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Dynamic Analysis of Petrochemical Project Progress - A System Dynamics Approach

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Abstract

Petrochemical projects are generally classified as high profit projects. On time finishing of these projects would be a critical factor for the development of the oil or gas based countries. Recent experiences in petrochemical project management in Iran, indicate some important problems in operating of these kinds of projects such as long delay and cost overrun. Considering the lost benefit of the projects delay, this paper aims to modeling the delay process using System Dynamic approach. This method provides a powerful support mechanism for resolving problems in highly complex and dynamic contexts. After a brief reference to delay causes in research and practice, the model is discussed. The results of this study emphasize the lack of available capacity effects on projects progress. Finally, the paper briefly debates the implication of the model structure for analyzing policies to solve the problem.

Keywords
Project, System Dynamic, Petrochemical Project.

1. Introduction

Large scale projects such as petrochemical projects are an index of economic and social progress of a country especially in oil or gas based countries. In recent decades, there has been a remarkable growth in the number, size and complexity of large scale petrochemical projects in Iran. Monitoring and management of these projects inevitably requires dealing with substantial schedule and cost overruns. Iranian National Petrochemical Company (NPC) as a government firm is concerned about enhancing organizational performance for increasing its profit and approaching to Iranian Petrochemical industry twenty year's vision. NPC (which is briefly introduced in section 2) planned to operate a large number of projects in 1997. In this year only two projects were under implementation. After four years, the number of ongoing projects was extremely increased up to 22 projects. In current decade, the Iranian petrochemical projects have suffered significant delay and cost overrun due to NPC emphasize on national executing capacity. Because of the national project provisions, more than 50 percent of a Petrochemical Project will be done by Iranian. Although lost benefit of these large scale projects is considerable, 80% delay is a usual percent in these projects.

Base on foregoing discussion, the analysis of delay problem which results in cost overruns and lost benefit is recently considered. A survey by Petrochemical Industry Development Management Company (PIDMCO, 2005), revealed delay sources which were created by indoor makers. These sources are extracted from Atomistic View and classified in several sections such as delays created by environmental variables, owner, maker, and design Engineering and Procurement part (EP). Yousefian and Alipoor (2006) classified petrochemical projects build and erection phase's challenges in 4 categories including owner, design engineer, contractors, and makers. Dibaii (2006) indicated that weakness in human resources management, personnel errors, owner and relationship method with joint ventures are the most important sources for delays which are related to design part of EPC projects caused only by design engineers. In a sample of five projects by Masoomian (2008), the most important challenges of petrochemical project management are finance, indoor maker's weakness to on-time delivering of equipments, and lack of risk management. In spite of all attempts with regard to solve the delay problem in petrochemical industry field, employing System Dynamic (SD) method to clarify the delay process of petrochemical projects is rarely reported in literature review. The aim of this study is to identify the substantial dynamics of delays in whole NPC projects during the last decade (1997-2008). In the following sections after presenting a brief history of NPC and system dynamics approach, results of the field study are described. Then, system dynamic modeling process including reference modes and dynamic hypotheses are explained. After that, the casual loop diagramming is developed by considering the preceding sections. Finally, some policies and the relationship between the field study results and casual dynamic analysis are discussed.

2. An Overview of Petrochemical Industry

The initial step towards development of the Iranian petrochemical industry dates back to 1963 when a fertilizer plant was installed in Shiraz (south part of Iran). In 1965, NPC was established to undertake the operation and development of the petrochemical industry. Since then, through joint investments with internationally recognized companies, NPC has established several petrochemical plants, which are operated by subsidiary companies that produce various chemicals for both domestic and foreign markets. The National Petrochemical Company's major activities focus on manufacture, production, sale, distribution and export of commodities derived from hydrocarbons and related materials, both organic and inorganic. In order to reduce imports and promote exports, NIPC has conducted various projects within the Five-Year Development Plans started from 1989. Reconstruction of damaged complexes due to the war during the period of the first development plan was considered from 1989 to 1994. Due to the fact that the experiences of the first development plan accelerated the second development plan targets acquisition, the Iranian Petrochemical Industry was rapidly grown from 1997 .In this year, the feasibility studies of a large number of plants was initiated, and in following years, implementation of these plants was started. Increase in the number of completed projects increased the production rate from 5.2 million ton in 1997 to 24 million ton in 2007.

3. System Dynamics Approach

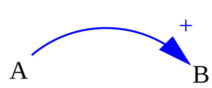
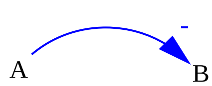
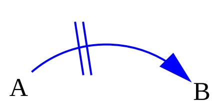
System Dynamic (SD) has been used widely to analyze industrial, economic, social, and environmental systems of all kinds since it was first developed in the late 1950s to apply control theory to the analysis of industrial systems (Turek 1995). SD modeling is useful for managing and simulation of processes with two major characteristics: (1) they involve changes over time and (2) they allow feedback-the transmission and receipt of information (Richardson and Pugh 1981). In this paper, we use the casual diagram modeling approach to describe conceptual model (Table 1 presents typical denotations used in the casual loop diagramming). This approach provides the means to describe the dynamic structure of petrochemical industry projects and, therefore, is an excellent foundation for exploring the behavior of petrochemical organizations before and after the implementation of policies. Recently, SD modeling has been applied to organization performance and project progress research and the literature on its application to project management is sizable. A useful summery of SD applied in project management is available in Lyneis and ford (2007). Ogunlana, Li, and Sukhera (2003) have shown that organization performance and projects progress could be studied using SD modeling. Specifically, Li (2008) implemented a generic model for project management base on rework.

Petrochemical projects:

- Are complex and consist of multiple interdependent components
- Are highly dynamic
- Involve multiple feedback processes
- Involve nonlinear relationships

According to above mentioned characteristics of these projects, SD is best suited to handle these situations more than any other modeling process.

Table 1: Types of casual links (Sterman 2000)

Casual	Denotation
	An increase (decrease) in variable 'A' increase (decrease) variable 'B'
	An increase (decrease) in variable 'A' increase (decrease) variable 'B'
	A significant time delay is involved in implementing the casual relationship between the variable 'A' and 'B'

4. Results of Field Study

This study employed three methods of data collection: interview, using questionnaire, and documents review. Information obtained from a variety of sources is important in conducting system development research because it provides comprehensive perspectives on the study, contributes to validation and cross-checking findings, and compensates for the limitations of one method of data collection with the strengths of the others. In order to elicit the sources of delay, first step is selecting some projects as a statistical universe. In table2, specifications of the representative projects are shown. In order to using comprehensive instances, the projects which experienced low and high delays were selected.

Table 2: Selected Projects specification

Project	initiation date	completed date	Delay	planned budget
Olefin 10	Apr-01	Aug-08	91%	11813
Aromatic 3	Sep-99	Jun-04	58%	4412
Fajr 1	Apr-99	May-04	56%	4888
Expansion of Fajr	Sep-03	ongoing	*121%	5743
Olefin 7	Jul-00	Feb-06	43%	12073
Amir Kabir HDPE	Jan-05	ongoing	*29%	1969
PET/PTA 1	Sep-98	Aug-06	135%	5175
PET/PTA 2	Sep-00	Mar-08	125%	5248
Olefin 6	Sep-98	Aug-05	51%	6116

*: delay percent is up to Nov-2008
Budget is based on year 2004 in billion rail

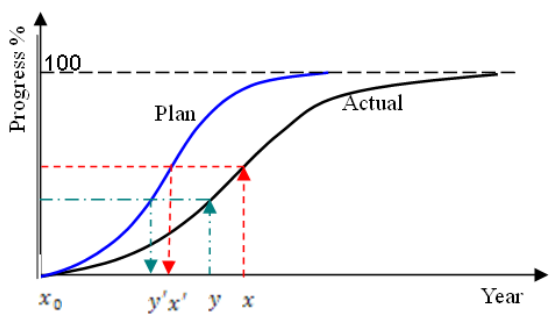


Figure 1: Delay definition

Due to the fact that there are different definitions for delay, it is necessary to introduce the Project initiation date and delay percent concept which is used in this paper. The date when the project's Letter of Credit (LC) is activated, is considered as initiation date. It is different from project definition date which is the date that project implementing works are started.

$$Delay\ (x) = \frac{x - x'}{x' - x_0} * 100 \qquad Yearly\ Delay\ (x) = \frac{x - x'}{y - y'} * 100 \qquad y = x - 1$$

The parameters x, x', x_0, y, and y' are shown in figure1.
Base on above relations, project delay at the end of the project is expressed as:

$$Delay = \frac{x(progress=100) - x'(progress=100)}{x'(progress=100) - x_0} * 100$$

The information is presented in this study is derived from seventeen NPC leading experts experiences. Table 3 shows the role types of these experts involved in the nine case projects. Table 4 contains the results obtained from data gathering. As can be seen in this table, the causes of considered projects delay could be entitled as:

1. Governmental instructions on NPC as a government firm
2. Deficiency of human resources management, especially in the field of hiring and staff training.
3. Lack of proper documentation to transferring the experiences
4. Inconsistency between initial planning and local dominated provisions
5. Government outdoor politics
6. Swift changes in contract Specifications such as cost of material or inflation.

Table 3: Interviewee roles

Generic role	Total Experts
NPC budget planning (NPC BP) engineer	3
project manager	7
Project planning and monitoring (P P&M) manager	4
NPC Planning and monitoring (NPC P&M) engineer	3

5. System Dynamics Approach

Discussion in this section is based on reference mode and cause-effect relationship (feedback) derived from situations under study.

5.1 Reference Mode

The reference mode is intended to specify the study focus. It is a graphical or verbal description of the time development chain of events or social processes of interest [1]. The reference mode was derived as a result of numerous data collection, information gathered through interviews and document review. In order to obtain the reasonable average delay, a weighting method is used to extract the delay curve which is presented in figure 2 and more than 50 projects are evaluated. The planned projects cost are utilized to normalize the individual projects delay. Inflation's effects and projects budget are also normalized base on their values in year 2004. According to this figure, as the number of projects increases, average yearly delay rises to a local maximum in year 2003 and then collapse. The jump observed in year 2005 is caused by an external factor deal with the considerable changes in government policies in this year. This changes affected the major aspects of the large scale projects, specially, contracts with foreign companies. Ignoring this mutation in average yearly delay percent, the general trend of delay curve rises and then falls .This behavior which is known as overshoot and collapse occurs when the ability of the environment to support growing the state of the system is eroded or consumed by the system itself.

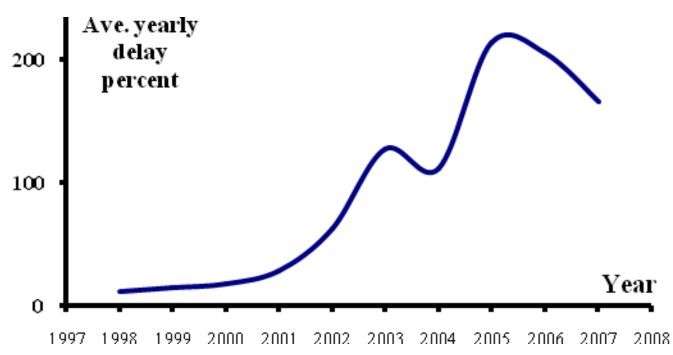


Figure 2: Reference mode

5.2 Dynamic hypothesis

Delay is driven primarily by two variables: actual Progress and desired progress (planed progress). The gap between these two variable leads to time overrun. Taking into account the reference mode, the following dynamic hypotheses are made to explore the cause-effect relationships that may be responsible for time overruns in Petrochemical Projects. Generally, in order to execute a specified number of projects corresponding to primary schedule, a certain executing capacity is required. As mentioned before, Iran National Petrochemical Company started to implement a lot of project in order to achieve the twenty years vision targets around 1997; however, required executing capacity for this large number of projects was not available in country. Due to the lack of the executing capacity, projects progress did not coincide to primary schedule and consequently, the number of finished projects was decreased. The number of ongoing projects increased as a result of decreased in the number of finished projects. On the other hand, definition of new projects leads to increase in the number of ongoing projects. From the other point of view, NPC decreased the definition of new projects in the following years through feedbacks of observed delay. The results of decrease in the project definition rate which is a policy to reduce the number of the ongoing projects were observed after about two years. This period of time is the gap between the definition date and initiation date of a new project. This delay (retardation) leaded to a higher time overrun. It should be noted that increase in the number of ongoing project, gradually, leads to increase in executing capacity. Hence, the average yearly project delay was reduced by decrease in the number of new projects and increase in executing capacity.

Table 4: Field study results

no.	Delay source	Project manager							NPC B-P engineer			P- P&M manager				NPC P&M engineer		
		1	2	3	4	5	6	7	1	2	3	1	2	3	4	1	2	3
1	Governmental instructions on NPC as a government firm	√	√	√	√	√	√		√		√	√	√			√		
2	finance	√	√		√			√		√	√							
3	Deficiency of human resource management	√	√	√	√	√	√		√	√		√	√	√	√	√		√
4	Inefficient cooperation system between owner and contractors	√	√		√		√		√		√						√	
5	Lack of proper documentation to transferring the experiences		√	√	√	√	√	√		√	√		√	√		√		√
6	Inconsistency between initial planning and local dominated provisions	√	√	√	√	√	√	√		√			√	√	√	√		√
7	Incomprehensive feasibility study		√		√	√	√	√										
8	Weakness of management		√	√	√						√	√	√			√		
9	Inappropriate organization chart	√			√	√	√						√	√				
10	Unavailability of previous experience in some parts of new petrochemical projects implementation	√	√		√		√		√	√		√	√	√		√		√
11	Government outdoor politics	√	√	√	√	√	√	√	√	√	√		√	√		√		
12	Project managers have not full authority	√	√			√	√		√			√						
13	Inappropriate bidding instruction		√		√	√	√	√				√					√	
15	Unavailability of proper long time planning strategy												√			√		
16	Ineffective cost management								√	√					√		√	
17	Swift changes in contract Specifications such as material cost or inflation	√		√		√		√	√	√		√		√	√		√	√

5.3 Model boundary

Model boundary shows the primary features included (endogenous), assumed (exogenous), and excluded (ignored). Number of ongoing projects, number of new projects, total activity, delay, progress, capacity, schedule pressure, wrong done work, and human resource are the primarily focused variable within the boundary. Political stability, local influence on projects execution, economical condition, and technology development are considered stable in model producing. Similarly, governmental incentives for promoting infrastructure are also constant. Inefficient bidding, effect of outdoor diplomacies, effects of government provisions on NPC performance, and organization's environment are ignored.

5.4. Casual diagram

The hypotheses (feedback loops) shown in figure 3 and figure 4 were explained as below. Obviously if the number of initiated new projects increases, NPC's total activity which is directly concern to the size and number of projects will increase. As can be seen in figure 3, the desired capacity is adjusted to the total activity whereas increase in available capacity up to desired capacity requires the some years. Therefore, the gap between available and desired capacity leads to decrease in projects progress. More over the increase in this gap results in increase in available capacity. Since progress dose not grow as primary schedule, the number of finished activity decrease. Initiation of new projects and reduction in finished activities keeps the total activity to be greater than expected. It should be noted that the capacity is executing capacity in the paper.

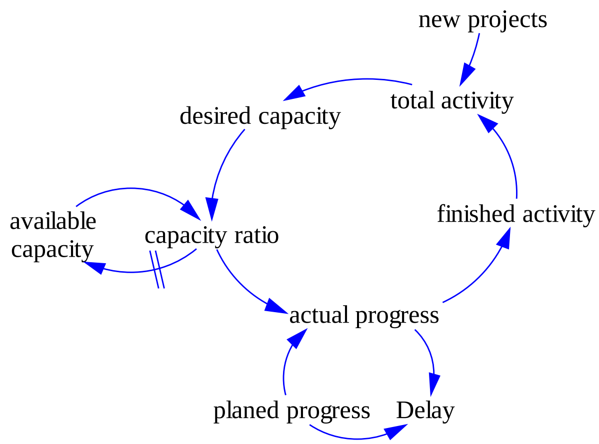


Figure 3: Basic loop

There are two steps to build the casual diagram, first, creating a diagram which is called “the basic loop” without considering lateral effects of the first level variables. Next, the lateral effects of the first step’s feature are added in the basic loop. Figure 4. illustrates how delay worsen the problem. It is known that schedule is one of the important measurements of project performance and finishing a project on time, is the primary goal of project manager. Time overrun has two different effects. First, when projects face delays, managers focus on the projects and try to compress the projects schedule or necessarily slip projects deadlines, and their attention to train the human resource will decease. Capacity is a general factor which changes by labor's population, human resources experience and their quality, and financing ability. Reduction in training leads to decrease in the available capacity growth. Another result of the schedule pressure is increase in incorrect done works (or errors) which are directly related to delay. These errors raise the total activity because of the reworks. Although activities in petrochemical projects design phase usually not weigh more than 10 percent of total project activities (Pahlavani 2005), but other phases such as civil, procurement, erection, and operation are affected by design process. Therefore, the errors which generally take place in design activities have considerable effects on project delay. Change in the number of initiated new projects is second outcome of delay in projects. Definition of new projects is directly influenced by perception of available capacity. If projects don’t follow schedule and have a lot of delay, NPC will decrease the number of new projects by some delay (about two years) and concentrate almost all available capacity to execute previous works. This policy results in total activities reduction which finally decreases projects delays.

6. Model Discussion

A good understanding of the dynamic delay process is a prerequisite of executing projects corresponding to their schedules. In this paper we explain the process of petrochemical projects progress from a holistic perspective and also identify the individual and situational factors that could increase or decrease progress. The dynamic features of the model show, the progress vary depending on capacity level, which is measured by cost. As discussed before, when the available capacity is less than the desired capacity, delay will appear. This fact indicates the importance of capacity intensification to delay reducing. In other words, if NPC before initiated a lot of projects, had planned to increase available capacity by hiring and training staffs, projects would progressed so much better than reality. On the other hand, if the number of new projects had raised respect to the available capacity, there would have been an opportunity to implement projects with reasonable delays. It is noticeable that new deified project requires around two years to initiate. If NPC paid enough attention to this fact and control the number of its defined projects base on average projects delay behavior, it would faced less delay.

7. Conclusion

Previous researches on petrochemical projects progress have commonly recognized several parameters which are responsible for schedule overrun. Also a domestic study indicated weakness in some management competencies (PIDMCO, 2006). However, they have not addressed the dynamics of the delay process. In order to address this issue, the research has presented a dynamic model developed using the concept of system dynamic. The research extracts the delay behavior in Iranian National Petrochemical Company projects using information obtained from data collection and interviewees. It is found; the lack of executing capacity is the main factor for time-overrun and its related loops. The results of system dynamics approach which is based on interview and document review is similar to the field study outcomes. Consequences of the field study could be extremely affected by labor experiences, their ability and quality, managerial skill, economical condition, and government policies. Except the last two parameters which are not considered in the model, the effects of other factors are evaluated in the executing capacity and training variable. The field study extracts the delay causes at the projects level but system dynamic approach find the source causes which are most responsible for delay using global view.

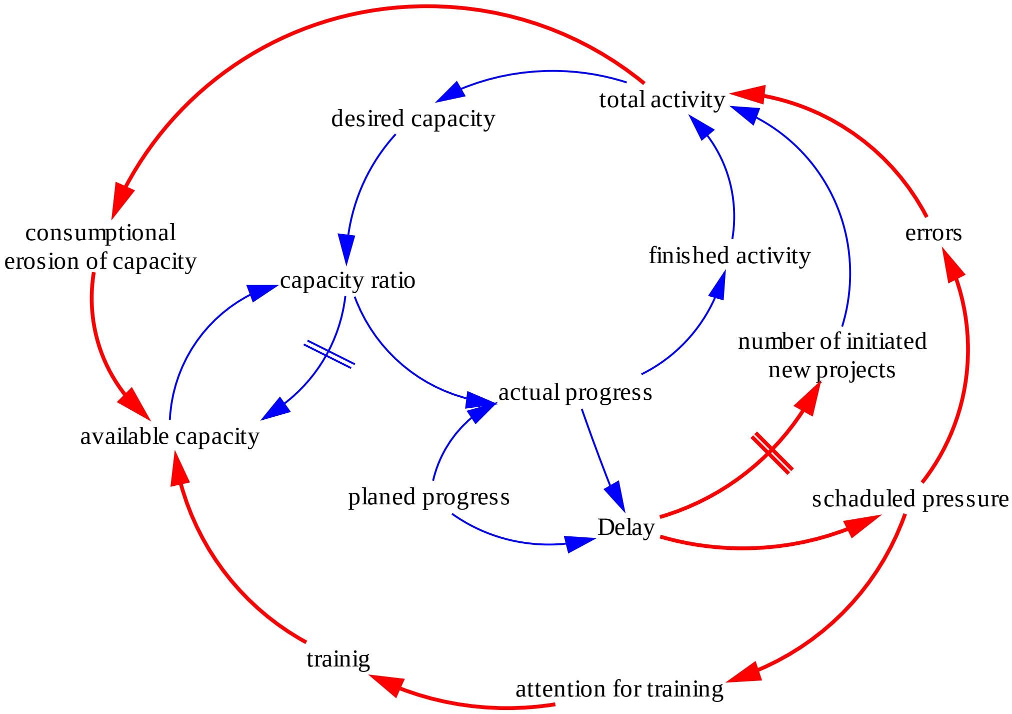


Figure 4: Lateral effects

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