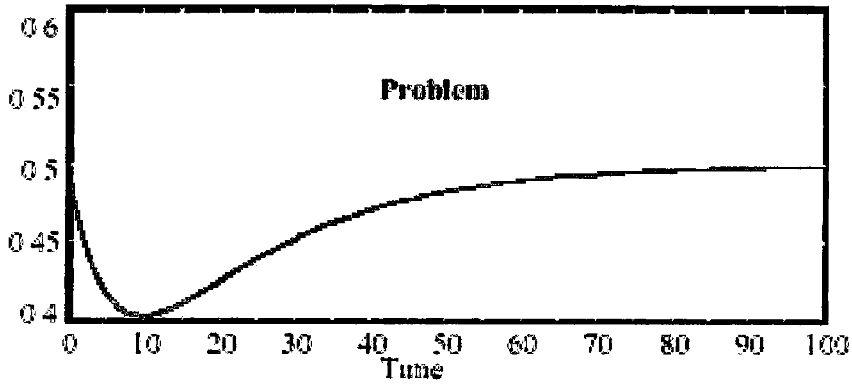
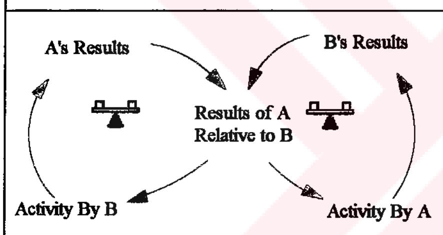
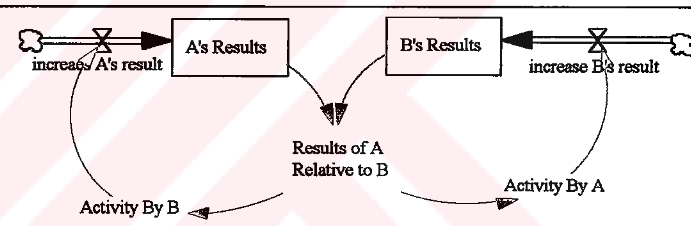


Figure B.2. Applying NUMBER to the archetype of fixes that fail.(Kim 2000)

In the time behavior of the Problem, one can find that the reduction of problem by introducing fix takes place rapidly, while its reappearance takes long time. This asymmetry in the time behavior of fix can provide a biasing impression that fix is efficient and the reappearance of the Problem is a natural phenomenon rather than a result of the fix itself. In this example, system behavior reinforces wrong belief in casual effectiveness. With this kind of biasing impression, one may become addicted to the measure of symptomatic fixes at every time when the problem reappears. In this way, system behavior of the archetype can provide additional insights into the fundamental problem of the archetype afflicting decision makers.

B.3. Escalation Archetype

Figure B.3. is the result of converting archetype of escalation into SD models by using NUMBER.

Causal map in the archetype	SD model converted with NUMBER
	

Equations

A's results=INTEG (increase A's result, 0.1)
Activity by A=IF THEN ELSE (Result of A Relative to B<0, 0.5, 0)
B's results=INTEG (increase B's result, 0.05)
Activity by B=IF THEN ELSE (Result of A Relative to B>0, 0.5, 0)
increase A's result=(1-A's results)*Activity by A*0.1
increase B's result=(1-B's results)*Activity by B*0.1
Result of A Relative To B=A's results- B's results

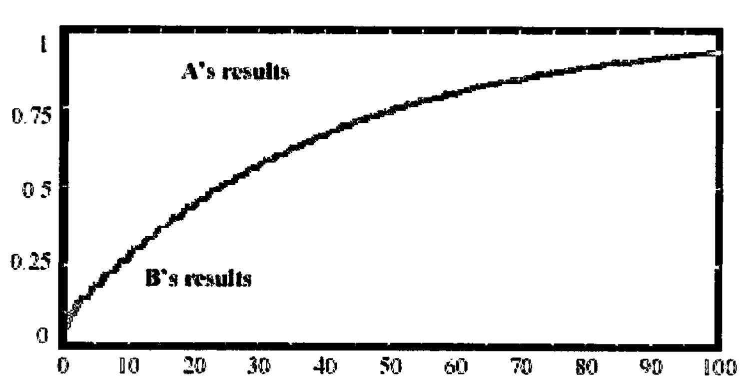
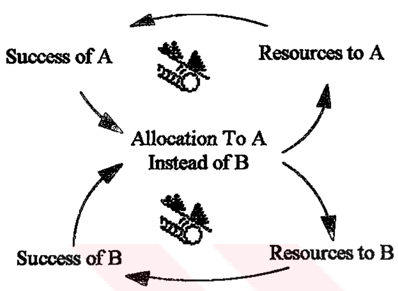
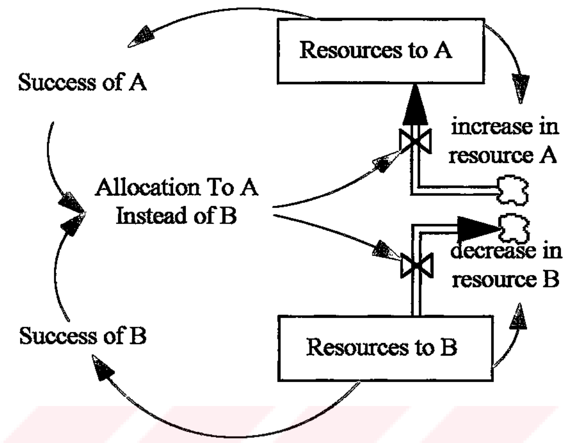


Figure B.3. Applying NUMBER to the archetype of escalation (Kim 2000)

B.4. Success to Successful Archetype

Figure B.4. is the result of converting archetype of success to the successful into SD models by using NUMBER.

Causal map in the archetype	SD model converted with NUMBER
	

Equations

Resources To A=INTEG (increase in resource A, 0.5)
Increase in resource A=(1-Resources To A)* Allocation To A Instead of B
Resources To B=Resources To B=INTEG(-decrease in resource B, 0.45)
Decrease in resource B=Resource To B* Allocation To A Instead of B
Allocation To A Instead of B=IF THEN ELSE (Success of A>Success of B, 0.05, -0.005)

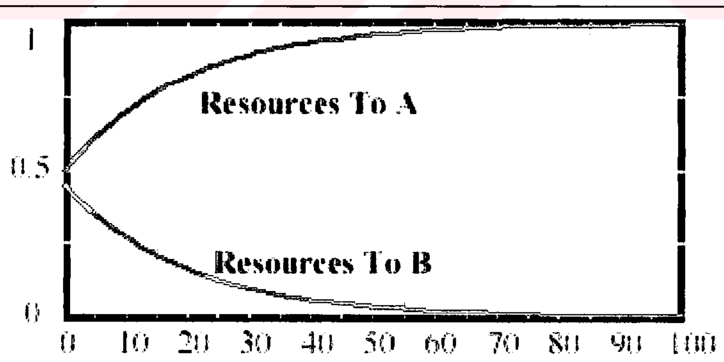


Figure B.4. Applying NUMBER to the archetype of success to the successful (Kim 2000)

The stock and flow diagram of Figure B.3. and Figure B.4. are as simple as their corresponding causal maps. Only the rate variables are added to the original causal maps. Even though these SD models are simple, they can produce time behavior of the level variables. Time behavior in Figure B.3. and Figure B.4. show escalation effects and the effects of success to the successful mechanism. In Figure B.3. results of A and B grow fast in the beginning, but their growing will stop near the limiting points of those variables. Also, Figure B.4. shows that resource for A will grow to his maximum, while resource of B will be depleted completely. These time behavior of the level variables cannot be elicited from the structures of causal maps alone, because there are no limiting factors in the causal maps. But, any variable cannot grow or decay infinitely. And thus the growing and decaying rates will be slowed down as they come to the extreme points.

By applying NUMBER to several system archetypes, one can find that causal maps can be converted into SD model without loosing their simplicity and thus their generic nature. At the same time one can simulate the simple and generic SD models derived from the causal maps. One can learn by observing system behavior as well as its structure. Furthermore, one can experiment various policy measures with the SD models.

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