System Dynamic Models for Construction Projects

By

Sze Yiu Gordon Kwok

B.S., Civil and Construction Engineering (1997)
Iowa State University

SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN CIVIL & ENVIRONMENTAL ENGINEERING
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February, 1999

Signature of Author ______________________________________
Department of Civil and Environmental Engineering
January 15, 1999

Certified by ______________________________________
Feniosky Peña-Mora
Assistant Professor of Civil and Environmental Engineering
Thesis Supervisor

Accepted by ______________________________________
Andrew J. Whittle
Associate Professor of Civil and Environmental Engineering
Chairman, Departmental Committee on Graduate Studies

System Dynamic Models for Construction Projects

By

Sze Yiu Gordon Kwok

SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING ON JANUARY 15, 1999 IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CIVIL & ENVIRONMENTAL ENGINEERING

ABSTRACT

This thesis studies the application of system dynamics principles and models to construction project negotiations and schedule. It helps improve the efficiency of the negotiation processes and allows planners to realize the shortcomings of their proposed schedules through showing the relationships and interactions between variables in the processes or the schedules. This research is conducted as an effort to demonstrate the usefulness of the system dynamics models on the construction industry. By developing robust system dynamics models, the efficiencies and the overall performances of the construction projects could be improved as the probability of project delay would be significantly reduced through much better planning and more efficient negotiation process.

Thesis Supervisor: Feniosky Peña-Mora
Title: Assistant Professor of Civil and Environmental Engineering

ACKNOWLEDGEMENTS:

This thesis is devoted to my family, my professors in Iowa State University and my thesis supervisor in MIT.

My family has been supporting me in every aspects of my life. Even though they are in Hong Kong and so far away from me physically when I am pursuing my degrees, they always give me support whenever I need. I always wonder if I could achieve this much without my parents' guidance and encouragement. Thus, I would like to thank them and my sister here for all the years of support and love they have been giving me.

Then, I would like to thank my professors, Mr. William R. Lee, Mr. Donald Wall and Professor David T. Kao, in Iowa State University, where I pursued my Bachelor degree. Mr. Lee is the first professor I met there and he has been my motivator since the first day I met him. I still remember everything he has told me. His high recommendation and expectation on me help me set my goal during my early college career and I am sure I would not be here in MIT if I did not meet him in Iowa State. I also wish his mother would get better very soon, as I know how much he loves her. Mr. Wall was my academic advisor, lecturer of one of my class and my listener when I was in Iowa State. I talked to him almost every single day and he helped me solve a lot of problems both personally and academically. I would like to thank him here for encouraging me to apply MIT at that time and wish him a very good time after his retirement. Dr. Kao is another important professor whom I met in Iowa State University. I love his class and I believe it is one of the best I have ever had so far. He gave me a lot of opportunities of helping his research and those experiences helped me conducting this research and writing this paper. Moreover, I highly respect him for returning his knowledge and contributing his own country and I wish I could do the same thing one day.

I would also like to thank my thesis supervisor, Feniosky Peña Mora, for helping me so much when we try to define this research topic. I wonder if I would ever be exposed to the System Dynamics principles and Negotiation Theory without his suggestion.

Just want to let all of you know my appreciation and wish you all the best.

Sze Yiu Gordon Kwok

January 3, 1999

TABLE OF CONTENTS

TABLE OF FIGURES:

CHAPTER 1

INTRODUCTION

This chapter will provide the motivation of conducting this research as well as its objectives and importance. The motivation is to develop a mechanism for providing more efficient ways for project management and control. Due to the complexity of the construction industry's value chain systems, negotiation process is one of the areas that could be improved to reduce more time in the project duration. On the other hand, a mechanism which can help the planners and construction managers realize the pitfalls of their proposed project schedules provides another motivation for conaucting this research. The objectives of this research is to apply system dynamics principles to improve the negotiation process and help planners of construction projects come up with better schedules by understanding the interactions of different elements of construction projects through system dynamics models and computer simulations. The importance of this research is to demonstrate that the system dynamics models can be used as tools to understand the impacts of change orders, to help planners visualize the potential problems of their proposed plans and allow them to trace the causes. It will then reduce the chance of getting cost and time overrun and the chance of encountering any cash flow problems. In such a case, the efficiency of the project control and the overall performance of the project can then be also significantly improved.

We will address the research background, which are the system dynamics principles and the negotiation theory, and the approach used in Chapter 2. Then, in each of the Chapter 3 and 4, one system dynamics model will be presented along with simulations results, discussion of the system's behaviors and policy analysis. The model presented in

Chapter 3 is for the negotiation process while the one in Chapter 4 is for the Hong Kong new airport. Some suggestions for further research areas are also provided at the last chapter of this thesis.

1.1 MOTIVATION OF THE RESEARCH

The motivation of conducting this research, System Dynamic Models for Construction Projects, starts from the thought of developing mechanisms to improve the efficiency and performance of the construction industry. In order to achieve this goal, it is necessary to understand the characteristics of this industry and then it will allow us to identify the areas where changes could be made to raise the quality and overall performance of construction projects.

Construction industry is considered to be one of the most complex industries in terms of the value chain system. Along construction industry's value-chain system, there are suppliers of concrete, steel beams, or construction equipment, architecture firms, electrical and mechanical engineers, structural engineers, geotechnical engineers, contractors, sub-contractors, construction managers, the clients and so forth. Depending on the size of the project, the number of professionals from each discipline could be enormous for a large-scale construction project. The size of such a large-scale project will not only increase the difficulties and costs of managing and coordinating the project but also reduce the easiness and the efficiency of communicating between different project participating parties. This less efficient communication may lead to unnecessary miscommunication between some parties and thus get into unfavorable conflict of interests. It may eventually lead to cost and time overrun. As there are so many participants in a construction project and the high likelihood of having unforeseen changes needed to be made for the construction projects as they proceed along, it is reasonably to assume that the potential of getting into conflicts is also higher than other industries. Those changes made during the construction projects often lead to new responsibilities and interests allocation among the participating construction firms. It is not uncommon that negotiation processes will be necessary to determine this new allocation. The negotiation processes provide means to the different parties not only for negotiating changes of the project but also to resolve disputes among participants of the project in order to obtain a new allocation which is considered to be well-balanced and fair by all of the participating firms.

However, the time needed for and the outcome from the negotiation process could vary in a great extent depending on the way the negotiation situation is framed; the skills, experience, attitudes of the negotiators as well as the negotiation strategies that they decide to use. As the construction projects are often worth several million dollars, any unnecessary delay in the negotiation could lead to substantial loss of one to all of the project participants. Hence, it will be the best interest for all of the negotiating parties to understand the "fair" shares of them and not wasting time in pushing other parties to agree on any unrealistic settlements. It is believed that with the assistance of a negotiation model, the dynamics of the negotiation processes can be better understood and visualized by the participating parties. In such a way, some of the difficulties in the negotiation process could be removed and hence shorten the time needed for the process as well as optimize the outcome of the process.

Negotiation is the means to come to an agreement when changes are made or are going to be made in the construction projects. However, change orders sometimes are not completely unavoidable if construction schedules are carefully planned, and projects well-managed and adeptly-coordinated. Therefore, shortening the negotiation process after the necessary changes is not the only possibility to minimize the impact from the change of orders. Through better construction project planning and management will also be able to minimize the chance of cost and time overrun due to the change of orders. In other words, the quality of the construction projects in terms of time and budget control would be improved if a mechanism could be developed to ensure the performance of negotiation process and quality of the project planning and management.

Meanwhile, the disastrous and problematic opening of Chek Lap Kok Hong Kong New Airport provides another motivation to conduct this research. It is believed that by analyzing the fallout of the airport and understanding the origins of the problems arose could be useful for improving the quality of planning, designing, coordinating and managing similar large-scale projects in the future. If the problems are originated from the construction schedules, it would be desirable to understand what are the areas of the construction projects required longer leeway time and much thoughtful sequence of tasks. Some of the critiques stated that the disastrous opening of the Hong Kong New Airport is due to the unrealistic construction schedule which attempt to force the airport opening day to match with the visit of Presidents of China, Jiang Zemin, and the United States, William Jefferson Clinton. Some other critics blamed the poor idea of moving hardware and facilities overnight from the Kai Tak Hong Kong Airport to the Chek Lap Kok Hong Kong New Airport. All of these critiques are now seemingly reasonable to account for the undesirable quality of the new airport. However, it would be much more helpful if all of these potential problem origins are discovered at the early stage of the project planning rather than as hindsight. Furthermore, it would be interesting to know how much the impact of restraining the time for the project and insufficient moving plan account for the dissatisfied opening day performance respectively. Therefore, it is motivated to develop a mechanism which not only will help planners and construction managers realize the pitfall of their proposed schedules and construction plans at early stage of the construction but also be able to report the impact of each factors. It then allows lowering the probability of getting under-expectation overall performance for a large-scale construction project.

1.2 OBJECTIVE OF RESEARCH

As it is stated earlier, the objective of this research is to develop a mechanism which will be able to help negotiators as well as construction schedulers and managers. It will help the negotiators shorten the negotiation process by obtaining the optimal strategy in a more efficient manner. On the other hand, it will help construction schedulers and managers realize the potential problems of their proposal at earlier stage of construction and allow them to understand the impact of certain factors, such as the implementation of a particular policy in the project.

The interdependence of each variables of the construction projects significantly increase the complexity of the negotiation and the planning processes, especially for those large-scale projects. Therefore, it will be highly desirable if any methodology or mechanism could be applied to help negotiators and project planners find the optimal solutions in a much easier and faster manner. This research is conducted as an effort to demonstrate the application of the system dynamics principles to the construction industry to simplify that complex but common situation. System dynamics principles is a tool to capture unorganized, complex and abstract situation into clearly defined causal loops. It allows tracing the source of any undesirable behavior of the system through model analysis. Then, the impact to the system by certain variables or the implementation of any particular policy can be examined through policy analysis. The results of policy analysis could help negotiators and construction schedulers/managers in similar manner. They inform the negotiators if their strategies will lead to any potential negotiation problem while they show planners if any project delay is likely to happen during the construction and the early stage of operation. Should any potential problem exists, the mechanism will provide some possible explanations to the negotiators/planners after policy analysis. After that, the optimal negotiation strategy and project plan/schedule in the collaborative environment can then be developed. This mechanism is expected to be able to assist negotiators/planners to obtain effective solutions for project conflicts and delays especially in large-scale projects. The system is also expected to lead negotiation participants through a process in which they understand more in depth about the impacts of their negotiation strategies as well as others' on the negotiation process.

It is the objective of this research to demonstrate the application of the system dynamics to limit the impact of the project delay due to change orders. Two applications will be identified in this research. The first one is to increase the effectiveness of the negotiation process and the performance of the negotiators. It is achieved by allowing the negotiators to have a clear picture of the whole negotiating process and those factors which will enhance or damp the rate of the process. The second one is using the case study from the new Hong Kong Airport to help planners come up better project schedules for managing and coordinating large-scale projects. In this case, it will need the help of the computer simulation in addition to the system dynamics principles to allow them visualize the potential problems of their then-proposed schedule and then looking for the optimal plan/schedule.

1.3 IMPORTANCE OF THE RESEARCH

As most of the global civil and construction engineering projects are in multimillion scale, any delay of construction schedule due to undesirable change orders during the project will very likely lead to significant amount of cost and time overrun. As the impact of the change orders could be minimized through better planning and more effective negotiation, developing a sophisticated and effective mechanism for the negotiation and planning could be not only a time saving but also a project resources saving tool. The mechanism would play a crucial role to prevent some of the unnecessary construction cost by helping the negotiators identify potential problems of their negotiation strategies and suggesting alternate strategies or positions. Moreover, the mechanism would help planners to visualize the potential problems of their proposed plan and help them trace the causes. It helps the planners identify the areas that need closer monitoring and allows them to come up with a modified project schedule with a longer leeway time for those unforeseen delays during the planning phase. The impact of the change orders could then be limited and hence reduce the probability of project delay.

Those construction projects heavily depend on the designed cash flow to finance themselves. A project delay may significantly increase the burden of the financing by not only lengthening the duration of cash outflow but also sacrificing the revenue generated from operating the facilities on time.

In some other situation, the impact of the project delay is not limited to the project participants or the clients only. It may lead to tremendous disturbance to the local community in which the project is built. For example, in our case study presented in Chapter 4, the project delay and change orders leads to disastrous opening of the Hong Kong New Airport and in turn brings in huge amount of economic loss to the society. Moreover, in that case, the public support to the Hong Kong Government was further slid to the historical low.

All in all, developing robust system dynamic models will allow improving the efficiency and overall performance of construction projects by limiting the impact of the change orders and lowering the probability of project delay through better planning and more efficient negotiation process.

CHAPTER 2

RESEARCH BACKGROUND AND APPROACH

In this chapter, the background in which this research is built upon, will be presented. The system dynamics principles and the negotiation theory will be discussed in order to help readers understand the models and discussion provided in the following chapters. After the research background is presented, the research approach used will also be given in the second portion of this chapter.

2.1 RESEARCH BACKGROUND

This research is built on the system dynamics principles and the negotiation theories will be the two tools used in this research. In addition to these two, VENSIM, which is a computer program used to perform simulation for the models built, is used to help users visualize the behavior of the system. Before presenting the models developed according to these theories, the following sections will be used to help readers understand some of the major ideas in system dynamics principles and negotiation theories.

2.1.1 PRINCIPLES OF SYSTEM DYNAMICS

Negotiation process involves a series of decision making and strategy changes. A question may arise, after a negotiation outcome is known, if the outcome is the same as what negotiator expected when he/she has chosen the strategy or it is significantly different. Then, it is important to know the reasons of any deviation in order to improve the choice of strategy and negotiator's thinking during the next negotiation process. Another question that is asked is if those deviations actually can be foreseen when the strategy has been chosen or it is totally unpredictable. In order to understand these questions, a systematic approach is needed to break down the complicated negotiation process into elements which allow us to understand the process.

The system dynamics modeling technique is the one chosen in this research for this purpose. It uses the casual loops and feedback structures to simplify a complicated system into a much easily understandable model. It then allows us to understand and identify the problematic elements in the system. Any effects which have been overlooked in the process will also be notified. Some of the fundamental ideas of system dynamics are presented as follows to help readers understand this research.

The complex behavior of a system, for example, negotiation process, does not arise from its components, rather usually from the interactions among the components of the system. All dynamics are due to the interactions of two types of feedback loops which are namely positive (or self-reinforcing) and negative (or self-correcting) loops. Positive loops tend to reinforce or amplify whatever is happening in the system while the negative loops counteract and oppose change in order to restore balance.

The following two simple loops could illustrate these important concepts of the system dynamics principles. In Fig. 2.1, the positive loop is formed by the two variables, *Truck Size* and the *Load of Construction Material.* The Truck Size represents the size of the truck used for delivering the construction materials from the suppliers to the construction site or storage while the Load of Construction Material represents the amount of materials to be delivered to the construction site. It is easy to understand that the larger the truck size, the larger the load of construction material could be delivered and hence the positive sign on the arrow connecting from the Truck Size to the Load of Construction Material. On the other hand, the larger the Load of Construction Material to be delivered, the larger the Truck Size is desired and hence another positive sign is on the arrow connecting from the Load of

Construction Material to the Truck Size. This loop is defined as a positive loop and it will keep carrying on. The size of the truck and the load of the construction will be increasing exponentially as the reference mode shown in Fig. 2.2.

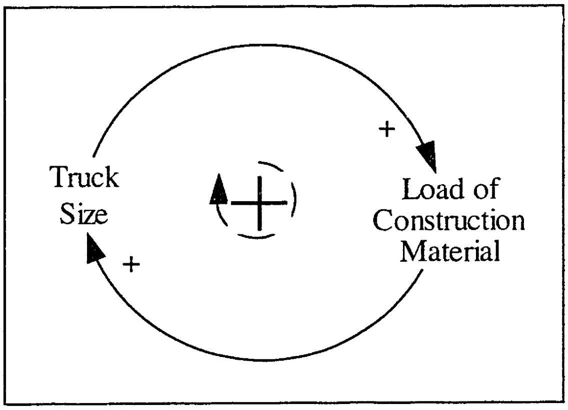

Fig. 2.1 Positive Feedback Structure

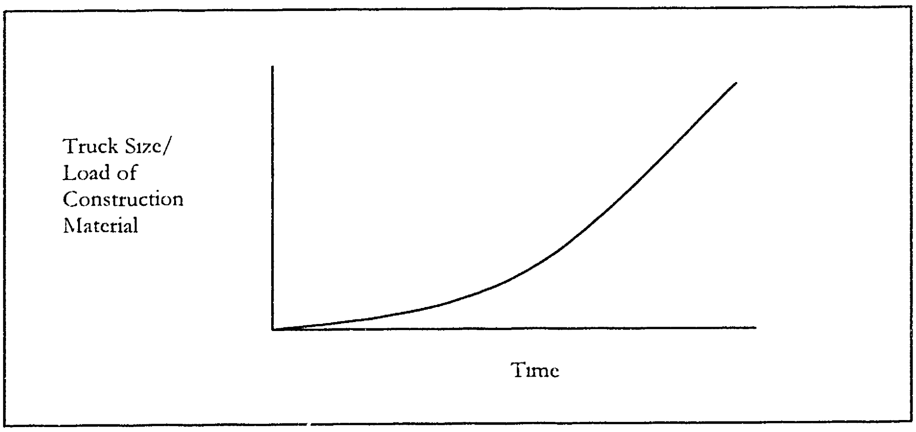

Fig. 2.2 Reference Mode for Positive Feedback Structure

On the other hand, the other type of loop, negative loop could be portrayed as the one in Fig. 2.3:

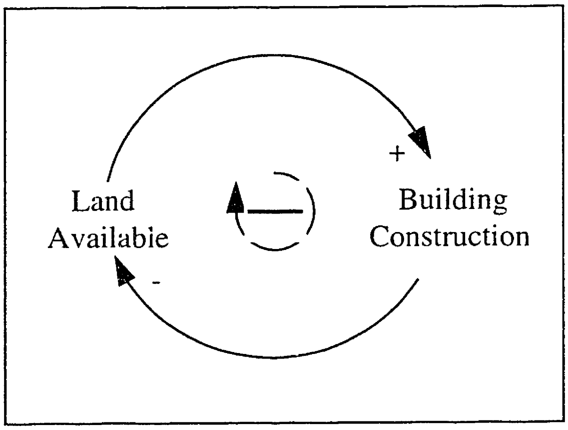

Fig. 2.3 Negative Feedback Structure

In Fig. 2.3, it is supposed that more construction can be taking place if more land is available for building construction and hence the positive sign is on the arrow connecting from *Land Available* to the *Building Construction*. However, it is obvious the land available for building is limited and hence the more building projects are taking place, the less land available left for other building construction projects. Thus, the minus sign is associated with the arrow connecting from the Building Construction back to the Land Available. The quantity of the land available for the building construction will be close to the reference mode shown in Fig. 2.4. The amount of land available will be decreasing at a faster rate at the beginning as more construction projects are taking place. However, as time proceeds, the rate of exhausting the available land will be slower as the amount of land available become less and less and the number of projects could be taking place become smaller and smaller. Finally, an almost steady amount of available land for construction will be reached.

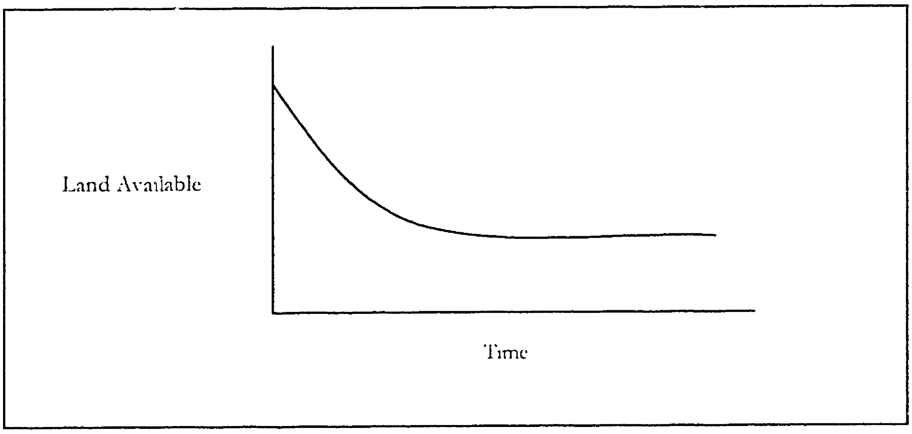

Fig. 2.4 Reference Mode for Negative Feedback Structure

These two simple structures describe the relationship between two elements within a system. However, these structures only help the modelers understand the relationship between elements. Stocks and flows are necessary to formulate the problematic situation which we would like to understand and analyze. Stocks are used to provide the information of the state at a particular time while the flows are used to describe the rate of changes of the state. Auxiliary Constants will also be used to provide information within the system and adjust the flows and some other auxiliary constants. In Fig.2.5, the stocks, flows and auxiliary

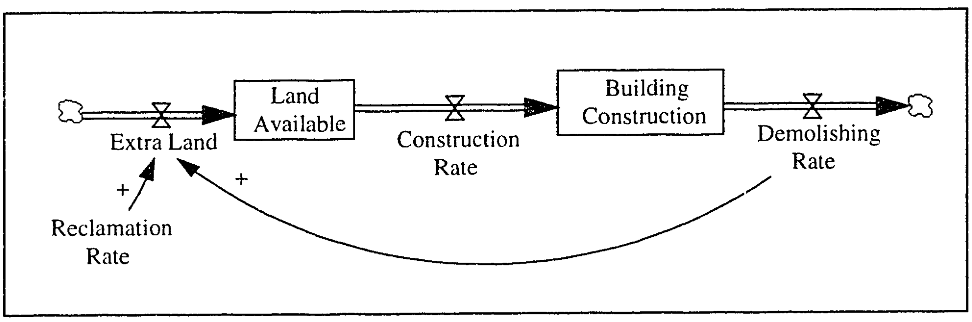

Fig. 2.5 System Dynamics Models with Stocks, Flows and Auxiliary Constant

constant is used to model the situation we have portrayed in Fig. 2.3, the negative feedback structure. The *Land Available* and *Building Construction*, which are variables in the boxes, are stocks while the *Extra Land*, *Construction Rate* and *Demolishing Rate*, which are represented by the pipelines with the valves, are the flows. *Reclamation Rate* is an auxiliary constant to account for the extra land obtained through reclamation other than those obtained from the demolished buildings.

The combination of stocks, flows and auxiliary constants will be used to formulate the situations which we would like to analyze in this thesis. In Chapter 3, the negotiation process, which is not uncommon during any construction projects, will be discussed with the aid of a negotiation model which breaks down the negotiation process into different elements. Those elements include the negotiators' positions, effect of negotiators' attitudes, weight of different issues, self concession rate and higher order concession rate. The interactions of these elements would generate different outcomes of the negotiation process. It is our interest to find out the best moves for the negotiator after the policy analysis and the results are presented in the Chapter 3.

In Chapter 4, a system dynamics model for the Hong Kong New Airport is presented. The model consists of 6 different sectors, namely Overall Performance, Public Satisfaction, Time Performance, Quality Performance, Opening Day Performance and Cost Performance. Each of these sectors represents one major area which we would like to analyze for the airport project. It would be our interest to implement different policy and see if the project performance could be improved. The results of different policies are compared and presented in that chapter.

2.1.2 NEGOTIATION THEORY

Negotiation is one of the common methods to be used to resolve perceived conflict of interests. Conflict is the perception of differences of interests among people. [Thompson, 1998]. There are three levels of conflict, such as intrapersonal, interpersonal and intergroup. Intrapersonal conflict is conflict that occurs within one person. Psychoanalysts state that this kind of conflict is the battle of drives or wills within a single individual. Interpersonal conflict is conflict between two or more people. On the other hand, intergroup conflict occurs between member of different groups which have different views in social, cultural or political categories [Thompson, 1998]. In this thesis, negotiation processes are referring to those resolving conflicts on the intergroup level as the negotiators are the representatives from different organizations participating in the same construction projects. According to the different sources of conflict, there are two different types of conflict, consensus conflict and conflicts of interest. Consensus conflict occurs when the opinions of two or more groups are not compatible with each other and they seek to reach an agreement of opinion [Thompson, 1998]. On the other hand, conflicts of interest is another major type of conflict at intergroup level. This kind of conflict occurs due to the scarce resource competition in which people perceive other parties as competitors of the same limited resources. The conflict will be over the allocation and control of the resources which are monetary or, in many other cases, are less tangible as responsibility, control, time services and favors [Thompson, 1998]. Conflict of interest can be resolved by several ways such as social justice mechanisms, which may be changing certain policies or dividing resources on the basis of equality, equity or need [Leventhal, 1976, Thompson, 1998]. Conflict of interest can also be resolved by negotiation, mediation or arbitration. Therefore, it is the major interest of this research to understand the negotiation process which is used to resolve conflicts of interests on the intergroup level. The system dynamics model for the negotiation process is built to serve this purpose and it is going to be presented in the Chapter 3.

2.1.2.1 Positional Bargaining Strategy

In positional bargaining, negotiators have their positions, which are their stated or desired wants, when they are negotiating for a particular issue. They take their positions in order to fulfill their interests, which are the underlying needs that negotiators have [Thompson, 1998]. For example, there is a project delay due to some unexpected foundation problems and the client is negotiating the project deadline extension with the contractor. The client is allowing the maximum of one month for extension because the cash flow will be significantly affected by the delayed revenue and the increased financial charges on the debts. However, the contractor has scheduled half of its workforce for another project after the original deadline and hence the workforce left will require the extension of two to three months. The negotiation position taken by the client is to achieve an agreement that the project will be delivered no later than one month after the original deadline while the one taken by the contractor is to ask for a two to three months of extension to fit its scheduled workforce. As we have stated at the beginning of this paragraph, the negotiators take their position in order to fulfill their interests. Therefore, in this example, the client is taking that position because he/she wants to lower the impact to the projected cash flow by avoiding the loss of revenues and financial charges. On the other hand, the contractor is taking that position because it does not want to affect the scheduled workforce for the other project due to this unexpected delay. In this example, as the negotiators' positions and interests are quite different, the negotiation process might take a long time until one of the parties give up their stated positions. One of the possible scenario in which the contractor will give up its position and agrees to the client's will be the contractor agrees to schedule the overtime after the client agree to pay extra charges to those overtime workhours. The position bargaining is usually time consuming before being able to achieve an agreement which both parties might not satisfied with. However, in some other negotiation which the needs could be met by a variety of ways and positions, it will be better off for the negotiators to move away from positional bargaining into a discussion of underlying interests and needs, hence the *Principled Bargaining*.

2.1.2.2 PRINCIPLED BARGAINING STRATEGY

The principled bargaining, which is also often called win/win negotiations, is a negotiation strategy which suggest negotiators should try to understand each other's underlying interests and then looking for one settlement that will be mutual beneficial to all negotiating parties. For example, there is a project in which the clients provide bonus for early finish and quality work. In such a case the project participants could try to negotiate a better information flow or reporting mechanism, which could improve the communication between the participants and hence reduce the risk of project delay and increase the chance of early delivery and getting the bonus. In this situation, the negotiating parties are negotiating on the same goal, delivering the project by the scheduled deadline. They are looking for a settlement which will be providing additional profit to their organizations while no one is going to lose any profit they are now holding. Hence, the settlement will be beneficial to everyone who is negotiating and it could be called a win/win situation.

However, it is not the interest of this thesis to determine if the positional bargaining is better than the principled bargaining. The interest is to understand the negotiation process and hence help negotiators determine the optimal policy to be implemented in the process. The combination of both positional and principled strategy would be used in the model of negotiation process if necessary.

The system dynamics principles can help us model the negotiation process. For example, consider two negotiators A and B are negotiating and negotiator A has decided to adapt the hard positional bargaining as he/she thinks that he/she could get what he/she is asking for by making sure his/her position is hard and strong enough. A thinks that B will finally give up his/her position if B knows that he/she is not going to give up his/her position. On the other hand, assuming negotiator B has not decided which negotiation strategy to use before entering the negotiation, what will be the possible outcome of the negotiation? There are two possible outcomes, the first one will be exactly like what negotiator A thinks while the other will be exactly different. Why is that result so extreme? Consider the feedback structure in Fig.2.6.

The two feedback structures can explain the outcomes perfectly. The balancing, negative feedback, loop is the one in negotiator A's mind and it will be the outcome of the negotiation process if the positive feedback is not present or is not strong enough to affect the negative one. However, if the situation is similar to the loops suggested above, the harder negotiator A sticks to a position, the worse his/her attitude is perceived by the negotiator B and hence the greater the resistance given by negotiator B to follow negotiator A's suggestion and hence the outcome will be further away from what negotiator A is asking for.

This is a simple example used to illustrate the usage of system dynamics for modeling the negotiation process and it will be further discussed and explained in Chapter 3.

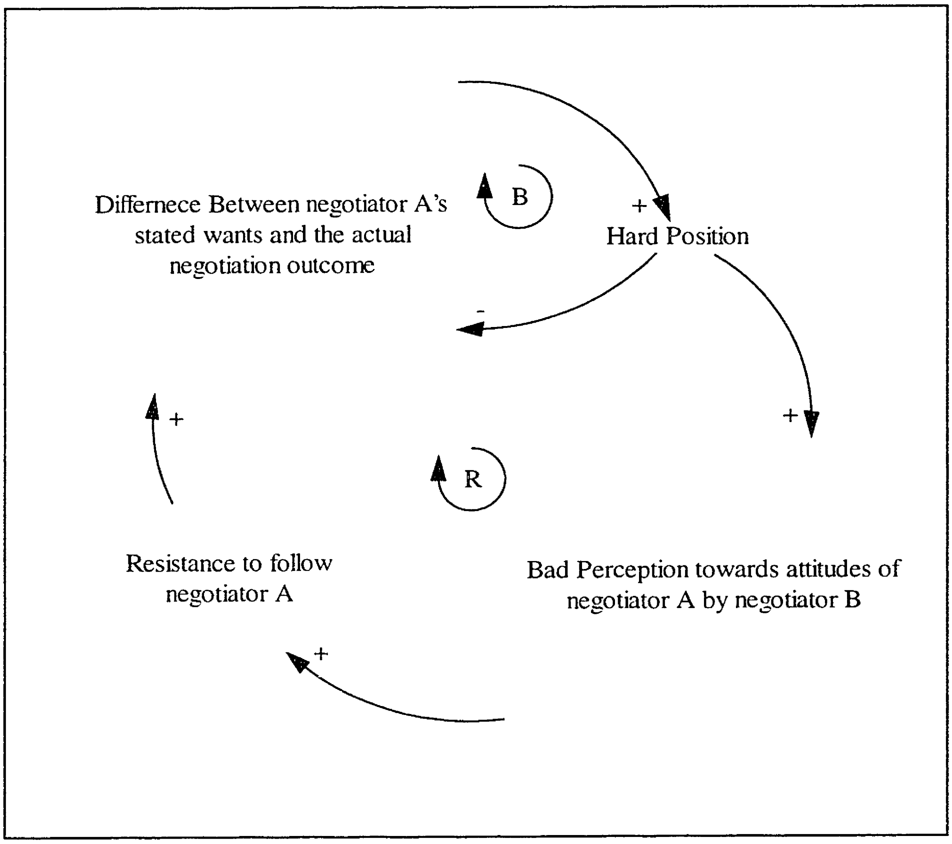

Fig. 2.6 Interactions of Feedback Structures

2.1.2.3 SELF CONCESSION RATE

In the simple negotiation model presented on previous section, the balancing loop could be understood as the *Self Concession Rate* [Darling and Mumpower, 1990]. It is the amount of interests which the negotiator decides to forgone in order to ensure the continuation of the negotiation process or reach a settlement. The decision is determined solely by the self interest of a particular negotiator. This self concession rate is determined by the concession rate of different issues with different weight for the negotiator. However, the self concession rate will not necessary be the action taken by the negotiator. He/she will consider the anticipated self concession rate from other negotiating parties before deciding his/her actual concession rate. In that case, the concession rate will be considered as the *Higher Order Concession Rate.*

2.1.2.4 HIGHER ORDER CONCESSION RATE

Higher order concession rate is the combination of the negotiator's self concession rate and the weighted sum of other's anticipated self concession rate. The weight of other negotiators' self concession rate could be determined by their attitudes and the rate of interaction such as the regular meeting schedule [Darling and Mumpower, 1990]. The rate of interaction may amplify or reduce the weight determined by the perceived attitudes of other negotiators. The higher order concession rate will be the one the negotiator offer on the negotiation table. The interaction of different negotiators' higher order concession rates will determine the actual profit held by each negotiating parties after each round of negotiation. The negotiation process will keep on going until one settlement has been found favored by all the negotiating parties.

2.2 RESEARCH APPROACH

2.2.1 IDENTIFY VARIABLES NEEDED TO BE CONSIDERED IN THE SYSTEM DYNAMICS MODEL AND CASE STUDY

A negotiation scenario and a case study of the Chek Lap Kok Hong Kong new airport will be presented in Chapter 3 and Chapter 4 respectively. From the information obtained through the scenario and the case study, variables needed to be considered in the system dynamics models are identified. The causal loop relationships between those variables will then be developed. These causal loops give the foundation of building the system dynamics models for the negotiation process and the Hong Kong new airport.

2.2.2 BUILDING MODEL

The whole negotiation process and problems encountered by the Hong Kong new airport will then be converted into models through system dynamic modeling techniques. The system dynamic technique is applied in order to show the mental models of the negotiators/decision makers as well as the unintended effects of their chosen strategy and decision. The computer program, VENSIM is used to formulate the models in this thesis. After the models are built, simulation will be run with the aid of VENSIM. The performance of our interested variables could be easily visualized through the graphs generated by the computer program. Thus, the effects of each elements of the models can be understood by tracing the causal loops throughout the models.

2.2.3 POLICY ANALYSIS AND SUGGESTIONS FOR IMPROVING SYSTEM PERFORMANCE

The first simulation is run with all the initial values of the variables or constants in the models. As mentioned previously, the effect of different elements could be traced throughout the models. Therefore, we look for some other policy which would improve the performance of our interested behavior of the models. For example, it is our interest to determine the optimal negotiation strategy which will allow the negotiator for getting close to his desired wants. With different combinations of negotiation positions, concession rates, weights of issues and effect of attitudes of other negotiators, different simulations have been run. The results are then compared and they give the negotiator further intuition of the negotiation process. On the other hand, our interest of the new Hong Kong airport case is to lower the chance of breaking down and having a disastrous opening day as well as ensure a satisfactory overall performance. Different policies, such as allowing more time to move into the new airport, more inspections for the problematic

Hong Kong Air Cargo Terminal Ltd. (HACTL) and hiring officials with higher management competence, have been implemented in the Hong Kong airport model and the simulation results are compared. Instead of being a hindsight and criticizing what policies should the officials have chosen, it is our interest to provide cautions and reminders to the management of other large scale projects. Moreover, it is our intention to improve the planning and management aspects of large scale projects by obtaining more intuition of them.

CHAPTER 3

SYSTEM DYNAMICS MODEL FOR THE NEGOTIATION PROCESS

The definition, purpose and typical behaviors of negotiation will be provided in this chapter. Then, the variables needed to be considered in the negotiation model will be defined before the model is presented. The negotiation rationale and the model for the two negotiating parties will be provided and then followed by the modifications needed for the multiple parties negotiation scenario. The formulations and the mechanisms of the model will be discussed along with those necessary user-defined graphs. After the model is fully explained, the different scenarios run in the simulations will be given. The results of those simulations will be discussed with the aid of the graphs obtained from the computer program, VENSIM, used in this thesis. The optimal negotiation strategy suggested from the set of simulations run will then be provided in the later portion of this chapter followed by the Negotiation Game, which is a convenient analysis tool built upon our developed negotiation model through the built-in game interface of VENSIM. It is developed for those negotiators who have never exposed to the system dynamics principles.

3.1 NEGOTIATION PROCESS

Negotiation is defined as a decision-making process by which two or more groups agree how to allocate scare resources to resolve the conflicts of interests throughout this thesis [Thompson, 1998]. Moreover, as the negotiation process is undergone in the collaborative environment. It is also called collaborative negotiation. In this type of negotiation, the negotiating parties are competing for common resources but also trying to achieve common goals. It could be illustrated by the following scenario. There are several construction companies from different countries formed a joint venture and working on a large scale project. For this particular project, the client is highly concerned with the quality and the duration of the project due to the significant impact of this project to the future growth of the client's company. The client has clearly stated in the contract that the joint venture will not receive its payments for each milestone until all the scheduled deliverables for each milestone has been finished at a level of quality stated in the contract. Moreover, as the client wants to speed up the construction of the project, it provides incentives to the joint venture that certain amount of bonus will be given if the project could be delivered earlier than the scheduled project delivery date without sacrificing the quality of the project. The amount of the bonus is calculated by considering the difference between the actual delivery date and the scheduled one. In other words, the earlier the delivery, the larger the amount of the bonus, which is, however, capped by a maximum number. As the bonus provides the incentive for the joint venture to speed up the construction, the construction firms of the joint venture will try to maintain a high level of cooperation by negotiating a better communication mechanism. Nevertheless, different construction firms may compete with each others for the resources, such as the money and time available, of the projects. Hence, the negotiating parties are in the collaborative negotiation in which they have a common goal, delivering the project by the scheduled deadline and collecting the bonus from the client, while they compete with each other while negotiating the allocation of the bonus.

3.2 Purpose and Typical Behavior of Negotiation

The purpose of the negotiation is to search for an agreement in which the negotiating parties feel that they have been fairly treated. According to the individual negotiators' strategies, each of them may have different interpretations of negotiation process. For those negotiators, who believe in the position bargaining strategy, negotiation process is a *zero-sum game*. It means that the gain of a particular individual party of the negotiation must be yielded from the loss of some other parties. Apparently the harder the position a negotiator is taking, the more likely the other negotiating parties will give up their positions earlier and hence he can get closer to his desired wants. However, the major problem of this strategy is a long lasting and non-productive negotiation will be created if most of the negotiating parties are not willing to give up their positions. It can be expected that more management resources will be needed in this situation and it means that the cost of the negotiation will be higher. On the other hand, for those negotiators who believe in the principled bargaining strategy, the negotiation process will be a mean of looking for a settlement which will yield profits to the negotiating parties but not necessary in the expense of any of them.

However, no matter what negotiation strategy is implemented, it is always true that negotiation process consists of ongoing exchange of information, decisions and feedback between different parties. It can be thought as a series of stages such as proposing, analyzing, decision making and offer adjusting. In the proposing stage, each of the negotiating parties are stating its desired wants to other parties. Then, the negotiating parties will analyze the proposal from other parties and decide if they should accept the proposals or return another one. These stages are the basic elements of the negotiation process. The different outcomes of the process are due to the interaction of other elements such as the negotiation strategies, concession rate and weight for different issues, the effect of attitudes/offers on the decision making and the frequency of interaction. All of these elements have been included in our system dynamics model which is presented in the following section.

3.3 SYSTEM DYNAMIC MODEL

As we have pointed out in the previous section, the negotiation process can be thought of as a series of stages. It is understandably to assume the negotiation rationale is very similar for all negotiators. The negotiators decide if they want to accept the proposals from other negotiating parties by comparing the actual profit they will collect to their stated wants in their own proposal. The ratio will then affect their choice of negotiating strategies or positions. The different positions taken will then affect the self concession rate of the negotiating parties after they consider the concession rate on each issues with their own assigned weights. The negotiator will then anticipate other parties' reaction to the existing negotiation situation and offer the higher order concession rate which is equivalent to their proposal for the next round of the negotiation process. The same process is undergone until all the parties find that the settlement is fair and satisfactory. The factors considered in the negotiation rationale can be summarized as the following:

- Number of Negotiating Parties
- Number of Issues Being Negotiated
- Desired Profit – the stated wants of the negotiator when he/she enters the negotiation or at the beginning of the new round of negotiation
- Actual Profit – the actual profit the negotiator can collect at the end of a particular round of negotiation
- Negotiation Position
- Concession Rate and Weights of Different Issues
- Effect of Attitudes on Deciding Higher Order Concession Rate

3.3.1 Model For Two Negotiating Parties

The simplest negotiation process will be the one with only two parties involved. In Fig. 3.1, the model is formulated to reflect the negotiation rationale of the negotiator. There are two loops in the model. The top loop is a mechanism to adjust the desired profit of the negotiator. The *Desired Profit* is adjusted by the *Concession on Desired Profit* which is determined by the *Ratio of AP (Actual Profit) to DP (Desired Profit)* and the *Time Pressure to Reach Agreement.* The *Time Pressure to Reach Agreement* is different for each negotiators because one organization may have some other projects at the early period of the project while the others may have projects at the later stages. In other words, the organizations with projects at the later stages may want to have reached a settlement earlier, otherwise, the pressure they felt as the negotiation proceeds will be greater. Hence, they will be more willing to lower their desired profit in order to reach an agreement at the later stage of the project. The time pressure function of each negotiator is represented by the look up graph, *Utility Function of Negotiator for Reaching Agreement due to Time Pressure* (Time Left Neg f). Then, the effect of the time pressure on changing the variable, *Concession on Desired Profit.* is determined by the look up graph, *Time Pressure Effect On Concession f.* However, the effect of the time pressure on the negotiator's desired profit concession rate is further adjusted by *Effect of the Actual Profit to Desired Profit Ratio on the Desired Profit Concession Rate* (Ratio Effect on Concession DP f), which is a function to lower the time pressure while the *Ratio of AP to DP* is too low for the negotiator. It is reasonably to assume the negotiator will be indifferent to reaching an agreement when they find the agreement is too far way from their stated wants.

On the other hand, the bottom loop is a mechanism to reflect the change of *Negotiation Position*, *Self Concession Rate* and *Higher Order Concession Rate.* The *Negotiation Position* is unique for each negotiators and is determined by the look up graph, *Ratio Effect Neg Pos f.* After the negotiator has decided his/her negotiation position, his/her *Self Concession Rate* will be determined according to his/her concession rate of different issues discussed in the process. The concession rate is obtained from the *Concession Rate f.* As different issues will have different weight to a particular negotiator, the *Weight* is used to adjust the concession rate of each issue and provide the *Self Concession Rate.* However, the negotiator will adjust his/her offer of concession after he/she anticipates the reaction of other negotiating parties. The concession rate in which a negotiator not only concern his/her self interested concession rate but also others is called *Higher Order Concession Rate.* It is assumed to be affected by the attitudes of other negotiators and the *Rate of Interaction.* The amount of effects from other's attitudes are estimated by the *Effect of Attitude* while the effects from rate of interaction are determined by the *Rate of Interaction f.* The *Higher Order Concession Rate* of each negotiator will then be their concession rate in this round of negotiation. The distributions of their *Higher Order Concession Rate* are obtained by the *Higher Order Concession Rate Distribution* and it will then adjust the *Profit Changing Rate* accordingly to reflect the *Actual Profit* the negotiator is holding at the end of this round of negotiation. The two loops interact and generate the outcomes for the negotiation process.

The model presented here is for two negotiating parties with three issues discussing in the negotiation. However, it is the interest of this research to formulate the model in a way which could be used for multiple parties and multiple issues. The necessary modification for this purpose is presented in the following section.

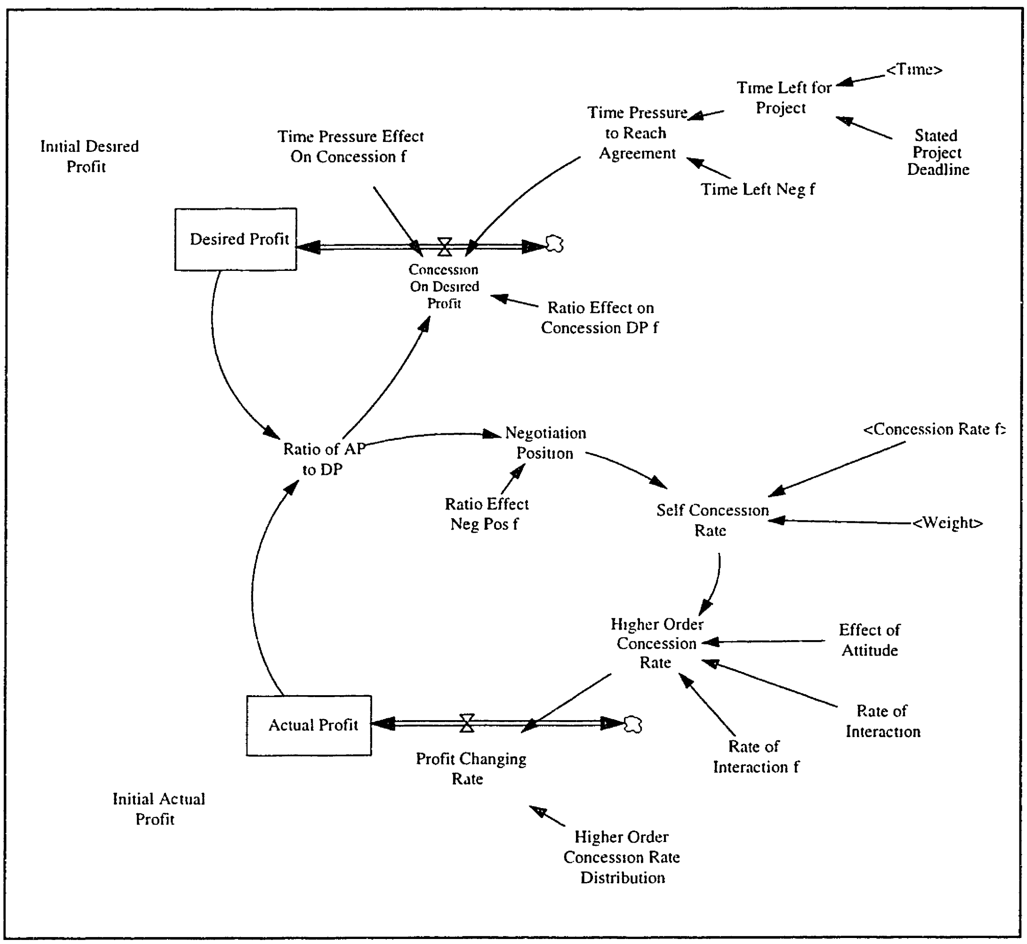

Fig. 3.1 System Dynamics Model for Negotiation Rationale

3.3.2 MODEL FOR MULTIPLE NEGOTIATING PARTIES

The *Negotiation Rationale* model, which is presented above, simulates the negotiation rationale for individual negotiator. Hence, it is not limited to the two parties negotiation scenario as stated in previous section. We could modify this model by using the subscript function of the VENSIM program and apply to multiple parties negotiation situation. Consider the following formulations for the two parties and multiple parties negotiation:

- In Two Parties Scenario:

  The effect of attitude on negotiator A by negotiator A (i.e. himself/herself) and negotiator B are :

  Effect of Attitude[A,A] = 1
  Effect of Attitude[A,B] = 0.5

  While the effect of attitude on negotiator B by negotiator A and negotiator B (i.e. himself/herself) are :

  Effect of Attitude[B,A] = 0.5
  Effect of Attitude[B,B] = 1

In these formulations, we know that the effect of attitudes on the negotiators are 1 by themselves while are 0.5 by the other. The values could be modified by the negotiators/modelers to correctly reflect the effect of the attitudes accordingly. However, the number of equations required to reflect this single variable is the square of the number of negotiating parties. In other words, the number of extra equations needed for the modification of the model for multiple parties could be increased significantly. Therefore, the formulations have been changed as the following for the multiple parties negotiation:

- In Multiple Parties Scenario:

  The effects of attitude *ON* negotiator A *BY Other* negotiators are:

  Effect of Attitude[A,Negotiator] = 1,0.5,0.5

In this formulation, the *Effect of Attitude* on negotiator A by negotiator A, B and C are 1, 0.5 and 0.5 respectively. If the number of negotiators is increased to, say 5, and the effects of the attitude by the additional negotiators are 0.3 and 0.4, then the modified formulation will be:

Effect of Attitude[A,Negotiator] = 1,0.5,0.5,0.3,0.4

In other words, the number of equations needed for this single variable is reduced to the actual number of negotiating parties but NOT the *square* of the number itself. It reduces the numbers of equations significantly and simplified the formulation and modification for additional negotiators.

The following pages will discuss the formulations of the Three Parties negotiation process to illustrate the idea of applying the system dynamics model on the multiple parties negotiation. The reasons for the chosen shape of the look up graphs, such as the *Utility Function of Negotiator for Reaching Agreement due to Time Pressure* (Time Left Neg f) and *The Effect of the Actual Profit to Desired Profit Ratio on the Desired Profit Concession Rate* (Ratio Effect on Concession DP f). After presenting the reasoning of the formulation, the results from the *Base Run*, in which all the initial values of the variables are used, and other implemented policy are compared in the Section 3.3.3 *Policy Analysis.*

First of all, we are going to examine the upper loop and the formulations associated with it. The *Utility Function of Negotiator for Reaching Agreement due to Time Pressure, Time Left Neg f,* for the Negotiator A, B and C are presented in Fig. 3.2 a, b and c respectively. The number of weeks left on the schedule is shown on the x-axis while the amount of pressure is shown on the y-axis. The duration of the project in our model is arbitrary set at 24 weeks and it could be easily changed by the modelers to represent the actual project situation. The pressure felt by the negotiator is set from 0 to 1 as shown in each of those figures. 0 represents the negotiator does not feel any pressure to reach an agreement while 1 means that he/she is experiencing a very great pressure and would like to take the agreement available in this round of negotiation.

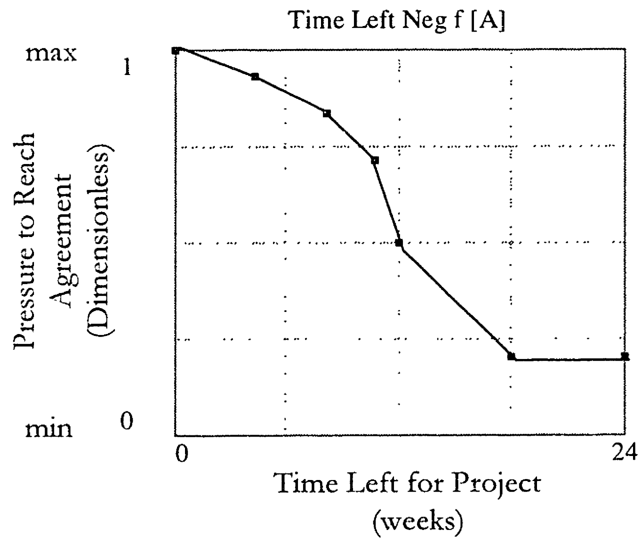

Fig. 3.2a Utility Function of Negotiator A for Reaching Agreement due to Time Pressure

In Fig. 3.2a, the values on x-axis represent the time left for the project, therefore, when the project just begins, the value on the x-axis should be just left of 24 as the project duration in our scenario is assumed as 24 weeks. Negotiator A feels only 20% of pressure in the first 6 weeks of the project (the time left for the project is changed from 24 to 18), then he/she starts to feel more pressure as the time left for the projects is decreased. From the sixth weeks to the 12^{th} weeks, the pressure is increased in a constant rate and reaches 50% at the end of the 12^{th} week. However, after passing the mark of half of the project duration, the Negotiator experiences a sudden increase in the pressure and then the pressure is increased in a decreasing rate. This utility function of the time pressure for the negotiator A may be due to the cash flow, schedule of other projects or limitation of some resources of the company and it is defined by the negotiator before he/she enters the negotiation process. As different negotiators are representing their own organizations, their utility functions should be unique and representing their own perceptions of pressure as the project deadline approaches.

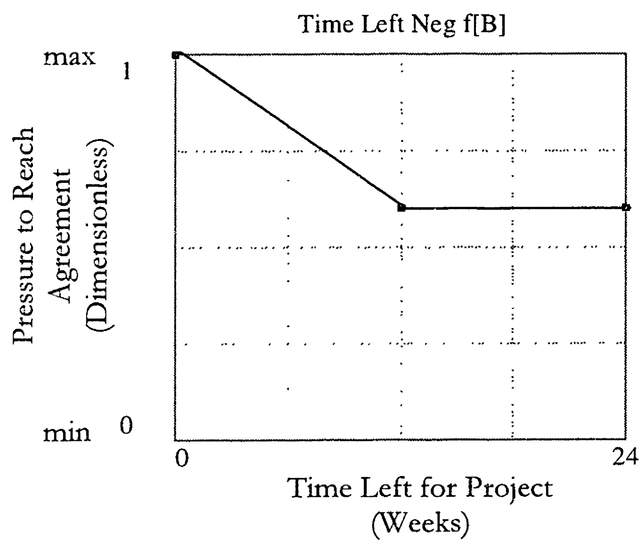

Fig. 3.2b Utility Function of Negotiator B for Reaching Agreement due to Time Pressure

In Fig. 3.2 b, the utility function of Negotiator B for the time pressure is different from that of Negotiator A's. In the first half of the duration of the project, the Negotiator B always feels the constant 60% pressure to reach an agreement. In other words, the Negotiator B is always more eager and willing to reach an agreement than the Negotiator A as his pressure is only in the range of 20 to 50% in the same period of time of the project. In the later half of the project duration, the pressure on the Negotiator B is increased constantly from 0.6 to 1.

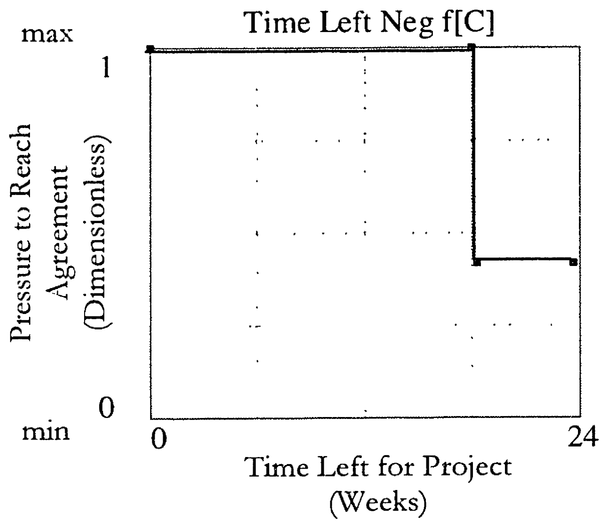

Fig. 3.2c Utility Function of Negotiator C for Reaching Agreement due to Time Pressure

Meanwhile, the utility function of Negotiator C is shown in Fig. 3.2c. From the beginning of the project to the end of 6th weeks, the pressure on the Negotiator C is 40%, which is lower than that of Negotiator's 60% while is higher than that of the Negotiator A's 20%. However, the pressure is significantly changed to 1 after the 6th weeks due to certain reasons such as limitations of resources or inflexibility of cash flow of their company. It means that the Negotiator C will be willing to take whatever offer available on the negotiation table after the end of 6th week of the project. However, there are two points needed to be keep in mind. The pressures for all the negotiators are 1 at the end of the 24th week of the project, which is the end of the project. Therefore, this model does not allow the negotiation breakdown which may not necessary be the case. It will be the modeler/negotiator 's decision to change this assumption and allow the negotiation breakdown under certain circumstances. The second point need to be reminded is the utility functions presented above are used to adjust the *Desired Profit* of each Negotiators only. In other words, as the deadline of the project is approaching, the time pressure felt by each negotiators make them to adjust their stated wants, *Desired Profit*, accordingly in attempt to achieve an agreement. However, their adjusted desired profits do not necessary match the offers from the other negotiators. If the *Actual Profit* they are getting is too far from what they are asking or expecting, the effect of time pressure on changing their concession rate for the *Desired Profit* will be reduced. It is adjusted by the look up graph of *Ratio Effect on Concession DP f.* The following are the defined look up graphs of *Ratio Effect on Concession DP f* for each negotiators. In each of those look up graphs, the *Ratio of Actual Profit to the Desired Profit* is shown on the x-axis. The range is from 0.5, which means the negotiating party is only getting half of what they are asking for, to 1, which means they are getting exactly what they want. The adjustment needed for the concession rate for the Desired Profit is shown on the y-axis. The adjustment is in the range of 0 to 1. The value one means all the time pressure will be taken into account for adjusting the concession rate of Desired Profit while zero means the concession rate of the Desired Profit will not be changed no matter how much pressure the negotiator is experiencing.

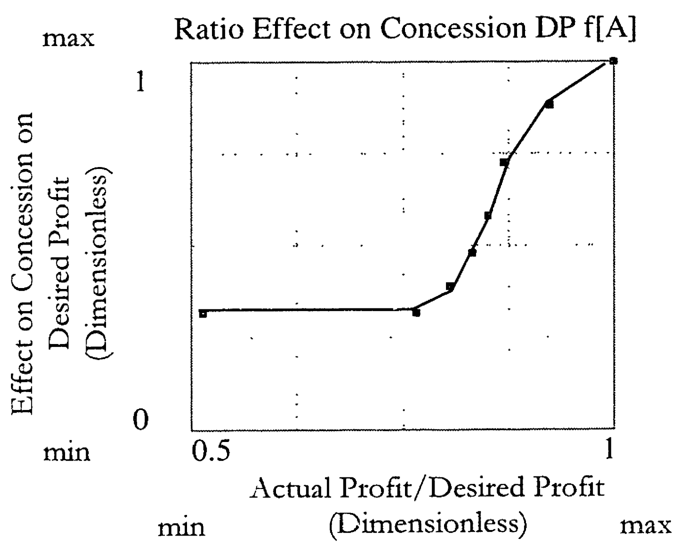

Fig. 3.3a The Effect of the Actual Profit to Desired Profit Ratio on the Desired Profit Concession Rate (Negotiator A)

In Fig. 3.3a, effect of the time pressure on the Negotiator A is decreasing at an increasing rate until they are getting 85% of what they are asking. At the *Ratio of Actual Profit to Desired Profit* equals 85%, the effect on the Negotiator A from the time pressure is dropped to about 58% of the values determined from the utility function for the time pressure. Then, when the ratio is lower than 85%, the effect is decreasing with a decreasing rate until the ratio is about 75%. When the *Ratio of Actual Profit to Desired Profit* is equal or lower than 75%, the effect of the time pressure is reduced to only 30% of the value determined by the utility function. In that case, the Negotiator A will not try to adjust a lot on his/her stated wants even if the deadline is approaching because he/she is getting only less than 75% of what he/she wants.

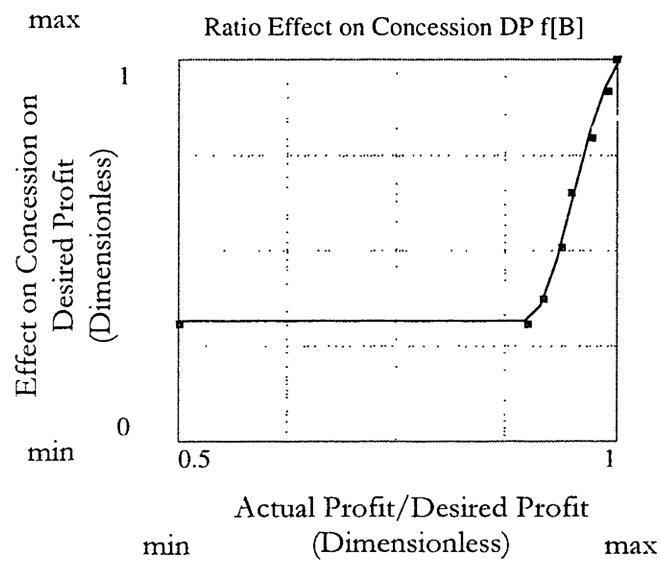

Fig. 3.3b The Effect of the Actual Profit to Desired Profit Ratio on the Desired Profit Concession Rate (Negotiator B)

In Fig. 3.3b, the adjustment from the *Ratio of Actual Profit to Desired Profit* for the Negotiator B is shown. The adjustment is decreasing almost linearly from 1 to 0.3 when the ratio is dropped from 1 to 0.9. After the ratio is lower than 0.9, the adjustment remains constant at 0.3. This negotiator can be considered as a hard position negotiator because he/she is not going to change his/her stated wants soon after he/she realizes he/she is getting less than 90% of what he/she is asking. Moreover, his/her adjustment for the time pressure is very significant. For 10% less than his/her stated wants, he/she neglects around 70% of the time pressure according to his/her utility function. In other words, the Negotiator B will not change much of his/her stated wants even if the deadline is getting so close when he/she is not getting almost all he/she is asking for.

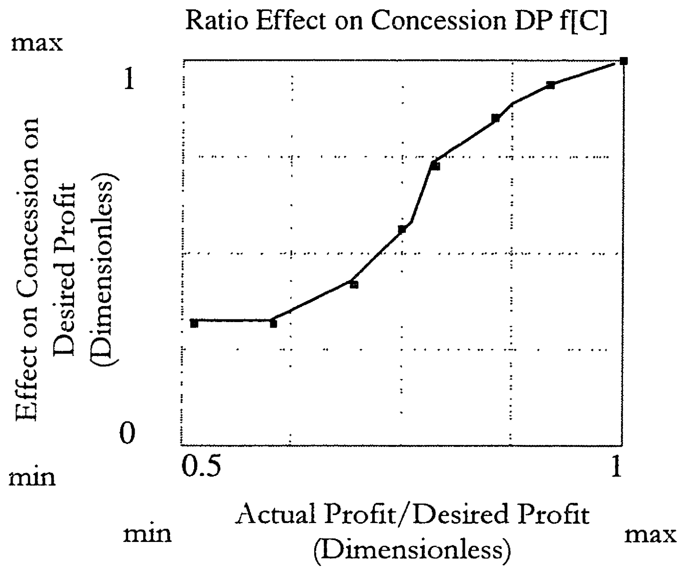

Fig. 3.3c The Effect of the Actual Profit to Desired Profit Ratio on the Desired Profit Concession Rate (Negotiator C)

In Fig. 3.3c, the effect of the profit ratio is decreased with an increasing rate until the ratio is about 75%. At 75% of the profit ratio, the effect is about 56%. Then, the effect of the profit ratio is decreased in a decreasing rate until the Negotiator is only getting around 60% of what he/she is asking. When Negotiator C is getting between 50 to 60% of his/her desires, the time pressure on him/her to reach the agreement is only 30% according to his/her utility function.

It is important to define the threshold which the Negotiator will not further adjust their concession rate or *Desired Profit.* For Negotiator A, his/her threshold is 75%. It means that he/she is asking for no less than 75% of his/her stated wants. If he/she is getting less than that threshold, he/she will be indifferent to rush and to achieve an agreement with other parties even if the deadline is approaching. For the similar reasoning, the thresholds of the Negotiator B and C are 90% and 60% respectively. We can interpret their thresholds as their bottom lines of the negotiation process and their willingness of adjusting their desired and self-interested profits to reach a agreement. In other words, the Negotiator C, who has the lowest threshold, is more willing to give up his/her own interests in order to achieve an agreement than the other two negotiators. On the other side, the Negotiator B is the one taking the hard position in this negotiation as he/she has the highest threshold, 90%, during the process.

Thus far, we have examined the reasoning and mechanism used to adjust the *Desired Profit* of each negotiators. However, the only reason of adjusting the *Desired Profit* is to continue the negotiation process and in attempt to achieve an agreement. After adjusting the *Desired Profit* and entering the new round of negotiation, the new negotiation positions of each negotiators are determined by their *Negotiation Position Function for Different Actual Profit to Desired Profit Ratio*, *Ratio Effect Neg Pos f[Negotiator]*, after comparing their *Desired Profit* to their *Actual Profit* from last round of negotiation. According to different negotiation strategies adapted by each negotiators, their *Negotiation Position Function* should be different and be defined to reflect their reactions to different *Actual Profit to Desired Profit Ratio*'s.

In Fig. 3.4a, the *Actual Profit to the Desired Profit Ratio* is shown on the x-axis while the *Negotiation Position* is represented on the y-axis. The *Negotiation Position* is in the range of 0 to 1. The value of 1 represents a hard position while the value of 0 represents a soft one. The positions, which the negotiators are taking, are mainly used as a 'signal' to determine their *Self Concession Rate* and then the *Higher Order Concession Rate.* Therefore, we could represent the positions by the values between 0 to 1 as long as the 'signal' can be carried over to the other elements of the model and return our interested response, such as the *Self Concession Rate* and the *Higher Order Concession Rate.* As we are not interested in measuring the positions themselves, it is not necessary to differentiate between a negotiator with a position equals 0.5 and another with a position equals 0.8. We are only interested in the values of the negotiators' *Self Concession Rate* and the *Higher Order Concession Rate* with respect to their positions.

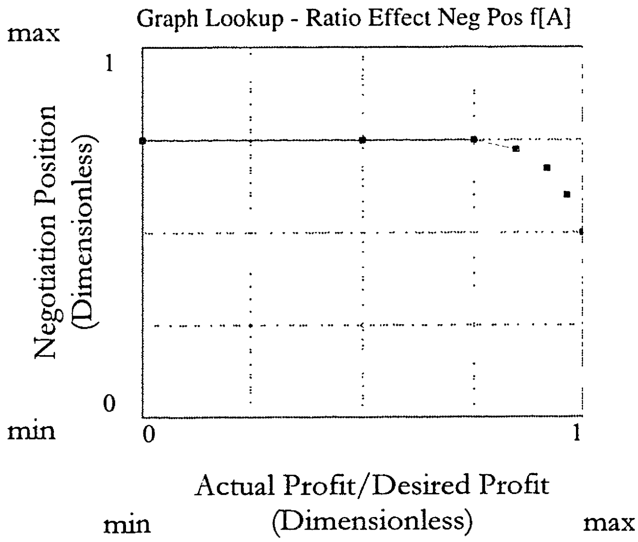

Fig. 3.4a Negotiation Position Function for Different Actual Profit to Desired Profit Ratio (Negotiator A)

The negotiation strategy used by the Negotiator A can be seen from the Fig. 3.4a. As we have previously explained, the Negotiator A has the threshold at 75% for the *Ratio of Actual Profit to Desired Profit.* It is again reflected in this figure by the curve between the ratio of 0.75 to 1. When the ratio drops below the threshold, 75%, it remains constant and it means that the negotiation position will no longer be adjusted. On the other hand, when we look at the shape of the curve, we will know how the Negotiator A's reaction is changing when his/her ratio is decreasing. The shape of the curve is concave downward, which means the position is getting harder in a decreasing rate. The decreasing rate can be interpreted as the Negotiator A is trying to take a stronger position to bring his/her ratio close to one when he/she is getting just less than 1. However, as the ratio is keep dropping, he/she is worrying that the stronger position may actually work against him/her and he/she is going to harden his/her position in a lower rate. Hence, the strategy of the positions to be taken in the negotiation turns out to be a concave downward curve. The range of the positions the Negotiator A is willing to take is between 0.5 to 0.75. He/she is going to take the moderate position, 0.5, when his/her *Ratio of Actual to Desired Profit* is 1 while he/she is taking a much stronger position, 0.75, when he/she is actually getting about 75% of his/her *Desired Profit.*

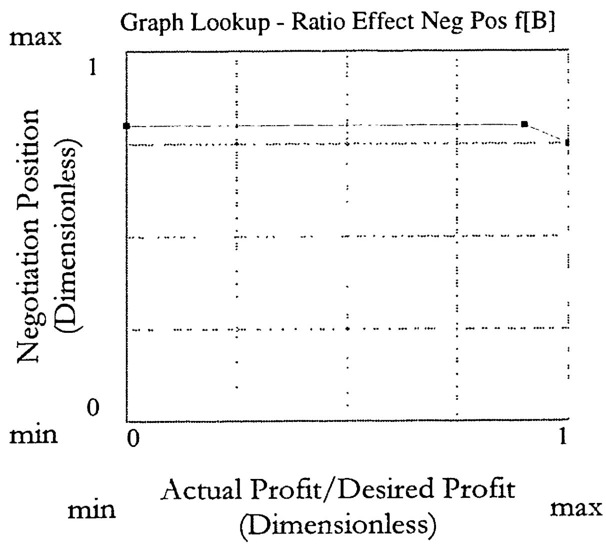

Fig. 3.4b Negotiation Position Function for Different Actual Profit to Desired Profit Ratio (Negotiator B)

In Fig. 3.4b, the different negotiation strategy chosen by the Negotiator B results on a different shape for the graph of the *Negotiation Position.* As we have stated earlier, the Negotiator B is the one adopting the hardest position. So, the range of his/her positions, which is between 0.75 to 0.8, is not as wide as Negotiator A's, which is from 0.5 to 0.75. Moreover, his/her strong position can be seen from another evidence. As his/her threshold is set at 90% as we have mentioned earlier, he/she is not changing position after he/she finds out that he/she is actually getting less than 90% of his/her stated wants. He/she is taking a moderate to strong position, 0.75, when he/she is actually getting what he/she wants, however, he/she will take a stronger position, up to 0.8, soon after he/she is getting just a little bit shy, say 0 to 10%, of what he/she wants. The straight line between the ratio of 0.9 to 1 means that the position is increasing linearly and constantly when he/she is getting lower ratio of the profits.

On the other hand, the Negotiator C is adopting a negotiation position strategy different from the other negotiators. It is shown in the Fig. 3.4c. As his/her threshold is set at 60%, he/she will not adjust his/her negotiation position after he/she is actually getting less than 60% of his/her desired profits. Hence, a horizontal line with the position of 0.75 will be taken for that range of the ratio. Then, when he/she is getting between 60 to 100%

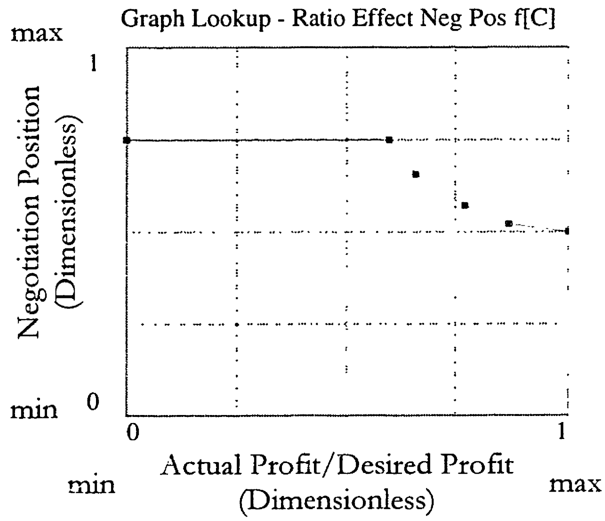

Fig. 3.4c Negotiation Position Function for Different Actual Profit to Desired Profit Ratio (Negotiator C)

of what he/she is asking for, his/her strategy and rationale of changing position is exactly opposite to that of the Negotiator A's. He/she is hardening his/her position in a increasing rate as a attempt to get a higher ratio of profits. The increasing rate of hardening the position results a curve which is concave upward even though the range of the positions for the Negotiator A and C are identical, 0.5 to 0.75, there is a major difference in the strategy. The Negotiator A harden the position right after the ratio is dropping from 1 to lower values while the Negotiator C does not change much of his position until he/she sees that he/she is only getting the threshold ratio.

As illustrated by the graphs of the *Negotiator Position*, there are countless of shapes can be chosen for the portion between the threshold and the 100% of the profit ratio. The negotiators should carefully defined their strategies of changing positions and reflected by the curves. Different shape of curve will lead to different outcomes of the negotiation and we will discuss this issue further in the consecutive section.

After the negotiator decides the negotiation position he/she is going to take in this round of negotiation, he/she needs to decide the amount of profit he/she is willing to foregone. This amount of profit is solely depending on the self interests and it is called the *Self Concession Rate*. It is formulated as the following:

$$\text{Self Concession Rate } \boldsymbol{i}$$

$$= \sum_{(\boldsymbol{i} = A,B,C,\ldots,N)\ (\boldsymbol{j} = 1,2,3,\ldots,n)} \text{Weight } \boldsymbol{i,j} * \text{Concession Rate f } \boldsymbol{i,j} (\text{Negotiation Position } \boldsymbol{i})$$

where *i* = Negotiator

j = Issues Being Discussed

Self Concession Rate *i* = Self Concession Rate of Negotiator *i*

Weight *i,j* = Weight of Issue *j* Perceived by Negotiator *i*

Concession Rate f *i,j* = Concession Rate Function of Issue *j* Defined by Negotiator *i*.

Negotiation Position *i* = Negotiation Position of Negotiator *i* Obtained from His/Her Negotiation Position Function

In other words, the *Self Concession Rate* of each negotiator is the sum of the weighted concession rates of each issues according to his chosen negotiation position. It is not uncommon to have different concession rates for different issues for a particular negotiator. Hence, the concession rate of each issues can be defined by each negotiator accordingly to reflect his strategy of changing concession rate. In our base run, we have assigned the same concession rates for different issues and different negotiators. The intention is to understand the impact of the overall strategy, such as the rate of adjusting *Desired Profit* and decision of choosing negotiation position, adapted by each negotiator on the outcome of the negotiation process. The assigned concession rate is shown in Fig. 3.5.

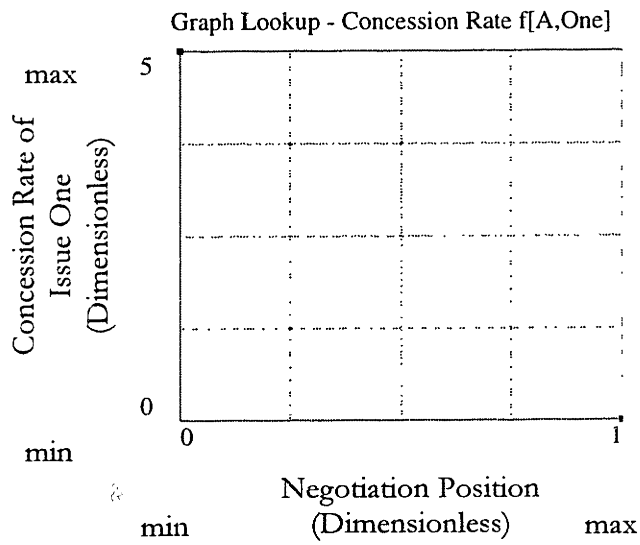

Fig. 3.5 Example of Concession Rate on Particular Issue by a Negotiator (The first issue by Negotiator A is shown)

In Fig. 3.5, the negotiation position adapting by a negotiator is shown on the x-axis while the amount of actual profit he/she is willing to foregone is shown on the y-axis. In our assigned concession rate, the amount of profit to be foregone by a negotiator is linearly proportional to the negotiation position. The harder the negotiator's position, the less the amount of profit he/she is going to give up in this round of position. It is assumed in the concession rate that no profit will be given up when the negotiator is taking a very hard position. On the other hand, the negotiator will only give up the maximum of 5 units of profit even when the negotiator's position is very soft. The purpose of using a linear concession rate here is only to help understanding the outcome of the simulated negotiation. It is highly recommended to tailor the concession rate after the outcome of the negotiation process is fully understood or a particular negotiation strategy has already been chosen.

As we have shown in the equation of the *Self Concession Rate*, the concession rates of each issues for each negotiator have to be weighted. The weight of issues are defined by the negotiator depending their own perception or their particular limitation of each issues. For example, if the organization, which the Negotiator A is representing, has some other projects in hand and it has a tight schedule of workforce, they will assign larger weights on any issues related to time and workforce. The negotiators can assign different weights on different issues to reflect their preferences, however, the sum of the weights of different issues have to be equal to 1. The following table summarizes the weights of different issues assigned by each negotiators in our base run.

Issues / Negotiator	One	Two	Three
A	0.5	0.3	0.2
B	0.3	0.4	0.3
C	0.2	0.3	0.5

Fig. 3.6 Summary of Weight of Different Issues by Different Negotiators

From the table, we can see that different negotiators have different issues which they will stress on during the negotiation. The Negotiator A finds the issue One is the most important to them while the Negotiator B and C find that issues Two and Three are the most important respectively. Different weight allocation scheme for the negotiating issues is expected to produce different outcomes for the negotiation. The effect of the allocation scheme will be further addressed in the following Section 3.3.3, Policy Analysis.

Up to this point, the negotiators should have already decided their own *Self Concession Rate* for this round of negotiation. However, how much profit they are really going to foregone, the *Higher Order Concession Rate*, will be the combination of their *Self Concession Rate*, *Effect of Attitude* and the *Rate of Interaction*. The formulation of the *Higher Order Concession Rate* of Negotiator A is shown as the following:

Higher Order Concession Rate[$\mathbf{i}_n$]

= (Effect of Attitude[$\mathbf{i}_n$, $\mathbf{i}_n$]*Self Concession Rate[$\mathbf{i}_n$]

+ $\sum_{j=1,2,\ldots,n-1}$ 0.1*Effect of Attitude[$\mathbf{i}_n$, $\mathbf{i}_j$]*(Self Concession Rate[$\mathbf{i}_j$]-Self Concession Rate[$\mathbf{i}_n$]))*Rate of Interaction f(Rate of Interaction)

where Effect of Attitude[$\mathbf{i}_n$, $\mathbf{i}_j$] = Effect of Attitude On Negotiator $\mathbf{i}_n$ By Negotiator $\mathbf{i}_j$

In this formulation, the *Higher Order Concession Rate* of Negotiator A is the sum of his own *Self Concession Rate* and the differences between his/her and the other negotiators' with the adjustment of the *Effect of the Attitude* and the *Rate of Interaction*. Except the *Effect of Attitude* on himself/herself, which has the value of 1, the *Effect of Attitudes* on a particular negotiator by the others will be assigned by that particular negotiator. In other words, the *Effects of Attitude* on Negotiator A by the Negotiators B and C are assigned by the Negotiator A. Moreover, the multiplier of 0.1 is included in the terms of the differences between the *Self Concession Rates*. This multiplier of 0.1 is interpreted as only 10% of the differences between the *Self Concession Rate of A* and the others' are considered during the determination of the *Higher Order Concession Rate* of the Negotiator A. This multiplier is to reflect the weight which the particular negotiator will assign to the differences between negotiator's *Self Concession Rate*. Therefore, higher percentage could be assigned if a particular negotiator feels that the *Higher Concession Rate* should be highly dependent on other's *Self Concession Rate* and vice versa. The values of the *Effect of Attitude* used in our base run are summarized in the Fig. 3.7.

However, the *Effect of the Attitude* should be adjusted according to the meeting schedule. Therefore, the *Rate of Interaction f* is introduced into the model and presented in Fig. 3.8. In that figure, the number of meetings held in a month is shown on the x-axis while the adjustment for the *Effects of Attitude* is shown on the y-axis. The *Rate of Interaction f* is formulated in a way that the Effect of Attitude is fully affecting the determination of the Higher Order Concession Rate when there are more than ten meetings per month. While the number of meetings is less than ten, the assigned values for the *Effect of Attitude* will be adjusted according to the Fig. 3.8.

Effect By / Effect on Negotiator	A (Value/Maximum Value)	B (Value/Maximum Value)	C (Value/Maximum Value)
A	1/1	0.5/1	0.5/1
B	0.5/1	1/1	0.5/1
C	0.5/1	0.5/1	1/1

Fig. 3.7 Summary of Effect of Attitudes on Different Negotiators

After each of the negotiators has decided their *Higher Order Concession Rate*, they have to decide the distribution of their forgone profits. For example, Negotiator A wants to distribute his foregone profits to the other negotiators evenly, so the factor for the distribution by Negotiator A on Negotiator B and C are 0.5 and 0.5 respectively. As the *Higher Order Concession Rate* is the forgone profit, hence the distribution factor for the negotiator himself has to be –1. The Fig. 3.9 provides the summary for the distribution factors used in our base run.

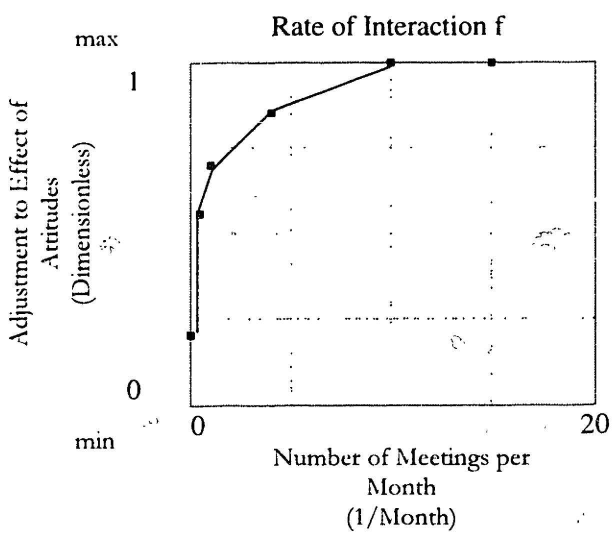

Fig. 3.8 Adjustment for the Effect of the Attitude according to the Frequency of Meeting

The products of the *Higher Concession Rates* and the distribution factors for each negotiators provide the profit changing rates for each of them. The profit changing rates will then adjust the *Actual Profits* of each negotiators and reflect the outcome of this round of negotiation. The entire procedure described above carries on for each round of negotiation and the outcomes of each round could be easily obtained through the computer simulation by VENSIM. The base run and some other policies, which have been implemented in the simulation model, are presented in the Section 3.3.3, Policy Analysis.

3.3.3 POLICY ANALYSIS

The *Base Run* is the simulation run with all the initial values used in our model. Some other simulation runs with different policies implemented are also provided following the graphs from the *Base Run*. For each of the simulation runs, the graphs of *Desired Profit* and *Actual Profit* are analyzed to provide some intuition of choosing the appropriate negotiation strategy.

By / Higher Order Concession Rate Distribution on	A (Value/Maximum)	B (Value/Maximum)	C (Value/Maximum)
A	-1 (Always Equals –1 for Himself/Herself)	0.5/1	0.5/1
B	0.5/1	-1 (Always Equals –1 for Himself/Herself)	0.5/1
C	0.5/1	0.5/1	-1 (Always Equals –1 for Himself/Herself)

Fig. 3.9 Summary of Higher Order Concession Rate Distribution by Each Negotiators

Base Run:

The *Desired Profit* of the *Base Run* is shown in Fig. 3.10a. We can see that the *Desired Profit* of each negotiators are declining. However, their critical changes of the *Desired Profit* happen at different particular time for each of the negotiators. The Negotiator C is the first one to lower his/her *Desired Profit*, followed by the Negotiator A and then Negotiator B. This pattern is due to their individual utility function for *Reaching Agreement due to Time Pressure*. As we have mentioned in the Section 3.3.2, the Negotiator C is the first one who will feel a larger change in pressure and hence it is reasonable that he/she is the first one to adjust his/her *Desired Profit*. For the similar reason, as the Negotiator A will have the critical change in the time pressure earlier than that of the Negotiator B, the Negotiator A will have lowered his *Desired Profit* earlier than the Negotiator B. After the *Desired Profit* of the negotiators are determined before the next round of negotiation, the *Ratio of Actual Profit to Desired Profit*

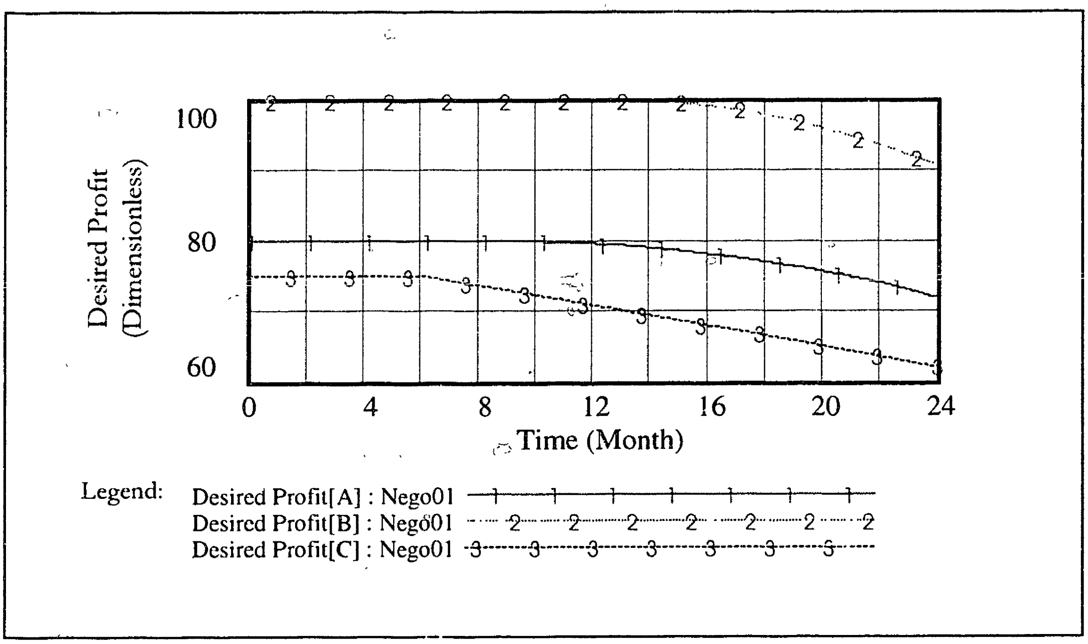

Fig. 3.10a Graph for Desired Profit

will determine the negotiation positions of each negotiators. Then, the *Self Concession Rate* of each negotiators will be decided according to their *Concession Rates* of each weighted issues.

After adjusting the *Self Concession Rates* by the *Effect of Attitudes* and the meeting schedules through the *Rate of Interaction f*, the *Higher Order Concession Rates* are determined for each negotiators. The *Higher Order Concession Rates* are then distributed according to their distribution factors and hence the *Actual Profits* of each negotiators after this round of negotiation will be determined. The *Actual Profits* of each of the negotiators throughout the negotiation process is shown in the Fig. 3.10b.

As shown in Fig. 3.10b, the *Actual Profit* of Negotiator A slightly increases starting after 8 months of negotiation. Negotiator B has more *Actual Profit* starting from the second month of discussion while the Negotiator C is losing his/her *Actual Profit* about the same time. The Fig. 3.10b shows the change of the *Actual Profit* throughout the process and hence an agreement will be reached at the particular time when all the negotiating parties find their

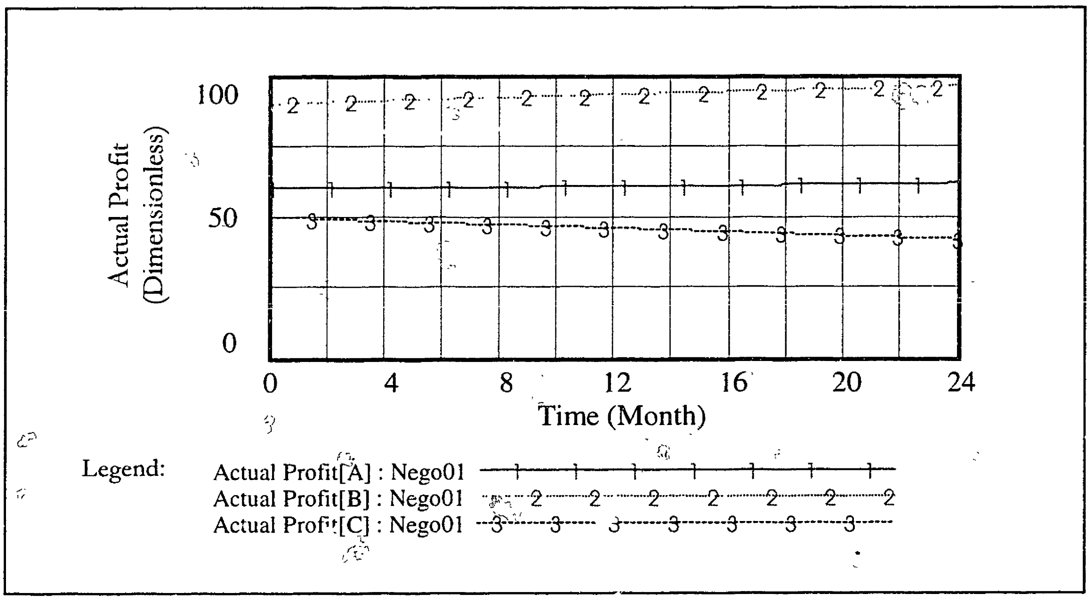

Fig. 3.10b Graph for Actual Profit

Actual Profit at that time is acceptable and they are willing to settle. It is important to keep in mind that the *Actual Profits* at 24th month is not necessary the settlement they would like to settle. Rather, it is the last settlement they can reach before the end of the project if they have not reached any agreement by the earlier rounds of negotiation. In other words, it will be more favorable to the Negotiator C if he/she reaches a settlement in the earlier rounds because his/her *Actual Profits* could only become further less while Negotiator B will be more beneficial if he/she waits till the end of the 24 months of negotiation. The reason of changing *Actual Profit* is the interaction of the loops in the model. By understanding some of the important elements, we could have some intuition of this process. In Fig. 3.10c, it shows the change of the negotiation positions throughout the discussion.

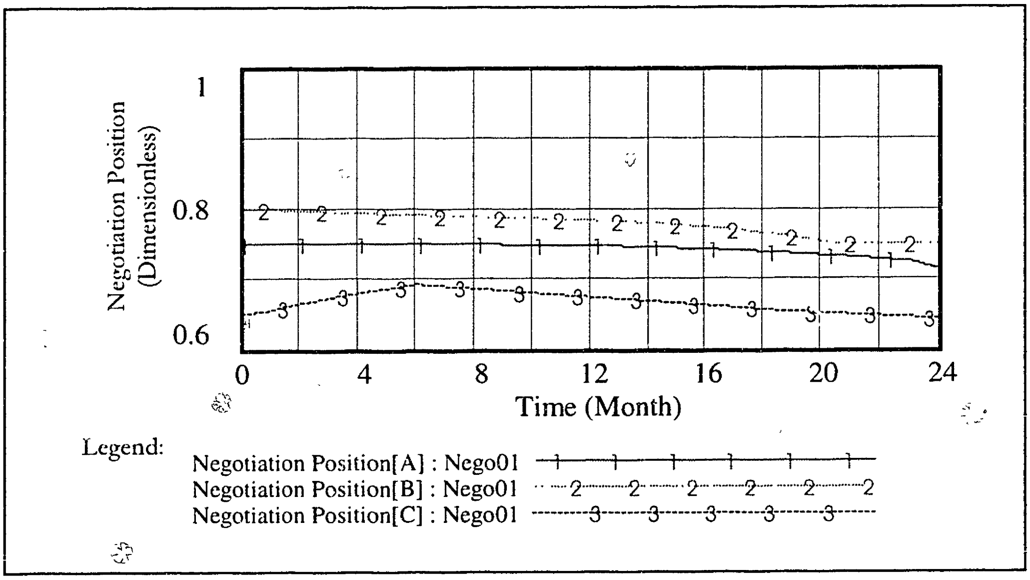

Fig. 3.12 Graph for Negotiation Position of Negotiators

The Negotiator C keep strengthening the position before the sixth month of negotiation as he/she knows that he/she will feel a significant increase in the time pressure after the sixth months to reach agreement due to his/her other projects' schedules. Therefore, he/she wants to reach a more favorable agreement by the sixth month by showing a stronger position. However, the others do not change much of their position and hence the *Actual Profits* of each negotiators have not changed much within that period of negotiation. After six months of negotiation, the Negotiator C will have to take a softer position associated with the lowered *Desired Profit* as shown in the Fig. 3.10a. After knowing the results of the *Base Run*, we would like to implement different policies to help us develop an approach for picking the appropriate strategy. The policies implemented are summarized as the following:

Nego 02:

In this Run, the *Concession Rate* of a Particular Issue by Negotiator A has been modified from the shape shown in the Fig. 3.5 to a concave downward curve as shown in Fig. 3.11.

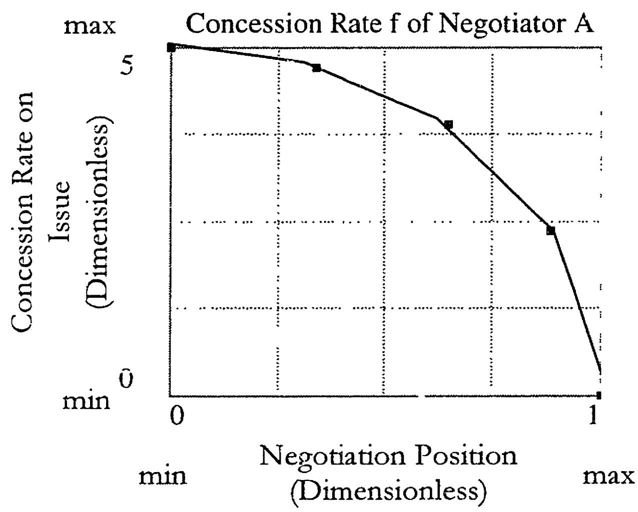

Fig. 3.11 Modified Concession Rate of Particular Issue by Negotiator A

When the *Concession Rate* is modified as shown, it means that the particular negotiator, which is Negotiator A in this case, will give up more than the rate in the *Base Run* for the same given negotiation position. The purpose of this run is to understand if there will be any changes in the *Actual Profits* of the negotiators.

Nego 03:

The *Concession Rates* of any particular issue are changed from the one shown in the Fig. 3.5 to the one shown in Fig. 3.12.

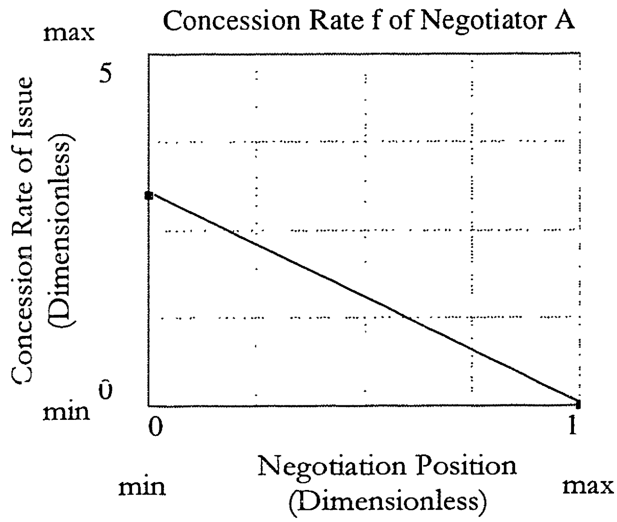

Fig. 3.12 Modified Concession Rate of Particular Issue by Negotiator A

The maximum concession rate has been changed from 5 units of profit to only 3 units. The purpose of this run is to understand the changes in the *Actual Profit* after the *Concession Rate* has been lowered by a particular negotiator. The results of the *Nego 02* and *Nego 03* in terms of the *Actual Profit* are shown in the Fig. 3.13 and are compared to the *Base Run, Nego 01*.

The Fig. 3.13 gives us a good evidence of the changes in the *Actual Profit* of the negotiators after the two policies are implemented. We will further discuss the changes in Section 3.3.4, Model Analysis and Suggested Strategies / Policies From Model.

The other policy, which we would like to implement and understand the impact on the *Actual Profits,* will be the allocation of the weight on different issues. In order to understand this policy, another set of simulations, *Nego* 04 and *Nego* 05, have been run.

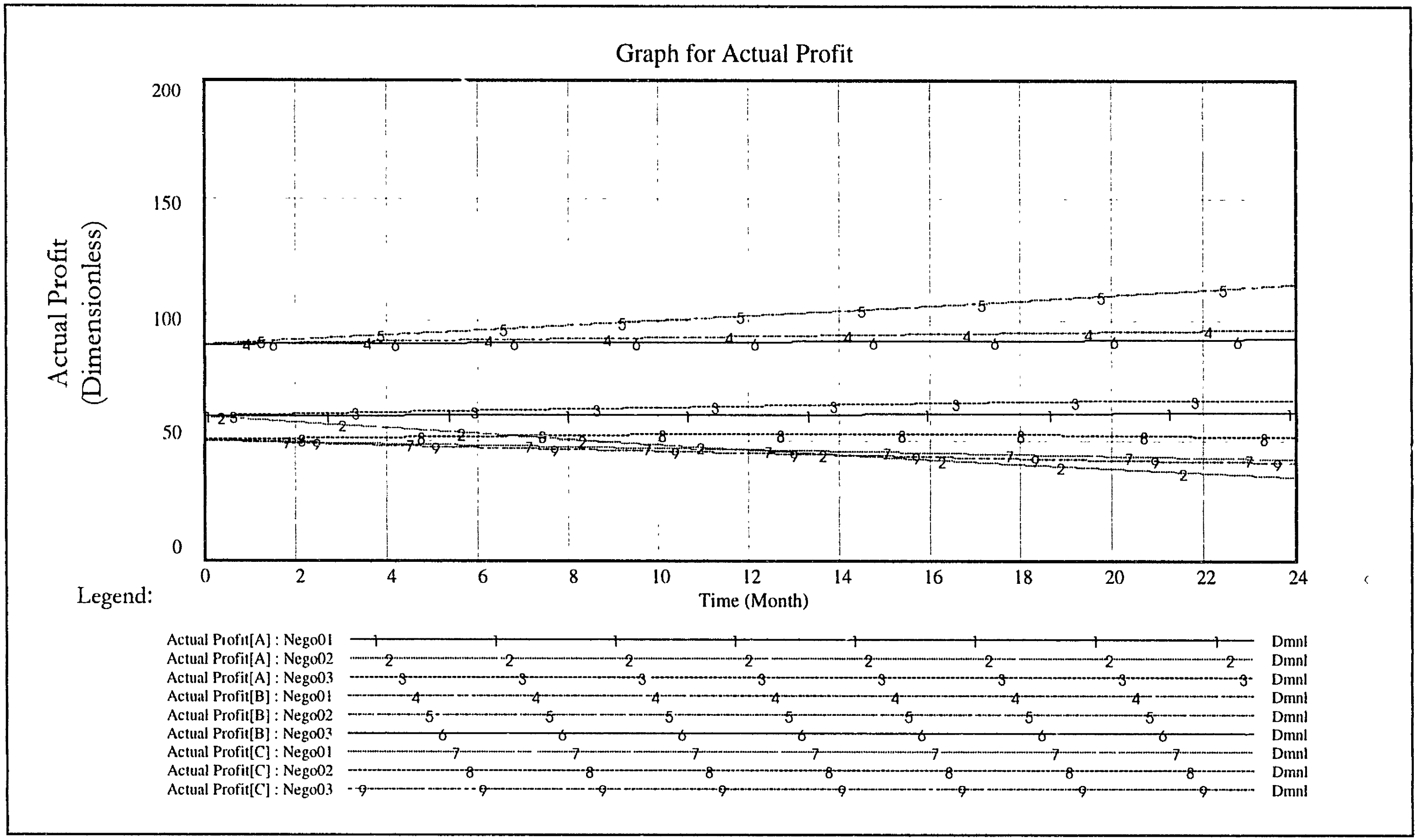

Fig. 3.13 Graph for Actual Profits of the Base Run (Nego 01), Nego 02 and Nego 03

Nego 04

In this simulation run, we have kept the same weight allocation scheme as the one used in the *Base Run*. However, different set of *Concession Rates* are assigned to all of the negotiators. For the *Concession Rate* with respect to the Issue One, it is changed from the one in Fig. 3.5 to that shown in the Fig. 3.12. The new *Concession Rates* for the Issue Two and the Issue Three are shown in the Fig. 3.14 and 3.15 respectively.

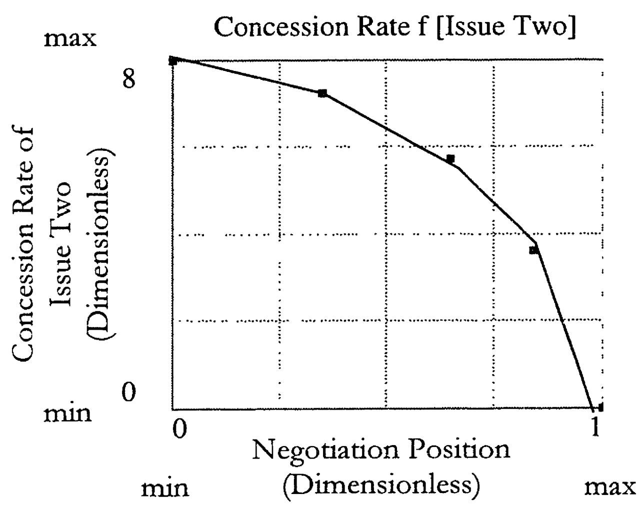

Fig. 3.14 Modified Concession Rate for Issue Two

Nego 05

We have changed the weight allocation scheme for the Negotiator C. The new weight associated with the issues are 0.5, 0.3 and 0.2 for the Issue One, Two and Three respectively. This allocation scheme is the same as the Negotiator A and we would like to understand the impact to the *Actual Profits*. The result of this run is compared to that of *Nego 04* and it is shown in the Fig. 3.16. The comparison of these two simulation runs will be further discussed in the Section 3.3.4, Model Analysis and Suggested Strategies / Policies From Model.

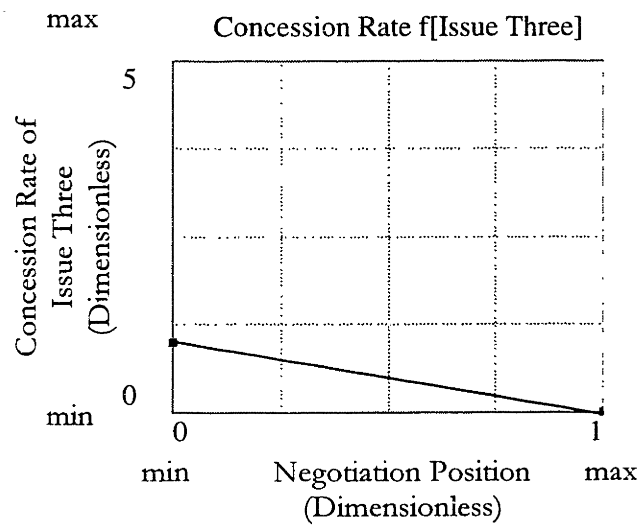

Fig. 3.15 Modified Concession Rate for Issue Three

3.3.4 Model Analysis and Suggested Strategies / Policies From Model

As we have known from the *Base Run*, the first negotiator who will feel the time pressure and needed to change the *Desired Profit* is likely to get less *Actual Profit* as the negotiation process goes on. So, we know the utility function for the *Time Pressure* is one important factor in the negotiation process. However, as this utility function might not be flexible enough to give the negotiator their preferred pattern, the negotiator could only try to reach an agreement by the particular time which they will have a critical change in the time pressure. On the other hand, if we know there is a particular time which an individual negotiator will likely give up larger amount of *Actual Profit* to reach an agreement, it will become an advantage to us. It might be wiser to push the negotiation past that mark in order to obtain more *Actual Profits* from the negotiation process. However, this does not necessary

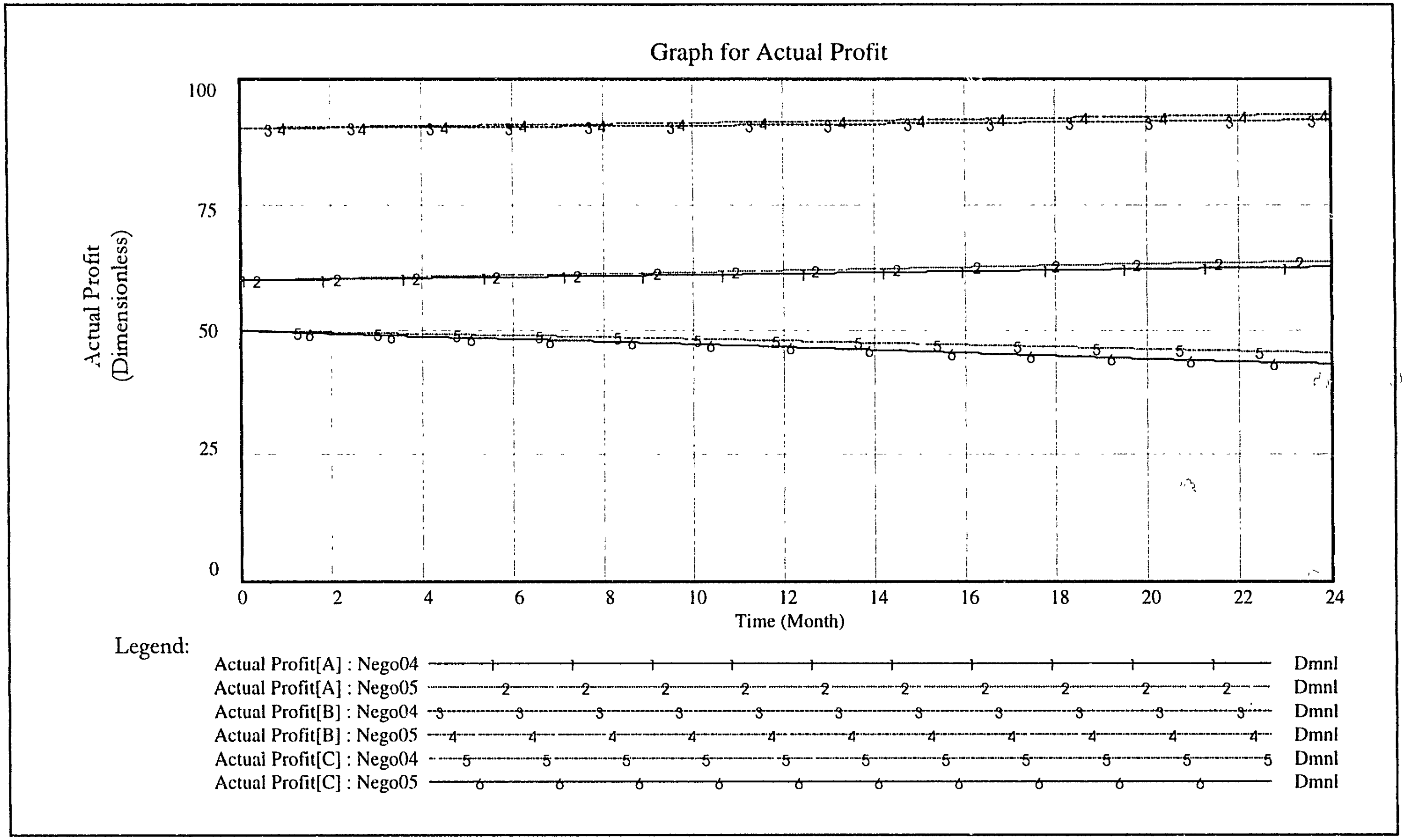

Fig. 3.16 Graph for Actual Profits of the Nego 04 and Nego 05

mean that we are no longer in the collaborative environment. Because as long as we are achieving the common goal, finishing the project on time and not hurting other parties while we are not getting marginal benefits, our negotiation is still considered to be a collaborative negotiation by definition.

Then, from Fig. 3.13 in which it shows the result of the *Nego 02* simulation run, we know that the concave downward concession rate will significantly lower the *Actual Profit* of that negotiator. The forgone *Actual Profit* from Negotiator A has been distributed to the others. The reason of this lowered *Actual Profit* is due to the early and large concession rate adapted by Negotiator A in this simulation compared to that adapted in the *Base Run*. It is reasonable to assume that the positions taken by each of the negotiators are harder during the early stage of negotiation because they would like to ask the most out of the negotiation process. However, the Negotiator A is now giving up more even when he/she is taking quite a hard position. In this case, he/she is getting less than, or giving up more than, he/she needs to during the early stage. As we can see from the simulation graph, the *Actual Profits* of each negotiators are following a trend of either keep increasing or keep decreasing. Therefore, when Negotiator A is giving up more than he/she needs to, compared to the *Base Run*, he/she can only get into the trend of getting less and less as the negotiation proceeds. The concave downward concession rate has made the Negotiator A become the one with the least *Actual Profit*, rather than Negotiator C being the one with the least in the *Base Run*. While the Negotiator B has the toughest position function and less time pressure as negotiation proceeds compared to the Negotiator C, his/her *Actual Profit* in this simulation is still the highest, with value larger than that in the *Base Run*.

Then, the results of the *Nego 03* shows that the *Actual Profit* of the Negotiator A can be increased by lowering the maximum value of his/her *Concession Rate* on some/all of the issues. By doing this, Negotiator A has increased his/her *Actual Profit* while the other negotiators are all getting less than that in the *Base Run*. This result can be explained by considering the lowered *Concession Rate* is equivalent to adapting a harder position during the position. It is because all the values on the *Concession Rate* function in this run are equivalent to those corresponding to a harder position in the *Base Run.* This is illustrated in the Fig. 3.17.

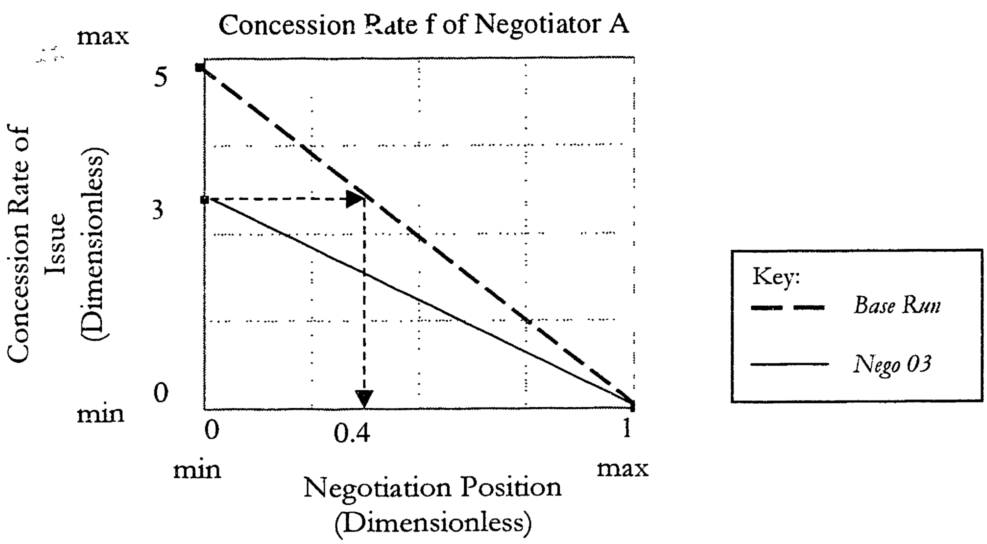

Fig. 3.17 Comparison of Concession Rate of Negotiator A

From Fig. 3.17, we can see that the maximum *Concession Rate* of the Negotiator A in the *Nego 03* is actually equal to the *Concession Rate* he/she will be taking when his/her negotiation position is 0.4 in the *Base Run.* Therefore, he/she is taking a harder position in this run and hence we can conclude that the increase in the *Actual Profit* of the Negotiator A is due to his/her hardened negotiation position while no change in his/her time pressure function.

After knowing to avoid having a concave downward concession rate function but to lower the maximum concession rate, we could have some more intuition by analyzing the simulation runs, Nego 04 and 05. The results are shown in the Fig. 3.16. The *Actual Profit* of the Negotiator C is lowered while the others are increased after the Negotiator C has changed his/her weight allocation scheme as the Negotiator A's in the *Nego 05.* It can be explained by looking at the *Self Concession Rate* of the negotiators. As we have explained in the earlier section, the *Self Concession Rate* of each negotiators is determined by the weighted mean of their *Concession Rates* of each issues. The *Concession Rates* of the Issue One, Two and Three have the important characteristics as summarized in Table 3.1:

CONCESSION RATE	CHARACTERISTICS
Issue One	The maximum concession rate is 3. It is a straight line concession rate.
Issue Two	The maximum concession rate is 8, which is the highest for all of the concession rates. Moreover, it is a concave downward curve.
Issue Three	The maximum concession rate is 1 only, which is the lowest for all of the concession rates. It is also a straight line concession rate.

Table 3.1 Characteristics of Concession Rates Used in the Nego 04 and 05

As the Negotiator C has changed his/her emphasis from Issue Three, which has the lowest maximum value for the *Concession Rate*, to Issue One in the *Nego 05*. His/her new *Self Concession Rate* will become closer to the characteristics of Issue One due to the new and heavier weight. In other words, his/her maximum value for the *Concession Rate* will now be higher than that in the *Nego 04*. According to the results of the *Nego 03*, we know the higher maximum *Concession Rate* will be equivalent of switching to a softer negotiation position function and it will lead to the loss of *Actual Profit*. This agrees to the result of the run, *Nego 05*. Therefore, by assigning heavier weights to the *Concession Rates* equivalent to a softer negotiation position function will lead to lowered *Actual Profits*. Then, it might be reasonable to assume that the Negotiator C will lose even more *Actual Profits* if they assign the heaviest weight to the *Concession Rate* of Issue Two. It is because that the *Concession Rate* of Issue Two has the highest maximum *Concession Rate* and the concave downward shape. In order to verify this expectation, we have run another simulation, *Nego06* and the result is shown in the Fig. 3.18.

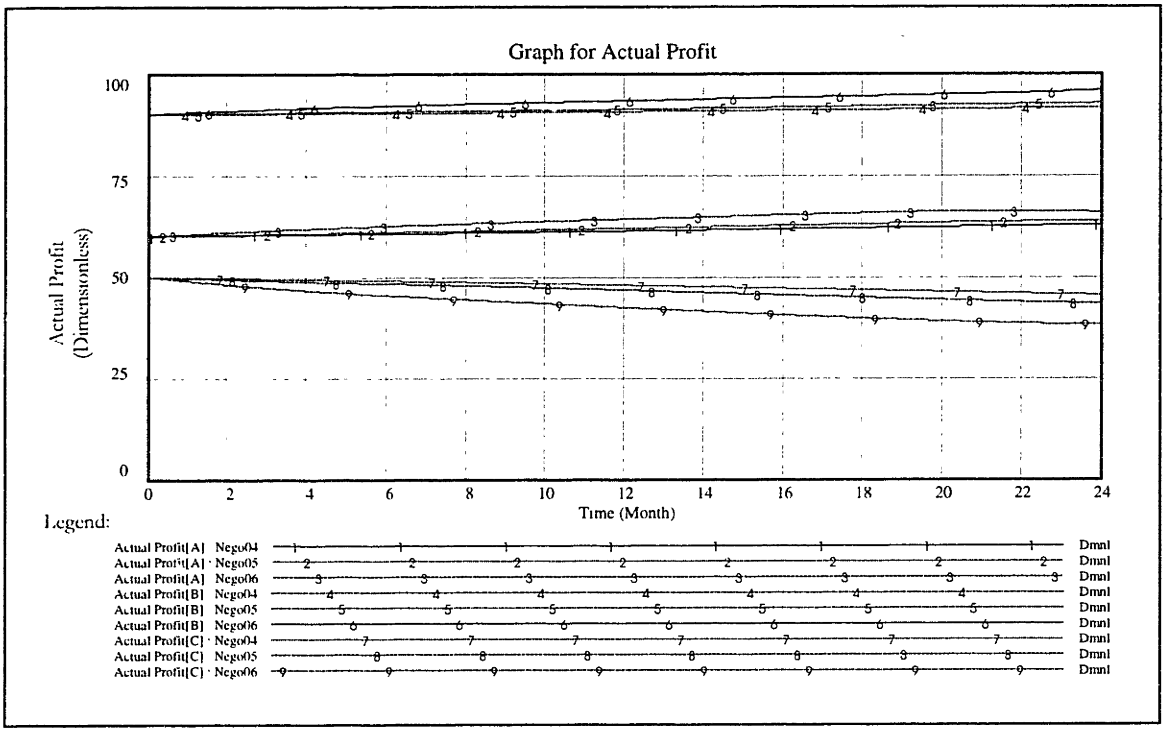

Fig. 3.18 Graph for Actual Profits of the Nego 04, Nego 05 and Nego 06.

The result agrees to what we have expected. The *Actual Profit* of the Negotiator C is further reduced while the other negotiators are getting more profits than those in the *Nego 05*. Therefore, we can conclude that assigning heavier weight to the softer *Concession Rate* will lead to a higher *Self Concession Rate* and it will lead to a drop in the *Actual Profit* of that particular negotiator, assuming the same *Higher Order Concession Rate* distribution factors, *Effect of Attitude* and *Rate of Interaction f* are used.

From all the simulation runs we have conducted for the negotiation model, we have found the following facts. They will be critical in order to determine the optimal or the most efficient strategy.

- Time Pressure Function – It is important not letting other negotiating parties know your critical changes in the *Time Pressure Function*, which mainly depends on the flexibility of your schedule or resources. From our *Base Run*, we know that the earlier you need to adjust your *Desired Profit*, the more likely you are going to get less *Actual Profit*, even if you are trying to take a harder position in the early stage of the negotiation.

- Concave Downward Concession Rate – As we have shown in the simulation run, *Nego 02*, we know that the concave downward *Concession Rate* will lead to a drop in the *Actual Profit*. It is due to the larger amount of forgone profit during the early stage of negotiation. Hence, it is important to determine the shape of the *Concession Rate* before the negotiation. It will be more beneficial if the negotiator can have a declined straight line function or even concave upward one if it is possible.

- Lower the Value for Maximum Concession Rate -- We have shown in the *Nego 03* that the lower value for the maximum *Concession Rate* will be equivalent to taking a harder negotiation position function. The harder negotiation position will lead to an increase in the *Actual Profit* of that particular negotiator.

- Avoid Assigning Heavy Weight to Softer Concession Rate – The comparison of the results from the runs, *Nego 04, Nego 05* and *Nego 06*, shows that assigning heavy weight to softer concession rate function will lower the negotiator's *Actual Profit* even if all the *Concession Rate* function remains the same. It is due to the change in the *Self Concession Rate* after the modification of the weight allocation scheme. Therefore, it is important to stress on either the issues which are the most flexible but quite beneficial to us or those are important to other negotiators but with little flexibility. In that case, we could always get the higher *Actual Profits* as we could take a harder position function on those issues.

Nevertheless, the simulation runs only serve the demonstration purpose. The negotiators should not limit their strategies to those tested and implemented in those runs. They may need to implement some other policies or use different combinations of policies implemented in our earlier sections. Moreover, some adjustments may be needed for the model to correctly reflect the situation of the negotiation. For example, the number of negotiators and issues in the models are arbitrary chosen as three respectively and they should be changed accordingly to the particular negotiation. The modifications can be easily done through the computer program, VENSIM (The Ventana Simulation environment Vensim DSS32 Version 3.0D1 Copyright © 1988-1997 Ventana Systems, Inc). It is the interest of this research to provide a handy model for the negotiators to implement different policies at different negotiation situation.

For those negotiators who have never been exposed to the ideas of system dynamics or have never used VENSIM, we have developed a *Negotiation Game* computer program. That program uses the game interface provided by the VENSIM and allows the negotiators to implement different combinations of preselected policies. The results of those implemented policies are shown on the screen after each time step and it allows the negotiators to change the policies in the middle of the simulated negotiation. The Negotiation Game is presented and is further explained in the Section 3.4, Negotiation Game.

3.4 NEGOTIATION GAME

The Fig. 3.19 shows the screen disply for the Negotiation Game. As this program is intended for those negotiators who have not exposed to the idea of System Dynamics principles or have never used VENSIM, we have designed it to show some of the main concerns during the negotiation such as the *Desired Profit*, *Actual Profit* and the *Negotiation Position* while to allow the users to implement different policies, which is the weight allocation scheme and the *Higher Order Conceession Rate* distribution factor. The users can also

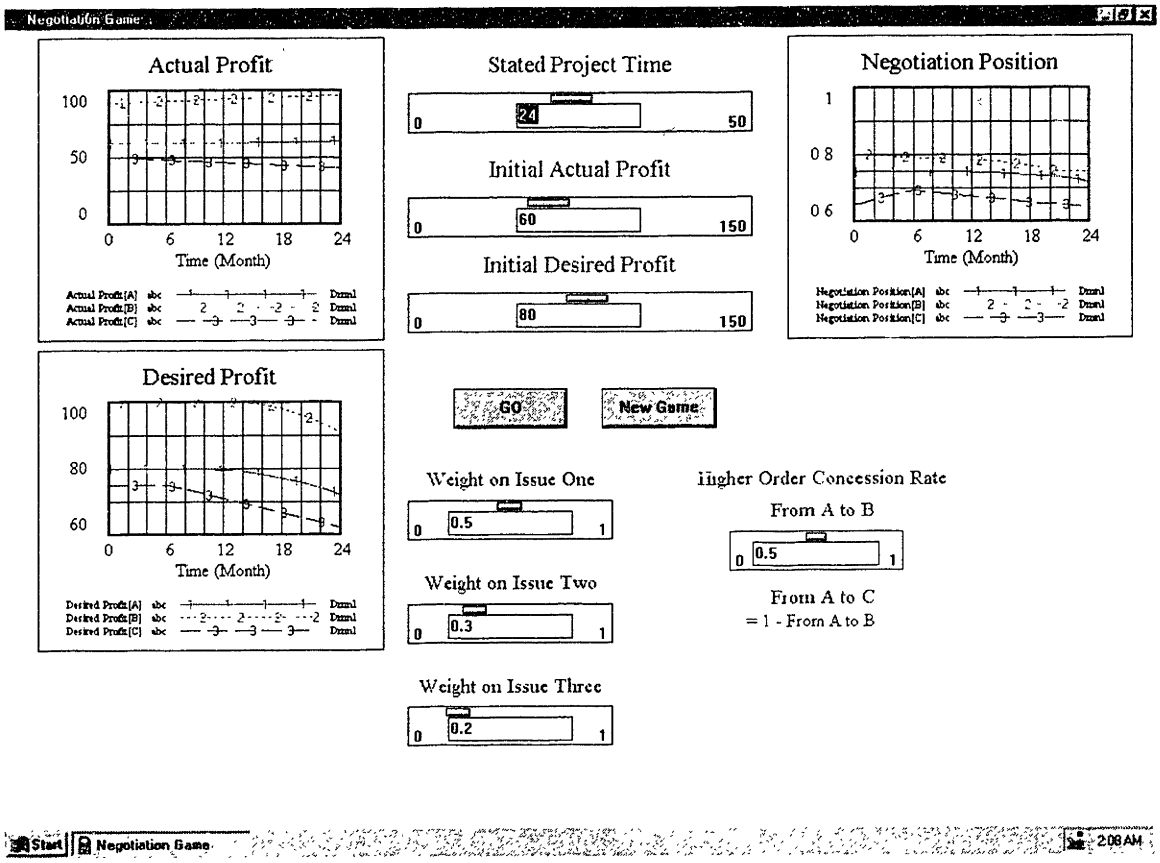

Fig. 3.19 Display of Negotiation Game

input the project duration, the initial *Actual Profits* and the initial *Desired Profit* according to their negotiaion. The time step set for this program is one month. Therefore, the changes in the *Actual Profit*, *Desired Profit* and the *Negotiation Position* can be seen one month after the policy is implemented and the negotiator can change to some other policy for the next time step. The negotiators then can implement different combination of policies at different time during the negotiation and determine the optimal strategy.

This program can provide the negotiators a handy tool to understand the changes of the main concerns in the negotiation. However, as there is a limitation to the number of policies can be implemented, they are advised to implement some other strategies in the original model discussed in the earlier section after they have obtained some intuition of the negotiation process from this Negotiation Game. The following step-by-step example is provided for helping users understand this handy tool.

Step 1:

First of all, the users need to input the project duration, their *Actual Profit* and *Desired Profit* before entering the negotiation as the *Stated Project Time*, *Initial Actual Profit* and *Initial Desired Profit* respectively at the spaces provided in middle column of the screen. For example, the Negotiator A is negotiating a project which is scheduled for 24 months and he/she is asking for 80 as the profit while he/she is having only 60 before the negotiation. The profit he/she is having right now is the *Initial Actual Profit* and hence is 60 for this case while the profit he/she is asking for is the *Initial Desired Profit* and hence equals 80 in this example. The project duration, 24 months, will be input as the *Stated Project Time* as shown in Fig.3.19. The range of input for the *Stated Project Time* is from 0 to 50 months and they are shown in the box under the *Stated Project Time.* Similarly, the ranges of inputs for the *Initial Actual Profit* and *Initial Desired Profit* are from 0 to 150, which are also shown in the boxes under their corresponding titles.

Step 2:

The users need to decide the weight allocation scheme for this negotiation. They have to assign weights for each of the issues while the sum of the weights for different issues always equals one. In this example, Negotiator A decides to assign 0.5 for Issue One while to assign only 0.3 and 0.2 for Issue Two and Issue Three respectively. The sum of the weights equals one as we have just stated. Hence, the 0.5,0.3 and 0.2 are input in each of appropriate boxes in the middle column of the screen. The ranges of weight can be assigned are also included in each of those boxes.

Step 3:

The last input needed by the user will be the *High Order Concession Rate* distribution factors for other negotiating parties. As we have explained in Section 3.3.2, Model for

Multiple Negotiating Parties, the *Higher Order Concession Rate* distribution factor for the user himself/herself is always –1 while the sum of the distribution factors for other parties always equals 1. In this example, as Negotiator A decides to distribute his/her *Higher Order Concession Rate* evenly, the distribution factors for the Negotiator B and C are the same, 0.5. However, when some other factors are used, the user can input the distribution factor for one party, say Negotiator B, and then the other's, i.e. Negotiator C's, will be one minus that distribution factor, which is Negotiator B's in this example.

Step 4:

The Negotiation Game is now ready to run. The users can now click on the GO button at the center of the screen and the program will simulate the results of the *Actual Profit, Desired Profit* and the *Negotiation Position* for one month. Those results will be shown on the appropriate graph as those in Fig. 3.19. The user can then review the results and understand the pros and cons of the last implemented strategy before deciding to use the same strategy or implement some other policy for the next month. After the decision is made, the user can click on the GO button again to simulate the outcome for the next month. The game will finish when the time reaches the *Stated Project Time*. However, the user can click on New Game button if he/she wants to quit anytime during the game.

CHAPTER 4

SYSTEM DYNAMICS MODEL FOR THE NEW HONG KONG AIRPORT PROJECT

Some of the information of the Hong Kong new airport located in Chek Lap Kok will be provided at the beginning of this chapter. Then, the problems encountered on the opening day are summarized along with the possible reasons for those fallouts. The system dynamics models built for this airport in order to analyze those fallouts will then be presented. The model consists of six different sectors, which represent areas of concern with the airport. The layouts and mechanisms for each of those six different sectors will also be provided along with the explanation of the formulations, mechanisms and look up graphs used in the VENSIM for this model. Policy analysis will be performed for different scenarios in order to understand the impact of the improved *Opening Day Performance* on the *Overall Performance* of the new airport. Simulation graphs obtained from VENSIM will be provided and discussed in the Section 4.2.2, Model Analysis and Suggested Strategies/Policies From Model, followed by suggested policies from the airport models.

4.1 SUMMARIZED INFORMATION OF HONG KONG AIRPORT

Hong Kong is one of the major Asian cities in the world with 6.6 million population and US$ 40 billion in GDP. As the demand of handling the flow of passengers and cargoes has been significantly increasing, the construction of a new airport has been proposed in the early 90's. The new airport is expected to replace the old international airport at Kai Tak – one of the busiest international airports for passengers and cargoes in the world. The new

Hong Kong International Airport, which locates at Chek Lap Kok, is one of 10 infrastructure projects known collectively as the Airport Core Programme (ACP). The whole developments program is consisted of 34 kilometers of expressways and tunnels; a high-speed rail link which connects the airport with Hong Kong's major population centers; the world's longest road-rail suspension bridge; a third cross-harbor tunnel linking Hong Kong to Kowloon, and a new town development. The total cost of the ACP was projected as HK$155.3 billion (US$19.9 billion) [Ajello, 1998; Hong Kong Airport Authority, 1998].

The Chek Lap Kok New International Airport was opened for business on July 6, 1998. The airport opened with a single runway and facilities which were able to meet the annual demands of 35 million passengers and three million tons of air cargo. A second runway and associated facilities are projected to be opened by the end of 1998 [Hong Kong Airport Authority, 1998]. In 1990, the Hong Kong Government established the Airport Authority, which was responsible for planning, designing and contracting the construction of the new airport. It was also responsible for the construction of the airport island, its runways and airfield, the passenger terminal complex and all on-island infrastructure. The Airport Authority would retain strategic control over airport operations and the airport business, while the private sector would operate individual businesses on the island under franchise and license agreements. On the other hand, the Hong Kong Government is responsible for air traffic control, police, fire services and other institutional facilities such as the airmail center [Hong Kong Airport Authority, 1998].

As the new airport is estimated to be worth US$ 20 billions, the government and the public had expected the airport to be a state of the art and one of the best in the world. However, due to the conditions and the constraints provided during the construction, the construction did not proceed as smooth as planned. Those conditions and constraints are mainly due to the time pressure, the political influence from the government, the organization structure which seems offering non-specialists the control over the technical consultants and the high dependence on foreign consultants and contractors [Hajari, 1998].

The construction of the new airport was under tremendous time pressure of finishing the projects by a very unlikely, if not impossible, opening day. Actually, the opening day of the Hong Kong Airport was once set at April 1998 and then it was pushed back to July 6, 1998. The reasons of rushing the completion of the New Hong Kong Airport are both economic and political. Hong Kong's $20 billion airport project includes not only Chek Lap Kok itself but also a network of expensive roads, rail lines and bridges. The sooner all could be started to provide service, the sooner revenues could be generated to pay interest on the huge debts incurred in construction. Hong Kong Airport Authority spokesman Clinton Leeks stated that pushing back the airport's opening merely nine weeks, from April to July 6, cost the authority more than $21 million in sacrificed income, as well as maintenance and interest costs [Ajello, 1998; Hong Kong Airport Authority, 1998; Law and Saludo, 1998].

The public believed that the Government of Hong Kong and Hong Kong Airport Authority was rushing the opening of the airport not only because they wanted to avoid the large amount of interest payment due to the delay of the project but also to use the inauguration to boost the public's satisfaction with the local government after the first but disappointing year under the Chinese government [Ajello, 1998]. It is widely believed in Hong Kong that the Hong Kong Government just could not afford to announce the delay of the opening day for the second time in 3 months, especially when Hong Kong is under the shadow of the worst economy recession and the highest unemployment rate in a decade [Hajari, 1998; Law and Saludo, 1998]. Moreover, many suspects that the opening day has been chosen on July 6 simply because the visit of the Presidents of China and the United States, who have officiated the formal inauguration on July 2 by landing and leaving from the new airport [Hajari, 1998; Law and Saludo, 1998].

As we stated in the previous paragraph, the airport was opened under the government's pressure. It is suspected that the government exerted the influence through the Airport Projects Steering Committee, which was headed by the Chief Secretary Anson Chan Fang On-sang, and the Airport Authority [Morrison, 1998]. The organization structure of the Airport Authority was criticized by former airport officials as it allows the senior management, who were mostly trained as government administrators and did not have the experience and competence to run and manage an airport in this scale, making key decisions rather than those local middle mangers who used to work at Kai Tak, old Hong Kong Airport. One consultant from consulting firm Mckinsey & Co. even said that the Hong Kong Airport Project provided a classic situation on a big project that nobody wanted to give the top people the bad news and the people who knew the problems probably weren't even in the meetings [Hajari, 1998].

There are two evidences that the Hong Kong Government had influenced the decision of the opening day. Firstly, Asiaweek questioned the Airport Authority's decision to ignore the warnings and reports, which pointed out that there were still a lot of serious deficiencies and potential problems at Chek Lap Kok, as well as documents from a subsidiary office coordinating the airport-related works which urge an October opening at the earliest [Morrison, 1998]. Moreover, the managing director of Hong Kong Air Cargo Terminals Ltd. (HACTL) had already warned that the overnight move from the Kai Tak Airport to the new airport in Chek Lap Kok was almost impossible [Ajello, 1998; Gittings, 1998; Law and Saludo, 1998].

From all the information summarized above, we could see that the airport project was under economic and political pressure to meet the deadline set by the Hong Kong Government and the Airport Authority. However, it maybe the scale of the project or the insufficient amount of information released, the public has never realized the chance of having a unsatisfactory performance for the operation on the opening day of the US$20 billion new airport [No, 1998].

4.1.1 FALLOUT OF GRAND OPENING

The opening of the Hong Kong new airport was disastrous [Gittings, 1998; Williams, 1998]. The rush opening led to the widespread breakdown, which included Chek Lap Kok's flight display, baggage, cargo and airbridge systems [Ajello, 1998; Braude, 1998; Cheung, 1998]. Flight information boards displayed the wrong gate numbers, or often none at all [Hajari,1998]. Apart from some 10,000 bags missing their flights on the opening day [Manuel, 1998; Smith, 1998] some passengers claimed to have waited up to five hours to retrieve their baggage, while even on July 7, which is the second day of operation, over 60% of flights were delayed by an hour or more [Cheung, 1998]. In addition to those problems, there were other deficiencies such as the unconnected phones, filthy toilets, unfinished construction work, escalators and ticket machines broke down and air-conditioning failed [Ajello, 1998; Hajari, 1998].

However, the poor performance did not stop there. The worst of all was the nine-story complex run by Hong Kong Air Cargo Terminals Ltd. (HACTL) [Gittings, 1998]. The facility, which like much else at Chek Lap Kok had been touted as the world's biggest and best of its kind, broke down after only a day of operation [Clarke and Tsang, 1998; Law and Saludo, 1998]. Software bugs prevented workers from tracking incoming and outgoing shipments. This cargo handling breakdown meant the loss of business at around US$16.7 million a day and 0.1 % drop in Hong Kong's GDP [Hajari, 1998; Law and Saludo, 1998]. The impact is significant not only to the economy but also to the Hong Kong government as the public's satisfaction level drops to the lowest point ever, 18% [Hajari, 1998; Morrison, 1998]. Moreover, Hong Kong officials feared a further decline in tourists, whose numbers had already plunged more than 20% in the first quarter of 1998 [Chung, 1998; Law and Saludo, 1998]. But the greatest fallout could emerge in the courts, as freight forwarders and others begin to lay claims for compensation against airlines, HACTL and the Airport Authority [Hon, 1998; Ku, 1998; Lee, 1998; Sui, 1998]. It is obviously that whatever time and interest payments the new airport saved by opening on July 6 could quickly and easily be wasted in years of litigation [Hajari, 1998].

4.1.2 Possible Reasons For Fallout

Experts have been trying to provide the reasons for the problematic opening of the expensive new airport. Most, if not all, of them found that forcing to open the airport for the visit of the Presidents of the China and the United States was the biggest mistake [Law and Saludo, 1998; Morrison, 1998]. It made the government officials afraid to suggest a later opening day even though a lot of reports had shown that the performance of the airport would be highly doubtful if it opened in July [Ku, 1998; Law and Saludo, 1998]. Secondly, experts criticized that officials were too concern with the sacrificed income only, without realizing the forced opening may lead to a lot of facilities breakdown which will be not only very costly but also long lasting [Ajello, 1998; Hajari, 1998]. Some other suggested reasons are the inefficient communication between the participants due to the large scale of the project [Cheung, 1998]. Some criticized that the designs of the airport facilities have been unnecessarily fancy and it increased the likelihood of the facilities breakdown [Wan, 1998]. The competence level of the management was another suggested reasons as experts argued that it slowed down the progress of the construction and led to insufficient amount of time left for testing the facilities before the operation [Gittings, 1998; Law and Saludo, 1998; Wan, 1998]. The moving strategy was another one severely criticized [Hajari, 1998; Law and Saludo, 1998]. Many believed that choosing to move overnight instead of by phases significantly limit the time for testing the new facilities and the inexperienced employees could not have enough time to get familiar with the new machines [Ajello, 1998].

It is the interest of this research to test these explanations by building a model for the problematic Hong Kong new airport. However, the model do not only serve the purpose of testing different suggested reasons, but also try to provide a rationale framework or a model template for the managers of other large scale projects. The model is built according to the system dynamics principles and it will be further discussed in the next section.

4.2 SYSTEM DYNAMIC MODEL FOR THE FALLOUT

The airport model consists of six sectors, namely *Overall Performance*, *Public Satisfaction*, *Time Performance*, *Quality Performance*, *Opening Day Performance* and *Cost Performance*. Each of the sectors represents an area of concern with the airport.Within the six sectors, there are variables commonly used in different sectors. Those variables become the links between different sectors and allow the information transfer between them. They make all the sectors work together as a system and it is our interest to analyse the impact of different policies on the system as a whole. We will describe the areas of concern of each sectors in the successive paragraphs. Moreover, the mechanisms of each of the sectors as well as the formualtions of some of the important elements or variables in each sector will also be discussed.

In the *Overall Performance* sector, we try to determine the *Overall Performance* of the airport by looking at the Cost Peroformance, *Time Performance* and *Quality Performance* with their associated weight. The idea is illustrated in the Fig. 4.1. As the total weight of different performances is equal to one, the better the *cost, time* and *Quality Performances*, the better the

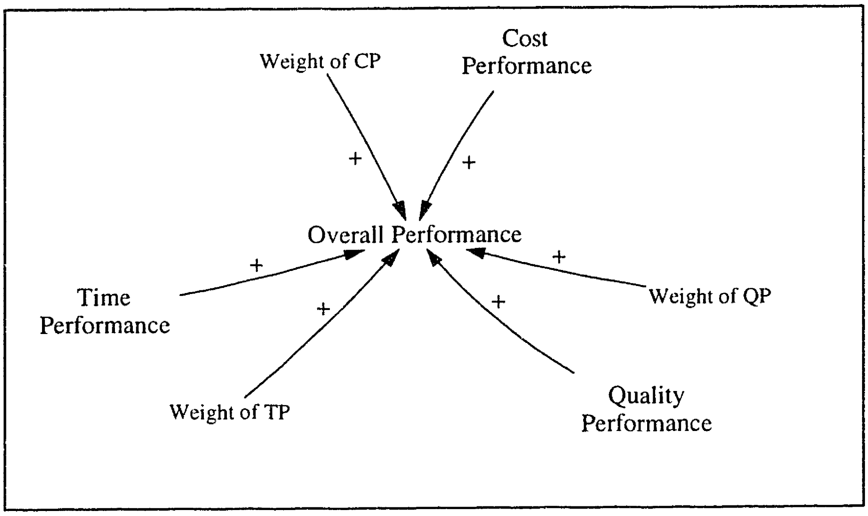

Fig. 4.1 Overall Performance

Overall Performance. It allows us to keep track of the *Overall Performance* throughout the model by looking at the graph generated after the simulation. The weights of each different performances are assigned by the users and they are all equal to 1/3 in our base run of this model. So, the performances with respect to the cost, time and quality are equally contributing to the overall performace of the new airport. Each of the Cost Performace, Time Performace and *Quality Performance* are determined in their respective sectors and the results of those sectors will feedback to the *Overall Performance* sector. Therefore, it will change whenever any of the other performances from different sectors has changed. This *Overall Performance* gives us a quick refernce of the status of the airport's *Overall Performance* at different times of the project.

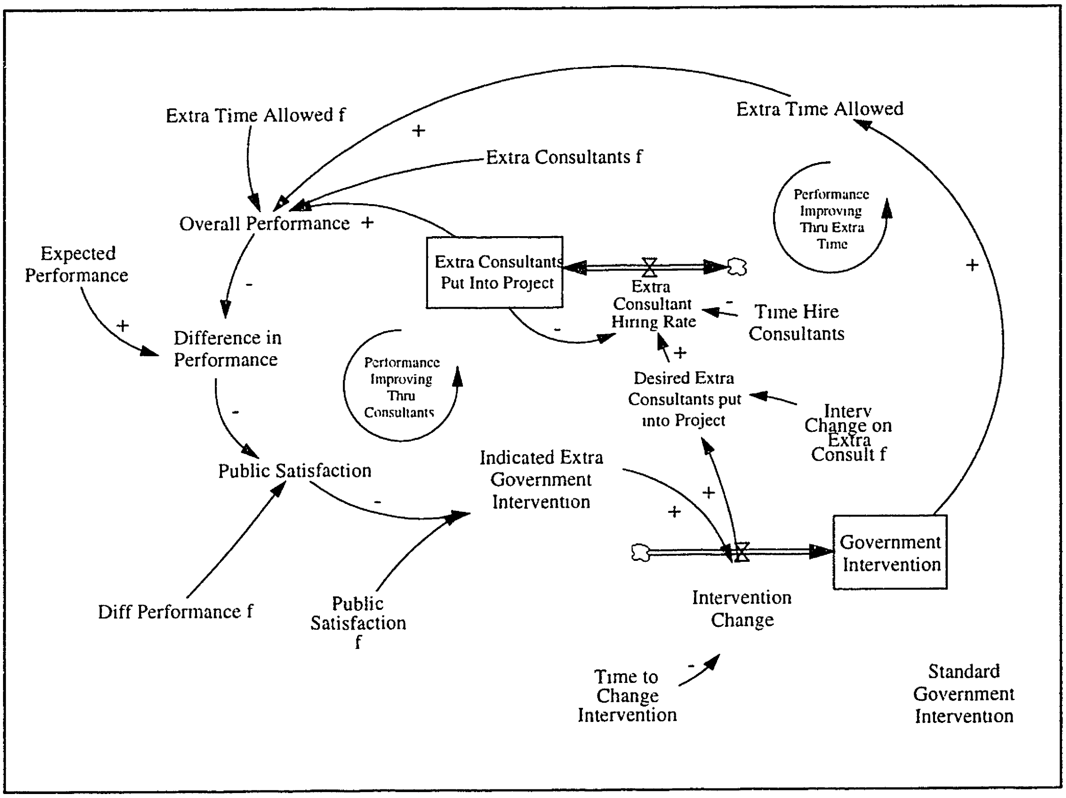

Fig. 4.2 Public Satisfaction

Then, the *Public Satisfaction* Sector is shown in the Fig. 4.2. This sector is consisted of two *Overall Performance* correcting loops, which are the *Performance Improving Thru Consultants* loop and *Performance Improving Thru Extra Time* loop. Both of the loops are using the *Public Satisfaction* level as a signal to determine if the government need to increase the intervention. The change of the government intervention will then be used to determine the desired extra consultants needed to put into the project. The desired number of extra consultants will then be compared to the existing number of extra consultants whom has already been employed. The number of the *Extra Consultants Put Into Project* is set at zero at the start of the project.

The change in the *Extra Consultants Put Into Project* will be achieved through the hiring/firing process. The *Overall Performance* will be improved by adding extra consultants and then compared to the *Expected Performance*. However, it is assumed the *Overall Performance* can only be improved by as much as 20% according to the *Extra Consultants f* shown in the Fig. 4.3. The difference between the *Overall Performance* and the *Expected Performance* will be the *Difference in Performance*, which will then determine the level of the *Public Satisfaction* according to the look up graph *Diff Performance f*.

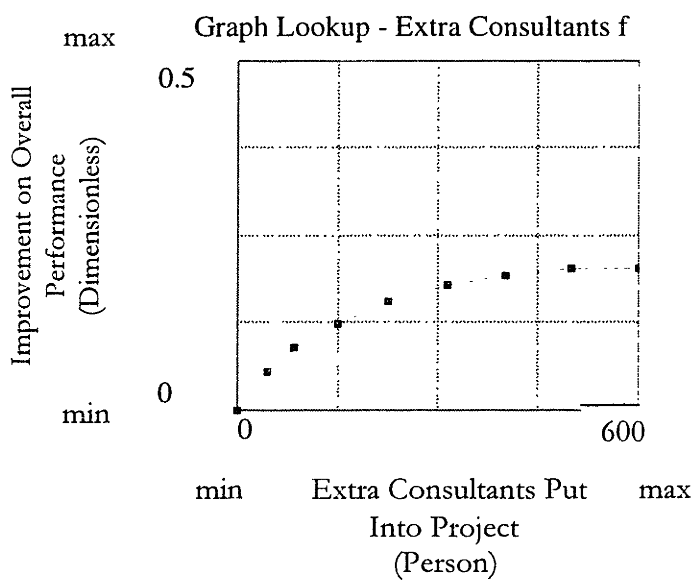

Fig. 4.3 Look up Graph for Extra Consultants f

In Fig. 4.4, it shows the relationship berween the *Difference in Performance* and the *Public Satisfaction* Level, the larger the difference in the performance, the lower the *Public Satisfaction* level with the minimum level is set at 0.2. On the other hand, the other loop, *Performance Improving Thru Extra Time* , is getting stronger when the level of the *Government*

Intervention is getting higher. However, the *Extra Time Allowed* is capped by 1.8 times of the *Stated Project Time*, the estimated project duration before the construction, in order to restrict the endless extension of project deadline. It is assumed in our model that the longer the project time is allowed, the *Overall Performance* could be improved. However, it is assumed the *Overall Performance* can only be improved by as much as 30% according to our predefined look up graph, Extra Time Allowed f, in Fig. 4.5.

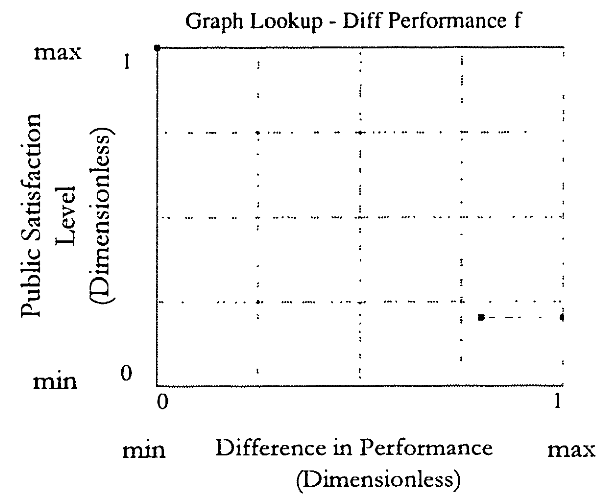

Fig. 4.4 Look up Graph for Diff Performance f

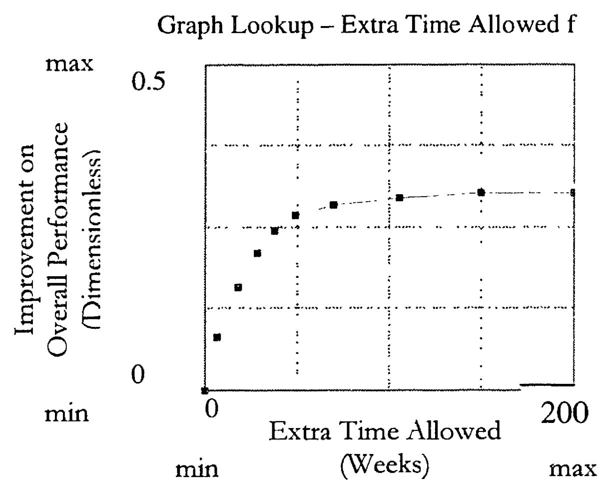

Fig. 4.5 Look up Graph for Extra Time Allowed f

Therefore, as the project proceeds, the *Overall Performance* will be determined by the performances with respect to the cost, time and quality. When the *Overall Performance* is getting too low compared with the *Expected Performance*, the difference will trigger the dissatisfied public to ask for a higher level of government intervention.. The increased intervention will be achieved by putting more consultants and they will improve the *Overall Performance* by as much as 20%. On the other hand, the increased government intervention will allow up to certain amount of extra time to improve the *Overall Performance* by as much as 30%. This sector is mainly depending on the *Public Satisfaction* level, which is an area which the Hong Kong Government want to increase by constructing this new airport.

As we have mentioned, the *Overall Performance* is determined by the *Time*, *Quality* and *Cost Performances*. Therefore the following paragraphs will discuss the corresponding sectors as well as the *Opening Day Performance* Sector, which will play a significant role in determining the *Quality Performance*.

In Fig. 4.6, it shows the mechanism of determining the *Time Performance*. Starting from the top of the figure, the number of the project participants will affect the variable *Project Size* and the *Communication Efficiency*. The larger the number of the project participants, the larger the *Project Size*. On the other hand, as each project participants has their own organization culture or administrative procedure, the *Communication Efficiency* could be varying in addition to the number of project participants. We have assumed the Initial Communication Efficiency to be 50% and it will be changed and be getting close as the time proceeds. The *Communication Efficiency* will be getting close to the Desired Communication Efficiency, *Desired ComEff*, with the average adjustment time to be the Reporting Interval. The *Desired Communication Efficiency* is the larger value of the *Achieved Communication Efficiency*, *Achieved ComEff*, and the *Minimum Communication Efficiency*, *Min ComEff*. Then the *Project Size* and the *Communication Efficiency* will determine the *Chance of Project Delay*. After knowing the *Chance of the Project Delay*, the *Indicated Actual Project Time* can be calculated in addition to the *Time Allowed HACTL Moving In* and the *Margins Allowed for Delay/Rework*. The *Time Allowed HACTL Moving In* and the *Margins Allowed for Delay/Rework* are set as 4 days and zero week respectively in our *Base Run*.

Then, the mechanism at bottom half of the Fig. 4.6 will be used to determine the *Time Performance* after knowing the *Actual Project Time* and the *Target Project Time*. The *Actual*

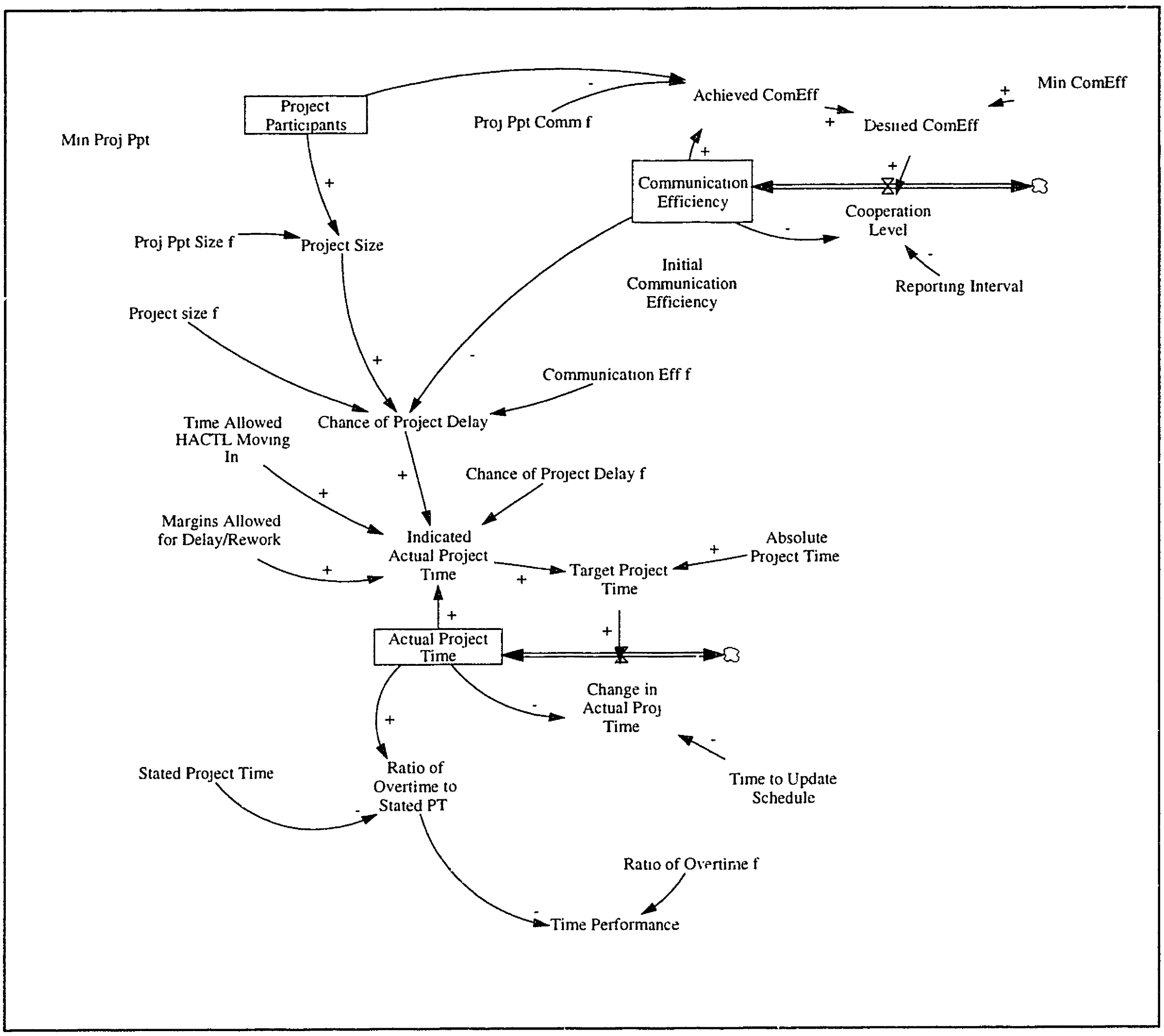

Fig. 4.6 Time Performance

Project Time is determined by the *Stated Project Time*, which is the estimated project duration before the construction begins, with the adjustment by the *Change in Actual Proj Time*. The schedule of the project is updated every 4 weeks in our *Base Run* and it is accounted by the variable, *Time to Update Schedule*. The *Target Project Time* is the minimum value of the two variables, *Indicated Actual Project Time* and the *Absolute Project Time*, which is the maximum allowable project duration and it is 150 weeks in our *Base Run*. After the *Actual Project Time* is determined, it will be compared to the *Stated Project Time* and it will provide the *Ratio of Overtime to Stated Project Time*, in which the amount of extra time needed for the project will be expressed as a percentage of the *Stated Project Time*. Then, the *Time Performance* will be determined according to the look up graph, *Ratio of Overtime f*, after knowing the ratio. The look up graph of *Ratio of Overtime f* is shown in the Fig. 4.7.

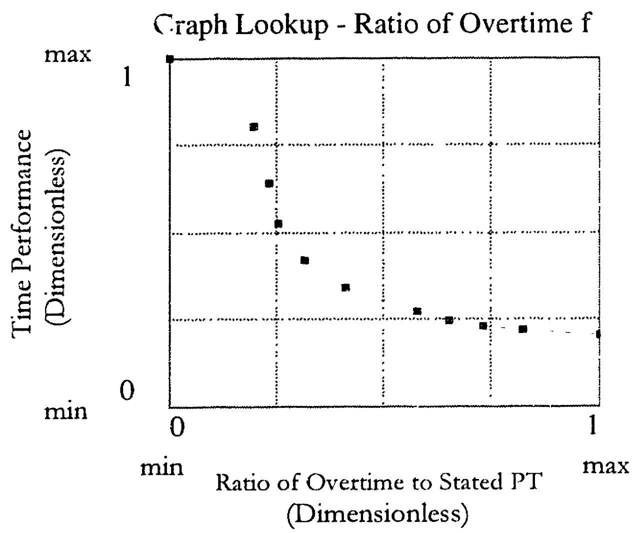

Fig. 4.7 Look up Graph for Ratio of Overtime f

The *Time Performance* will be dropping linearly from 1 to 0.8 when the ratio is increasing from 0 to 0.2. After the ratio passes the 20% mark, the *Time Performance* will drop significantly and it will become only about 0.38 when the ratio is about 35%. The *Time Performance* will hit the lowest value, 0.2 when the extra time equals to the original scheduled duration. This look up graph is user-defined and it should correctly reflect the client's perception of the *Time Performance*. The *Time Performance* determined in this sector will then feed back to the *Overall Performance*.

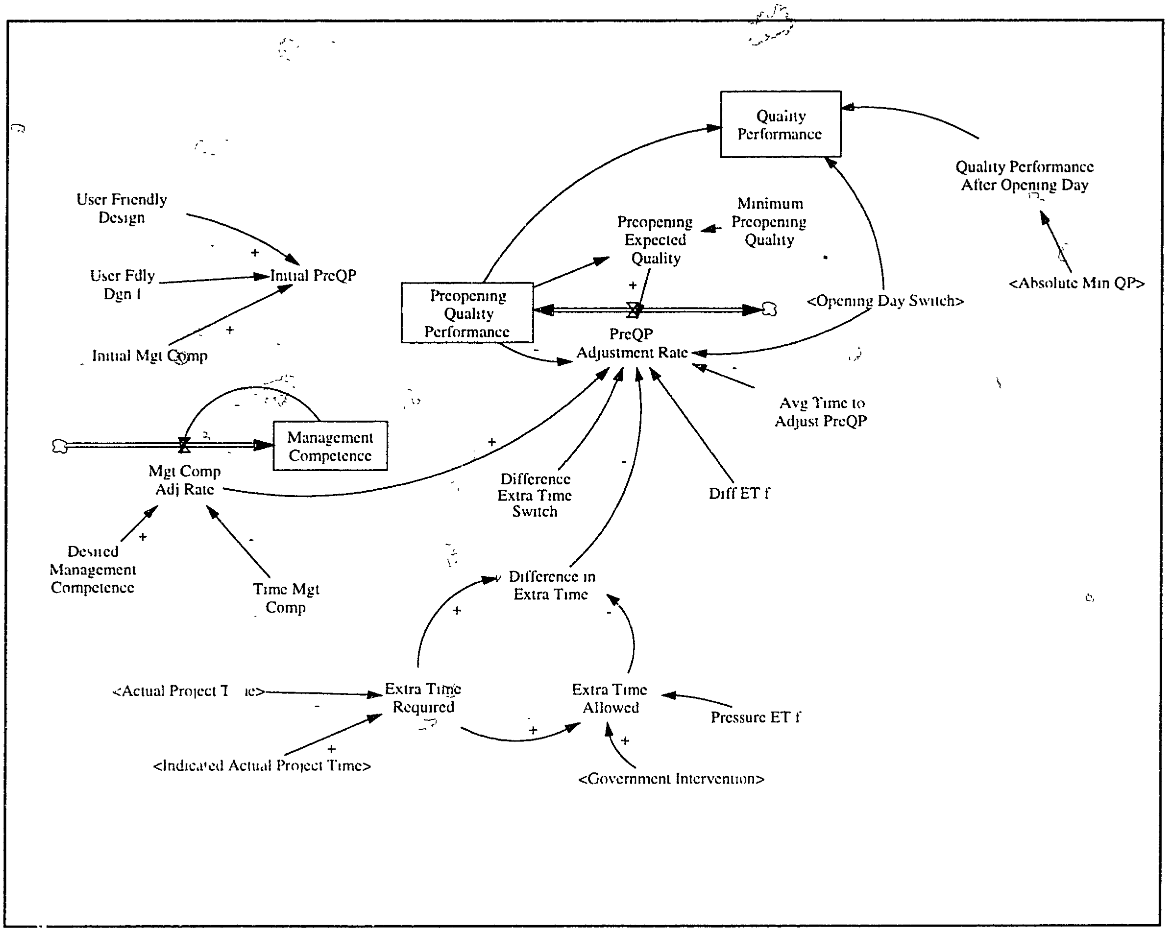

Fig. 4.8 Quality Performance

The mechanism used to determine the *Quality Performance* is shown In the Fig. 4.8. The bottom half of the figure shows the usage of the information obtained from the *Time Performance* sector. The *Indicated Actual Project Time* and the *Actual Project Time* determined from the *Time Performance* sector are used to provide the *Extra Time Required.* Then the *Extra Time Allowed* will be determined according to the *Extra Time Required,* the *Government Intervention* and the look up graph for the relationship between the *Government Intervention* and the amount of extra time will be allowed, *Pressure ET f.* The *Difference in Extra Time* will then be determined and it will be used to in the calculation of the *Preopening Quality Performance Adjustment Rate, PreQP Adjustment Rate.* The adjustment rate consists of the *Management*

Competence Adjustment Rate, *Mgt Comp Adj Rate*, the look up graph for the relationship the *Difference in Extra Time* and the adjustment rate, Diff ET f, and the adjustment rate for getting close to the *Preopening Expected Quality*.

The *Preopening Expected Quality* is the larger value of the *Minimum Preopening Quality*, which is 75 % in our *Base Run*, and the *Preopening Quality Performance*. The initial value of the *Preopening Quality Performance* is calculated by the *Initial Management Competence* and ease of using the facility, *User Friendly Design*. Then, the *Preopening Quality Performance* will be keep being adjusted according to the progress of the project until the opening day, when the *Opening Day Switch* is on.

The *Quality Performance* is comprised of two portions, which are the *Preopening Quality Performance* and the *Quality Performance After the Opening Day*. The *Preopening Quality Performance* is determined as explained above while the *Quality Performance After the Opening Day* is determined in the *Opening Day Performance* Sector. The *Quality Performance* will then feed back to the *Overall Performance* sector.

In the sector of *Opening Day Performance*, as shown in the Fig. 4.9, we capture the problematic areas and the systems broken down on the opening day of the Chek Lap Kok airport. Those areas are the breakdown of the Hong Kong Air Cargo Terminal Ltd, (*HACTL Breakdown*), the breakdown of the flight information screen display system, (*Flight Info Screen Blank*) the problems of unconnected phones (*Ratio of Working Phone*) and the high percentage of missing or misdirected luggage (*Luggage Missing Percentage*). Two other areas of concern are also included in this sector, the *Chance of Breakdown* and the *Effect From Time Allowed*. The *Chance of Breakdown* is determined by the time allowed for the HACTL to move in before the opening day , *Time Allowed HACTL Moving In*, and how well the officials of the HACTL informed the Airport Authority about the chance of breakdown if they are forced to move without sufficient preparation, *Frankness of Officials*. The five constants, *Time HACTL Working*, *Time FIS*, *Time Working Phone*, *Time LMP* and *Time Time Allowed*, are the average time needed to fix those problematic areas or to adjust to the desired level of

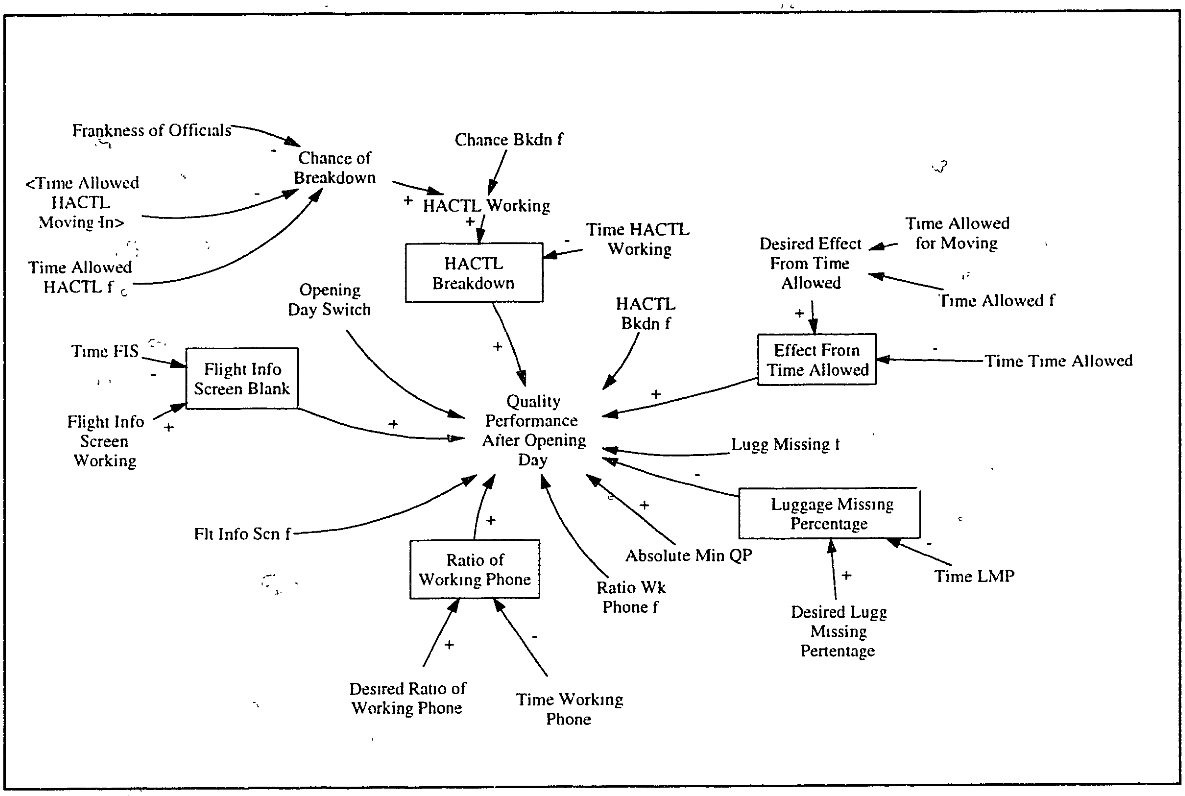

Fig. 4.9 Opening Day Performance

performance. The built-in SMOOTH function in VENSIM is used to provide the exponential smoothing for those interested problematic areas with different average time constants are used as mentioned. The *Quality Performance After Opening Day* is formulated as the following:

Quality Performance After Opening Day

= MAX(Absolute Min QP, Opening Day Switch*(Flt Info Scn f(Flight Info Screen Blank)*HACTL Bkdn f(HACTL Breakdown)*(1-Lugg Missing f(Luggage Missing Percentage))*Ratio Wk Phone f (Ratio of Working Phone)*Effect From Time Allowed))

Despite the formulation seems very complicated, it is indeed very simple. The *Quality Performance After Opening Day* is the larger value of the absolute minimum *Quality Performance*, Absolute Min QP, and the product of the performances of those problematic areas and the *Effect From Time Allowed.* As a lower percentage of missing luggage is preferred, therefore we have used the *1-Lugg Missing f(Luggage Missing Percentage)* in our formulation. The Absolute Min QP is set as 0.25 in our *Base Run* and it means the *Quality Performance* is not allowed to fall below this threshold. The client may stop the construction or switch to other constructors if it happens. It should be a clause defined in the contract and it is not ours intention to discuss any further here. The *Quality Performance After Opening Day* will be fed back to the *Overall Performance* sector through the *Quality Performance* sector. In our later section, Policy Analysis, we will implement policy which will improve the *Quality Performance After Opening Day* and see if it will significantly improve the *Overall Performance.*

The *Cost Performance* sector is shown in the Fig. 4.10, in which the cost performance is determined by the ratio of the cost difference, *Ratio of Cost Diff.* The ratio is calculated by

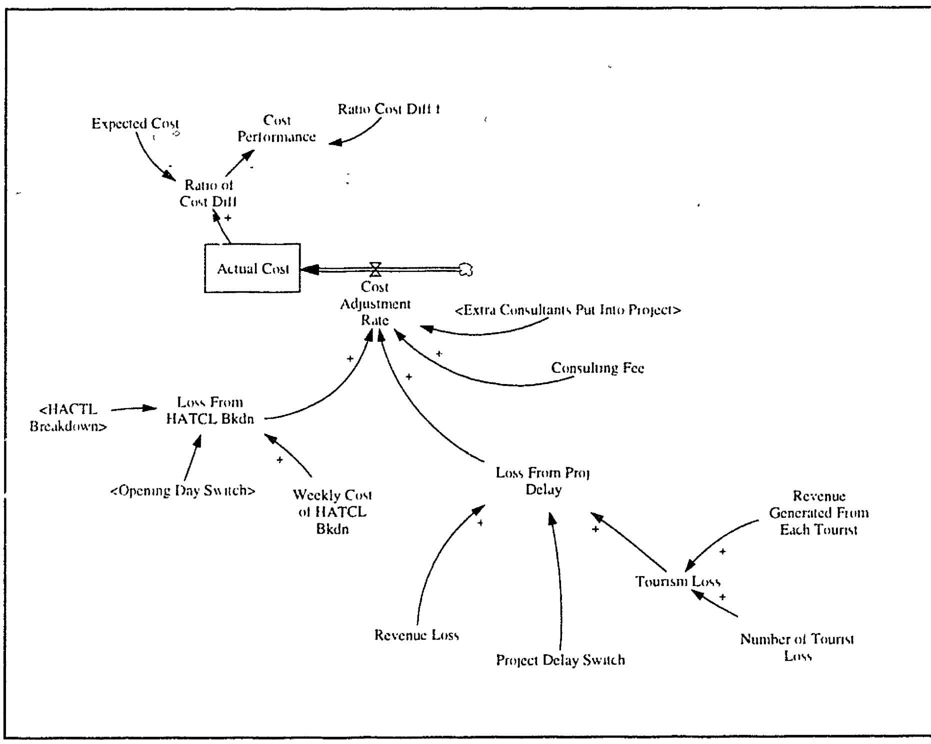

Fig. 4.10 Cost Performance

dividing the difference between the *Expected Cost* and the *Actual Cost* by the *Expected Cost* while the *Actual Cost* is obtained by adjusting the *Expected Cost* with the *Cost Adjustment Rate*. The adjustment rate is comprised of the *Loss From HACTL Breakdown*, *Loss From Project Delay* and the *Consulting Fee* from the *Extra Consultants Put Into Project*. The *Loss From HACTL Breakdown* is the weekly cost of the HACTL breakdown until the facility is again properly operated. On the other hand, the *Loss From Project Delay* is the summation of the *Revenue Loss* and the *Tourism Loss*, which is the product of the *Number of Tourist Loss* and the *Revenue Generated From Each Tourist*. The *Extra Consultants Put Into Project* is determined in the *Overall Performance* sector after the level of the *Government Intervention* is changed according to the *Public Satisfaction* level. This sector will determine the *Cost Performance* which will then be fed back to the *Overall Performance* sector.

4.2.1 POLICY ANALYSIS

The *Base Run*, as we have previously defined, is the simulation run with all the initial values used in our model. However, in this airport model, the *Base Run* will be the simulation which could closely represent the actual situation, a state of the art airport with a disastrous opening. Then, the graphs of the *Base Run* from the six different sectors are presented in the following. Some other graphs from the simulation run in which we have improved the *Quality Performance After Opening Day* will be provided after the discussion of the *Base Run*. The improvement is made through the implementation of several different policies such as increasing the *Time Allowed For Moving*, reducing the *Chance of Breakdown* and increasing the *Time Allowed HACTL Moving In*. Each of the goals of different policies will be further discussed in the later paragraphs.

In the Fig. 4.11, we can see there is a big drop of the *Overall Performance* at 100th week, which is the week of the opening, after the construction begins. Even though the *Stated Project Time* , which is the estimated project duration before the construction starts, is set as 75 weeks, the actual project duration is way over that estimation. The opening day is at the

Base Run:

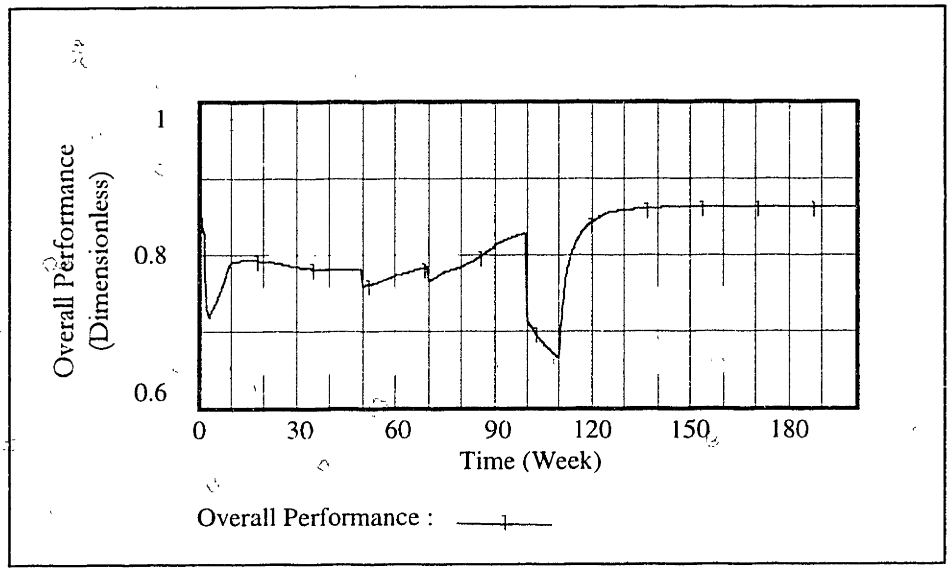

Fig. 4.11 Graph for Overall Performance

100th week and the *Overall Performance* is significantly dropped from the 82% to only 71%.The *Overall Performance* hits the lowest, 66%, at the 110th week and then slowly climb back to about 86% at 130th week. In order to understand the change of the overall performance, we have to look at the simulation results from the other sectors. While the *Time Performance*, *Quality Performance*, the *Opening Day Performance* and the *Cost Performance* will be the main sectors to determine the overall performance, the *Public Satisfaction* sector will improve it through the extra consultants or extra project time.

The Fig. 4.12 shows the difference between the *Overall Performance* and the *Expected Performance*. As we have set our *Expected Performance* to be 1 in the *Base Run*, the shape of the graph is actually a mirror image of the *Overall Performance*, Fig. 4.11.

As we have explained earlier, the difference in performance will determine the *Public Satisfaction* Level according to the Fig. 4.4 and hence we have obtained a graph for the *Public Satisfaction* as shown in the Fig. 4.13. It is not surprising that we get a exactly the same graph

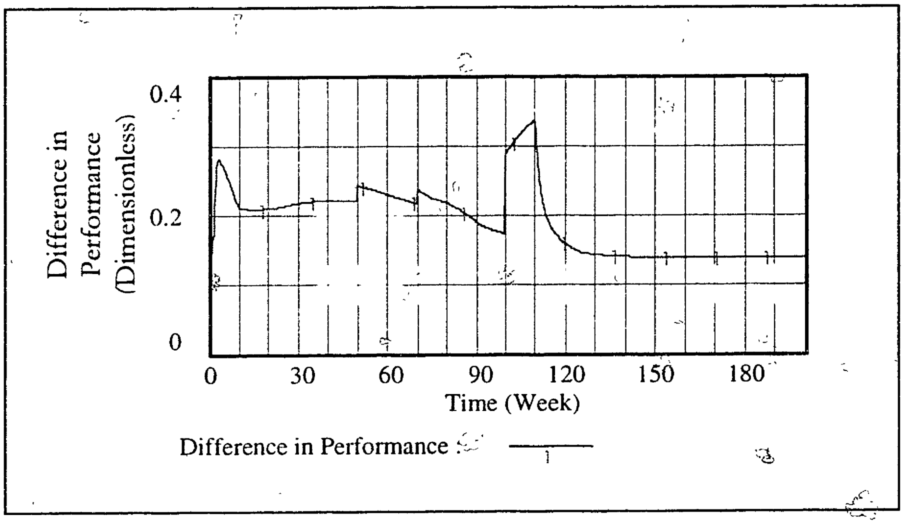

Fig. 4.12 Graph For Difference in Performance

as the Fig. 4.11 because our look up graph for the *Diff Performance f* is a 45-degree line with a minimum *Public Satisfaction* Level set at 0.2 whenever the *Difference in Performance* is larger than 80%. Thus in our *Base Run*, the shape of the graphs are identical for the *Overall Performance* and the *Public Satisfaction*.

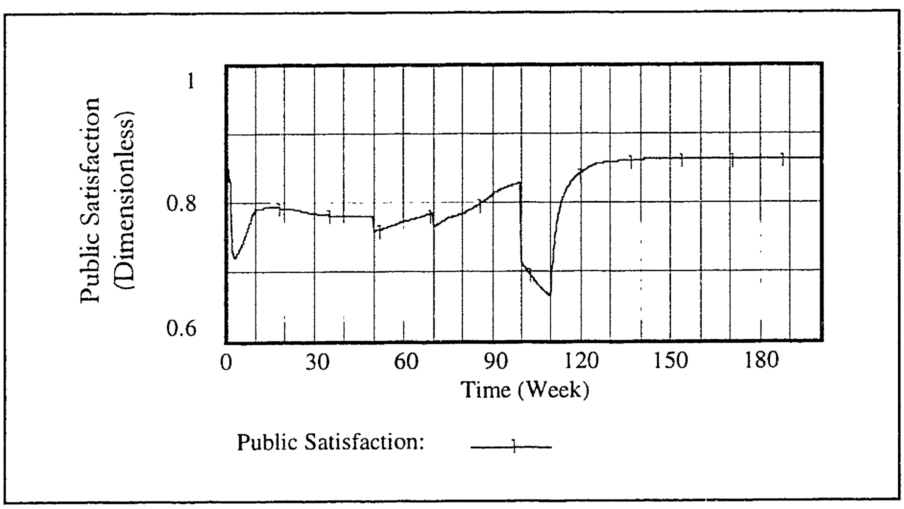

Fig. 4.13 Graph for Public Satisfaction

Then, we are interested in understanding the shape of the graph for the *Time Performance*, shown in the Fig 4.14. It is shown in the graph that the *Time Performance* is very poor and remains at around 20% after the 10th week. In other words, the extra time required for this project has been very high since the 10th week. As the *Indicated Actual Project Time* is determined by the *Chance of Project Delay, Time Allowed HACTL Moving In* and the *Margins Allowed for Delay/Rework* by the following formulation:

Indicated Actual Project Time

= Actual Project Time*(1+Chance of Project Delay f(Chance of Project Delay))+"Margins Allowed for Delay/Rework"+Time Allowed HACTL Moving In/Conversion factor from day to week

As the only changing variable in the formulation is the *Chance of Project Delay*, it will be the reason for the poor *Time Performance*. The Fig. 4.15 shows the simulation results for the *Chance of Project Delay*. The chance of delay is increased from 40% to 46% shortly after the project starts. It remains at that level till the 50th week, which is the two-third of the estimated project duration. By referring to the formulation, we can roughly know that the project duration will be around 110 weeks at that time. The extra time needed is around 47% of the original project duration and hence the *Time Performance* has been poor shortly after the project starts. This is due to a poor or too optimistic estimation for the project duration. If the stated project time was estimated to be longer at the very first place, the *Overall Performance* could be easily increased due to a much more satisfactory *Time Performance*.

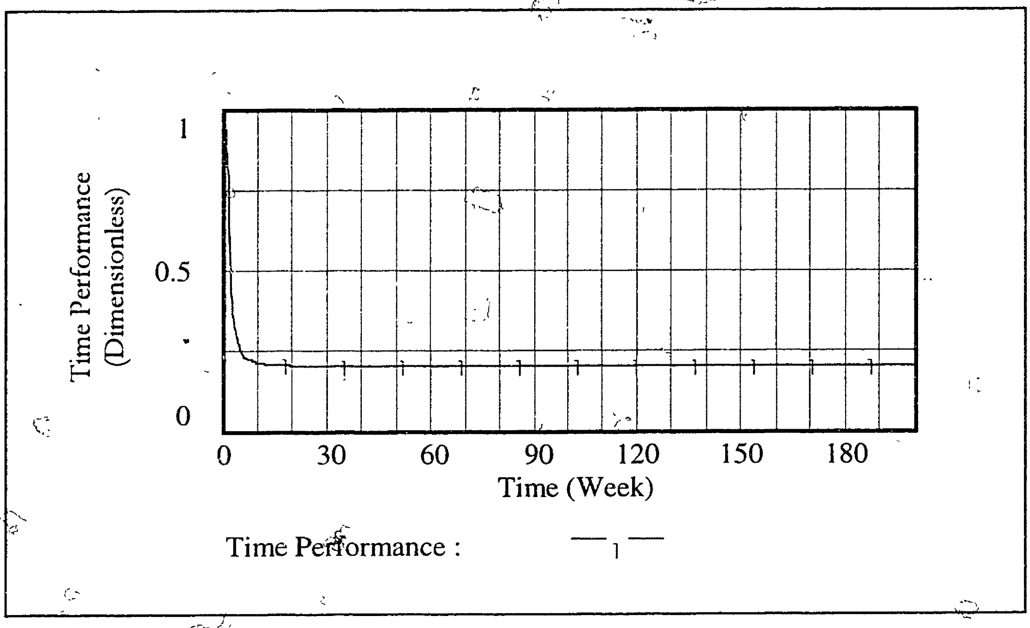

Fig. 4.14 Graph for Time Performance

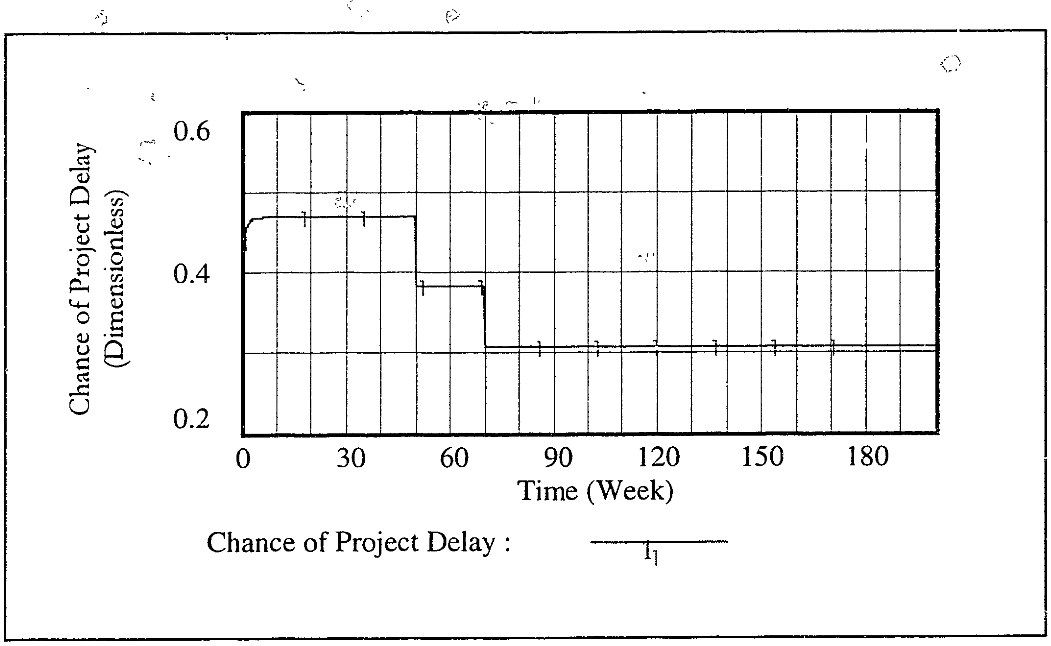

Fig. 4.15 Graph For Chance of Project Delay

In the Fig. 4.16, it shows that the change of the *Quality Performance* as the project proceeds. The *Quality Performance* is very poor at the beginning because the non-user-friendly design and the relatively low competence level of the management. Then, as the time goes on, the increased competence level of the management and the exponential smoothing mechanism we have provided in this sector start to raise the *Quality Performance.* It is raised to get closer to our *Minimum Preopening Quality*, which is a standard we would like to achieve and we set it as 0.75 in the *Base Run.* However, as the larger difference between the extra time required by the constructor and the amount allowed by the Hong Kong government at the beginning and till mid-way of the project, the *Quality Performance* is lowered. Then, when the *Difference in Extra Time* is getting smaller, the *Quality Performance* is starting to rise again until it drops significantly and hit the lowest level, 25%, on the opening day. The *Quality Performance* remains at that lowest level till the 110th week and finally climbs all the way back to full scale at about 140th week. In other words, it takes like 10 months to bring the *Quality Performance* from the 25% mark back to the 100% performance.

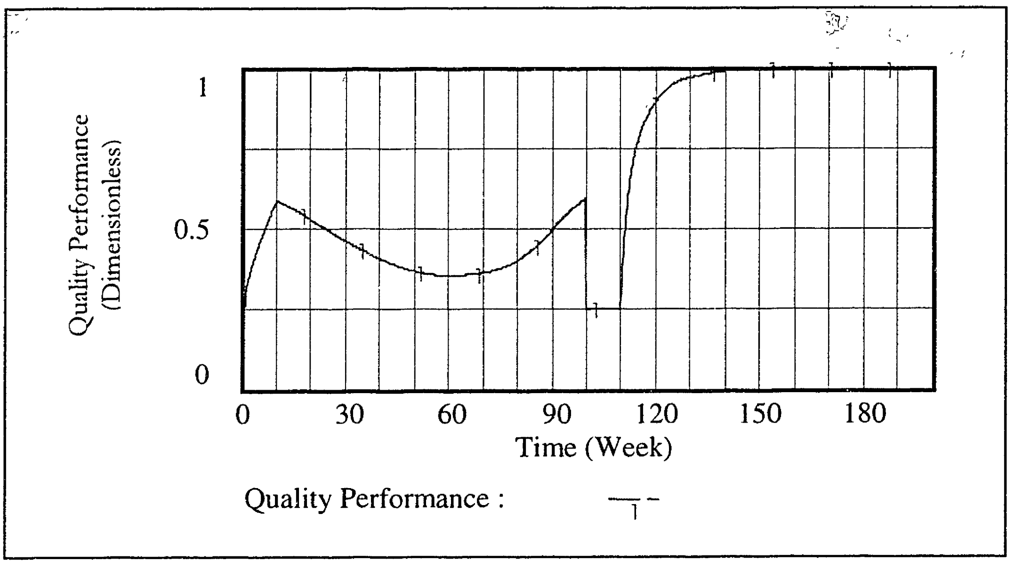

Fig. 4.16 Graph for Quality Performance

The Fig. 4.17 shows the simulation result for the *Quality Performance* After Opening Day. The portion before the 100th week should be neglected as it is due to the our intention of formulating the *Quality Performance* on the opening day. The *Quality Performance* before the Opening day should be referred to the *Quality Performance* sector.

The *Quality Performance* on the opening day is disastrous as it is only 25%. It reflects the real situation. Then, the performance is getting better and finally reaches the full scale at the 140th week. Again, it needs like 10 months to improve the poor *Quality Performance* to the expected level, 100 as assumed in our *Base Run*.

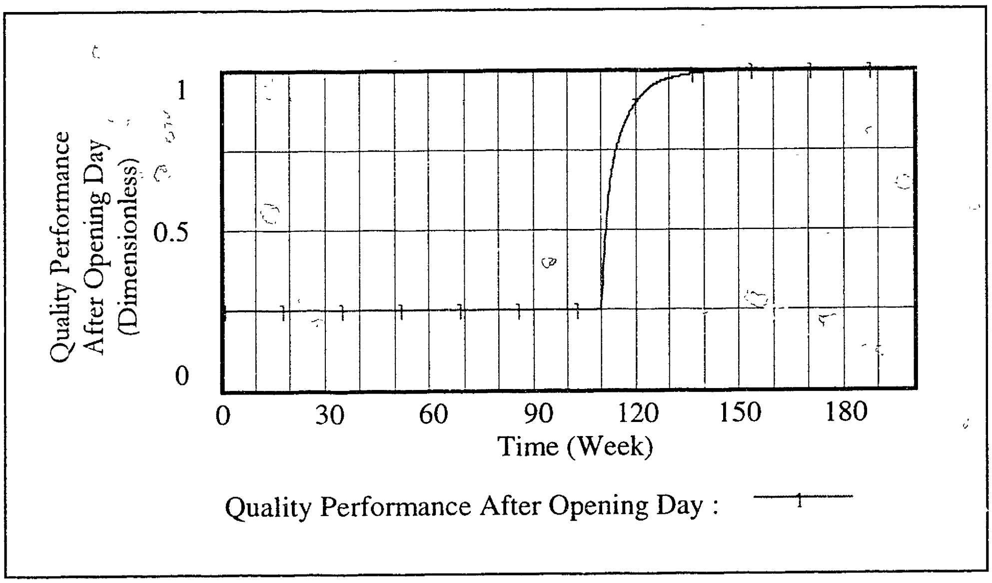

Fig. 4.17 Graph for Quality Performance After Opening Day

The graph for the *Cost Performance* from the *Base Run* is shown in the Fig. 4.18. Because we have formulated the *Actual Cost* in the *Cost Performance* sector as the *Expected Cost* with the adjustment from the *Cost Adjustment Rate*, the *Actual Cost* will be equal to the *Expected Cost* unless the *Cost Adjustment Rate* is changed from the initial value, zero, to some other value. The *Cost Adjustment Rate* is changed from zero to about US$ 96 million at the 75th week, the original project duration because the *Loss From Proj Delay* starts to kick in the sector. As the loss due to the delay is assumed to be a constant weekly cost, the *Cost*

Performance drops linearly after the 75th week until the opening day. After the airport starts to operate at the 100th week, the *Loss From Project Delay* drops back to zero while the enormous loss from the breakdown of HACTL starts to pull down the cost performance exponentially. The *Cost Performance* never bounces back due to our formulation in the *Cost Performance* sector. In this sector, the *Actual Cost* could only be higher than the *Expected Cost* as the *Cost Adjustment Rate* is never to be negative. Moreover, the interpretation of the *Cost Performance* in this sector should be how close the *Actual Cost* is to the *Expected Cost.* Therefore, even though the airport may generate a large amount of revenue and profit several months later, the *Cost Performance* of this project itself at that time will not be changed because the earnings does not mean a lowered construction cost/*Actual Cost* of this airport project.

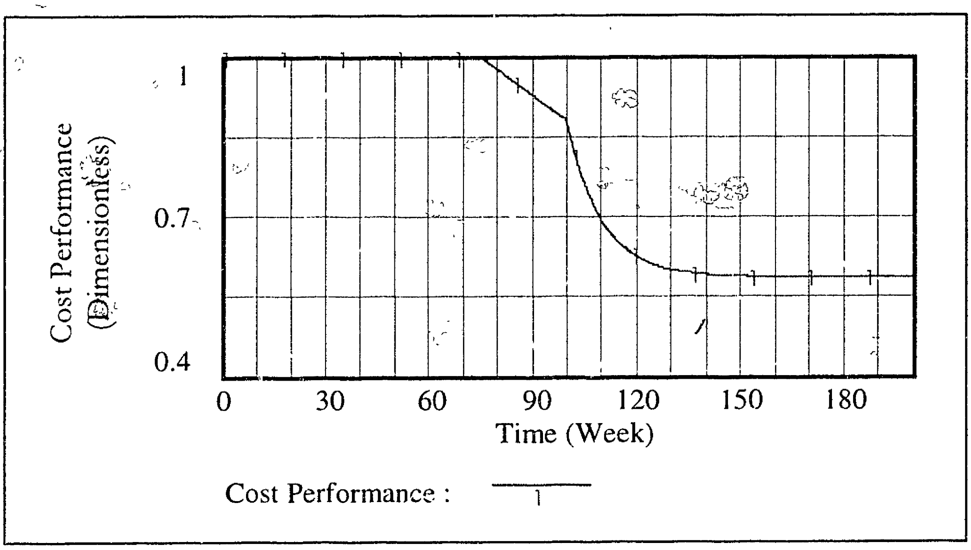

Fig. 4.18 Graph for Cost Performance

As we have simulated the *Base Run* and knowing the *Overall Performance*, it gives us a benchmark that we could be used to compare with other simulation runs in which we have implemented different combination policies. In this thesis, we have limited our policies to those will improve the opening day performance. It is because the graph of the *Overall Performance* from the *Base Run*, Fig. 4.11, shows that the *Overall Performance* can be considered as satisfactory before the opening. The *Overall Performance* has an average of about 78% until the sharp drop during the opening week. The *Overall Performance* hit the lowest, 66%, during the 110th week and then climbs back to about 85% after the 130th week. In other words, if we could limit the drop during the opening week to the 110th week, the *Overall Performance* should be around 80% during most of the project duration. Moreover, the public will be more satisfied with this airport project and find it a justified investment by the Hong Kong government. The following paragraphs will discuss the policies implemented to improve the *Opening Day Performance* in this thesis.

AirRunI:

In this scenario, we have increased the *Frankness of Official* from 0.5, which is used in the *Base Run*, to 0.8 and the *Time Allowed HACTL Moving In* from the original 4 days to 21 days. The purpose of these two changes is to lower the *Chance of Breakdown* under 0.8 and hence the HACTL will not breaking down during the opening week according to our model. We are interested in knowing the improvement of the *Overall Performance* after removing the problematic HACTL.

AirRunII:

This scenario is the same as the *AirRunI* except we have reduced the fixing time for the other problematic systems. We have assumed that we have lowered the fixing time of the flight information display and the phone, the timed needed to reduce the luggage missing percentage and the time needed to remove the effect on operation due to the insufficient moving time from Kai Tak to Chek Lap Kok to only 70% of the values used in the *Base Run*. These reductions are assumed to be achievable through a better installation during the construction or allowing longer time for testing and inspection before the opening. In this scenario, we are interested in finding out how much time can be saved in order to achieve the similar *Overall Performance* obtained in the previous scenario, *AirRunI*.

AirRunIIIa:

In this scenario, we have assumed the flight information screen will not have any problems during the opening in addition to the scenario of *AirRunII* . It is assumed that the testing and inspection has been sufficiently performed before the opening day and eliminate the chance of breaking down.

AirRunIIIb:

We have assumed that we can remove the problem of the non-working phone in addition to the scenario described in the *AirRunIIIa.*

AirRunIIIc:

The problem of the missing luggage is assumed to be non-existent with all the same situation used in our scenario *AirRunIIIb.*

These three scenarios should be considered as a set of sub-scenarios in which some other problematic areas are removed while the HACTL is ensured to be working perfectly during the opening day. Similar to the purpose of the *AirRunI*, we would like to know the improvements of the *Overall Performance* after removing reach of those problematic areas. Moreover, in the *AirRunIIIc*, as we have removed all the problematic areas or system broken down, the *Overall Performance* is expected not having drop anymore during the opening week. In such a case, the new airport should be operated smoothly on the opening day.

AirRunIVa:

In *AirRunIVa*, the *Time Allowed for Moving*, which is the time allowed for the facilities moving from the Kai Tak airport to the new Check Lap Kok airport, is increased from the value used in the *Base Run*, 1 day, to 7 days. The moving time allowed in this scenario is the time needed to have a smooth transition between the airports according to our user-defined look up graph, *Time Allowed f.* .

AirRunIVb:

The only modification we have made in this scenario compared with the *AirRunIVa* is we only allow 5 days for moving instead of 7 days. We are interested in knowing the impact on the *Overall Performance* by shortening the moving time by two days.

The *AirRunIV's* are the another set simulation runs built on the *AirRunIIIc*. In other words, we are trying to implement some other policies to further improve the *Overall Performance* after the removal of all the problematic areas.

The simulation results of the scenarios described above are presented in the Fig. 4.19, 4.20, 4.21 and 4.22.

4.2.2 Model Analysis and Suggested Strategies/ Policies From Model

The Fig. 4.19 shows that the *Overall Performance* is almost the same for the two scenarios even though the HACTL breakdown is removed from the opening day in the *AirRunI*. However, the *Overall Performance* of the *AirRunI* does not drop further after the opening day as it does in the *Base Run*. The performance has been improved by 6 %, from 66% in the *Base Run* to 72% in the *AirRunI* during the 110th week. Then, the most important finding of these simulations is the improvement of the *Overall Performance* after the 110th week. The equilibrium *Overall Performance* of the *AirRunI* is increased to 96% after the 120th week compared with the equilibrium overall performance, 86%, reached by the *Base Run* during the 140th week. The improvement is 12% of the original value while the time need to reach the equilibrium is reduced to only half of the original value, 40 weeks in the *Base Run*. It proves that this policy is very efficient in improving the long term *Overall Performance*. The large improvement of the *Overall Performance* is due to the much better *Cost Performance* of the *AirRunI* as shown in the Fig. 4.23. It is because the cost adjustment rate is significantly reduced in the *AirRunI* by removing the *Loss From HACTL Breakdown*.

The *AirRunIV's* are the another set simulation runs built on the *AirRunIIIc*. In other words, we are trying to implement some other policies to further improve the *Overall Performance* after the removal of all the problematic areas.

The simulation results of the scenarios described above are presented in the Fig. 4.19, 4.20, 4.21 and 4.22.

4.2.2 Model Analysis and Suggested Strategies/ Policies From Model

The Fig. 4.19 shows that the *Overall Performance* is almost the same for the two scenarios even though the HACTL breakdown is removed from the opening day in the *AirRunI*. However, the *Overall Performance* of the *AirRunI* does not drop further after the opening day as it does in the *Base Run*. The performance has been improved by 6 %, from 66% in the *Base Run* to 72% in the *AirRunI* during the 110th week. Then, the most important finding of these simulations is the improvement of the *Overall Performance* after the 110th week. The equilibrium *Overall Performance* of the *AirRunI* is increased to 96% after the 120th week compared with the equilibrium overall performance, 86%, reached by the *Base Run* during the 140th week. The improvement is 12% of the original value while the time need to reach the equilibrium is reduced to only half of the original value, 40 weeks in the *Base Run*. It proves that this policy is very efficient in improving the long term *Overall Performance*. The large improvement of the *Overall Performance* is due to the much better *Cost Performance* of the *AirRunI* as shown in the Fig. 4.23. It is because the cost adjustment rate is significantly reduced in the *AirRunI* by removing the *Loss From HACTL Breakdown*.

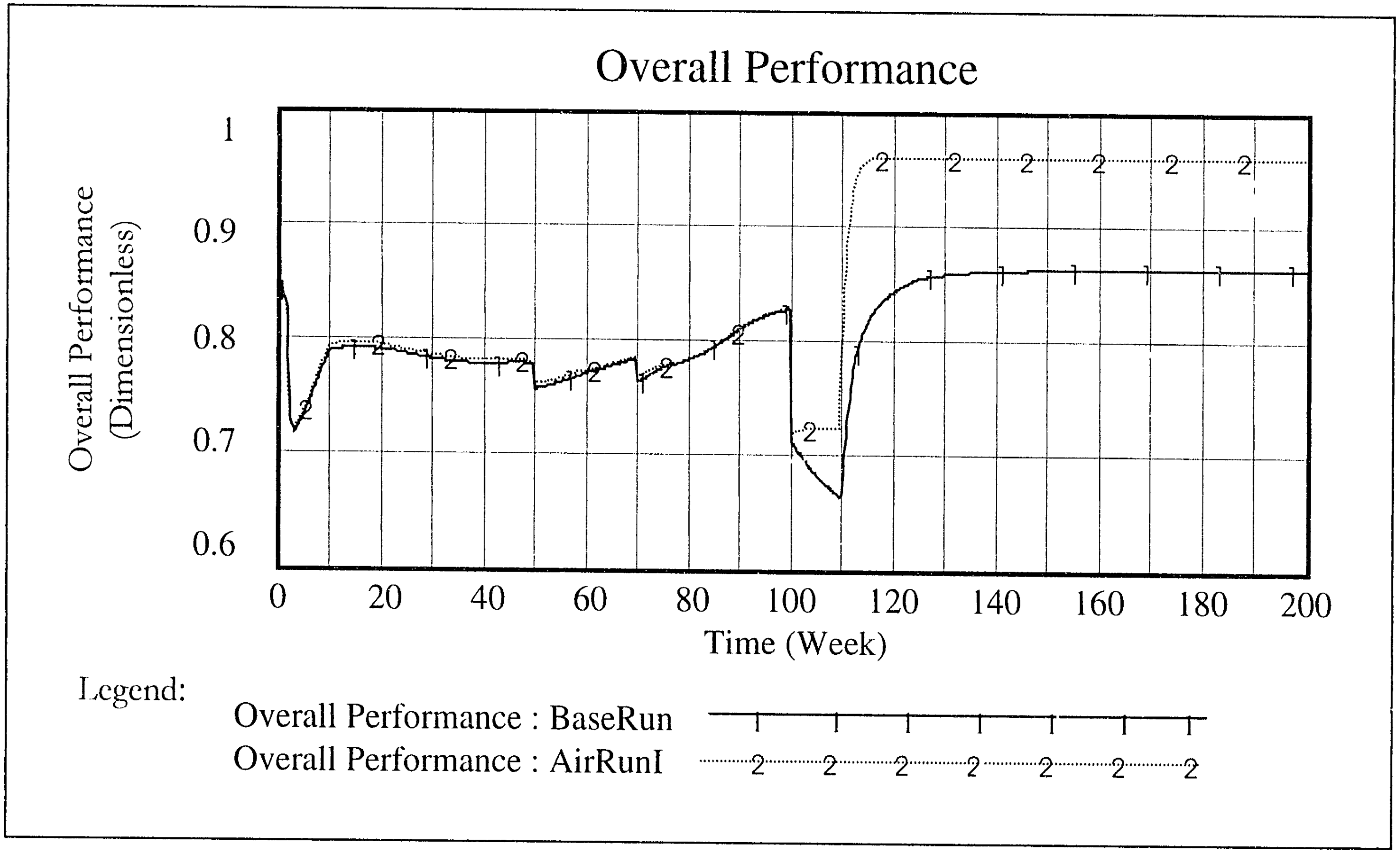

Fig. 4.19 Graph for Overall Performance from Base Run and AirRunI

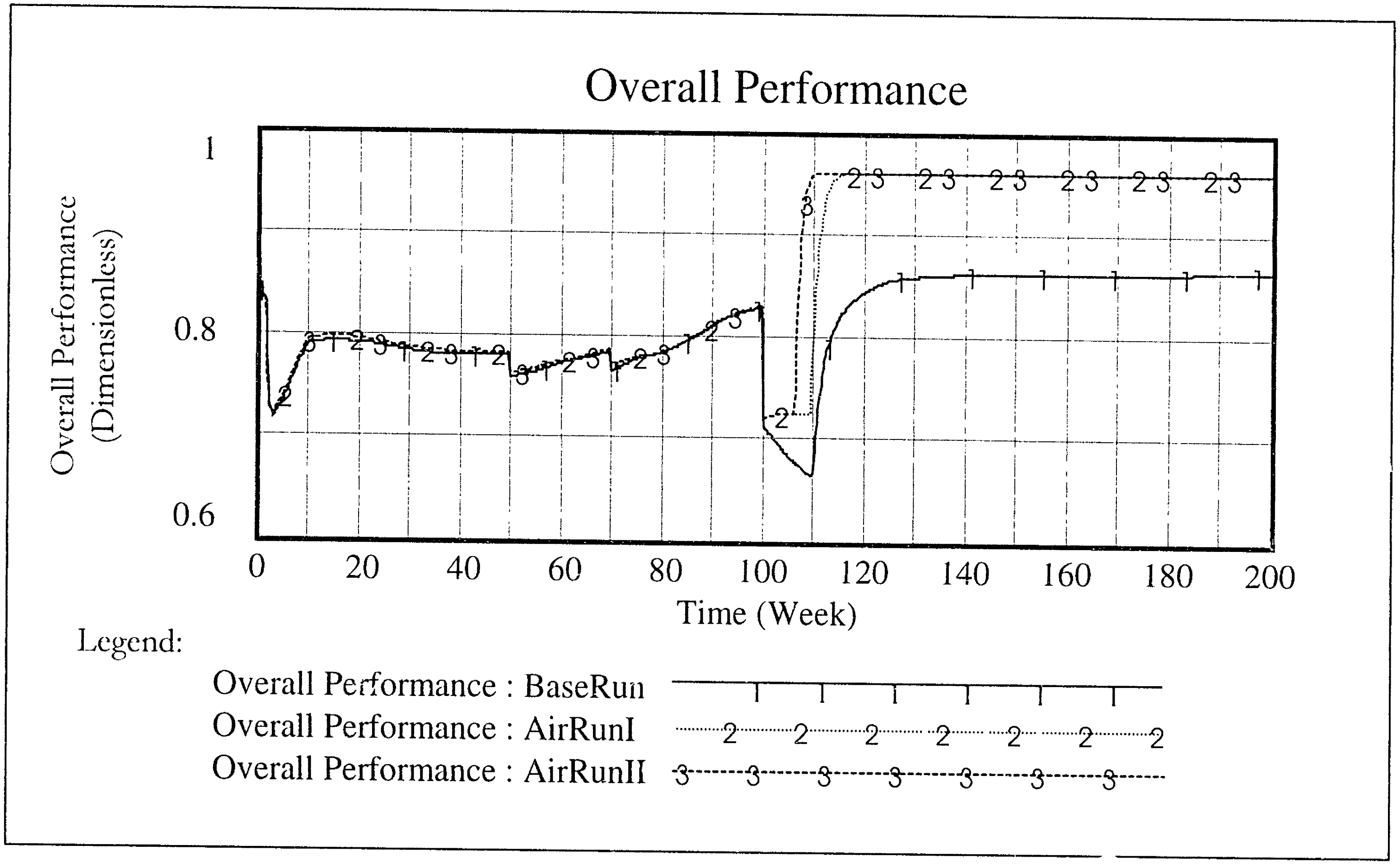

Fig. 4.20 Graph for Overall Performance from Base Run AirRunI and AirRunII

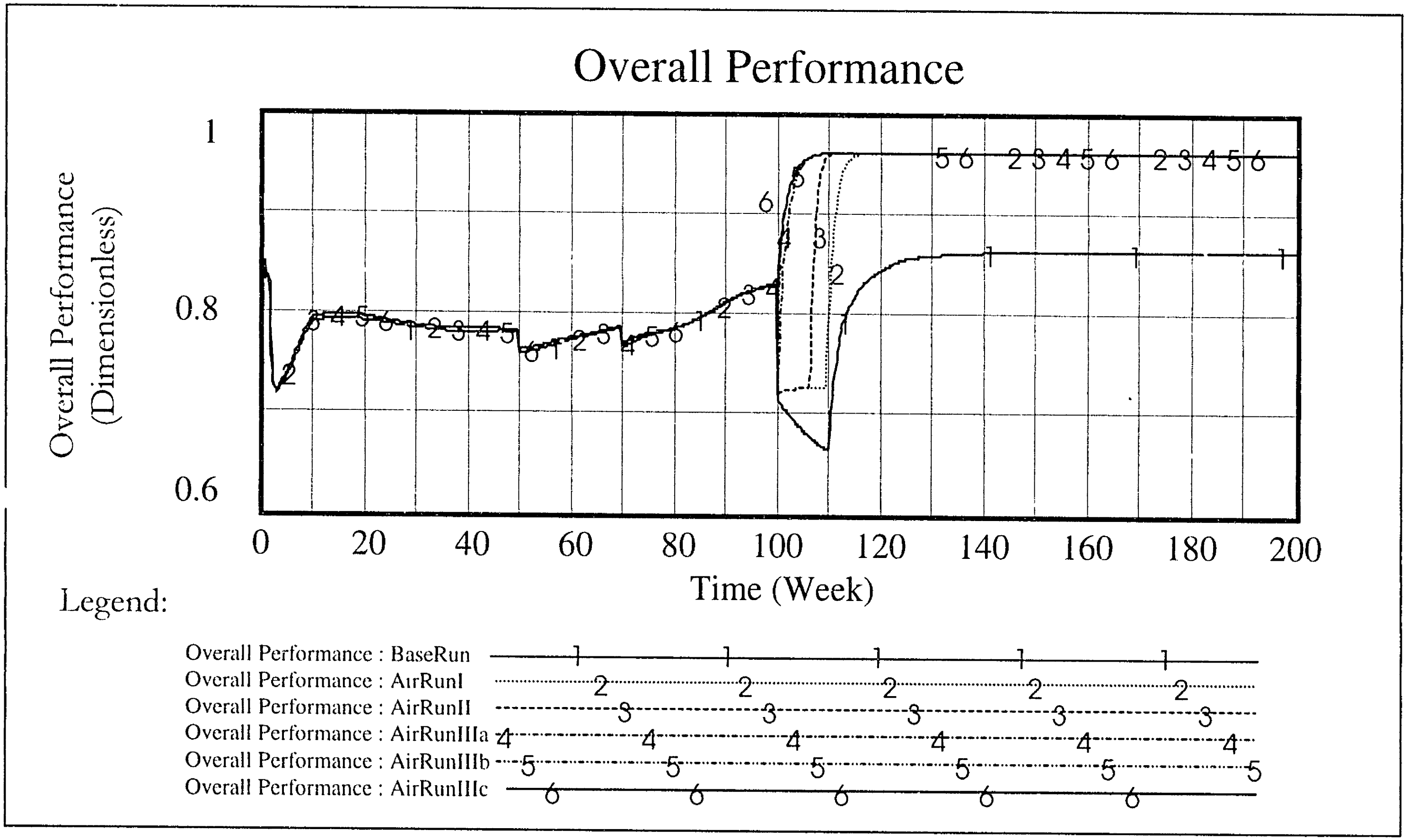

Fig. 4.21 Graph for Overall Performance from Base Run, AirRunI, AirRunII and AirRunIII's

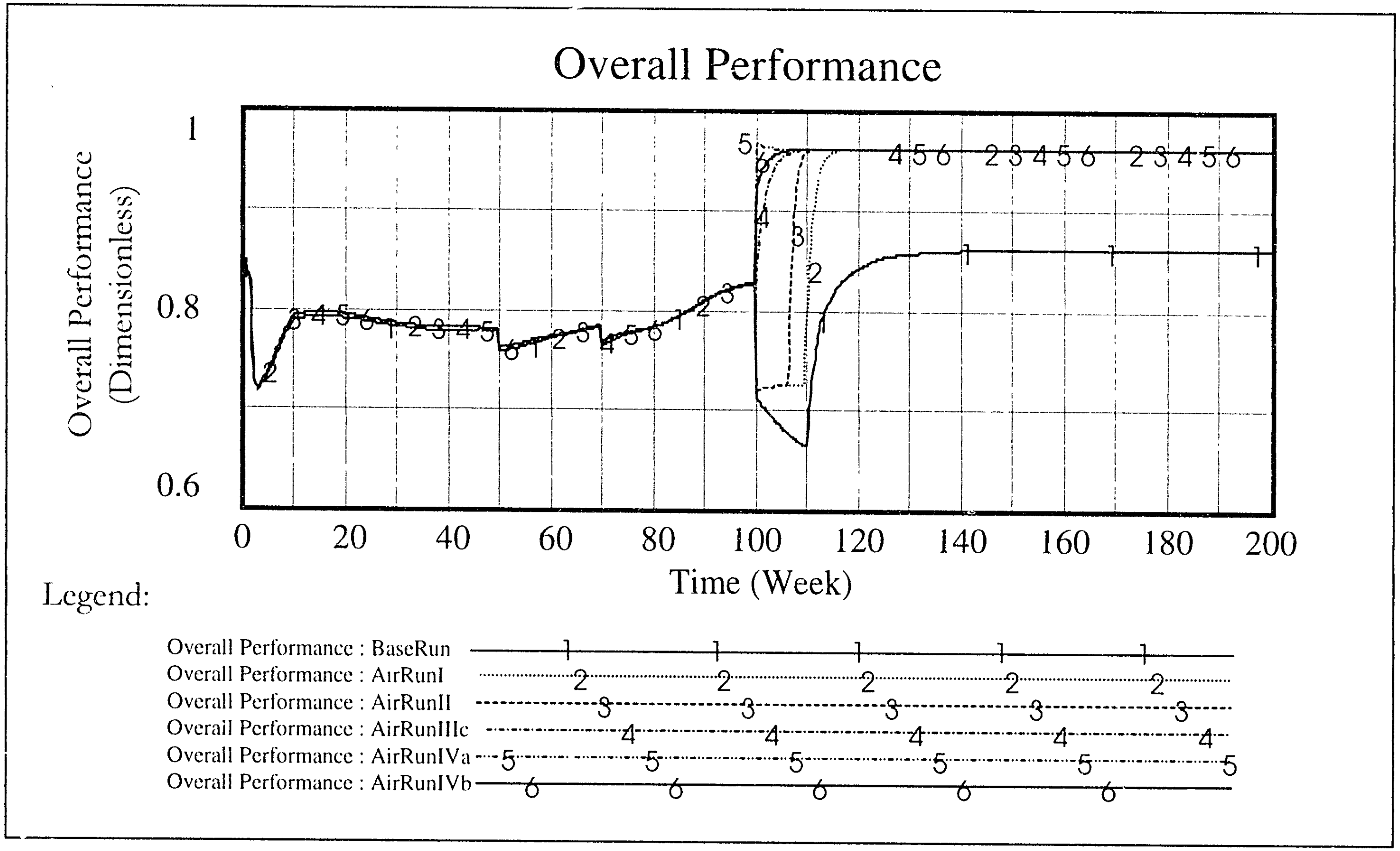

Fig. 4.22 Graph for Overall Performance from Base Run, AirRunI, AirRunII, AirRunIIIc and AirRunIV's

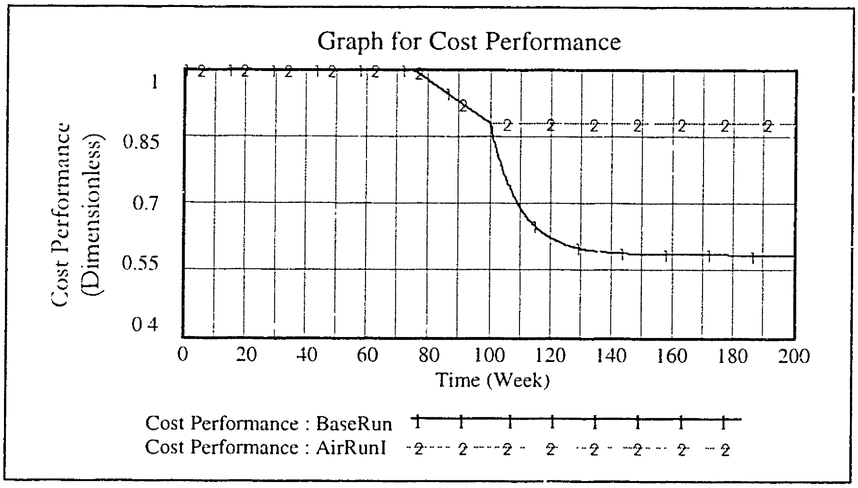

Fig. 4.23 Cost Performance Comparison for the Base Run and the AirRunI

According to the results given by the simulations, the official of the HACTL should be much honest to the Airport Authority that they need the extra time to move in the new facility. In our implemented policy, the moving time should be increased from 4 days, which is the case in the reality, to 3 weeks in order to reduce the *Chance of Breakdown*. The chance should be reduced low enough that the HACTL will be operated smoothly according to our model.

Then, from the Fig. 4.20, we have noticed that the *Overall Performance* for the scenario, *AirRunII*, is almost identical, except the time needed to achieve the equilibrium value is reduced from about 20 weeks in the *AirRunI* to 10 weeks in this case. In other words, by reducing the fixing time of different areas by 30% though a good practice of installation or operating and testing before the opening day, it can save 10 weeks of time to reach the maximum and equilibrium overall performance. This policy does not improve the *Overall Performance* as it does by implementing the *AirRunI*, however, it increases the efficiency of the policy implemented in the *AirRunI*.

As the *Overall Performance* was improved significantly in the scenario *AirRunI*, it is interesting to know if the *Overall Performance* can be further improved by removing some other problematic areas. Therefore, another set of simulations, *AirRunIII's*, are run and the results are shown in the Fig. 4.21. Surprisingly, the *Overall Performance* has not been further improved in this scenario compared to the *AirRunII*. It can be explained by the *Cost Performance* sector. As the other systems do not change the *Cost Adjustment Rate* no matter how much they improve their respective performance, therefore, the *Cost Adjustment Rate* stays the same as the *AirRunII* and so does the *Cost Performance*. However, in the three scenarios, *AirRunIIIa*, *AirRunIIIb* and *AirRunIIIc*, in this set of simulation, the simulation results are different from those of the previous runs. The *AirRunIII's* does not have the extended dropped *Overall Performance* that lasted more than six weeks. Actually, the *Overall Performance* of the simulation *AirRunIIIc* does not even drop during the opening week. It is reasonable result because we have stated in previous paragraph that this particular run should not experience any drop during the opening as all the problematic areas have been removed. In other words, the *Overall Performance* of this scenario climbs from the opening day and finally reach the equilibrium during the 110th week. On the other hand, even though the *Overall Performance* of the *AirRunIIIa* and *AirRunIIIb* dropped right after the opening, they need only 1 week and 0.5 week respectively to recover to the level of performance right before the opening day. All the scenarios of AirRunIII's reach the equilibrium *Overall Performance* by the 110th week and it is similar to the time needed in the *AirRunII*. In this set of simulations, we know that by removing the problem of blank flight information display, the time of staying low *Overall Performance* will be significantly reduced to 1 week. However, by removing another problematic area, the impact on the *Overall Performance* will be very limited. Therefore, ensuring the flight information display working on opening day is another policy we can implement in order to improve the overall performance, however, the policy of ensuring other systems to be working will be needed to be justified by comparing the additional cost to the marginal benefits.

Finally, the Fig. 4.22 shows the graphs for our last set of simulation, *AirRunIV's*. The *AirRunIVa* allows one week to move form the old airport to the new one to ensure a smooth transition. The *Overall Performance* after the opening day is the highest of all the simulations and reaches about 97% before dropping back to 96% as all the other runs other than the *Base Run*. The *AirRunIVb* allows only 5 days to move and we observe that the difference between these two different *AirRunIV*'s is very little. The additional two days of moving will boost up the performance on the opening week only and it will have the same performance about 5 weeks after the opening. Nevertheless, it might be a better strategy to move in as the scenario of *AirRunIVb* because the *Overall Performance* is 92% during the opening day and climbs to the equilibrium level, 96% in the next 5 weeks. The public might have a better impression of the new airport as they will consider the performance of the airport is improving rather than dropping as the scenario of *AirRunIVa*.

All in all, the results of the simulations show us that the most important policy to be implemented should be the one can keep the HACTL problem-free. It can be achieved by allowing a longer time, about 3 weeks as suggested in our model, for the company to move in before the opening day. The extra time allows more operating and testing for the facility and hence significantly reduces the chance of the system breakdown. Moreover, the officials from the HACTL could help reduce the chance of this system too by simply being honest to the Airport Authority.

The policies, which could remove the problems of other areas, could definitely further improve the *Overall Performance* but the impact will not be as significant as the one just discussed above. It will be the policy makers' choice to justify these policies by comparing the marginal costs to the additional *Overall Performance*. However, the time allowed for moving from the old airport to the new one is proven not as important as those critics suggested according to our model.

CHAPTER 5

FURTHER RESEARCH AREA

5.1 ADJUSTMENT FOR NEGOTIATION MODEL IN GLOBALIZED MARKETS/MULTI-NATIONAL PROJECTS

There is an accelerating trend towards globalization in the design and construction industry today. The degree of globalization varies from setting up local offices by a multinational design and/or construction firm and working on local construction projects to working in a collaborative environment by forming joint venture with firms from different countries for a large construction project. In either case, it is obvious that adjustments are needed to be made for basic project management principles that are applied to the domestic construction projects by local firms. As the globalization trend continues, the interactions between professionals worldwide are increased. They are expected and required to work together with people with varying ideological, social and cultural backgrounds. This requires not only good communication skills but also a throughout understanding of different issues under global operation. Some of the issues will be social, cultural, political and economic aspects of collaborating firms, the geographical location of the firms as well as the organization structures and natures of the construction projects. In order to establish and maintain collaborative working relationships, all of the issues just stated should be well-considered and understood by the professionals participating the projects. However, it might take them such a long time to aware the importance and existence of all of these issues and make the right adjustments for their projects. Some of the results of being incapable of making appropriate adjustments in time will be budget overrun, schedule delay or even project failure.

However, good understanding of different issues in global operation will not necessarily provide construction firms the effective ways for project control and having successful projects. It is important not only to identify the variables, such as different geographical location, work ideologies, political and economic context, social and cultural background, needed to be considered when organizations are negotiating in global environment but also to understand their relationships and interactions. Identifying these variables in the global negotiation process allows us to analyze their effects and importance to the construction firms working in collaborative environment. Conducting case studies for international projects in a manner similar to our Hong Kong new airport case could be one of the approach used to analyze and estimate those effects and importance of each variables.

On the other hand, it will be helpful if we have a layout, which could assist the negotiators to identify the critical issues that should be considered in the global negotiation process. The layout will be built according to different elements of the process. Those elements are, for example, political and economic environment, social and cultural background, geographical location, organization structure and project nature as well as basic negotiation theories addressed in Chapter 2. It will be similar to the one shown in the Fig. 5.1. As shown in the figure, there are different issues under each element. Those different critical issues under each element could be identified by conducting case studies or literature researches. For example, some of the issues we may need to consider under the element of cultural aspect will be the perception of fairness, the way of conducting meeting and negotiation as well as the attitudes of negotiators from different countries.

After the layout is built, those issues will become the additional variables in our negotiation model presented in Chapter 3. The effects of different issues can then be estimated by running different simulations. By doing this, we extend the usage of our negotiation model to those taking place in the joint venture in which project participants are from different countries. In addition, some other modifications can be made to improve the compatibility of our model to the other common negotiation situation. Those changes are, for example, considering the chance of negotiation breakdown by providing an extra mechanism to determine the likelihood of negotiation breakdown in the model and considering the more realistic non zero sum gain scenario by adding extra inflows or outflows into the stocks representing the Actual Profits of the negotiators. Examples for the sources of the extra inflow can be the incentives package provided by the client for encouraging early delivery of the project.

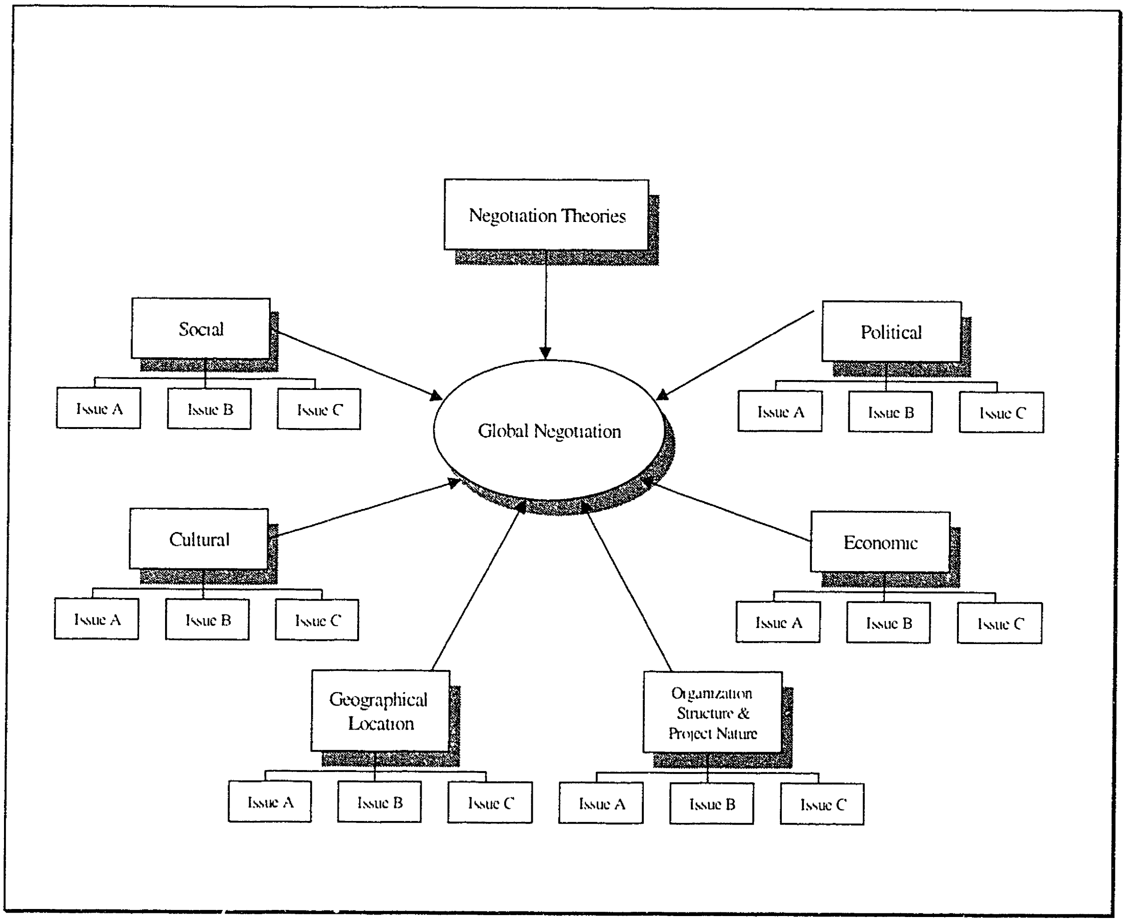

Fig. 5.1 Model for Global Negotiation

5.2 APPLICATION OF NEW HONG KONG AIRPORT MODEL FOR OTHER LARGE-SCALED CONSTRUCTION PROJECT

The purpose of conducting case study for the Hong Kong new airport and building system dynamics models for that case is not only an attempt to demonstrate the application of the system dynamics principles on the large scale construction project but also to provide some sort of template for other similar projects. For other projects, the areas of concern may not be the same as those in our Hong Kong airport case. However, some of the sectors built in that model or some of the adjustment mechanisms used in those sectors can be re-used for other projects after some modifications. For example, the *Overall Performance* sector should be compatible for most, if not all, of the projects. Then, as each project should have their own characteristics, the variables and their formulations should be modified to reflect those unique features. For example, the HACTL is the unique feature of the Hong Kong new airport and should only be in the Hong Kong airport model. However, there may be some other critical systems which could highly affect the project's performance in some other cases. Those variables relating to those systems should replace the mechanisms, which relates to the HACTL, used in the *Opening Day Performance* sector of our airport model.

Further researches could be conducted to explore some principles which could help the model users to modify the developed airport models to serve as a template for their own projects. Changing the developed airport model to a generic model or some sort of molecules, which the user can easily use and reproduce a tailor-made model, will be another interesting area to work on.

5.3 CONCLUSION

In this thesis, we have demonstrated the application of the system dynamics principles and models on the construction project. It helps improve the efficiency of the negotiation processes and allows planners to realize the short-comings of their proposed schedules through showing the relationships and interactions between variables in the processes or the schedules.

As we have stated in the previous chapters, the impact of implementing different negotiation strategies on the result of the negotiation process might not be easily predicted as we assumed in our mental models. The decision making process, preferences and negotiation strategies of other negotiating parties will introduce side effects into our mental models and the outcomes then might be significantly changed. On the other hand, as construction projects are complex as well as the pitfalls of the proposed project schedules and the impacts of change of orders might not be foreseen easily, the project might encounter time and cost overrun due to insufficient understanding of those factors by the project planner during the planning stage or the construction phase. In either case, the system dynamics models and the simulation runs for different scenarios could help analyze the complex system, which is usually consisted of a lot of variables and elements, as we have shown in the Chapters 3 and 4.

For example, after we have implemented different negotiation strategies in the negotiation model, we understand that there are critical factors to be considered when determining the optimal and the most efficient strategy. Those factors are the *Time Pressure* functions of the negotiators, the shape of the negotiators' *Concession Rates* of each issue, the value of the maximum *Concession Rates* and the assignment of the weight to different issues by each negotiator. By understanding the importance of these factors and how they are going to influence the outcomes of the negotiation process, it allows us to be better informed compared with solely relying on the negotiators' experience and their mental models.

Then, in Chapter 4, the system dynamics model and the results of different simulation runs help us simplify the complex situation provided by the large scale project by breaking it down into different sectors. They also allow us to visualize the effects of those different sectors on the *Overall Performance* of the project. The impacts of implementing different policies on the project can also be seen in a much handy manner. All of these could help the planners come up better project schedules during the planning stage and the construction managers implement more efficient policies during the construction phase and they are now making their decisions base upon the simulation results rather than those much less sophisticated mental models.

With the aid of the system dynamics models, such as the Hong Kong airport model presented in Chapter4, we could explore different possible policies and scenarios in the planning phase in order to reduce the chance of getting enormous loss due to the time or cost overrun. For example, we have simulated different runs for scenarios in which we attempt to improve the *Overall Performance* of the Hong Kong new airport through a better *Opening Day Performance.* From those simulation results, we find out that the most efficient way of raising the *Overall Performance* will be keeping the Hong Kong Cargo Terminal Ltd. (HKCTL) problem-free. It is suggested by our model that the system breakdown can be avoided through a longer moving time in addition to the officials from the HKCTL being more honest with the Airport Authority. The longer moving time is needed for that company because it can perform much throughout operating and testing for their new facility.

All in all, this research is conducted as an effort to demonstrate the usefulness of the system dynamics models on the construction industry. By developing robust system dynamics models, the efficiencies and the overall performances of the construction projects could be improved as the probability of project delay would be significantly reduced through much better planning and more efficient negotiation process.

REFERENCES

Ajello, R. (1998), *Terminal Illness Hong Kong Moves Airports in One Nights-But the Transition is Far From Painless*, Asiaweek, July 17, 1998.

Bennett, J. (1991), *International Construction Project Management: General Theory and Practice.* Butterworth-Heinemann Ltd., Oxford, England

Brams, S. (1990), *Negotiation Games – Applying Game Theory to Bargaining and Arbitration*

Braude, J. (1998), *The Fine Judicial Line*, South China Morning Post, July 26, 1998.

Braude, J. (1998), *Hall of Lost Footsteps*, South China Morning Post, August 2, 1998.

Carmel, E. and Herniter, B.(1989), *MEDIANSS: Conceptual Design of a System for Negotiation.* Ninth Conference on Decision Support Systems.

Cheung, J. (1998), *Airport Watch to be Extended for Five Months*, South China Morning Post, August 1, 1998.

Cheung, J. (1998), *Doorless Cage Where Chickens Walk Free*, South China Morning Post, July 31, 1998.

Cheung, J. (1998), *Legislators Demand Full Account for Blunders*, South China Morning Post, July 8, 1998.

Choong, T.S. (1998), *Bugs That Bite Kuala Lumpur's Computer Problems*, Asiaweek, July 17, 1998.

Chung, Y. (1998), *Confusion Will Not Deter Visitors, Says Tourism Chief*, South China Morning Post, July 13, 1998.

Clarke, R. and Tsang, D. (1998), *Trade Chief Blasts Cargo Handler*, South China Morning Post, July 17, 1998.

Darling, T. and Mumpower, J. (1990), *Modeling Cognitive Influences on the Dynamic of Negotiations*, Proceedings of the Twenty Third Annual International Conference on System Sciences, IEEE Computer Society Press.

Fisher, R. and Ury, W. (1991), *Getting To Yes*, Penguin Books, New York.

Gittings, D. (1998), *Disaster Years in the Making*, South China Morning Post, July 19, 1998.

Gittings, D. (1998), *Expert Hands Needed at Helm*, South China Morning Post, July 26, 1998.

Gittings, D. (1998), *HACTL's Haste Remains a Mystery*, South China Morning Post, July 22, 1998.

Gittings, D. (1998), *It's simple, the Top Men Must Go*, South China Morning Post, July 19, 1998.

Gittings, D. (1998), *Lack of Action Needs an Answer*, South China Morning Post, July 15, 1998.

Hajari, N. (1998), *Taking Off Too Soon. Late Flights, Lost Baggage and Fruit Rotting on the Tarmac Have Many Asking Whether Hong Kong Rushed the Opening of Its Overhyped New Airport*, Time Asia VOL. 152 NO. 2

Hon, S.M. (1998), *Bosses Roasted as Committee Vents Fury*, South China Morning Post, July 18, 1998.

Hon, S. M. (1998), *Call for Legco Investigation into Problems*, South China Morning Post, July 9, 1998.

Hon, S. M. (1998), *Kai Tak Flights Not an Option*, South China Morning Post, July 16, 1998.

Hon, S. M. (1998), *"Time for Answers, Not Axe"*, South China Morning Post, July 9, 1998.

Hon, S.M. and Lee, S. (1998), *"Too Early" for Decision on Legal Action against HACTL*, South

China Morning Post, July 17, 1998.
Hong Kong Airport Authority (1998), *New Airport Brief*, Hong Kong Airport Authority Official Homepage, http://www.hkairport.com, 1998.
Ku, G. (1998), *Call for $1b. Loan to Firms*, South China Morning Post, July 19, 1998.
Ku, G. (1998), *October Opening No Better, Says Director*, South China Morning Post, July 17, 1998.
Lau, C. K. (1998), *Diversion Dilemma,* South China Morning Post, July 17, 1998.
Law, S. L. and Saludo R. (1998), *What Went Wrong? Learning from the Foul-ups at Chek Lap Kok*, Asiaweek, July 24, 1998.
Lee, S. (1998), *Airbridge Collision Leads to Shutdown*, South China Morning Post, July 17, 1998.
Lee, S. (1998), *Airport Freight Managers Resign*, South China Morning Post, July 15, 1998.
Lee, S. (1998), *Freight Firms "Risk Collapse"*, South China Morning Post, July 17, 1998.
Lee, S. (1998), *Police Ready to Kick out Sightseers*, South China Morning Post, July 14, 1998.
Leventhal, H. (1976), *The Distribution of Rewards and Resources in Groups and Organizations. In Advances in Experimental Social Psychology*. Academic Press, New York.
Lewicki, R., Litterer, J., Saunders, D., Minton, J., (1993), *Negotiation*, Richard D. Irwin, Inc., Illinois.
Lo, A. (1998), *Guided Tours for Hordes of Sightseers*, South China Morning Post, July 20, 1998.
Love, S. (1989), *Achieving Problem Free Project Management*, John Wiley & Sons, Inc., United States.
Manuel, G. (1998), *Bags of Trouble for Airlines*, South China Morning Post, July 8, 1998
Morrison, A. (1998), *A Date with Disaster Hong Kong's Airport Fiasco Suggests a Disregard of Operational Realities*, Editorial, Asiaweek, July 31, 1998
Morrison, A. (1998), Countdown to a Fiasco, Asiaweek, July 24, 1998
Myerson, R. (1979), *Incentive Compatibility and the Bargaining Problem*, Econometrica, 47:61-73.
No, K. Y. (1998), *Airport Deputy "Loses Face"*, South China Morning Post, July 12, 1998.
Ordeshook, P. (1986), *Game Theory and Political Theory: An Introduction*, Cambridge University Press, Cambridge, UK.
Potter, A. (1995), *Delivery System of Choice*, Construction Business Review, November/ December.
Saunders, D. and Wong, J. S. (1998), *Clients Maybe Put off for Good*, South China Morning Post, July 17, 1998.
Schloss, G. (1998), *Worst over, Says Cathay Chief*, South China Morning Post, July 12, 1998.
Sierra, M. C. (1995), *Managing Global Alliances-Key Steps for Successful Collaboration*, Addison-Wesley Publishing Company, Wokingham, England.
Smith, A. (1998), *Fury on Left-luggage Flight*, South China Morning Post, July 9, 1998.
Smith, R. and Davis, R. (1983), *Negotiation as a Metaphor for Distributed Problem Solving*, Artificial Intelligence. 20:63-109.
Sui, C. (1998), *Truckers Forced to Go out of Business*, South China Morning Post, July 22, 1998.
Thompson, L. (1998), *The Mind and Heart of the Negotiator*, Prentice Hall, New Jersey.
Tien, J. (1998), *Chek Lap Kok: the Bill Must Be Paid*, South China Morning Post, July 14, 1998.
Tiong, R. (1996), *CSFs in Competitive Tendering and Negotiation Model for BOT Projects,* Journal of Construction Engineering and Management, September 1996, pp.205-211.
Trauner, T.J. (1990), *Construction Delays*, R.S. Means Company, Inc., Massachusetts.
Vernon-Wortzel, H. and Wortzel, L. H. (1997), *Strategic Management in the Global Economy*,

John Wiley & Sons, Inc., New York.

Wan, L. R. (1998), *Airport Beset by thousands of Sightseers*, South China Morning Post, July 13, 1998.

Wan, L. R. (1998), *Bosses Must Resign or be Fired, Says ADPL*, South China Morning Post, July 13, 1998.

Wan, L. (1998), *Xinhua Full of Praise for 'Masterpiece'*, South China Morning Post, July 9, 1998.

Williams, C. (1998), *Crowds Continue to Visit Despite Warnings from Authority*, South China Morning Post, July 19, 1998.

Williams, C. (1998), *Drilling May Have Driven Down Dolphin Numbers*, South China Morning Post, August 3, 1998.

Williams, C. (1998), *New All Bad for Media Distributor*, South China Morning Post, July 9, 1998.

Wong, W. Y. (1998), *Perfection "Still Weeks Away"*, South China Morning Post, July 8, 1998.

Woodward, J.F. (1997), *Construction Project Management Getting It Right First Time*, Thomas Telford Publishing, Heron Quay, London.

APPENDIX A

Document for System Dynamics Model for Negotiation Process:

(01) Actual Profit[Negotiator]= INTEG (
Profit Changing Rate[Negotiator],
Initial Actual Profit[Negotiator])
Units: Dmnl
The Actual Profit of the negotiator throughout the negotiation process

(02) Concession On Desired Profit[Negotiator]=
Time Pressure Effect On Concession f[Negotiator](Time Pressure to Reach Agreement
[Negotiator])*Ratio Effect on Concession DP f[Negotiator](Ratio of AP to DP
[Negotiator])
Units: Dmnl/Month
The concession rate of each party

(03) Concession Rate f[A,One](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[A,Two](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[A,Three](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[B,One](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[B,Two](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[B,Three](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[C,One](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[C,Two](
[(0,0)-(1,5)],(0,5),(1,0))
Concession Rate f[C,Three](
[(0,0)-(1,5)],(0,5),(1,0))
Units: Dmnl/Month
The concession rate on each issue by individual negotiator

(04) Desired Profit[Negotiator]= INTEG (
-Concession On Desired Profit[Negotiator],

Initial Desired Profit[Negotiator])
Units: Dmnl
The desired profit of the negotiating party throughout the process

(05) Effect of Attitude[A,Negotiator]=
1,0.5,0.5
Effect of Attitude[B,Negotiator]=
0.5,1,0.5
Effect of Attitude[C,Negotiator]=
0.5,0.5,1
Units: Dmnl
The effect of the negotiator's attitude on the concession rate

(06) FINAL TIME = 24
Units: Month
The final time for the simulation.

(07) Higher Order Concession Rate[A]=
(Effect of Attitude[A,A]*Self Concession Rate[A]+0.1*Effect of Attitude[A
,B]*(Self Concession Rate[B]-Self Concession Rate[A])+0.1*Effect of Attitude
[A,C]*(Self Concession Rate[C]-Self Concession Rate[A]))*Rate of Interaction f
(Rate of Interaction)
Higher Order Concession Rate[B]=
(Effect of Attitude[B,B]*Self Concession Rate[B]+0.1*Effect of Attitude[B
,A]*(Self Concession Rate[A]-Self Concession Rate[B])+0.1*Effect of Attitude
[B,C]*(Self Concession Rate[C]-Self Concession Rate[B]))*Rate of Interaction f
(Rate of Interaction)
Higher Order Concession Rate[C]=
(Effect of Attitude[C,C]*Self Concession Rate[C]+0.1*Effect of Attitude[C
,A]*(Self Concession Rate[A]-Self Concession Rate[C])+0.1*Effect of Attitude
[C,B]*(Self Concession Rate[B]-Self Concession Rate[C]))*Rate of Interaction f
(Rate of Interaction)
Units: Dmnl/Month
The higher order concession rate which is the concession rate not only concern the own concession rate but also considering how much the other given up.

(08) Higher Order Concession Rate Distribution[A,A]=
-1
Higher Order Concession Rate Distribution[Negotiator,B]=

0.5,-1,0.5
Higher Order Concession Rate Distribution[Negotiator,C]=
0.5,0.5,-1
Higher Order Concession Rate Distribution[B,A]= GAME (
0.5)
Higher Order Concession Rate Distribution[C,A]= GAME (
1-Higher Order Concession Rate Distribution[B,A])
Units: Dmnl
The distribution of the higher order concession to the negotiating parties. As that is the amount of profit willing to foregone, the facto must be -1 to himself while the sume of the others will be 1.

(09) Initial Actual Profit[A]= GAME (
60)
Initial Actual Profit[B]= GAME (
90)
Initial Actual Profit[C]= GAME (
50)
Units: Dmnl
The initial Actual Profit obtained by each negotiator before negotiation

(10) Initial Desired Profit[A]= GAME (
80)
Initial Desired Profit[B]= GAME (
100)
Initial Desired Profit[C]= GAME (
75)
Units: Dmnl
The desired profit the negotiation party wants from the negotiation

(11) INITIAL TIME = 0
Units: Month
The initial time for the simulation.

(12) Issue:
One, Two, Three
The issues is being negotiating is listed as above. It can be increased to whatever number the user prefers. In that case, adjustment of models are required.

(13) Negotiation Position[Negotiator]=

Ratio Effect Neg Pos f[Negotiator](Ratio of AP to DP[Negotiator])
Units: Dmnl
The negotiator's position

(14) Negotiator:
A,B,C
The negotiating parties is listed.

(15) Profit Changing Rate[A]=
Higher Order Concession Rate[A]*Higher Order Concession Rate Distribution
[A,A]+Higher Order Concession Rate[B]*Higher Order Concession Rate Distribution
[A,B]+Higher Order Concession Rate[C]*Higher Order Concession Rate Distribution
[A,C]
Profit Changing Rate[B]=
Higher Order Concession Rate[A]*Higher Order Concession Rate Distribution
[B,A]+Higher Order Concession Rate[B]*Higher Order Concession Rate Distribution
[B,B]+Higher Order Concession Rate[C]*Higher Order Concession Rate Distribution
[B,C]
Profit Changing Rate[C]=
Higher Order Concession Rate[A]*Higher Order Concession Rate Distribution
[C,A]+Higher Order Concession Rate[B]*Higher Order Concession Rate Distribution
[C,B]+Higher Order Concession Rate[C]*Higher Order Concession Rate Distribution
[C,C]
Units: Dmnl/Month
The rate of adjusting the actual profit

(16) Rate of Interaction=
4
Units: 1/Month
Number of meeting per month

(17) Rate of Interaction f(
[(0,0)-(10,1)],(0,0.2),(0.453172,0.552632),(1,0.7),(4,0.85),(10,1))
Units: Dmnl
The adjustment to the effect of the attitude \!\!

(18) Ratio Effect Neg Pos f[A](
[(-10,0)-(1,1)],(-
10,0.75),(0,0.75),(0.5,0.75),(0.75,0.75),(0.845921,0.723684
),(0.918429,0.671053),(0.966767,0.600877),(1,0.5))
Ratio Effect Neg Pos f[B](
[(0,0)-(1,1)],(0,0.8),(0.9,0.8),(1,0.75))
Ratio Effect Neg Pos f[C](
[(0,0)-(1,1)],(0,0.75),(0.6,0.75),(0.661631,0.653509),(0.770393,0.570175)
,(0.867069,0.517544),(1,0.5))
Units: Dmnl
The effect of the ratio on the negotiator's position\!\!\!

(19) Ratio Effect on Concession DP f[A](
[(0.5,0)-(1,1)],(0.5,0.3),(0.75,0.3),(0.805136,0.385965),(0.832326,0.47807
),(0.85,0.58),(0.870091,0.723684),(0.924471,0.877193),(1,1))
Ratio Effect on Concession DP f[B](
[(0.5,0)-(1,1)],(0.5,0.3),(0.9,0.3),(0.918429,0.372807),(0.939577,0.504386
),(0.95,0.65),(0.962236,0.79386),(0.977341,0.916667),(1,1))
Ratio Effect on Concession DP f[C](
[(0.5,0)-
(1,1)],(0.5,0.3),(0.6,0.3),(0.699396,0.412281),(0.75,0.5625),(0.78852
,0.719298),(0.856495,0.850877),(0.918429,0.934211),(1,1))
Units: Dmnl
The effect of the ratio of the desired profit to the actual
profit on the concession rate of desired profit\!\!\!

(20) Ratio of AP to DP[Negotiator]=
Actual Profit[Negotiator]/Desired Profit[Negotiator]
Units: Dmnl
The ratio of the actual profit to the desired profit

(21) SAVEPER =
TIME STEP
Units: Month
The frequency with which output is stored.

(22) Self Concession Rate[Negotiator]=
SUM(Weight[Negotiator,Issue!]*Concession Rate
f[Negotiator,Issue!](Negotiation
Position
[Negotiator]))
Units: Dmnl/Month
The self concession rate of each party

(23) Stated Project Deadline= GAME (
24)
Units: Month
We assumed the project is scheauled to be delivered in 2 years.

(24) Time Left for Project=
max(Stated Project Deadline-Time,0)
Units: Month
The amount of time left for the project

(25) Time Left Neg f[A](
[(0,0)-
(24,1)],(0,1),(4.35045,0.929825),(7.75831,0.833333),(10.4411,0.70614
),(12,0.5),(18,0.2),(24,0.2))
Time Left Neg f[B](
[(0,0)-(24,1)],(0,1),(12,0.6),(24,0.6))
Time Left Neg f[C](
[(0,0)-(24,1)],(0,1),(17.99,1),(18,0.4),(24,0.4))
Units: Dmnl
The estimated amount of pressure on the party to reach the
agreement. As different negotiating parties might have different
number of projects in hand, their pressure function might
vary.\!\!\!

(26) Time Pressure Effect On Concession f[A](
[(0,0)-(1,5)],(0,0),(0.2,0),(0.5,0.5),(1,2))
Time Pressure Effect On Concession f[B](
[(0.0)-(1,2)],(0,0),(0.6,0),(0.725076,0.692982),(0.876133,1.14912),(1,1.5
))
Time Pressure Effect On Concession f[C](
[(0,0)-(1,5)],(0,0),(0.4,0),(0.595166,0.942982),(0.770393,1.57895),(1,2))
Units: Dmnl/Month
The concession rate on the desired profit by each party due to
the time pressure\!\!\!

(27) Time Pressure to Reach Agreement[Negotiator]=
Time Left Neg f[Negotiator](Time Left for Project)
Units: Dmnl
The time pressure exerted on the particular negotiating party

(28) TIME STEP = 0.0625
Units: Month
The time step for the simulation.

(29) Weight[B,Issue]= 0.3,0.4,0.3
Weight[C,Issue]= 0.2,0.3,0.5
Weight[A,One]= GAME (0.5)
Weight[A,Two]= GAME (0.3)
Weight[A,Three]= GAME (0.2)
Units: Dmnl
The weight of each issue to individual party

APPENDIX B

Document for Negotiation Game:

```
:SCREEN WELCOME
COMMAND,"",0,0,0,0,,,SPECIAL>SETTITLE|Negotiation Game
COMMAND,"",0,0,0,0,,,SPECIAL>LOADMODEL|Negotiation.mdl
!COMMAND,"",0,0,0,0,,,SPECIAL>READCUSTOM|Negotiation.vgd
TEXTONLY,"Negotiation",-9,10,100,0,C|Arial|45|I|0-0-255,
TEXTONLY,"Game",15,19,100,0,C|Arial|45|I|0-0-255,
TEXTONLY,"For Multiple Parties & Issues",0,35,100,0,C|Arial|25|I|0-0-255,
TEXTONLY,"Copyright © 1998 Gordon Kwok",0,45,100,0,C,
TEXTONLY,"Press any Key to Continue",0,58,100,0,C|Arial|18|B|0-0-255,
TEXTONLY,"Software subject to restriction of the license agreement",0,75,100,0,C ,
TEXTONLY,"Copyright © 1998 Gordon Kwok ALL RIGHTS
RESERVED",0,78,100,0,C ,
ANYKEY,"",0,0,0,0,0,,,STARTGAME


:SCREEN STARTGAME
! Do some housekeeping
COMMAND,"",0,0,0,0,,,GAME>ENDGAME
COMMAND,"",0,0,0,0,,,SIMULATE>RUNNAME|?Name for new simulation output
(NOT BASE!!!)
COMMAND,"",0,0,0,0,,,SPECIAL>CLEARRUNS|0
COMMAND,"",0,0,0,0,,,GAME>GAMEINTERVAL|1.0
COMMAND,"",0,0,0,0,,,MENU>GAME|o

COMMAND,"",0,0,0,0,,,GAME>GAMEON
CLOSESCREEN,"",0,0,0,0,,,,CONTROL

:SCREEN CONTROL
!  Define the plot
TOOL,"ActualProfit",3,1,30,38,,,CUSTOM>ACTUAL_PROFIT
TOOL,"DesiredProfit",3,40,30,38,,,CUSTOM>DESIRED_PROFIT
TOOL,"Negotiation Position",68,1,30,38,,,CUSTOM>NEGPOSITION

!  Define the slider, price output, and associated text

TextOnly,"Stated Project Time",35,3,30,0,C|Times New Roman|16||255-0-0
SLIDEVAR,"Stated Project Deadline",35,8,30,5,,L|0|50|[0|50|1]
```

```
TextOnly,"Initial Actual Profit",35,16,30,0,C|Times New Roman|16||255-0-0
SLIDEVAR,"Initial Actual Profit[A]",35,21,30,5,,L|0|150|[0|150|1]

TextOnly,"Initial Desired Profit",35,28,30,0,C|Times New Roman|16||255-0-0
SLIDEVAR,"Initial Desired Profit[A]",35,33,30,5,,L|0|150|[0|150|1]

TextOnly,"Weight on Issue One",29,55,30,0,C|Times New Roman|14||255-0-0
SLIDEVAR,"Weight[A,One]",35,59,18,5,H,L|0|1|[0|1|0.05]

TextOnly,"Weight on Issue Two",29,68,30,0,C|Times New Roman|14||255-0-0
SLIDEVAR,"Weight[A,Two]",35,72,18,5,H,L|0|1|[0|1|0.05]

TextOnly,"Weight on Issue Three",29,81,30,0,C|Times New Roman|14||255-0-0
SLIDEVAR,"Weight[A,Three]",35,85,18,5,H,L|0|1|[0|1|0.05]

TextOnly,"Higher Order Concession Rate",56,55,30,0,C|Times New Roman|14||255-0-0
TextOnly,"From A to B",56,59,30,0,C|Times New Roman|14||255-0-0
SLIDEVAR,"Higher Order Concession Rate
Distribution[B,A]",63,63,15,5,H,L|0|1|[0|1|0.05]

TextOnly,"From A to C",56,70,30,0,C|Times New Roman|14||255-0-0
TEXTONLY,"= 1 - From A to C",55,73,30,0,C|Times New Roman|12||0-0-255


!TextOnly, "Negotiators",35,3,15,0,C
!  Game Control buttuns
BUTTON,"GO",44,45,10,5,C,Gg,GAME>GAMEON.CONTROL
BUTTON,"New Game",57,45,10,5,C,,,STARTGAME
```

Appendix C

Document for System Dynamics Model for the New Hong Kong Airport Project :

(001) Absolute Min QP=
0.25
Units: Dmls
The absolute minimum level of QP

(002) Absolute Project Time=
150
Units: Week
The government strictly enforce the project to be delivered no later than 150 weeks after the project started

(003) Achieved ComEff=
Communication Efficiency*Proj Ppt Comm f(Project Participants)
Units: Dmls
The existing level of communiation efficiency between the project participants

(004) Actual Cost= INTEG (
Cost Adjustment Rate,
Expected Cost)
Units: Dollar
The actual project cost as the project proceeds

(005) Actual Project Time= INTEG (
Change in Actual Proj Time,
Stated Project Time)
Units: Week
The amount of time estimated according to the progress of the project.

(006) Avg Time to Adjust PreQP=
20
Units: Week
The average amount of time required to improve the PQP

(007) Chance Bkdn f(
[(0,0)-(1,1)],(0,1),(0.8,1),(0.801,0),(1,0))

Units: Dmls
\!\!HATCL operates OK = 1; Breakdown = 0\!

(008) Chance of Breakdown=
1-(0.5*Frankness of Officials*Time Allowed HACTL f(Time Allowed HACTL Moving In))
Units: Dmls

(009) Chance of Project Delay=
Communication Eff f(Communication Efficiency)*Project size f(Project Size)
Units: Dmls
The chance of the project will be delayed due to the project size, and the effieciency of the communication.

(010) Chance of Project Delay f(
[(0,0)-(1,1)],(0,0),(0.3,0.3),(0.534743,0.504386),(0.794562,0.679825),(1, 0.75))
Units: Dmls
The estimated extra time in terms of fraction of the stated project time according to the chance of the project delay\!\!

(011) Change in Actual Proj Time=
(Target Project Time-Actual Project Time)/Time to Update Schedule
Units: Week/Week
The change of the actual project duration according to the progress of the project

(012) Communication Eff f(
[(0,0)-(1,1)],(0,0.8),(0.0906344,0.776316),(0.220544,0.714912),(0.359517, 0.618421),(0.5,0.5),(0.595166,0.403509),(0.688822,0.333333),(0.800604,0.267544),(0.912387,0.219298),(1,0.2))
Units: Dmls
The impact of the efficiency of the communication to the chance of the project delay\!\!

(013) Communication Efficiency= INTEG (
Cooperation Level,
Initial Communication Efficiency)
Units: Dmls
The estimated efficiency of communication depending on the

cooperation level between and within the participating organizations, the frequency of the report and the number of participants.

(014) Consulting Fee=
2000
Units: Dollar/person/Week

(015) Conversion factor from day to week=
7
Units: Day/Week
Conversion factor for day to week

(016) Conversion factor of week to year=
52
Units: Weeks/Year
Conversion Factor

(017) Cooperation Level=
(Desired ComEff-Communication Efficiency)/Reporting Interval
Units: Dmls/Week
This is the level which could be adjusted by changing the reporting period and hence increase the communication efficiency

(018) Cost Adjustment Rate=
Consulting Fee*Extra Consultants Put Into Project+Loss From HATCL Bkdn+Loss From Proj Delay
Units: Dollar/Week
The rate of increasing the sctual cost

(019) Cost Performance=
Ratio Cost Diff f(Ratio of Cost Diff)
Units: Dmls
The cost performance of the project

(020) Desired ComEff=
MAX(Achieved ComEff,Min ComEff)
Units: Dmls
The desired level of communication efficiency for finishing the project on time

(021) Desired Effect From Time Allowed=

Time Allowed f(Time Allowed for Moving)+STEP(1,100)-STEP(Time
Allowed f(
Time Allowed for Moving),100)
Units: Dmls
The desired effect from time allowed

(022) Desired Extra Consultants put into Project=
Interv Change on Extra Consult f(Intervention Change)
Units: consultants
Thenumber of extra consultants will they put into the project

(023) Desired Lugg Missing Pertentage=
0.3-STEP(0.3,100)
Units: Dmls
The desired luggage missing percentage is zero.

(024) Desired Management Competence=
0.85
Units: Dmls
The desired level of management competence.

(025) Desired Ratio of Working Phone=
150/350+STEP(0.9,100)-STEP(150/350,100)
Units: Dmls
The desired ratio of working phone is 90%

(026) Diff ET f(
[(0,-0.08)-(1,0)],(0,0),(0.0966767,-0.017193),(0.232628,-
0.0357895),(0.441088
,-0.0470175),(0.8,-0.05),(1,-0.05))
Units: Dmls/Week
The impact of forcing the airport to be finished by the time it
supposed to be.\!\!\!

(027) Diff Performance f(
[(0,0)-(1,1)],(0,1),(0.8,0.2),(1,0.2))
Units: Dmls
Estimated relationship between the public satisfaction to the
difference in the performance\!\!

(028) Difference Extra Time Switch=
IF THEN ELSE(Time>10, 1 , 0)
Units: Dmls

(029) Difference in Extra Time=
(Extra Time Required-Extra Time Allowed)/Extra Time Required
Units: Dmls

(030) Difference in Performance=
(Expected Performance-Overall Performance)/Expected Performance
Units: Dmls
The ratio of the difference in the overall performance to the expected performance.

(031) Effect From Time Allowed=
SMOOTH(Desired Effect From Time Allowed, Time Time Allowed)
Units: Dmls
The effect of the time allowed for the equipments moving from Kai Tai Airport to Chek Lap Kok New airport

(032) Expected Cost=
2e+010
Units: Dollar

(033) Expected Performance=
1
Units: Dmls
The expected overall performance by the public. It is set to 1 , which is very high, as the amount spent on this project and the high volume of advertisement from the government and the mass media.

(034) Extra Consultant Hiring Rate=
(Desired Extra Consultants put into Project-Extra Consultants Put Into Project
)/Time Hire Consultants
Units: consultants/Week
Hiring rate of extra consultant

(035) Extra Consultants f(
[(0,0)-
(600,0.5)],(0,0),(47.1299,0.0526316),(85.1964,0.0877193),(150.453,
0.122807),(226.586,0.153509),(315.408,0.177632),(400.604,0.190789),(500,0.2
),(600,0.2))
Units: Dmls
The improvement on the overall performance through the extra consultants.It is assumed the maximum improvement would be 20%

increase on the overall performance \!\!\!

(036) Extra Consultants Put Into Project= INTEG (
Extra Consultant Hiring Rate,
0)
Units: consultants
The extra consultants have been successfully hired and put into
project

(037) Extra Time Allowed=
min(Extra Time Required*Pressure ET f(Government
Intervention),1.8*Stated Project
Time)
Units: Week

(038) Extra Time Allowed f(
[(0,0)-
(200,0.5)],(0,0),(6.64653,0.0789474),(18.7311,0.155702),(28.3988,0.208333
),(38.0665,0.243421),(49.5468,0.267544),(70.0906,0.282895),(105.74,0.29386
),(150,0.3),(200,0.3))
Units: Dmls
The improvement of the overall performance due to the extra time
allowed \!\!

(039) Extra Time Required=
Indicated Actual Project Time-Actual Project Time
Units: Week
The extra time asked by the participants in the projects.

(040) FINAL TIME = 200
Units: Week
The final time for the simulation.

(041) Flight Info Screen Blank=
SMOOTH(Flight Info Screen Working,Time FIS)
Units: Dmls
The flight information screen is not working on the opening day
and is assigned the value of 0. It will be fixed at the rate
corresponding to the Time FIS

(042) Flight Info Screen Working=
0+STEP(1,100)
Units: Dmls
Now the flight information screen is working

(043) Flt Info Scn f(
[(0,0)-(2,1)],(0,0.2),(0.999,0.2),(1,1),(2,1))
Units: Dmls
If the flight info. screen go blank, the airport could only
performs at 20% of capacity.\!\!

(044) Frankness of Officials=
0.5
Units: Dmls

(045) Government Intervention= INTEG (
Intervention Change,
Standard Government Intervention)
Units: Dmls
The amount of government intervention put into the airport
project due to the standard coordination practice and the public
dissatisfaction by the underexpected performance.

(046) HACTL Bkdn f(
[(0,0)-(1,1)],(0,0.2),(0.5,0.2),(0.549849,0.385965),(0.622356,0.557018),(
0.716012,0.714912),(0.821752,0.846491),(0.92145,0.951754),(1,1))
Units: Dmls
\!\!When the HACTL breakdown, it allows the airport perform only
20% of the capacity.\!

(047) HACTL Breakdown=
SMOOTH(HACTL Working,Time HACTL Working)
Units: Dmls
The chance of the HACTL will be breakdown is determined by the
factor of frankness of officials and the time allowed HACTL
movinging in ahead of the opening day. If it will breakdown, it
will be fixed at the rate determined by the Time HACTL Working

(048) HACTL Working=
Chance Bkdn f(Chance of Breakdown)+STEP(1,100)-STEP(Chance Bkdn
f(Chance of
Breakdown),100)
Units: Dmls
When the HACTL is working properly, the factor on the Quality
Performance After Opening Day is 1.

(049) Indicated Actual Project Time=

Actual Project Time*(1+Chance of Project Delay f(Chance of Project Delay)
)+"Margins Allowed for Delay/Rework"+Time Allowed HACTL Moving In
/Conversion factor from day to week
Units: Week
The indicated actual project time considering the chance of project delay, margins allowed for delay and rework as well as the time allowed HACTL to move in

(050) Indicated Extra Government Intervention=
Public Satisfaction f(Public Satisfaction)
Units: Dmls
The amount of extra government intervention according to the public's opinion and the satisfaction level

(051) Initial Communication Efficiency=
0.5
Units: Dmls
The initial level of communication efficiency when the project starts

(052) Initial Mgt Comp=
0.5
Units: Dmls
Initial level of management competence

(053) Initial PreQP=
1*Initial Mgt Comp*User Fdly Dgn f(User Friendly Design)
Units: Dmls
The initial level of PQP

(054) INITIAL TIME = 0
Units: Week
The initial time for the simulation.

(055) Interv Change on Extra Consult f(
[(0,0)-(0.6,600)],(0,0),(0.0652568,118.421),(0.222961,315.789),(0.389728,452.632),(0.5,500),(0.6,500))
Units: consultants
The estimated relationship between the extra consultants will be put into the project according to the level of the extra government intervention.\!\!\!

(056) Intervention Change=
Indicated Extra Government Intervention/Time to Change Intervention
Units: Dmls/Week
The rate of changing the government intervention

(057) Loss From HATCL Bkdn=
(1-HACTL Breakdown)*Opening Day Switch*Weekly Cost of HATCL Bkdn
Units: Dollar/Week
The loss due to the HACTL breakdown

(058) Loss From Proj Delay=
(Revenue Loss+Tourism Loss)*Project Delay Switch
Units: Dollar/Week
The loss of the sirport due to the loss from the tourism, the loss business to the nearby airport, the loss from sacrificed revenue, interest costs, etc.

(059) Lugg Missing f(
[(0,0)-(1,1)],(0,0),(1,1))
Units: Dmls

(060) Luggage Missing Percentage=
SMOOTH(Desired Lugg Missing Pertentage, Time LMP /Conversion factor from day to week)
Units: Dmls
The guessed amount of luggage missing/misplaced on the opening day is 30%. it is then fixed at the rate according to the Time LMP

(061) Management Competence= INTEG (
Mgt Comp Adj Rate,
Initial Mgt Comp)
Units: Dmls
The nowledge level of the top management in this project. Average is assumed to be 0.5 and full knowldege is 1.

(062) "Margins Allowed for Delay/Rework"=
0
Units: Week
At the time the project is scheduled, it is under tremendous time pressure to finish by the day of Hong Kong turnover. So, there are sources wondered if there is no margin for the delay

and rework.

(063) Mgt Comp Adj Rate=
(Desired Management Competence-Management Competence)/Time Mgt
Comp
Units: Dmls/Week
Rate of increasing the management competence

(064) Min ComEff=0.4
Units: Dmls
The minimum level of communication efficiency required for
finishing the project

(065) Min Proj Ppt=60
Units: participants
The minimum number of participants remaining in the project

(066) Minimum Preopening Quality=0.75
Units: Dmls
75% of full capacity is expected when the airport starts to
operate

(067) Number of Tourist Loss=
1e+007
Units: Persons/Year
The number of tourists enter Hong Kong per year

(068) Opening Day Switch=
IF THEN ELSE(Time>=100 , 1 , 0)
Units: Dmls

(069) Overall Performance=
min(((Cost Performance*Weight of CP+Quality Performance*Weight of
QP+Time
Performance
*Weight of TP))/(Weight of CP+Weight of QP+Weight of TP)+Extra Consultants
f
(Extra Consultants Put Into Project)+Extra Time Allowed f
(Extra Time Allowed),1)
Units: Dmls
The overall performance of the airport considering the time,
cost and quality aspects.

(070) Preopening Expected Quality=

MAX(Minimum Preopening Quality,Preopening Quality Performance)
Units: Dmls
The level of preopening quality performance

(071) Preopening Quality Performance= INTEG (
PreQP Adjustment Rate, Initial PreQP)
Units: Dmls
The quality performance before the airport starts to operate

(072) PreQP Adjustment Rate=
((Preopening Expected Quality-Preopening Quality Performance)/Avg Time to Adjust PreQP+(1-Opening Day Switch)*(Mgt Comp Adj Rate)+0.5*(1-Opening Day Switch)*Difference Extra Time Switch*Diff ET f(Difference in Extra Time))*(1-Opening Day Switch)
Units: Dmls/Week
The rate of adjusting the PQP

(073) Pressure ET f(
[(0,0)-
(1,1)],(0,0),(0.5,0.5),(0.592145,0.605263),(0.661631,0.714912),(0.731118
,0.824561),(0.8,1),(1,1))
Units: Dmls
The pressure come from the government to hurry the project\!\!

(074) Proj Ppt Comm f(
[(0,0)-
(600,1)],(0,0.8),(50,0.8),(132.931,0.741228),(204.23,0.627193),(270.695
,0.438596),(300,0.3),(500,0.3))
Units: Dmls
The estimated effect on the communication effiency due to the number of the participants in the project.\!\!

(075) Proj Ppt Size f(
[(0,0)-
(400,1)],(0,0),(26.435,0.27193),(45.3172,0.421053),(65.71,0.583333
),(97.432,0.745614),(125.378,0.850877),(151.813,0.916667),(200,1),(300,1))
Units: Dmls
The project size is rated between 0 to 1 depending the number of participant like contractors, subcontractors, design firms, etc. It is considered to be a large, ie "1", project if the number of participants is more than 200. \!\!\!

(076) Project Delay Switch=

IF THEN ELSE(Time>=Stated Project Time:AND::NOT:Opening Day
Switch=1,1 ,
0)
Units: Dmls
The switch is on when the project is longer than stated project
time

(077) Project Participants=
250-STEP(150,50)-STEP(40,70)
Units: participants
The number of participants in this project is assumed to follow
the schedule of 250 contractors at the beginning of the job.
Then, 100 at the week of 50 and 50 at the week of 70. If the
project is finished on time, all the participants will leave at
week of 75 otherwise 50 contractors will stay until the project
is delivered.

(078) Project Size=Proj Ppt Size f(Project Participants)
Units: Dmls

(079) Project size f([(0,0)-(1,1)],(0,0.5),(0.5,0.5),(1,0.8))
Units: Dmls
The estimated relationship between the chance of the project
delay and the project size. We assumed that no matter how small
the project is, the chance of the delay is 0.5 and then the
chance is increasing linearly for project larger than 0.5 in
size until the maximum of 80% of chance when the project is
large, size =1. \!\!

(080) Public Satisfaction=Diff Performance f(Difference in Performance)
Units: Dmls
The public's level of satisfaction to the airport.

(081) Public Satisfaction f(
[(0,0)-
(1,1)],(0,0.5),(0.172205,0.469298),(0.332326,0.421053),(0.486405,0.346491
),(0.655589,0.223684),(0.75,0.125),(1,0))
Units: Dmls
The amount of extra government intervention due to the public's
satisfaction level to the airport.\!\!\!

(082) Quality Performance=
IF THEN ELSE(Opening Day Switch=1,Quality Performance After
Opening Day ,

Preopening Quality Performance)
Units: Dmls
The quality performance of the project

(083) Quality Performance After Opening Day=
MAX(Absolute Min QP,Opening Day Switch*(Flt Info Scn f(Flight Info
Screen Blank
)*HACTL Bkdn f(HACTL Breakdown)*(1-Lugg Missing f(Luggage Missing
Percentage
))*Ratio Wk Phone f(Ratio of Working Phone)*Effect From Time
Allowed))
Units: Dmls
The quality performance on and after the opening day.

(084) Ratio Cost Diff f([(0,0)-(1,1)],(0,1),(1,0))
Units: Dmls

(085) Ratio of Cost Diff=(Actual Cost-Expected Cost)/Expected Cost
Units: Dmls
Ratio of cost difference to the expected cost

(086) Ratio of Overtime f(
[(0,0)-
(1,1)],(0,1),(0.2,0.8),(0.23565,0.640351),(0.256798,0.52193),(0.317221
,0.416667),(0.413897,0.337719),(0.58006,0.27193),(0.652568,0.245614),(0.7311
18
,0.22807),(0.821752,0.219298),(1,0.2))
Units: Dmls
The impact of overtime to the time performance of the airport

(087) Ratio of Overtime to Stated PT=
(Actual Project Time-Stated Project Time)/Stated Project Time
Units: Dmls
The ratio of the amount of overtime to the scheduled project
duration

(088) Ratio of Working Phone=
SMOOTH(Desired Ratio of Working Phone , Time Working Phone)
Units: Dmls
The initial ratio of working phone is 150/350. It is then fixed
at the rate depending on Time Working Phone

(089) Ratio Wk Phone f([(0,0)-(1,1)],(0,0),(0.9,1))
Units: Dmls

(090) Reporting Interval=1
Units: Week
The time interval between the reports submittal among the project participants

(091) Revenue Generated From Each Tourist=500
Units: Dollar/person
The amount spent per tourist per week

(092) Revenue Loss=300000
Units: Dollar/Week
According to Hong Kong Airport Authority spokesman, the 9 weeks delay of the projects cost $USD $2.7 million for the sacrifice income, interest costs, etc.

(093) SAVEPER = TIME STEP
Units: Week
The frequency with which output is stored.

(094) Shown=Consulting Fee*Extra Consultants Put Into Project
Units: Dollar/Week

(095) Standard Government Intervention=0.3
Units: Dmls
The estimated amount of intervention government will put into a project for coordination and monitoring.

(096) Stated Project Time=75
Units: Week
The scheduled project duration

(097) Target Project Time=min(Absolute Project Time,Indicated Actual Project Time)
Units: Week
The desired project duration by the government

(098) Time Allowed f(
[(0,0)-
(10,1)],(0,0),(1.66163,0.350877),(2.74924,0.548246),(3.98792,0.732456
),(5.40786,0.903509),(7,1))
Units: Dmls

(099) Time Allowed for Moving=1
Units: Day

(100) Time Allowed HACTL f(
[(0,0)-
(60,1)],(0,0),(9.96979,0.29386),(16.6767,0.469298),(19.7583,0.54386
),(21.9335,0.605263),(24.6526,0.671053),(27.5529,0.732456),(30.8157,0.811404
),(34.2598,0.877193),(37.3414,0.925439),(41.3293,0.973684),(45,1))
Units: Dmls
The relationship between the chance of the breakdown of HACTL and the time allowed for that company to move in before the opening day of airport. Time is measured in days. The maximum amount in our consideration is 60 days.

(101) Time Allowed HACTL Moving In=4
Units: Day
The amount of time allowed HACTL to move in ahead of opening day.

(102) Time FIS=1.5
Units: Week
The average time needed to correct the computer program error in the flight information screen.

(103) Time HACTL Working=10
Units: Week
The minimum number of weeks required to fix the problems in the HACTL

(104) Time Hire Consultants=2
Units: Week
The amount of time needed to hire consultants to improve the overall performance

(105) Time LMP=5
Units: Day
The amount of time to fix this problem

(106) Time Mgt Comp=15
Units: Week
The estimated number of weeks to improve the management competence

(107) Time Performance=Ratio of Overtime f(Ratio of Overtime to Stated PT)
Units: Dmls
The time performance of the airport

(108) TIME STEP = 0.25
Units: Week
The time step for the simulation.

(109) Time Time Allowed=3
Units: Week
The average time to adjust the effect from time allowed

(110) Time to Change Intervention=20
Units: Week
The average time needed to change the level of intervention by government

(111) Time to Update Schedule=4
Units: Week
The average time to update the existing projet schedule

(112) Time Working Phone=2
Units: Week
The amount of time to fix the problems associated with the phones

(113) Tourism Loss=Number of Tourist Loss/Conversion factor of week to year*Revenue Generated From Each Tourist
Units: Dollar/Week
From the statistics data of the Hong Kong Government, there are around 10 million tourist per year and each of them spend around USD100 per day.

(114) User Fdly Dgn f(
[(0,0)-
(1,1)],(0,0.2),(0.2,0.2),(0.332326,0.47807),(0.516616,0.692982),(0.73716
,0.877193),(1,1))
Units: Dmls
The impact of the design to the quality performance \!\!\!

(115) User Friendly Design=0.35
Units: Dmls
The easiness of using the airport facility by the passenger. Average is 0.5 while 1 is consider to be difficult to understand/inconvient to use

(116) Weekly Cost of HATCL Bkdn=5.9e+008
Units: Dollar/Week

(117) Weight of CP=0.333333
Units: Dmls
Weight of Cost on the overall performance

(118) Weight of QP=0.333333
Units: Dmls
Weight of Quality on Overall Performance

(119) Weight of TP=0.333333
Units: Dmls
Weight of Time on overall performance

THESIS PROCESSING SLIP

FIXED FIELD: ill. ______ name ______

index ______ biblio ______

▶ COPIES: (Archives) Aero Dewey (Eng) Hum

Lindgren Music Rotch Science

TITLE VARIES: ▶☐ ______

NAME VARIES: ▶☐ ______

IMPRINT: (COPYRIGHT) ______

▶ COLLATION: 139 l

▶ ADD: DEGREE: ______ ▶ DEPT.: ______

SUPERVISORS: ______

NOTES:

cat'r: date:

page:

▶ F36

▶ DEPT: C.E.

▶ YEAR: 1999 ▶ DEGREE: S.M.

▶ NAME: KWOK, Sze Yiu Gordon