CORPORATE STRATEGY IN FORWARD INTEGRATION
OF AN OIL COMPANY

A study of the implications of an oil company's
diversification into the petrochemical business
and the design of appropriate corporate
strategies for its achievement.

by

Rokneddin Ansari-Sereshki

B.Sc. in Mathematics, Statistics and Computing (Thames Polytechnic)
M.Sc. in Operational Research (London School of Economics)

Thesis submitted to the University of Bradford in
fulfilment of the requirements for
the degree of
Doctor of Philosophy
November, 1980

تقدیم به پدر و مادر و خواهران عزیزم

To my Father, Mother and Sisters — with love

ABSTRACT

The aim of this thesis is to explore the diversification of a major oil company into the petrochemical business and then through thorough analysis to recommend the appropriate corporate strategies to be followed by the petrochemical subsidiary of such a company in the 1980's and the 1990's.

The petrochemical industry has undergone great changes during the last decade. In the early 1970's it entered a new era of maturity, however due to the misplannings of the late 1960's extending to the early 1970's the industry was suddenly faced with significant overcapacity which has persisted to the present date and is expected to last well into the 1980's. The 1974 oil crisis caused a further decline in the growth of demand, hence exacerbating the situation.

During the seventies the industry has had to operate under increasing material prices, unlike the past, which when coupled with the problem of overcapacity and the resulting deterioration of prices, has caused considerable decline in the financial ability of the companies to finance their capital expenditure programmes through internal cash generation (which was the case in the industry's 'golden era'). This situation is threatening the long term viability and survival of the petrochemical businesses.

A System Dynamics model for a hypothetical petrochemical subsidiary of a major oil company has been constructed which embodies all the policies inherent in such a system. The dynamic behaviour of the model closely resembles that expected from the real system such as the declining financial ability,

which is mostly due to the inflationary conditions.

Through thorough analysis, the impact of varying inflation level on the performance of the system was explored, and the need for adopting suitable accounting policies which would take account of the replacement costs of assets, during periods of high inflation, was proposed.

The adoption of a number of policies led to a certain degree of improvement in the financial performance of the system, and these are recommended concerning the corporate strategy of the company for the next two decades.

Finally it was discovered that due to the low level of growth of demand (compared to the past), the large economic sizes of the petrochemical plants and the market share consensus, the companies will have to go into joint ventures in the future.

PREFACE

This thesis should be of interest to management scientists and decision-makers within the petrochemical industry, as well as the academics. It demonstrates how the System Dynamics modelling technique could be applied to strategic corporate planning issues and help to illuminate the trouble areas. For those readers not familiar with the technique, Forrester's (1962) 'Industrial Dynamics' and Coyle's (1977) 'Management System Dynamics' are highly recommended.

Chapter 1 describes in detail the evolution of the petrochemical industry together with its characteristics and most pressing problem. Those familiar with the industry can omit this chapter.

In chapter 2 the reasons for the diversification of the oil companies into the petrochemical business and their strategies are discussed. In doing so the forward integration of 10 major oil companies into the chemical field are explored. Industrialists may also omit this chapter.

In chapter 3 other studies of relevance to this present work are discussed together with the definition of the problem, the aim of the research, the method of approach, the boundary of the system, the nature of the organization, our 'confidential' contacts with a number of companies, the geographical boundary of operation and finally the chemical products selected for the study and the choice of feedstocks.

In chapter 4 the equation formulation of the most important relationships of the model are discussed, full listings of which are given in appendices A and B. The equations are written according to DYSMAP notation (Coyle, 1977).

Chapter 5 discusses the validity of the model together with its dynamic behaviour.

In Chapter 6 a thorough analysis of the poor financial performance of the system is carried out and certain recommendations are made. The robustness of the model is also examined and hence those parameters which are of a sensitive nature are identified. A number of policies which lead to a certain degree of improvement in the financial performance of the system are also discussed and recommended as elements of future corporate strategy for the company.

Chapter 7 summarizes the overall conclusions together with recommendations made for future areas of research.

ACKNOWLEDGEMENT

I would like to take the opportunity, at this point, to acknowledge the co-operation and help of a number of people and organizations which made the undertaking and the completion of this work possible.

First of all my most sincere thanks are due to Dr. R. G. Coyle whose help, guidance and encouragement throughout the three years of my research work has been invaluable.

I should like to give my deepest gratitude to Professor J. C. Higgins for awarding me the scholarship which made my research possible at the System Dynamics Research Group.

In my research I have had the invaluable co-operation of the executives of a number of major oil and chemical companies who have discussed and commented on my work and also suggested some very important factors to be included, which is very much appreciated. Unfortunately, due to reasons of 'confidentiality' I am unable to thank them by name.

My appreciations are extended to the staff of the Management Centre Library, particularly Mr. N. Hunter, the Computer Centre for their excellent services, and also Mrs. R. Pyrah who kindly undertook the typing of my thesis.

Finally and most of all my thanks are due to my wife whose continuous personal involvement and encouragement were invaluable throughout my research.

R. ANSARI-SERESHKI

THE MANAGEMENT CENTRE,

UNIVERSITY OF BRADFORD, NOVEMBER 1980.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

THE PETROCHEMICAL INDUSTRY

1.1 Historical Perspective

The development of the petrochemical industry falls within three eras, the 1900-1936, 1936-1973 and the post 1973. From the 19th century to about 1936, a coal-based basic organic chemical industry developed in the U.S. and Europe. The organic chemicals required during this era were mainly in the form of dyestuffs intermediates, solvents, alcohols and carboxylic acids. By around 1920 the first small quantities of petroleum-based petrochemicals were manufactured for the automotive industry in the form of anti-freeze, paints and various additives. Later, plastics, synthetic rubbers, synthetic fibres and syndets came to the market, however their total raw material requirements were small. The basic organic chemicals were produced mainly from coal by-products and from acetylene derived from calcium carbide and/or molasses.

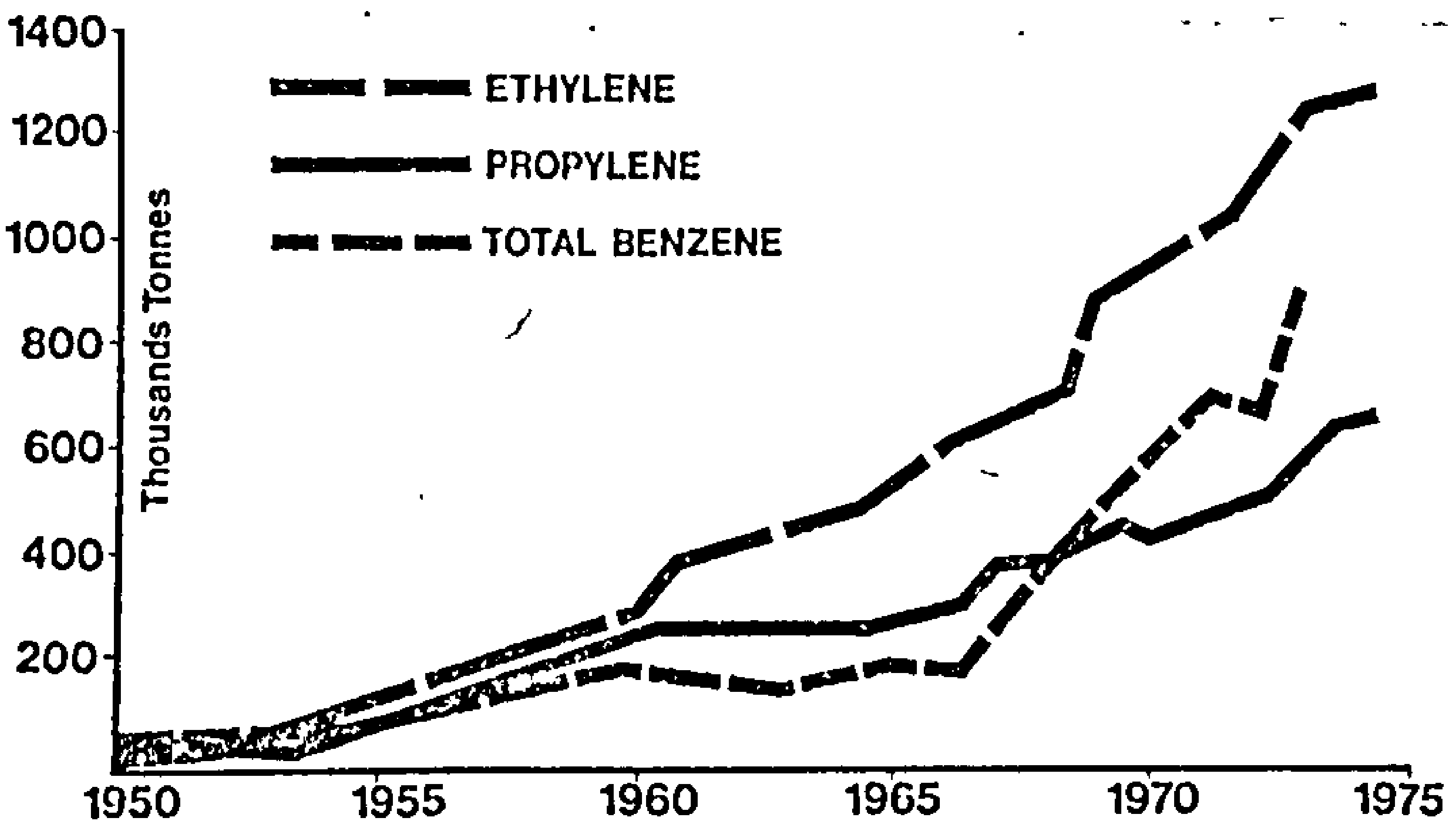
The second world war strongly influenced major developments in the U.S. in petroleum-based chemical activities (especially concerning the production of styrene and butadiene for the manufacture of polymers and synthetic rubbers, ethylene for polyethylene and cyclohexane for adipic acid for nylon) in order to meet a wartime demand far in excess of that which the traditional coal and agriculture sources could supply.

Among the countries with an important chemical industry only the U.S. was at that time a petroleum producer, hence there was no incentive to use oil as raw material. However, in the late 1940's the change from coal to petroleum occurred in the European chemical industry due to (Taylor, 1977):-

the growth in demand during the war for gasoline and synthetic products substituting for scarce natural products; the new oil supplies of the middle East; the huge expansion of the oil refining industry in Europe in the post-war period by the U.S. oil multinationals; the relative ease of transformation of petroleum hydrocarbons into basic chemicals compared with the use of alternative carbon sources; and economic reasons concerning the comparative lower cost of oil.

The growth of this industry has since been very remarkable with world production of petrochemical products increasing from just a few hundred tons in 1920 to 3.5 million in 1950 and to about 70 million tons in 1976, with an average annual growth of more than 14 percent during the 1970-1976 period (UNIDO/ICIS, 1978). The rapid growth of the industry especially during the 1950-1970 period, at about 2.5 times the GDP growth in the same period, was due to an almost explosive growth in demand for polymer materials together with the inadequate competitiveness of the traditional materials either quantitatively or economically. In order to appreciate the magnitude of this rapid development, figure 1.1 demonstrates as an example the production of the industry's three main products, ethylene, propylene and benzene in the U.K. in 1950 and shows the growth in demand through to 1974.

Fig. 1.1 Key Organic Chemical Production in UK 1950-1974



Source: Chemistry and industry, A. W. Taylor, The Petrochemical Industry - some perspective views, 1 January 1977.

It can be observed that the industry expanded rapidly, especially during the last fifteen years for reasons mentioned earlier. This rapid expansion was also significantly assisted by the availability of petroleum based raw materials. The raw material for plants in Europe was a light naphtha, then in surplus supply. In the U.S. LPG was mainly used as feedstock.

The cracking of naphtha for ethylene yielded a range of co-products involving costly purification and separation processes (these plants were more complex than those in the U.S., based on LPG) which consequently increased the production cost of the olefins. The imbalance between the manufacture of co-products and the demand as chemicals for the major products led to:- efforts for up-grading the worth of the co-products from their value as fuel; the development of integrated petrochemical complexes and the maximum increase in plant sizes commensurate with technical risk and the reduction of investment cost per ton of product.

The development of the large ethylene plant was absolutely necessary if Europe and Japan were to become cost competitive with the U.S. production, based on the simpler and artificially low costed feedstocks (natural petroleum gases). In order to appreciate the magnitude of this development, it can be noted that in the 1950's a large naphtha-based ethylene plant produced 50000 tons/year. However, by the end of the 1960's the large ethylene plants were producing 500000 tons/year in one single train (Taylor, 1977) and currently the production of olefins and particularly that of ethylene is the major operation of this industry.

The evolution of the large scale modern petrochemical complexes was facilitated by the adaptation of the technology of large scale oil refining which decreased investment costs per ton of product, and by the spreading of overheads and semivariable costs. This trend which was more visible during the 1960's led to the provision of capacity ahead of demand in order to reap the benefits from large-scale operations. However, the consequence of this strategy was that either in a down-turn in demand or in anticipation of full plant capacity utilization of a new large plant, prices were lowered to unprofitable levels.

However this era of rapid development, during which profitability was overlooked in anticipation of larger gains in the future, came to an end in the early 1970's. At some point during this period the petrochemical industry entered a new era in which the factors which had favoured the industry during the past two decades began to diminish in their effects. The emergence of new producers in Eastern Europe and in the developing countries highlighted the overcapacity in the developed countries at a time when the faster substitution phase of most petrochemicals other than plastics was tailing off; the feedstock costs stopped going down and started to move up instead, thus increasing the weight of variable costs over fixed costs; the benefits of plant economies of scale reached their peak at least for the foreseeable futures (currently a growing number of experts, such as L. A. Carmichael, the director of process economics, believe that maximum economies of scale for ethylene plants have levelled off at about 1.2 to 1.5 billion lbs/year (Davis, 1978)); the laws of diminishing returns began to apply to technical innovation developments due, in part, to "non-productive" research such as on pollution abatement and toxicology. As a result of these changes the growth rates of the industry began to slow down (even without the steep price rises of oil in 1973). In terms of the growth curve of the industry it can be said that some time during this period the petrochemical industry passed through a transition from adolescence into maturity.

The sudden quadrupling of oil prices in 1973 affected the slow-down of the industry further. However, the immediate effect of the 1973 oil crisis was to promote a world-wide boom in petrochemicals in the first half of 1974 as downstream customers of petrochemicals stockpiled in advance of the next price rise. After that, the important and promising petrochemical business developments that had been built up with the developing countries, virtually collapsed (Von der Hyde, 1978).

In 1973 there were demands for new investments in the industry due to the very strong market demand for petrochemical products, which lasted up to the middle of 1974. In the developed countries, with high consumption, price increases and shortages towards mid 1974 led to changes in buying habits, savings on materials and substitution for better cost-performance materials. Due to the same reasons their exports to the developing countries did not continue to grow.

The petrochemical industry regarded the following year of recession, 1975, as a realistic adjustment to the changed world market situation. Consequently there were hardly any suggestions of new investments in the industry. The industry also realized the impact of the end-user on the demand for petrochemical products. During this period, because of product surpluses and differences in production costs in the various regions, petrochemicals were subject to price pressures from the market at a time when production costs increased due to lower plant capacity utilization rates.

Towards the end of 1975 the petrochemical market situation started to recover and this continued in certain areas into 1976. However, later in that year it became apparent that the recovery was to be short-lived and by Autumn 1977 the world market receded strongly back to the bottom levels of late 1974.

Later, in July 1978 some positive signs of market recovery in the more depressed areas of Western Europe and Japan started appearing. In order to appreciate the severity of the depression throughout these two regions, the ethylene capacity on the ground or under construction amounted to some 17 million tons, compared to a demand of 11 million tons in 1978 in the former region (Champion, 1978) and the ethylene production totalled only 3.9 million tons compared with a capacity of 6 million tons in 1977 in Japan (Davis 1978). These large overcapacities were partly due to the planning pitfalls that stem from the 1960's. During its period of most rapid growth, the 1960's, the petrochemical industry was badly served by forecasts of market demand based on:- the optimistic acceptance of exponential market growth predictions that led to overcapacity; and the double counting of export markets as this industry became more international.

However, more recently some improvements in the planning of capacity and a more realistic approach to the estimation of future demand for petrochemical products have been adopted. On the whole, the petrochemical industry seems to have learnt from past mistakes and the consequences of earlier recessions have not occurred again. However, in order for the petrochemical industry to get back in balance and remain there, it is absolutely essential that the individual firms involved in this business adopt a more disciplined approach to new investment and pricing than they have in the past.

1.2 The Main Basic Products of the Industry

The main petrochemical base products are olefins (ethylene, propylene and butadiene), aromatics (benzene and xylenes) and methanol. These products are produced through two major processes known as:- steam cracking, employed mostly for the production of olefins, however it can be used for the production of aromatics; catalytic reforming, which is the source of aromatics. In addition to the above processes, steam reforming is employed for the synthesis of ammonia and also methanol.

There are numerous paths leading from the basic petrochemical products, mentioned above, to the end products (see figure 1.2). However, the main routes are as follows:- ethylene and propylene are the basis of the most important plastics; aromatics are the basis of synthetic fibres (non-cellulosic); and butadiene is the basis of the most important of synthetic rubbers; and methanol is the basis of formol which is one of the constituents of adhesives. Ethylene is by far the most important of all the basic petrochemicals and its worldwide production is nearly double that of propylene and benzene (UNIDO/ICIS, 1978).

1.3 The Main End Products of the Industry

Plastics production constitutes more than half of the total petrochemical production (excluding fertilizers). The output of these products is growing rapidly due to their potential demand.

Concerning the other main end products, such as synthetic rubber, fibres and detergents, their production grew very fast during the last twenty years due to their rapid substitution of the traditional products such as natural rubber, cellulose fibres and soap. It should be mentioned that the substitution of these products is not complete. The production of these products is tapering off due to their already high degree of substitution. The growth of the main end products of the industry is illustrated in table 1.1

Figure 1.2 INTERNAL STRUCTURE OF THE PETROCHEMICAL INDUSTRY

Table 1.1 World production of the main end petrochemicals (millions of tons)

	1950	1960	1970	1974	1975
Plastics	1.5	7.0	30.2	44.6	38.5
Synthetic fibres	0.1	0.7	5.1	7.5	7.5
Synthetic rubbers	0.7	2.0	5.9	7.7	7.4
Detergents	0.7	3.5	9.0	11.0	10.8
Total	3.0	13.2	50.2	70.8	64.2

Source: UNIDO/ICIS, First World-wide Study on the Petrochemical Industry : 1975-2000, December 1978.

1.4 The Raw Material Requirements of the Industry

Generally, petrochemicals possess a higher carbon to hydrogen ratio than crude oil. Therefore, the structure of the petrochemical industry restricts the choice of the raw materials which can be used economically to produce the basic building blocks used in the preparation of the organic synthetic products.

The building blocks are produced mainly from naphtha, other oil refining cuts and petroleum gases and despite the substantial price increases of oil since 1973 the raw-material and fuel structure of the industry have remained unchanged. However, in the future it will be necessary to upgrade the heavy end of the oil barrel concerning the hydrogen required. This will be necessary because of the competition in acquiring naphtha between the petrochemical industry on one hand and the energy and transport industry on the other. Therefore, the necessity of flexible multiple feedstock crackers arises even at the price of increased investment costs to optimise the utilization of the "total" oil barrel in order to reduce the raw material supply problem of the industry in the future (UNIDO/ICIS, 1978).

1.5 The Financial Aspects of the Industry

The petrochemical industry is highly capital-intensive and the investments involved are of a very large magnitude. In recent years the construction costs for plants have increased very significantly as demonstrated in table 1.2.

Table 1.2 Construction cost indexes

Year (average)	Index
1960	100
1966	132
1967	137.6
1968	145.9
1969	155.6
1970	174.9
1971	188.9
1972	202.2
1973	227
1974	274
1975	305.8
1976	340.6

Source: BEICIP (Bureau d'Etudes Industrielles et de Cooperation de L'Institut Francais du Petrole)

It can be observed that the increase in costs between 1972 and 1974 was in fact higher than the inflation rate prevailing at the time. This large increase can be considered as being only partly a direct result of the rising cost of energy and its impact on the manufacturing cost of building materials. However, the major part of the rise in construction costs were an indirect outcome of the increase in the cost of energy caused by the demand and supply situation. Petrochemical companies, worried about the increasing cost and the supply of energy, put massive orders for plants at a time when major plants were already under construction thus exacerbating the situation. In the latter half of 1974, the demand for petrochemical products fell which consequently affected the construction industry. The rise in construction costs became much more moderate and a more balanced situation of the supply and demand for plant is expected in the future with the effect of the construction cost index increasing in line with the general inflation level. It is worth mentioning that a new plant constructed in 1977 cost nearly double that of a similar plant in 1970. The present high investment requirements of major projects will put pressure on companies to go to the money markets for external financing and also to participate in joint ventures. This is very much unlike the golden days of the industry when its very high growth rate enabled it to make large investments, sustained innovation efforts, and the ability to finance its own activities. The oil companies, because of their vast financial resources, are today one of the few exceptions in terms of being able to finance internally most of their own petrochemical activities.

1.6 Ranges of Investment Cost for Petrochemical Plants

Estimated ranges of investment costs per ton of product for 27 major petrochemicals are given in table 1.3. It can be observed from this table that investments do not vary as a linear function of capacity. In fact they are related by a power function whose exponent is 0.7 (or thereabouts) up to capacities of about 200000 metric tons/year, and approaches 1 for capacities of more than 400000 metric tons/year, indicating little, if any economy of scale. This is due to the fact that at higher capacity, the number of cracking heaters and heat exchangers is just proportional to capacity, since at this level the biggest capacity units are being installed. In addition large towers must be field welded, rather than shop fabricated, adding to costs (Davis, 1978).

Going through the table, it can also be observed that the capital costs, per annual ton of product, of the olefins plant is lower than that of aromatics. It is also evident that the capital costs of intermediate products such as vinylchloride and styrene used in the production of plastics are significantly lower than those intermediates used in the production of synthetic fibres (e.g. caprolactam, DMT). The capital costs of plastics and synthetic rubber plants are also much lower than those of synthetic fibres. The general conclusions drawn from the above analysis are:- firstly, the bigger the plant the lower is the installed cost per annual ton of product and therefore the advantages of the economies of scale would lead to lower production costs, however there is a disadvantage and that is, the larger the plant the bigger is the risk of running

Table 1.3 Estimation of installed cost for petrochemical plants

(Battery limits licence fees included - 1977 European conditions)

Product	Capacity range 10^3 t/year	Installed cost range $/ton of product	Process-remarks
Ethylene	200 - 400	650 - 500	Naphtha steam cracking
Propylene	100 - 200	(1) (1)	butadiene extraction
Butadiene	32 - 64		benzene extraction
Benzene	58 - 116		toluene hydrodealkilation
Ethylene	150 - 300	500 - 380	Ethane steam cracking
Benzene	40 - 66		
O.xylene	38 - 63	520 - 430	Catalytic reforming aromatics extraction
P.Xylene	100 - 165	(2) (2)	
Methanol	200 - 500	180 - 150	
Ethylene oxide	60 - 100	370 - 340	Oxygen basic process
Vinylchloride	100 - 250	370 - 250	Oxychloration including ethylbenzene production
Styrene	100 - 250	400 - 270	
Acrylonitrile	100 - 250	750 - 520	
Caprolactam	50 - 150	1800 -1150	
DMT	50 - 80	950 - 830	
TPA	70 - 100	880 - 750	Amoco process
Adipic acid	100 - 150	600 - 500	
Hexamethylene diamine	30 - 50	500 - 400	
Low-density polyethylene	50 - 150	800 - 600	
High-density polyethylene	50 - 100	1000 - 800	
Polyvinyl chloride	50 - 100	400 - 340	Suspension process
Polypropylene	50 - 100	900 - 750	
Polystyrene	30 - 80	700 - 460	
Alkylbenzene	20 - 40	200 - 170	
Polybutadiene	30 - 50	600 - 530	
SBR	30 - 80	300 - 250	
Nylon fibres (yarns)	5 - 12	2300 -1500	Caprolactam polymerization and spinning
Acrylic fibres (staples)	10 - 15	1450 -1400	Acrylonitrile polymerization and spinning
Polyester fibres (staples and yarns)	10 - 15	1450	TPA polymerization and spinning

(1) Per ton of ethylene (2) Per ton of aromatics

Source: UNIDO/ICIS, First World-Wide Study on the Petrochemical Industry: 1975 - 2000, December 1978.

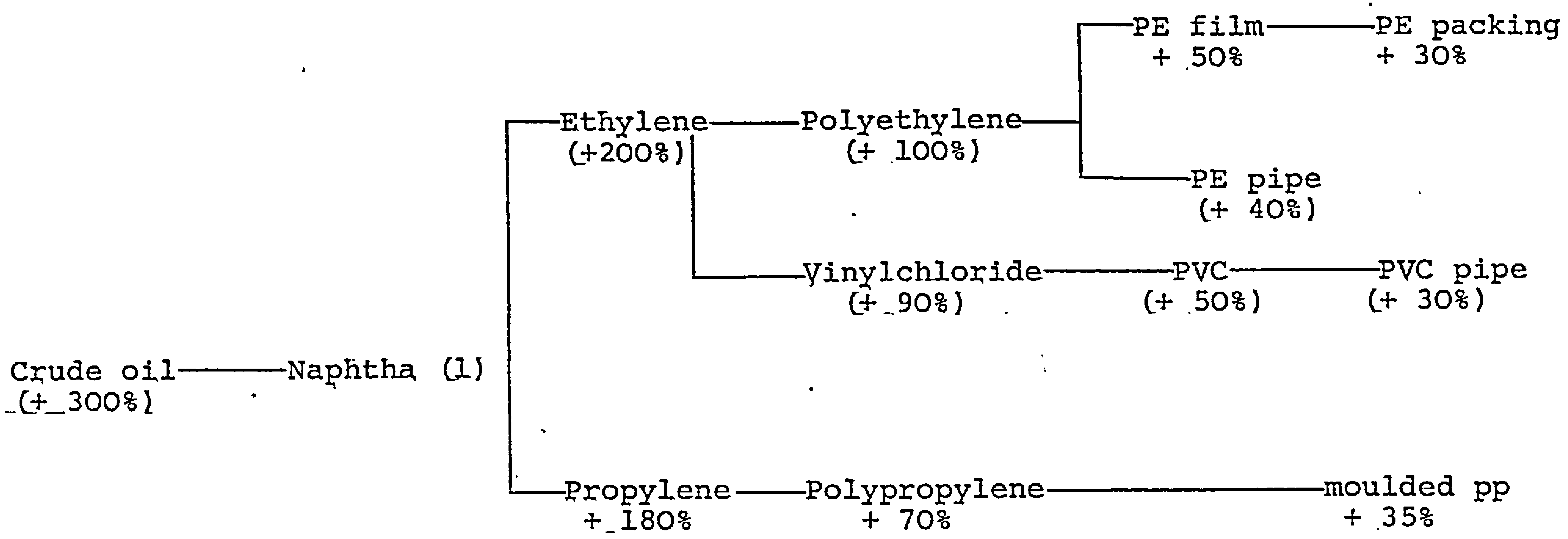
below capacity for longer periods; secondly, the majority of the products within the larger capacity ranges fall within the lower capital cost ranges; finally, plastics, synthetic rubbers and their intermediate and basic raw materials are generally produced in plants of larger sizes with lower capital costs per annual ton of product, whereas synthetic fibres and their intermediate and basic raw materials are produced in plants of comparatively smaller sizes with higher capital costs per annual ton of product.

1.7 The Production Cost Structure of the Industry

The production costs of olefins and aromatics are affected by the cost of raw materials, energy, manpower, the total investment, also the plant size and the year in which the plant was built.

One of the dominant factors in raising the production costs is the upward trend in the price of oil used as raw material and also as energy which is well demonstrated by figure 1.3 describing the impact of the increase in price of oil on olefins and their intermediate and end products. It can be observed that the impact is less further down the stream. Table 1.4 presents a more thorough analysis of this impact on petrochemicals, taking as an example the production of ethylene. Analysing the production costs, it can be observed that the cost of raw materials increased more than 6 times whereas the total production cost increased 3.6 times from 1972 to 1977. Another important aspect of the above analysis is the total production cost advantage, of nine percent, of the plant built in 1972 over an

Figure 1.3 Impact of the crude oil cost increases on petrochemical products cost between June 1973 and June 1974.



(1) Naphtha price is dependant on the offer and demand situation: it can vary up to some extent, independently from the crude price. During the considered period, the naphtha price increase amounted to 400%.

Source: NEDO, Increased cost of energy - Implication for UK industry

Table 1.4 Increase in olefins manufacturing cost (mid-1977)

		Naphtha Steam cracking	Naphtha Steam cracking	Naphtha Steam cracking
Capacity tons/y ethylene		300 000	300 000	300 000
Economic conditions		Prevailing in 1972	Prevailing in 1977	Prevailing in 1977. Unit erected in 1972. Investment in 1972
Fixed capital cost MM $		104	184.3	104
Manufacturing cost MM $				
Raw materials c/		21 150	129 600	129 600
Utilities		1 080	2 200	2 200
Catalysts & chemicals		620	1 000	1 000
Manpower		700	1 100	1 100
Other charges a/		6 750	12 000	12 000
Amortization & return		19 800	35 000	19 800
Total manufacturing cost		50 100	180 900	165 700
Products prices & sales d/	10³ t/y	$/ton	$/ton	$/ton
Ethylene	300	90	315 b/	280 b/
Propylene	139	55	193 b/	172
Butadiene	38.2	150	520 b/	465
Propane LPG	12	32	130	130
Butane LPG	44.2	32	130	130
Gasoline	195.8	45	168	188

a/ Maintenance, overhead expenses, insurance, general facilities, interest on working capital.

b/ Ratio of olefins prices have been kept constant in the table. In fact, ratio between ethylene and propylene prices is slightly decreasing from 1972 (1.6) to 1977 (1.4). Ratio of ethylene versus butadiene prices is now close to 0.9. Olefins prices corresponding to 1977 conditions, considering these present ratios, would be as follows: Ethylene 320 $/ton, Propylene 220 $/ton Butadiene 370 $/ton

c/ Raw material naphtha = 960,000 ton/year

d/ Products:

Ethylene	- 300,000 ton/year	Propylene	- 139,000 ton/year
Butadiene	- 38,200 " "	Propane	- 12,000 " "
Butane	- 44,200 " "	Gasoline	- 195,000 " "

Source: UNIDO/ICIS, First World-Wide study on the Petrochemical Industry: 1975 - 2000, December 1978 identical plant built in 1977. This is entirely due to the historical cost accounting conventions and the companies operating on this basis will find it extremely difficult to finance the replacement of their old plants at the end of their useful life under inflationary conditions (Elbedeiwy, 1979).

It is also evident that during this period, the fixed costs decreased sharply from nearly forty percent to just under twenty percent. The variable costs consisting of feedstocks and utilities are now very much dominating, having risen from 44.4 percent in 1972 to 72.9 percent in 1977 and 79.5 percent for a plant built in 1972. Because of this dominance, the effects of economies of scale and consequently the necessity of building as large a plant as possible have declined to a certain extent since 1973. This is justified when considering that a 15 percent increase in the price of feedstocks for a 100000 tons/year styrene plant operating at full capacity would bring manufacturing costs to the same level as those of a 65000 tons/year plant. On the other hand an increase of 20% in investment costs due perhaps to a location requiring greater construction costs because of undesirable local circumstances would have the same effect (UNIDO/ICIS, 1978).

Another reason behind the diminishing importance of building larger plants is due to the huge investments involved in such plants, requiring continuous production at a rate as close to the full capacity as possible otherwise great losses can occur. There is a break-even point between 75 to 80% (Davis, 1978). Below that the plant is running at a loss and especially in the case of large plants (500000 ton/year or more) the losses

Table 1.5 Petrochemicals Typical Production Costs (mid-1977)

Product	Capacity 10^3 t/year	Fixed capital cost MM US$	MANUFACTURING COST 10^3 US$/year							
			Raw Materials	Utilities	Catalysts Chemicals	Manpower	Other Charges	Amortiza-tion and return	Total manufac-turing cost	Product cost ($/ton)
Methanol	200	44	21 120	300	300	750	2 860	8 360	33 690	168
Vinyl chloride	150	50	37 560	4 515	1 900	1 065	3 250	9 500	57 790	385
Styrene	150	55	44 930	6 390	1 460	975	3 575	10 450	67 780	452
Caprolactam	80	120	18 400	9 624	12 000	1 215	7 800	22 800	71 839	764*
DMT	60	60	16 170	3 610	330	1 065	3 900	11 400	36 475	608
TPA	80	78	20 636	5 700	400	1 065	5 070	14 820	47 691	596
Ethylene oxide	80	27	25 600	1 328	200	750	1 755	5 130	34 763	435
Acrylonitrile	100	71	25 960	6 300	3 500	1 110	4 615	13 490	54 975	550
PVC	70	30	28 030	820	300	2 070	1 950	5 700	38 870	555
Hd polyethylene	70	65	23 700	2 620	1 000	1 395	4 225	12 350	45 290	647
Ld polyethylene	110	86	36 600	3 190	1 920	1 395	5 590	16 340	65 035	591
Polystyrene	50	30	22 600	620	200	1 920	1 950	5 700	32 990	660
Polyester fibres	12	20	8 894	50	400	3 750	1 300	3 180	17 574	1 460
Nylon fibres	10	25	8 404	59	300	4 500	1 620	4 750	19 633	1 964
Acrylic fibres	10	16	5 610	59	400	3 000	1 040	3 040	13 149	1 315
Polybutadiene	40	25	14 800	1 368	1 500	1 575	1 625	4 750	25 618	640
SBR	60	18	26 380	2 232	1 700	1 875	1 170	3 420	36 777	613

*Taking into consideration a by-products valorization amounting to 10.7 million $/year.

Source: UNIDO/ICIS, World-Wide Study on the Petrochemical Industry: 1975-2000, December 1978.

are very substantial indeed. To illustrate this point the production costs for a 200000 tons/year styrene plant working at 80% capacity are equal to those of a 100000 tons/year plant working at full capacity (UNIDO/ICIS, 1978).

Table 1.5 presents the manufacturing costs of 17 major intermediates and end petrochemicals for average plant sizes.

1.8 The Worldwide Assessment of the Industry:- Past, Present and Future

In recent years the general slow-down of the economy in industrialized countries coupled with the massive increases in production costs have slowed-down the petrochemical market growth. However, the decline has been limited due to the simultaneous higher price increases of the competitive natural products.

The declining petrochemical market growth has caused over-capacity in the industry. Because of this very undesirable phenomenon, delays in capacity additions and/or the construction of new petrochemical complexes are anticipated until there is more harmony between supply and demand. Meanwhile, the industry faces extremely serious difficulties concerning market outlets and competition.

1.9 The Factors Affecting the Demand for Petrochemicals

Income and standard of living constitute the most important factors responsible for the growth of the demand of petrochemical products. The elasticity per caput of most petrochemical products has been quite high in most regions, the most dynamic of which are the plastics (see table 1.6).

The degree of substitution of petrochemicals is the second most important factor in the growth of demand and provided the product is well suited to the demand in its sector of application, then the initial growth rate is fast followed by a slow-down as a relative point of saturation is reached. There onwards the market growth resembles that of the sector of application as a whole.

Further, the degree of substitution does not generally exceed 80 percent of the whole market. It should also be mentioned that the potential market for plastics is practically unlimited especially in packaging, transport and the construction industry and the future annual demand is expected to be in the order of hundreds of kilos per capita. Synthetic rubber and fibres on the other hand have a much smaller potential market and their future annual demands are expected to be in the order of tens of kilos per capita (UNIDO/ICIS, 1978).

Price is another factor affecting the demand for petrochemicals. As expected, the demand varies in inverse proportion to the price and this phenomenon is very well demonstrated by the growth in demand for plastics during the sixties and early seventies encouraged by the fall in prices (constant value) of these products during the same period due to technological improvements, larger production units and strong competition between manufacturers. These factors together with overcapacity in some cases depressed prices to levels very close to production costs. In order to put the effect of the overcapacity on the profitability of the industry into perspective it can be noted that for example in 1977 a 20 percent drop in the output of a large plant required

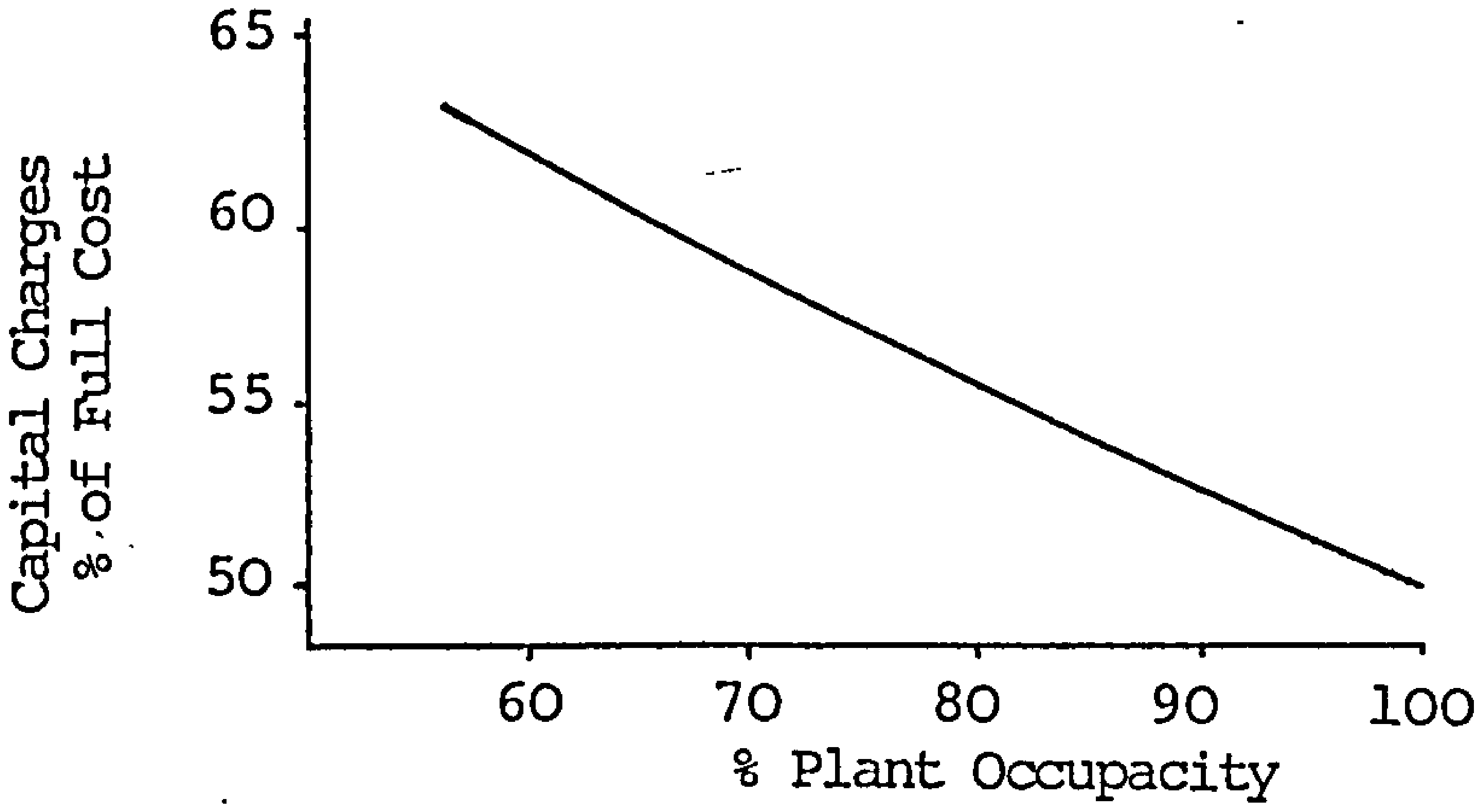
Table 1.6 Main characteristics of the world demand for plastics, by region

Region	Average growth rate (percentage per year)				Consumption level kg/capita	Elasticity per caput		Structure of the demand % thermoplastics/total plastics			
	1965/70	1970/75	1975/80	1980/85	1975	1975/80	1980/85	1973	1975	1980	1985
Western Europe	15.20	4.87	12.69	10.03	36.0	3.5	2.7	67.9	65.8	73.0	75.5
Eastern Europe	n.a.	n.a.	11.0	10.0	13.5	3.35	2.6	-	46.7	66.0	71.5
North America	9.70	3.63	12.27	10.98	47.2	3.2	2.8	66.2	68.6	73.5	79.0
Latin America	21.30	15.68	15.28	15.22	5.89	4.3	4.0	67.3	67.2	74.5	78.0
Africa:											
North Africa	19.10	18.42	17.46	15.35	2.4	3.7	3.5	82.2	82.8	82.5	84.0
West Africa	19.80	16.52	18.52	16.56	1.0	3.2	2.9	84.0	82.6	84.0	86.0
East Africa	18.70	12.79	16.30	13.88	1.05	5.6	4.5	87.8	83.4	83.5	84.5
Central Africa	9.40	20.71	16.28	13.26	1.65	4.3	3.6	81.9	83.3	83.0	84.5
South Africa	14.90	13.18	13.05	10.89	9.4	5.0	4.0	70.0	70.1	74.5	78.5
Asia (excl. China)											
Middle East	21.50	12.90	18.36	16.40	5.17	2.0	1.85	80.2	83.2	85.0	88.0
East Asia	22.90	13.50	15.40	13.36	9.47	2.15	1.9	78.9	79.9	81.5	83.5
Japan	23.40	0.53	13.26	11.99	40.2	2.0	1.7	72.2	73.0	75.0	78.0
South Asia	22.10	9.80	17.97	14.91	0.80	5.7	4.2	79.8	79.9	81.5	84.0
Pacific area	14.80	11.99	12.47	11.04	38.6	3.6	2.6	67.8	70.0	73.5	78.5
Total world	14.24	7.9	12.9	11.3				66.6	66.4	73.4	77.4

Source: UNIDO/ICIS, First World-Wide Study on the Petrochemical Industry: 1975-2000, December 1978.

an uncompetitive rise in price of 13 percent to compensate. When considering a large ethylene plant (500000 tons/year), the capital charges and return on capital required are 50 percent of the total cost less the value of chemical byproducts at full production, but increase to a dominating 60 percent when operating at two thirds of capacity (see figure 1.4).

Fig. 1.4 Ethylene Production
Effect of Reduced Occupacity



Source: Chemistry and Industry, A. W. Taylor, The Petrochemical Industry - Some perspective views, 1 January 1977

This strengthens the fact that the basic olefins and aromatics manufacture, that is necessary to the economy, based on feedstocks which are coproduced in oil refining, producing a number of intermediates as coproducts in ratios not necessarily according to the demand structure, is not necessarily stable and therefore needs profits relative with the risk involved in such investments.

In the past, prices were significantly greater than production costs and were mainly determined by competition with natural products. Because of their quality and low production costs, petrochemicals could be marketed at prices substantially higher than their costs, thereby generating large profits enabling companies to self finance new projects and research.

Prior to 1967 the industry mainly consisted of small production units and therefore those manufacturers capable of using large single stream units were happy to let the smaller manufacturers set a "price umbrella" under which they themselves acquired huge profits without endangering the interests of their competitors.

However from 1967 onwards the increasing number of larger production plants, coming on stream, affected the prices more and more to the extent that current prices are relatively down (apart from the temporary boom in 1974) to the level required by the biggest manufacturers to provide them with an adequate return on investment.

The boom during 1973-1974 was mainly due to the overestimation of the coming increase in price of oil by the petrochemical processors, who then increased their stocks in order to safeguard against a future increase (Champion, 1978). The supply and demand situation also hindered the increase in prices. Tables 1.7 and 1.8 illustrate respectively the international price trends for 17 petrochemicals during 1970 - 76 and the huge price rises suffered by Western European contract prices for 21 petrochemicals between January 1974 to July 1975 compared to 1972. It can be observed that the change in contract prices did not resemble the increases in raw materials and investment costs which have so deeply influenced the production cost structure of petrochemicals, especially those of the basic products.

During 1972 - 1976 the price of naphtha increased by about 600

Table 1.7 Petrochemical products prices (FOB USA)
(current US ¢ per lb)

YEAR PRODUCT	1970	1971	1972	1973	1974	1975	1976
Ethylene						11.8	12.9
Butadiene			8	9.6	18.2	15.6	18.6
Benzene	21.2	19.8	21.4	35.8	113	29.3	80.6
O.xylene	3.5	3.1	3.1	5.0	10.4	7.4	10.9
P.xylene	5.9	5.9	5.6	6.9	11.5	14.4	16.7
Styrene	6.3	5.5	5.8	13.6	24.0	17.8	19.3
Caprolactam	18.8	19	20	21.7	53.0	39.7	40.4
DMT	15.2	14.1	14.1	14.3	25.4	22.8	23.4
VCM	5.2	5.0	5.0	5.8	11.3	10.5	13.8
Ld polyethylene	13.5	13.7	12.1	16.8	33.8	26.4	27.3
Hd polyethylene	13.4	12.8	12.2	16.0	34.6	24.6	26.3
PVC	19.2	19.7	20.1	24.7	34.3	28.5	27.4
Polybutadiene	18.7	20.1	19.7	19.4	32.7	30.1	32.0
SBR	17.7	17.6	17.4	19.1	27.4	29.8	30.7
Nylon yarn not text	151	138	104	104	139+14	114	149
Polyester staple	49.5	40.2	36.2	48.5	66.5	47.2	51.2
Acrylic staple	65.6	61.2	55.5	51.0	63.2	58.1	59.0

Source: UNIDO/ICIS, First World-Wide Study on the Petrochemical Industry: 1975 - 2000, December 1978.

Table 1.8 Contract prices indexes

PRODUCT	AVERAGE 1972	JAN. 1974	JULY 1974	JAN. 1975	JULY 1975
ETHYLENE	100	280-345	310-340	290-350	290-340
PROPYLENE	100	200	325	310	295
BUTADIENE	100	260	290	255	210
BENZENE	100	350-380	435-470	370-400	310-335
ORTHOXYLENE	100	405	425	290	250
PARAXYLENE	100	160	375	350	260
PHENOL	100	395-465	465-475	310-375	250-295
ACETONE	100	290	420	320-370	320
PHTALIC ANHYDRIDE	100	420	370	210	210
DIOCTYLPHTALATE	100	215	290	225	195
STYRENE	100	300	360	240	200
ETHYLENE OXIDE	100	110	250	250	225
LOW-DENSITY POLYETHYLENE	100	130-160	185-210	165-185	115-125
HIGH-DENSITY POLYETHYLENE	100	170	185	160	150
POLYSTYRENE	100	135-150	190-250	180-240	140-170
POLYPROPYLENE	100	140	150	130	115
P.V.C.	100	135	170	155	145
NYLON YARN		100	135	115-120	80-95
POLYESTER YARN		100	100	78	60-70
ACRYLIC FIBRE		100	130	105	90-95
S.B.R. (Early 1973)	100	140	167	178	175

Source: European Chemical News, 3 October 1975 percent, whereas during the same period the price of ethylene increased by 360 percent. Therefore, it can be concluded that if naphtha-related production costs of ethylene are approximated to be around 72 percent of the total costs then the ethylene price rises have matched rather well the naphtha price rises but have not taken into account the capital cost inflation due mainly to overcapacity which kept prices down (UNIDO/ICIS, 1978).

However, it is expected that in the future the overall situation will tend towards equilibrium and that price trends will be more related to the variation in the production cost elements. Therefore, the production costs will in fact be dependent on two major factors:- firstly, the price of crude oil; secondly, the overall inflation (general price index charges: investment related, manpower, maintenance, etc.). In 1978 the respective shares of the prices, of some petrochemicals, that are expected to vary in the future according to the crude oil price and the general inflation were estimated and are given in table 4.5 (in section 4.9).

CHAPTER 2

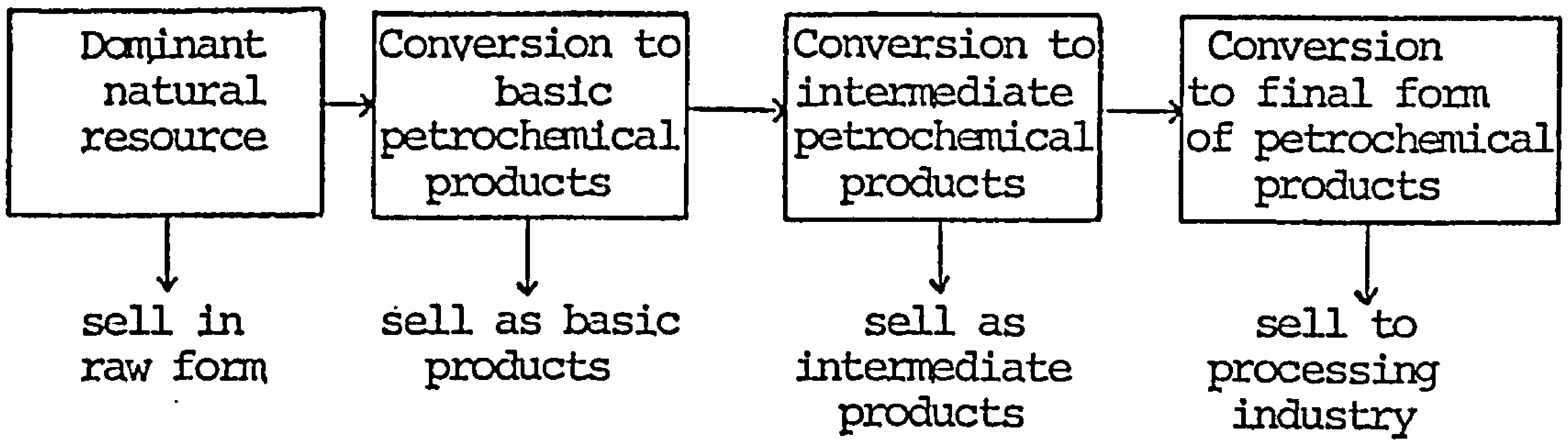
THE OIL COMPANIES' DIVERSIFICATION INTO PETROCHEMICALS

2.1 The Reasons, Strategies and Justification of the Oil Companies Forward Integration into Petrochemicals

The multinational oil companies have the perceived aim of diversifying their resources to become energy companies and to find profitable outlets for their large cash flows. To this end, they are diverting a larger portion of their total investments into downstream petrochemical operations from basic to intermediate to "commodity type" end petrochemicals. This strategy is well demonstrated, for example, by Shell's capital expenditure in chemicals manufacturing which has increased from nearly 7% of the Company's total capital expenditure in 1974 to nearly 22% in 1978 (Annual Report of Royal Dutch Petroleum Company, 1978).

Figure 2.1 illustrates the businesses of the oil companies which are defined by products representing various stages of conversion of the basic resource.

Figure 2.1 The Businesses of the Oil Companies



As a consequence of substantial capital expenditure their petrochemical manufacturing capacity and market share is growing, compared to that of the other manufacturers. For example in 1978 the U.S. production capacities of basic products had increased by nearly 60% of the 1974 capacity level (UNIDO/ICIS, 1978) and the oil companies accounted for 85% of this increase (for more information see tables 2.1 and 2.2).

The questions arising now are:- Why are they increasing their involvement in the petrochemical industry? How are they increasing their activities? Finally, is their move into the chemicals business a good proposition?

Concerning the first question, it should be mentioned that an oil company has as a key strength access to large quantities of oil and gas that is used extensively in a wide range of products and market applications. However, the world's reserves of oil are depleting very fast and this has caused concern among the oil companies in looking for changes in the areas of its application in order to utilize the lighter and the more expensive fraction of this resource in the areas with highest returns and to make much more use of the heavier and the less expensive fraction in the energy and transport sector. To this end they have been considering areas with as much value added as possible, especially petrochemicals. This choice seems to be justified when considering the very high manufacturing value added by the petrochemical industry. At the time when the price of crude oil, in the U.S., was 9 Dollars/barrel, the value of this barrel increased to 13 Dollars when refined and sold as gasoline. The same barrel of crude oil upgraded to a petrochemical intermediate such as glycerine was worth about 50 Dollars. Further processed into petrochemical end products, the value of the barrel of crude oil went up to between 100 and 200 Dollars (UNIDO/ICIS, 1978).

Another important aspect of the first question, concerns the chemical affiliates of the oil companies who no longer enjoy the privilege of receiving more raw materials, at discriminatory prices,

Table 2.1 The Oil Companies' Share of U.S. Chemical Capacity

	1974			1978			1982**		
	Number of producers	Number of oil companies	Oil companies' % share of industry capacity	Number of Producers	Number of oil companies	Oil companies' % share of industry capacity	Number of producers	Number of oil companies	Oil companies' % share of industry capacity
High-density polyethylene	12	4.50	32.8%	12	5.50	39.3%	13	5.50	43.0%
Low-density polyethylene	12	4.50	27.7	13	5.50	32.8	13	5.50	34.4
Polypropylene	9	4.00	51.6	12	6.00	55.6	12	6.00	53.1
Polystyrene	19	3.00	22.2	16	5.00	30.9	16	5.00	29.4
Polyvinyl chloride	23	2.00	10.6	22	2.00	10.3	22	2.00	9.6
Acetone	13	5.50	35.2	13	5.50	43.4	14	5.50	38.7
Acrylonitrile	4	1.00	24.5	4	1.00	18.3	4	1.00	18.3
Alkylbenzene, linear	4	1.00	31.9	4	1.00	36.9	4	1.00	36.9
Benzene	32	24.00	79.8	33	26.50	85.0	34	26.90	80.9
Cumene	12	10.00	63.5	14	11.00	60.5	15	12.00	63.2
Cyclohexane	9	8.00	97.4	9	8.00	97.7	9	8.00	97.8
Ethylene	23	10.50	42.5	25	12.00	57.3	27	12.38	58.1
Ethylene glycol	11	2.50	10.7	11	2.50	11.7	13	3.10	13.3
Isopropanol	4	3.00	63.6	4	3.00	74.6	4	3.00	74.6
Orthoxylene	12	9.00	86.3	12	9.00	86.9	12	9.00	86.9
Paraxylene	11	9.50	86.5	11	9.00	87.4	11	9.00	86.9
Phenol	11	3.00	9.0	12	4.00	21.3	12	4.00	18.7
Phthalic anhydride	9	3.00	21.5	9	3.00	18.2	9	3.00	17.3
Propylene	35	23.50	68.4	35	24.00	78.0	38	24.38	75.2
Propylene glycol	5	1.50	23.9	5	1.50	23.6	5	1.50	23.6
Propylene oxide	5	1.50	29.1	5	1.50	28.8	5	1.50	26.5
Styrene	11	4.50	27.4	10	4.50	27.2	11	4.50	23.9
DMT	5	1.00	10.2	3	-	-	3	-	-
TPA	2	1.00	80.4	2	1.00	93.2	2	1.00	93.2
Total terephthalates	5	1.00	29.5	4	1.00	45.6	4	1.00	45.6
Vinyl chloride	10	2.00	31.7	11	2.00	25.3	12	2.00	21.6

Table 2.1 The Oil Companies' Share of U.S. Chemical Capacity (continued)

	1974			1978			1982**		
	Number of producers	Number of oil companies	Oil companies' % share of industry capacity	Number of Producers	Number of oil companies	Oil companies' % share of industry capacity	Number of Producers	Number of oil companies	Oil companies' % share of industry capacity
Caustic soda	23	3.00	10.6	25	3.00	10.2	25	3.00	9.1
Chlorine	30	4.50	11.6	32	4.50	11.2	32	4.50	10.0
Soda ash	8	1.00	3.5	6	1.00	6.6	6	1.00	12.9
Sodium tripolyphosphate	6	2.00	18.2	6	2.00	14.7	6	2.00	14.7
Titanium dioxide	6	1.00	6.0	6	1.00	5.8	6	1.00	5.0
Ammonia	58	12.50	31.9	65	21.47	27.9	65	21.47	26.8
Ammonium phosphates	28	4.25	9.8	31	3.25	9.7	30	3.25	9.3
Phosphate rock	17	2.25	15.9	19	2.25	17.3	19	2.25	16.7
Phosphoric acid	29	4.00	7.5	31	4.00	8.1	31	4.00	11.8
Potash	9	2.00	34.8	9	2.00	31.9	9	2.00	31.9
Urea	34	8.0	22.2	35	6.00	18.0	37	6.00	17.8

Includes share of joint ventures

** Preliminary. Data: current as of December 31, 1978

Source: First Boston estimates based on a survey of producers and trade literature.

Table 2.2 The Oil Companies' Share of U.S. Ethylene Capacity
(Millions of pounds)

	1974		1978		1979		Preliminary 1982	
	Yearend capacity	% share of capacity	Yearend capacity	% share of capacity	Yearend capacity	% share of capacity	Yearend capacity	% share of capacity
Union Carbide	4,270	17.4%	5,000	14.2%	5,000	13.6%	5,000	11.7%
Dow Chemical	3,750	15.3	3,675	10.4	3,675	10.0	4,675	11.0
Atlantic Richfield	605	2.4	3,205	9.1	2,705	7.3	2,705	6.4
Shell Chemical	1,900	7.7	3,040	8.6	4,340	11.8	5,840	13.7
Gulf Oil Chemicals	1,570	6.4	2,860	8.1	2,860	7.8	2,860	6.7
Phillips Petroleum	1,140	4.6	2,140	6.1	2,140	5.8	2,140	5.0
Amoco Chemicals	-	-	2,000	5.7	2,000	5.4	2,000	4.7
Exxon Chemical	1,870	7.6	1,870	5.3	1,870	5.1	3,100	7.3
Texaco	500	2.0	1,500	4.3	1,500	4.1	1,500	3.5
Eastman Kodak	800	3.3	1,250	3.5	1,250	3.4	1,250	2.9
Puerto Rico Olefins[1]	1,000	4.1	1,000	2.8	1,000	2.7	1,000	2.4
Northern Petrochemical	800	3.3	935	2.6	935	2.5	935	2.2
Cities Service	900	3.7	900	2.6	900	2.4	900	2.1
Mobil Chemical	450	1.8	900	2.6	900	2.4	900	2.1
Du Pont	800	3.3	800	2.2	800	2.2	800	1.9
Allied Chemical, BASF Wyandotte and Borg-Warner Joint Venture	720	2.9	720	2.0	720	2.0	720	1.7
Conoco Chemicals [2]	635	2.6	635	1.8	635	1.7	635	1.5
Monsanto and Conoco Joint Venture	-	-	630	1.8	630	1.7	1,500	3.5
Chemplex [3]	525	2.1	525	1.5	735	2.0	735	1.7
El Paso Products	520	2.1	520	1.5	520	1.4	520	1.2
US Industrial Chemicals	400	1.6	400	1.1	400	1.1	400	1.0

Table 2.2 The Oil Companies' Share of U.S. Ethylene Capacity (continued)
(Millions of pounds)

	1974		1978		1979		Preliminary 1982	
	Yearend capacity	% share of capacity	Yearend capacity	% share of capacity	Yearend capacity	%share of capacity	Yearend capacity	% share of capacity
BF Goodrich	350	1.4	350	1.0	350	1.0	350	0.8
SunOlin Chemicals 4	225	0.9	225	0.6	225	0.6	225	0.5
Monsanto 2	750	3.1	120	0.3	120	0.3	120	0.3
Olin 5	100	0.4	100	0.3	100	0.3	100	0.2
USS Chemicals	-	-	-	-	500	1.4	500	1.2
Corpus Christi Petrochemicals 6	-	-	-	-	-	-	1,200	2.8

[1] A joint venture of PPG Industries and Commonwealth Oil and Refining (CORCO).

[2] See also Monsanto and Conoco joint venture listed separately.

[3] A joint venture of American Can Company and Getty Oil.

[4] A joint venture of Olin and Sun Company.

[5] See also SunOlin listed separately.

[6] A joint venture of Champlin Petroleum, a subsidiary of Union Pacific, (37.5%); ICI Americas, a subsidiary of Imperial Chemical Industries Ltd. (37.5%); and Soltex Polymers, a subsidiary of Solvay et Cie (25%). Data current as of December 31, 1978.

Source: First Boston estimates based on survey of producers and trade literature.

than the chemical companies due to the recent tightening of the supply situation. Prior to 1973, chemical producers could purchase naphtha or gas liquids at low prices due to the surplus of supplies. However, this is not so any more due to the faster growth of demand for the light end of the barrel compared to the heavy end.

The U.S. petrochemical industry faces the same problem concerning the supply of feedstocks due to the exhaustion of its natural gas reserves during the past decades. As a measure of decline it can be noted that by 1985 only 50% of the U.S. ethylene production is expected to be based on LPG compared to 75% in 1979 (Joseph, 1979). Consequently, this raw material is not cheap any more. In the future petrochemical plants will have to be based entirely on naphtha and gas oil, the prices of which will be determined through competition with the energy and transport industry. Consequently, due to the feedstock supply situation the oil companies have an advantage over petrochemical companies in the control of a variety of raw materials some of which may be cheaper than others at any given time due to the significant price fluctuations, either for seasonal or structural reasons. They also have the advantage, through further processing, in upgrading the sales value of return streams (e.g. mixed gases, pyrolysis gasoline and heavy residues such as pitch) from steam crackers based on liquid feedstocks. However, this advantage can only be realized if a close inter-relationship exists between the chemical producer and the operator of a large refinery complex.

Concerning the second question, it can be observed from table 2.3 that the oil companies are active in commodity (i.e. basic and intermediate) and some even pushing further downstream into the commodity type (i.e. large tonnage thermoplastics) petrochemicals. Commodity chemicals are defined as chemicals sold on the basis of their specifications only and not by their performance on a downstream processing machine, or in a product incorporating or made from the chemical in question. Therefore, the marketing of commodity chemicals is relatively uninvolved and depends mainly on the price.

Table 2.3 Main chemical interests for oil Companies

Products	BP	Amoco	Arco	Exxon	Shell	Texaco	Gulf	Mobil	Phillips	ATO/CFT/CFR	Veba
Monomers for plastics	*	*	*	*	*	*	*	*	*	*	*
Thermoplastics	*	*	*	*	*		*	*	*	*	*
Fabricated plastics/packaging	*	*		*	*			*	*		
GP rubbers					*	*			*		
Speciality rubbers				*	*				*		
Ethylene oxide & derivs.			*		*	*					
Propylene oxide & derivs.			*		*	*					
Fiber intermediates	*	*	*	*	*	*	*	*	*	*	*
Plasticizers/detergents	*			*	*	*					
Thermosetting resins	*				*						
Chemical solvents	*		*	*	*	*					*
Hydrocarbon solvents	*		*	*	*	*		*	*	*	*
Fertilizers		*		*				*	*		*
Agrochemicals					*		*				
Oil additives		*		*	*	*		*			
Speciality chemicals				*	*	*	*		*		*
Coatings				*				*			
Inorganic products								*			

Source: W. C. Thomson, "Oil and/or Chemical Refineries", Hydrocarbon Processing, February 1978.

However, only a very small number of the oil companies have actually participated in the high chemistry areas such as dyestuffs, pharmaceuticals, fine chemicals and intermediates and their total investments in these areas are very small indeed.

For example, even though most oil companies produce the intermediates used in the production of synthetic fibres, very few are actually producing the end products.

Further the power relationships between oil and petrochemical multinationals conform to a pattern approaching lasting co-operation, where the strength of their respective staying powers (implies the dominant possession and/or control of an object of negotiation) are basically complementary and not conflicting, and it is characterized by a mutual respect. This situation is reflected in their long-standing involvement in basic products, where oil companies through joint ventures and/or supply arrangements provide the larger portion of the petrochemical industry's needs for basic petrochemicals. This situation is practically generalized throughout the world with the exception of several U.S. petrochemical companies such as DOW that have basic olefins production based on associated gases and some EEC petrochemical companies such as ICI which produces basic petrochemicals in collaboration with Phillips Petroleum at the oil refining end (Thomson, 1978). Further examples of this co-operation is given by BP's joint ventures with Bayer and with Rhône Poulenc, and Shell with BASF in the production of basic petrochemicals during the past two decades. On the other hand Hoechst has had supply arrangements with Caltex and Marathon.

There is no distinction between oil and petrochemical companies in Italy due to their respective forward and backward integration during the past.

In the U.S. companies such as Dow, Union Carbide and Monsanto worried about the security of their basic petrochemical supply sources and also because of certain economical advantages have built up large basic petrochemical plants. As regards their future investment intentions, a policy of self sufficiency in basic petrochemicals as opposed to manufacturing an excess amount for sale on the markets is expected. By contrast, prior to 1973 companies such as DuPont although worried about the cost and the source of their basic raw materials preferred to depend wholly on the purchases of these materials, mainly through the multinational oil companies. However, because of the tightening of the supply situation since 1973 DuPont has been recently discussing with Atlantic Richfield about the possibility of a joint cracker, so are Monsanto with Conoco, and ICI and Solvay with Champlin (Thomson, 1978).

Concerning the third question of whether the oil companies move into the petrochemicals business is a good proposition it must be mentioned that the oil companies have been accused of being responsible for the overcapacity prevailing during the 1960's. Today, the main worry of the petrochemical companies is the possibility of the oil companies causing the same problem in the future which will be disastrous for the whole industry. This entails a very thorough study of the impact of any future capacity expansions on the future supply and demand relationships.

However, there are already signs that the petrochemical producers have adopted a more conservative approach towards expansion policies. Therefore the supply and demand situation is expected to be much more balanced in the future, as opposed to the late 1960's and the early 1970's.

Another point regarding the third question concerns the cost advantage of the oil companies. Since 1973 there has been a major shift in the production costs of petrochemicals (especially those of basic products). Thus the oil companies have in this area an advantage over petrochemical companies and their cost edge is extended further down as far as the large tonnage plastics. However, it should also be mentioned that the oil companies will find it extremely difficult to compete in terms of cost efficiency with some petrochemical companies specializing in certain petrochemicals.

At this point it is very important to discuss and examine the diversification of a number of oil companies into the petrochemical business. It is also beneficial to know how the traditional chemical companies view the petrochemical activities of the multinational oil companies and to find out how they cope with the competition from them.

2.2 The Analysis of the Diversification of a Number of Oil Companies into Petrochemicals

Traditionally the oil companies operate their different businesses, including petrochemicals, under strict secrecy due to their competitors and the host governments. Therefore, it is extremely difficult to find out about their petrochemical activities and the only sources of information available are their own published reports which contain the minimum information required by their shareholders, and certain articles appearing from time to time in chemical journals. In this section of Chapter 2 we shall discuss a recent interview made with the top executives of a number of oil companies (Lurie, 1979) during which they discussed their chemical businesses and we will also comment on the truth of what the companies said by referring to information sources where available.

The oil companies argue that petrochemicals are a natural extension of the hydrocarbon business because the technology is similar and the oil companies had the feedstocks and the cashflow. Concerning the technology factor the petrochemical companies have repeatedly accused the oil companies of buying their way into the petrochemicals business by licensing their technology. However, this does not hold entirely when considering that some of the oil companies actually helped to create the petrochemical business. For example in the case of Exxon the creation dates back to 1920 when a small plant at the company's Linden, New Jersey, refinery produced isopropyl alcohol in commercial quantities. Later in 1930's it invented butyl rubber. There are other numerous examples such as, Acrylonitrile by Sohio, High-density polyethylene by Phillips, terephthalic acid by Amoco and Mobil, the development of the manufacturing process for linear surfactant alcohols (Alfol) by Conoco, the development of a new oxidation process for propylene oxide by ARCO, a new process for making moulds and cores without using heat by Ashland, the development of the first process to manufacture ammonia from natural gas 50 years ago by Shell. Shell also built the first plants to manufacture synthetic ammonia from natural gas; built the first plants to make synthetic glycerine and styrene - butadiene rubber; and were the first to produce ethyl alcohol via hydration of ethylene.

Of course not every oil company built on its own technology. Some companies bought their way in, some developed new products and some did both.

Concerning the feedstock factor the oil companies argue that their current market share in the petrochemicals business is not due to their subsidizing of chemical operations by pricing feedstocks below market prices and that more importantly, all their business decisions have always been made viewing market alternatives. However, as discussed earlier in section 2.1, the oil companies have access to cheaper feedstocks which would consequently affect their competitiveness against the traditional chemical companies.

Finally, with regard to the cashflow factor, high cash generation and restricted investment opportunities often leads to attempts at diversification (Moslehshirazi, 1979). However in the case of the oil companies' diversification into the chemical business, the chemical companies have often accused them of being adversaries of the chemical business, overlooking the sizable investments made by the oil companies in support of the rapidly growing chemical industry. In the future, even larger investments will be required by the industry especially in the U.S. because of the declining natural gas production which will force the decisions to build heavy-liquid crackers costing more than 500 million dollars. The capital expenditure required for these plants, coupled with a large co-production of associated energy products, significantly limits the list of companies who can participate on a stand alone basis. Concerning the associated energy products, it is worth mentioning that a typical 1.5 billion lbs/year olefins plant processes 70000 bbls/day of gas oil or other feeds, and turns out a number of products (high-octane blending stocks for gasoline and fuel oil) for which an independent petrochemical company has no logistical and marketing networks. An obvious answer, and one being seen more and more, is a greater move to form joint ventures, including oil company partners (the examples of which are given in section 2.1). Only very few chemical companies have the cashflow capacity to undertake such an investment, and none without jeopardizing their ability to invest in downstream products.

2.2.1 The investments of the oil companies in the chemical industry

The oil companies have been investing very heavily in the petrochemical industry during the recent decades. For example, the capital investments of Shell's chemical subsidiary in the U.S. for the 1976-78 period increased to a massive sum of 1.7 billion dollars which was three to four times the petrochemical industry's average, relative to company size (Royal Dutch/Shell Group of Companies' Financial and Operational Information, 1969-78). A further 500 million dollars is being invested on an olefins complex that will be completed at Norco, Los Angeles, in 1981, which will make Shell the largest U.S. ethylene manufacturer (see table 2.2).

Exxon's investments are no less impressive and the company claims to be the fifth-largest chemical company in the U.S. and thirteenth-largest in the world. It has currently a number of projects under construction including a low-density polyethylene plant in Texas and an ethylene plant in Scotland.

Gulf made a significant new round of expansions during the 1976-79 period which doubled its ethylene and propylene capacities and increased its LDPE and HDPE capacities. The expansion also included entry into new areas such as polypropylene and polystyrene.

Mobil doubled its ethylene capacity in the early 1970's and later in 1977 acquired Styrenics (Polystyrene and ABS resins) from Dart Industries. In 1962 Mobil acquired Krondite, makers of plastic clotheslines and plastic bags which became the basis for its plastics division and today it claims to be the largest manufacturer of disposable plastic products.

Texaco has also been investing heavily on productive capacity for aromatics, olefins, ethylene glycol, urethane and chemical additives for oils and greases. The petrochemical division has been receiving roughly 10% of the Corporation's capital budget, which runs to 1 - 1.5 billion dollars/year.

Continental oil's Conoco chemicals, is claimed to be one of the most successful petrochemical divisions of an oil company (Lurie, 1979). It has centred its investments in mainly two areas, surfactants and PVC. Conoco entered the surfactants business in 1948 with a 25 million lbs/year detergent alkylate plant at Baltimore and kept adding to capacity, integrated backward with the construction of a plant to extract paraffins from kerosine, then integrated forward to convert alkylates to sulfonates. Today, Conoco together with its Spanish and Japanese affiliates account for one third of the world's detergent alkylate production. Conoco entered the PVC market by acquiring Carbon, a plastic pipe manufacturer, in 1964. This was followed with the purchase of Thomson Apex, a producer of resins. VCM and ethylene plants were built four years later. The olefins complex provided backward integration for PVC and Alfol alcohol. Conoco is expanding its ethylene capacity further by bringing on stream, in 1980, an ethylene cracker which is a joint venture with Monsanto.

Phillips has recently made substantial investments in order to increase its ethylene and high-density polyethylene capacity. The company is particularly rich in cyclohexane accounting for nearly half the U.S. total.

Among the relative newcomers, Standard Oil's Amoco Chemicals is one which has done the most catching up, primarily through vast capital investments. Amoco's rate of spending between 1967-77 was three times that of the industry's average, relative to company size which consequently:- quadrupled Amoco's para-xylene capacity to reach 37% of the industry's total in the U.S. ; more than tripled purified terephthalic acid capacity (45% of industry total in the U.S.) ; increased ethylene capacity by 2 billion lbs/year; and more than tripled propylene capacity. The foundation for Amoco's pre-eminence in terephthalates was laid in 1956 with acquisition of Mid-Century Corporation from Scientific Design. Amoco Chemicals was organised a year after the Mid-Century acquisition to combine Standard's aromatics marketing activities and adapted that company's techniques for commercial production of purified terephthalic acid. Today it is Amoco's biggest single product and its technology is licensed worldwide. In the 1964-75 period, Amoco also acquired 10 companies, mostly fabricators of plastic household products which were to be supplied for their raw materials by the polymer resin plants being built during the same period. The largest single acquisition, about 100 million dollars, was Avisun, maker of polypropylene resin and film. Avisun's 50% share in Palchogue-Plymouth put Amoco into the fabrics business. Amoco's capital budget was around 230 million dollars in 1978 and 1979 and is expected to grow to about 300 million dollars/ year by 1984. The company's investment in 1979 focused on downstream operations: additional plastic bottle (PET) plants (the company has five such units and plans five more) and other products, such as carpet backing, that use its raw materials.

Occidental's initial investment in the chemical business was the acquisitions of Best Fertilizers and Jefferson Lake Sulphur (and its subsidiary Jefferson Lake Petrochemicals of Canada Ltd.) in 1963. However, the company's real move into the petrochemicals came five years later, in 1968.

Arco's investments are mainly in organic chemicals, thermoplastics resins, aromatics, fertilizers and chemical intermediates. Its position is especially dominating in proplyene oxide with nearly half the industry's capacity in the U.S. The company has plants currently under construction for making MTBE, a high octane blending component, and PMDI, used in urethane plastics.

Ashland's initial investment in petrochemicals was in the addition of an aromatics unit to a refinery in the early fifties. Ten years later it developed the technology to build the first petroleum naphthalene plant in the world. By 1967 Ashland had spent some $200 million on plants and acquisitions and put them all together to form Ashland Chemical. Ashland Chemical includes two businesses, each of which may be unique for an oil company's subsidiary: distribution of chemicals, and foundry products.

2.2.2 Sales and profitabilities of the petrochemical businesses of the oil companies

The petrochemical sales of the oil companies have increased rapidly during the last two decades. In 1962 the oil companies' share was less than 1.7 billion dollars or just 6% of the industry's total of 29.3 billion dollars in the U.S. However, by 1978 the petrochemical sales of the 24 major U.S. oil companies reached 24 billion dollars which was 16% of the petrochemical industry's total of about 150 billion dollars.

Concerning the profitability of the industry, an unpublished report prepared for one chemical company gives the operating profit margin (i.e. ROI) of representative group of oil companies' chemical divisions in the 6-7% range for 1976 and 5-6% for 1977; and the operating margins for five top chemical companies in the 7-19% range for 1976 and 7-16% for 1977. Further, several consultants, the names of whom have not been revealed (Lurie, 1979), believe that the petrochemical divisions of the oil companies fail the profitability test and justify their belief by pointing to the sales and earnings of the chemical subsidiaries of 24 major U.S. oil companies in 1978 and their respective changes since 1977 (see table 2.4). However, the above conclusion, based upon only the sales and the earnings for a particular year and their changes since the previous year, is not necessarily valid. In order to examine the profitability of a particular company it is necessary to study a number of performance measures including the rate of return on investment, long-term rather than short-term profitability, etc. The long-term approach is essential in such an examination because companies do go through periods of rapid expansion in assets and also at times do sell off undesirable assets which would consequently affect measures such as the ones mentioned above.

We shall now discuss and evaluate the businesses of the subsidiaries of a number of major oil companies in more detail in order to see how they compare against the studies mentioned above.

Royal Dutch/Shell group (the 40-60 Anglo-Dutch) has the largest chemical business of any oil company. The company's 1978 sales reached 4.9 billion dollars (Royal Dutch/Shell Group of companies' Financial and Operational Information, 1969-78). Shell U.K. Ltd. is the second largest petrochemical manufacturer after ICI. The company claims that it had a modest profit on petrochemicals in the U.K. in the first six months of 1979, in contrast to a 30 million dollars loss in 1978.

Table 2.4 Sales and Earnings of the Petrochemical Subsidiaries of the Oil Companies

	Sales		Earnings*	
(Millions of dollars)	Total in 1978	Change from 1977	Total in 1978	Change from 1977
Exxon Corp.	$4,653.0[1]	+11.1%	$268.0	+20.7%
Shell Oil	2,710.0[1]	+16.4	100.0	-17.0
Standard Oil (Ind.)	1,831.6	+12.6	45.5[2]	+14.8
Gulf Oil	1,752.0[1]	+38.8	81.0	+ 8.0
Occidental Petroleum	1,719.4	+ 6.0	38.5[2]	-52.5
Phillips Petroleum	1,536.0[1]	+ 8.9	60.0[2]	-20.0
Atlantic Richfield	1,512.0	+22.4	91.0	+18.2
Mobil Corp.	1,361.0[1]	+13.1	153.0	+16.8
Texaco Inc.	935.9[1]	+ 4.7	54.7[2]	- 7.4
Ashland Oil	882.9	+10.4	15.7[2]	+97.4
Standard Oil (Calif.)	831.0	+12.0	25.0[2]	-13.8
Tenneco Inc.	808.0	-[3]	54.0	-[3]
Conoco	680.8[1]	+35.0	61.3[2]	+12.4
Union Oil of Calif.	678.1	+20.9	105.2	+67.2
Cities Service	415.8[1]	+ 3.5	16.0[4]	-50.2
Kerr-McGee	375.4	+16.0	37.0	NA
Standard Oil (Ohio)	327.7	+ 4.1	19.7	-36.7
Northern Natural Gas	235.3	+ 4.8	12.9[2]	- 2.2
El Paso Co.	206.4	+ 5.3	15.7	-57.5
Houston Natural Gas	175.6	+ 8.1	29.6[4]	+22.5
American Petrofina	167.9	- 3.8	22.0	+47.1
Pennzoil Co.	151.5	+ 5.0	34.7	+ 5.7
Getty Oil	125.5	- 3.9	18.0	-31.0
Clark Oil	23.3	+ 2.0	6.1	- 7.2

*Pre-tax operating income, unless otherwise noted.

[1] Including transfers to the company's other divisions.

[2] Net after-tax income.

[3] Company made significant acquisitions in 1977-1978; comparable 1977 data not reported.

[4] Including equity in earnings of chemical affiliates.

Source: "Oil and Chemicals Era of peaceful co-existence", Chemical Week, 17 October 1979.

Exxon's sales of chemicals have increased from 295 million dollars in 1960 to nearly 4.7 billion dollars in 1978 (see table 2.4). The company claims that its chemical division's return on capital employed was 12.01% in 1978 and that during the 1974-78 period its returns have been comparable with the return on capital employed of other major U.S. chemical companies (the ranges of which were given earlier).

Mobil's chemical division has also grown very rapidly during the past two decades. Its sales have increased from 7 million dollars in 1960 to nearly 1.4 billion dollars in 1978 and the parent company has expressed satisfaction with the return on its chemical sales.

Conoco is one of the most profitable petrochemical divisions of an oil company. Its 1978 net earnings of 61 million, on sales of 680 million dollars, exceeded its 1960 sales of 55 million dollars. The company claims a 35-40% return on assets and credits it to low cost incremental expansions, high value added, the highest sales per employee in the industry and strong emphasis on R and D.

Gulf achieved chemical sales of $1.752 billion dollars in 1978. The company claims that its chemical profits are marginally better than oil and considerably more volatile (no figures available).

Phillips's sales of petrochemicals have increased from 195 million in 1960 to an estimated 2 billion dollars in 1978. Phillips's chemical division attributes breakthroughs in its laboratories as being largely responsible for its strength in some key chemicals, notably carbon black, synthetic rubber and polyethylene plastics. The parent company claims that the return on capital between the parent company and its chemical subsidiary (no figures available) have been varying from year to year due to the narrowing of the gap between the cost and the price of petrochemicals. For the longer term the company expects a little less return on chemicals than on petroleum.

The petrochemical sales of Standard Oil's Amoco have grown from under 400 million in 1969 to 1.8 billion dollars in 1978. Amoco's return on chemical assets of $1.6 billion dollars was 3% in 1978. This low rate of return was claimed to be partly due to the rapid expansion in assets, which averaged 22% during the 1974-78 period. However, the company believes that their chemical operations will exhibit good growth and profitability in the long term.

Occidental's chemical subsidiary (Hooker Chemical) had sales revenue of 1.719 billion dollars in 1978 consisting of:- $796 million worth of chemicals and plastics; $593 million worth of fertilizers, other agrochemicals and sulphur; $254 million worth of metal finishing; and $75 million from Occidental's petroleum subsidiary in Canada. Among the advantages of being a part of an oil company are the availability of parent company's research facilities and its financial capability, and Occidental's chemical subsidiary is thereby benefiting from:- a process recently developed for the manufacture of hemihydrate phosphoric acid which will cut production costs by 15-18 dollars/ton; and also the funding of an $86.6 million waste to energy plant at Niagara Falls that is expected to save the company over 10 million dollars/year in power costs (i.e. an ROI of nearly 12%).

Atlantic Richfield's chemical sales have increased from $50 million in 1960 to $1.5 billion in 1978 and the company's chemical subsidiary (ARCO) claims that if the Corporation allocates them the required capital, they can reach sales of more than $4 billion dollars by 1984-85. However, the parent company has expressed dissatisfaction with ARCO's return on investment (no data available).

Ashland's Industrial Chemicals and Solvents claims to be the largest reseller of chemicals in the U.S. and only about 30% of the products it sells are made by Ashland. Ashland's chemical sales reached $883 million and according to the parent company, Ashland Chemical's return on investment compares very well with the rest of the company.

Having discussed the sales and the profitability of the petrochemical subsidiaries of a number of major oil companies, substantiating with data where available, their performance does not seem to be as low as those given in the two studies referred to earlier in this section. Of course, there are obviously a number of companies such as ARCO and Amoco whose ROI is not satisfactory at the moment due to reasons given earlier, but their poor profitability cannot be generalized to apply to other companies such as Exxon, Continental and Gulf, which are showing adequate return on their chemical investments during a period when the petrochemical industry faces large overcapacities of production.

2.2.3 Problems and Financial Losses Involved in the Diversification of the Oil Companies into the Chemical Business

In this section we shall discuss some of the problems and the financial losses which the oil companies faced in their move into the chemical business in order to be able to make a more thorough analysis of their strategies, in the next section.

Exxon went into fertilizers in Latin America, the Philippines and South Africa without foreseeing the extent of worldwide marketing from large scale plants. Substantial importation of fertilizers took place in areas of the world which Exxon had expected would rely on local production. Consequently, the company divested parts of its fertilizer business including the sales of two fertilizer plants in Aruba to Grace at a considerable loss. Neither companies have revealed up to now the exact transaction involved in the deal.

Mobil, like Exxon, moved into the fertilizer business by acquiring Virginia Carolina Chemicals and likewise retreated from the retail fertilizer and ammonia production but retained Carolina's phosphate reserves in Florida.

Phillips also found out that it had no particular strength in the very competitive nylon and polyester fibres market (which very few oil companies have participated in due to the marketing difficulties) and therefore retreated but retained its strong position in olefins fibres. It also retreated from vinyl calendering in the U.S. and PVC and polystyrene in Belgium for the same reason. The company has sold a total of $275 million worth of chemical assets in the past two decades.

Ashland owned plastic pipes, plastic housewares, plastic film and synthetic rubber businesses. However, they were not big enough to compete, therefore the company had either to expand in these areas or retreat and due to the strong competition prevailing at the time they decided to retreat.

In 1978 Ashland sold two other chemical businesses which were not profitable including:- three coatings resins plants to Kellogg for about $20 million but retained its speciality and polyester resins business; and its Chemical products Division (fatty acids) to a subsidiary of West Germany's Schering for $60 million. As a result of all these divestitures the company expects better returns on its chemical assets in the future.

In addition to chemicals, Ashland oil has also sold more than half of the $1.4 billion worth of properties it considered not essential to its corporate strategy. Part of that money has been used to buy large quantities of its own shares.

2.2.4 Strategies of the Oil Companies on their Chemical Businesses

Having discussed the reasonings behind the diversification of the oil companies into chemicals and the evolution of their businesses during the recent decades with special emphasis on the nature of their investments, the growth of their sales, their profitabilities and some of their misinvestments, we are now in a position to state, evaluate and comment on the differences of their overall strategies on their petrochemical businesses.

While the oil companies have much in common (e.g. feedstocks and money) their strategies differ in certain respects. Shell's emphasis is on the expansion of its basic olefins and aromatics production capacities (see table 2.2). The company has participated in the high chemistry areas (see table 2.3), however its total investments in these fields are very small compared to its total chemical assets.

As a result of some of the misinvestment in the 1960's, during the late 1960's and early 1970's Exxon limited further new capacities (see table 2.2) and concentrated on structuring the company. Like Shell, Exxon is concentrating on the expansion of its olefins and aromatics production capacities and its overall strategies for the 1980's is based on logical additions to its product line and technical emphasis on trimming feedstock and energy requirements.

Gulf's strategies are basically similar to those of Shell and Exxon and the company is currently interested in moving further into intermediates. The products which the company is interested in, include phenol, alpha-olefins, polyolefins and synthetic lubes. The company is also interested in plastic fabricating and is looking for a high technology area synergistic with its plastics resin position. Gulf already manufactures plastic oil cans and owns an engineering company which manufactures pipes, tanks and vessels. The company made a controversial acquisition in 1977 involving the take-over of Kewanee Oil, however the deal also included two speciality chemical divisions which are not the sort of businesses the oil companies are efficient in and hence aiming for. Gulf, on the other hand, claims to be satisfied with these divisions and believes that some of their businesses have good potential as a new platform for growth, and that they will add many dimensions to Gulf's different businesses and therefore the company will support them strongly.

Mobil is also actively involved in olefins, aromatics and plastic resins and its overall strategy is based on self-sufficiency in these areas. The company is also looking towards the commercialization of a new resin developed in its laboratories (poly - para - methyl - styrene) as a replacement for polystyrene; further expansions of plastic shopping bags in supermarkets (Mobil is closest to the consumer with its plastic bags); polyethylene film for pallet overwraps; and oriented polypropylene as a replacement for cellophane.

Texaco, on the other hand, has adopted a more conservative strategy towards the chemical business.

The company is not interested in downstream products such as plastic pipes, wrapping paper and plastic bags and prefers to grow in areas where it has marketing strength including aromatics, olefins, ethylene glycol, urethane and chemical additives for oils and greases. Another area in which the company looks for growth is the production of synthetic gas from coal, based on Texaco's proprietary process (Chemical Week, 8 August 1979). However, due to the huge capital required (i.e. $300 million), its first plant which was initiated recently is a joint venture with Southern California Edison.

Conoco is concentrating on the expansion of its surfactant and PVC businesses together with self-sufficiency in their raw materials.

Phillips's strategies are similar to Texaco's. That is, to expand in areas where they have marketing strength and retreat from those where they have no particular strength. Areas in which the company is successful include ethylene, h.d.p.e. and Cyclohexane. Phillips has expressed doubt on the success of the proprietary technology developed by some of the oil companies for downstream projects due to the difficulties of getting into a new business at a time of high energy costs.

Standard Oil's strategy during the last two decades has been to move further down, into the processing of petrochemicals which has involved the acquisition of many companies, mostly fabricators of plastic household products whilst at the same time building up rapidly its olefins, aromatics and resins production capacities to meet the raw material requirements of its fabricating plants. The company's spendings in 1979 focused on downstream operations mainly involving the acquisition of additional plastic bottle plants and also carpet backing plants. Its future strategy is also based on the growth of downstream operations: the expansion of its moulded products line; entry into the manufacturing of containers for personal care products; and pushing plastic bottles into the beer bottle market.

Occidental, unlike other oil companies, has no feedstock tie in with its chemical operations. The company has stated in the past that it went into chemicals because the chairman wanted to diversify and found chemicals attractive. Its strategy has since been to grow in mainly two areas, resins and fertilizers.

Atlantic Richfield's chemical subsidiary (ARCO) hopes to grow very rapidly in order to attain, in a few years time, sales level comparable to those achieved by major oil companies such as Shell and Exxon. Arco is depending on the parent company's financial backing and R and D facilities in order to achieve this objective. The company puts special emphasis on R and D and has recently developed new processes for making methyl tertiary butyl ether, polymeric isocyanates, adipic acid and caprolactam, and work is currently in progress on a new ethylene oxide process.

Ashland's strategy has been to solidify its chemical business by selling those assets which were not very profitable. The subsidiary includes two rather unique businesses: distribution of chemicals, selling products most of which are actually produced by other manufacturers; and foundry products.

At this point we shall state our overall conclusions based on the analysis of the strategies of the oil companies on their chemical businesses. The most important conclusion drawn from the analysis presented in this section and from table 2.1 concerns the concentration of the majority of the oil companies on the large tonnage, commodity and 'commodity type' chemicals (e.g. olefins, aromatics, intermediates and plastic resins). Of course it is true that some companies like Shell, Gulf and Mobil have participated in the high chemistry areas and the downsream plastic fabricating business but their total investments in these fields are very small compared to their total chemical assets. Standard Oil is probably the one with most substantial downstream chemical assets among the oil companies, however as we mentioned earlier the parent company is not satisfied with the profitability of its chemical operations. It is also worth mentioning that Ashland which had some downstream chemical assets similar to those of Standard, sold them due to their low returns.

The question arising now is why the majority of the oil companies invest in the large tonnage (i.e. commodity and 'commodity type') and not the more sophisticated (i.e. performance) chemicals. This is due to the very nature of these products. In the case of commodity and commodity type chemicals, which are sold on the basis of their specifications only, marketing is relatively uninvolved depending mainly on the price, and since as we discussed earlier the oil companies have an advantage over chemical companies in having access to cheaper raw materials, therefore they can easily compete with them on the basis of price. However, in the case of performance chemicals, bought on the basis of both their specifications and the results when using them (the clients of which are generally dispersed), marketing involves a wide variety of major activities and also the price. The activities include: frequent technical services at customer level; support by a technical service laboratory; advertising, both technical and institutional; and financing the working capital for clients in the form of raw materials credit. Consequently, since the oil companies do not necessarily have the logistical and marketing networks required for this type of activity, it would be very difficult for them to participate in this area. Further, the oil companies would also find it extremely difficult to be price competitive in this area because of the cost efficiency of the chemical companies in high chemistry fields.

2.3 The Views of the Chemical Companies on the Diversification of the Oil Companies into the Chemical Business and their Strategies for Coping with the Competition from the Oil Companies

In this part we shall discuss the views of some of the more traditional chemical companies on the diversification of the oil companies into the chemical business together with their strategies for coping with the competition (Lurie, 1979).

Most of the chemical companies are very critical of the chemical operations of the oil companies especially during the 1960's and early 1970's. They blame the oil companies' irresponsible use of cash as the cause of their past contributions to overcapacity and accompanying price cutting. Some, like Dow, believe that apart from Exxon, Shell and Phillips the other oil companies actually entered the chemical business as price cutters. However, this belief does not seem realistic because as it is known across this industry, price cutting entry is self limiting due to the constant change, improvement and also introduction of new petrochemical products. They also claim that due to the oil companies' price cutting, things have been made uneconomic for them in certain areas (e.g. oxo alcohols, olefins). The chemical companies are also very critical of some of the oil companies which have, in the past, rushed into the downstream operations and were later forced to abandon them due to bad experiences.

The chemical companies see the advantages of the oil companies in their cashflow, raw materials and dominating position in chemical building blocks (products for which low cost is the dominating factor). However, they are unimpressed with their profits in value added chemicals and research and believe that most oil companies do not have an understanding of the upgrading techniques involved in the industry. They also consider the quality and performance characteristics of the oil companies' chemical plants inferior to their own on the basis that most chemical companies research and design their own plants while most oil companies go to engineering companies and buy processes. The companies further claim that those oil companies which have bought their way into the chemical business are not doing well and that they only managed to enter because of penetrating easy markets such as polystyrene, low-density polyethylene, ethylene glycol and styrene monomer. Finally, most chemical companies have the opinion that chemicals are a sideline for most oil companies and do not receive the dedication that oil does.

However, in the decades since the oil companies began their diversification into petrochemicals, most chemical companies have learnt that the oil companies need the chemical output to maximise return on plant, and also a healthy industry to further process that output. Consequently the relationship between the oil and chemical companies has to be satisfactory in order for the system to operate smoothly and rather than competing, the two should give each other support in reaching the end market. Therefore today, most chemical companies respect the oil companies as tough competitors, reliable suppliers, sizable customers and even partners. The chemical companies respect, in particular, the first line oil companies as good and fair competitors due to their demand of high returns on chemical assets, which keeps prices up. However, in certain areas the chemical companies have found the competition very difficult due to low prices (e.g. terephthalates, DMT, TPA). Concerning the supply of their raw materials, the chemical companies prefer to purchase from oil companies (usually on a long term basis) rather than other chemical companies because they have found them more dependable (particularly for the way they honoured contracts during turbulent times, e.g. 1973-74), and also there is no conflict of interest.

2.3.1 The Strategies of the Chemical Companies for Coping with the Competition from the Oil Companies

At this point it is worth finding out about the strategies of the chemical companies for coping with the competition from the oil companies. Generally the chemical companies believe that the overall impact of the oil companies entry into the chemical business has been to push chemical companies further downstream (for example 18½ cent worth of ethylene makes 60 cent worth of speciality polyethylene). The chemical companies answer to the competition from the oil companies includes R and D, higher technology, strength in marketing, value added and leadership in product areas, and they believe that the oil companies do not necessarily have these strengths. Some companies concerned about the costs and potential shortages of their petrochemical feedstocks have begun to integrate backwards in order to reduce the risk. Among these companies are: Dow which is building a 180000 bbls/day refinery in Texas; Du Pont which has formed two joint ventures with National Distillers and Conoco for the manufacture of carbon monoxide and synthesis gas, and gas exploration, respectively; ICI which has formed joint ventures with Champlin Petroleum and Soltex Polymer for an olefin cracker, and with Chevron for oil and gas exploration; finally Monsanto which has formed a joint venture with Conoco to expand its olefins and aromatics capacity. However, companies like Union Carbide have no plans for any backward integration (oil and gas), claiming that they do not understand the oil business.

2.3.2 The Views of the Chemical Companies on the Strategies of the Oil Companies

Finally, since the strategies of the oil companies on their petrochemical businesses are of great importance to this present research, it is worth discussing what the views of the chemical companies are, on this matter. Union Carbide believes that the oil companies are unlikely to build more ethylene plants because of low returns and the need to build new refineries for the required feedstocks. However, Carbide and also Dow believe that the economics and the nature of the chemical business will force the oil companies to integrate forward in order to gain better returns on their investments. Du Pont on the other hand believes that the oil companies tend to move downstream on a logical and selective basis. Finally, Grace does not expect the oil companies to move forward any further, on the assumption that the oil companies are not going to use their cashflow for investments that do not make any sense; and does not see them as a threat in chemical fields beyond those areas in which they already are. At this point we would like to comment that the views expressed by companies such as Union Carbide and Dow are quite different from our own conclusions about the strategies of the oil companies (presented earlier), however the views held by Grace and Du Pont are more in line with ours and for the same reasons. Further, First

Boston's study on the diversification of the oil companies into the chemical business, which will be discussed in chapter three, also makes similar conclusions to those of Grace, Du Pont and our own.

CHAPTER 3

RELATED STUDIES AND PROBLEM DEFINITION

3.1 Other Related Studies

There have been very few studies carried out in this area which have been published, however in the next section we shall discuss three major studies which are of special value to this present work.

3.1.1 The UNIDO Study

The first world-wide study on the petrochemical industry was prepared by the International Centre For Industrial Studies (ICIS) of the United Nations Industrial Development Organization (UNIDO) in 1978. The study related to two problems which the Lima mandate poses. Briefly, the Lima declaration and plan of action on industrial development and co-operation was adopted at the second general conference of UNIDO in March 1975, and was approved by the general assembly at its seventh special session. The mandate emphasizes the importance of the role of industry as a dynamic tool of growth for achieving rapid socio-economic developments in the developing countries and calls for a rise in the share of the developing countries to a minimum of 25% of the total world industrial production by the end of the 20th century. It particularly encourages the developing countries to give priority to the development of basic industries such as petrochemicals in order to strengthen their industrial structure and hence capture a more significant portion of the world trade. However, two problems arise from the Lima declaration: firstly, to investigate the involvement of each sector of the industry in reaching the 25% target; secondly, to evaluate the size of the resources required to achieve such a target.

The UNIDO/ICIS study relates to the investigation of both the above problems in the petrochemical sector. Concerning the first problem, the study makes a detailed global assessment of the petrochemical industry together with a comprehensive analysis of its structure and development from the past up to its likely state by the turn of the century. Regarding the probable share of the developing countries in the total global petrochemical production by the end of the 20th century, the study explores three scenarios: firstly, the tendencial scenario (the future is the continuation of the past conflicting situation although it can be unacceptable by the developing countries interested in a structural change in the petrochemical industry); the most probable scenario resulting from an objective analysis of the constraints and implementation possibilities; and finally the normative scenario inspired for instance by the Lima target and the degree of co-operation needed to achieve it.

Regarding the second problem, the study has developed a model of the world petrochemical industry capable of simulating future behaviour. The model is then employed to assess the size of the resources required by each of the above three scenarios. The study also informs the industrialised and the developing countries in detail of the implications and the degree of co-operation needed in carrying out any of the three scenarios.

Concerning the modelling technique, the report states that due to the lack of internationally comparable data it was not possible to employ any time extrapolation technique to forecast to the end of the 20th century as is common in the industry. Hence, sophisticated forecasting methods capable of quantifying long term trends were developed incorporating qualitative considerations. Concerning the modelling methodology we are not really able to state any constructive comment because the report does not give a documentation of the relationships embodied in the model. However, the study as a whole is very well founded covering all aspects of the industry together with its most pressing problems with particular emphasis on overcapacity. Although the study is not of direct relevance to our research, since our problem concerns the strategic management decision making at the company level, a great deal of insight has nevertheless been gained of the nature of the industry. The report has also gathered a tremendous amount of data on the world petrochemical industry some of which has been used and acknowledged in our study. Finally an important point concerning our research is that the report has explored the consequences of errors in the forecasting of demand on the planning of future capacities and concluded that significant overcapacity would result according to the period of misplanning and the size of the error in the growth of demand.

The overall prediction of the report concerning the achievement of the Lima target is that, according to the present market realities and the projects on hand the two sides (i.e. the developed and the developing countries) will be in a more conflicting situation in the short term, however expects closer co-operation in the medium and the longer term.

3.1.2 The McKinsey Study

A major study was undertaken by McKinsey and company for the National Economic Development Office in 1977, in order to investigate the prospects for the Western European plastics materials industry in the 1980's and identify a range of strategies by which the U.K. might increase its share of the EEC market. They estimate the future demand for plastics in Western Europe and also quantify the range of uncertainty about their forecasts. They then estimate what capacity was already committed to meet that uncertain future demand in order to work out the range of additional capacity requirements. They further explore the factors that affect decisions to construct capacity in order to determine how manufacturers would probably expand their capacity in the U.K. under present circumstances and then assess the scope for actions by any one or a combination of the parties to the NEDC, that could have an influence on the present capital investment pattern and the likely nature of that influence.

The study suggests that during the 1980's the plastics industry in the U.K. could achieve a trade balance with the EEC depending on new initiatives, otherwise the most it can do is to hold its present share of the market, however there are also factors at work that could cause a further deterioration. It also emphasizes the necessity of the decisions which had to be made in 1978 if the full range of U.K. strategy options for achieving a trade balance were to be kept open.

The study states that due to the forecast growth in demand, considerable additional capacity will be required throughout the EEC towards the end of the 1980's, but expects the current high level of excess capacity to continue well into the 1980's. In contrast to this conclusion, they believe that the plants committed for the U.K. are unlikely to enable the industry to maintain or increase its current market share, beyond the beginning of the 1980's, and therefore conclude that the U.K. is likely to require additional capacity some years prior to the rest of the community. McKinsey acknowledges the manufacturers fears of the magnitude of the uncertainty about the future demand for plastics and states that although future capacity requirements are very sensitive to this uncertainty, the U.K. will still be in need of additional capacity at least one or two years before the rest of the community.

Based on this conclusion, the study sets out a number of strategic options open to the U.K. plastics materials industry. Firstly, the U.K. could decide to halt any further capacity expansions until the community's overcapacity is absorbed, however McKinsey believes that this strategy would result in the growth of imports.

The second strategy involves the expansion of capacity in the U.K. to meet the local demand and also for exports, bearing in mind that the rest of the community will find it extremely difficult to do likewise due to their significant overcapacity. This strategy is believed to give the producers in the U.K. the opportunity of satisfying the future growth in the European plastics consumption which would otherwise be met by new local plants. The study stresses the importance of the appropriate marketing strategies for the success of this option, however it places more emphasis on the timing of bringing adequate capacity on stream when the market needs it, arguing that otherwise the opportunity to balance the trade with the EEC would be lost. Finally, the third option which is a compromise between the first and second, involves sufficient expansion of production capacity so as to protect the current share of local and export markets while the rest of the community are in surplus capacity and then accelerate the expansion programme in order to reach the target (i.e. trade balance) by 1990. McKinsey believes that this strategy carries the least risk concerning any unforeseen changes in the growth pattern of demand or capacity build up in other areas. This strategy is believed to place the U.K. in an adequate position for speeding up or slowing down the capacity expansion programme according to changes in the supply and demand situation.

McKinsey acknowledges the losses which would be incurred in increasing production capacity ahead of demand which would consequently frighten any investor, however he states that the options facing the U.K. are either to pay the cost so as to have a reasonable chance of meeting its target (i.e. trade balance), or to postpone the expansion of capacity until a later date which would consequently mean that there would be less certainty of meeting the target.

Regarding the first option, McKinsey doubts whether the U.K. will be able to offer enough incentives to the potential investors unless steps are taken to encourage their participation. This doubt stems from certain commercial impediments to expansion, believed to diminish the United Kingdom's marginal economic and technical attractiveness to be chosen as a site for plastics manufacturing plants in order to supply plastic materials to European markets.

McKinsey proposes a number of initiatives, intended to enhance the United Kingdom's chances of expanding sufficient capacity in order to achieve its target (i.e. trade balance with the EEC). Among these initiatives are on the one hand, shifts in individual companies' strategies, marketing priorities and joint venture arrangements, believed to be of significant importance; and on the other hand the government's involvement in influencing the construction of a gas-gathering pipeline in the North Sea to supply the petrochemical industry with liquid gases at attractive prices and also the construction of new petrochemical intermediate plants. Further, the study points to the unimpressive performance of the construction industry in the U.K. concerning their longer construction duration times compared to the rest of the EEC and calls for initiatives to alleviate this undesirable phenomenon so as to give the companies the opportunity to delay decisions on capacity expansions, if so desired, for as long as feasible without jeopardizing their chances of satisfying any possible future growth in demand.

Our overall comment on this study is that, it is very much of a qualitative nature in the way of bringing to attention a number of initiatives which could help the U.K. to reach its objective (i.e. trade balance) and also suggesting a number of strategy options to achieve this target. However, the study does not have the scope of evaluating:- the costs of the recommended initiatives to encourage investment, and the potential benefits and risks associated with such investments, in order to decide if any of the three strategy options are advantageous to be adopted. Further the analytical approach to the study involves very simple statistical analysis for demonstrating the ranges of capacity build up in the U.K. under different strategies taking into account some degree of uncertainty about the future demand forecasts and although the study stresses the importance of the impacts of the decision making interval, errors in forecasting, and plant completion times on the capacity planning process, due to the simplicity and the inadequacy of the analytical technique employed, the study does not thoroughly explore the sensitiveness of the process to each of these three parameters.

Our major criticism of this study concerns their statement of the oil crisis of 1973 and the world recession being the major causes of the interruption of the rapid growth the petrochemical industry experienced up to the early 1970's. Of course, these two factors did affect the slowdown of the industry, however the major cause of the decline in the rate of the growth of demand for petrochemicals was, as we discussed in Chapter 1, due to the industry reaching the age of maturity and this is acknowledged by many of the executives of the chemical industry, for example N. Champion, the finance and planning director of BP Chemicals (Champion, 1978).

Finally McKinsey's study is of special interest to this present work because it covers the range of products selected for this study and also contains some very valuable information about the petrochemical industry.

3.1.3 The First Boston Study

A major statistical study with the objective of assessing "the myth and realities of the oil companies' aggressive move into the chemicals business" was undertaken by First Boston Corporation in May 1976.

The study concentrates on the companies in the U.S.A., however since most oil companies are multinational, the findings are applicable in a wider context. The study looks back to the 1960's when the oil companies were first accused of being responsible for the poor profitability of the industry and states that their investigation of the facts show that the accusations were unfounded.

It states that it was the chemical industry's own dynamics that caused overcapacity, price wars and profit erosion. This conclusion is based on the following reasons:- industry unit costs were falling through the development of larger and more efficient plants and productivity steadily rose by between 6 and 10 percent per year; ease of entry into the industry had improved to the point where 'off-the-shelf' technology was available. The study further states that these factors together with excellent unit volume growth prospects encouraged aggressive expansions not only by oil companies, but also by the food, steel and tyre industries plus chemical companies. The newer, lower production cost plants soon dictated pricing for the entire industry as they rapidly accounted for a significant portion of the total capacity.

The study states that the oil companies <u>were</u> responsible for a share of the chemical industry's problems in the 1960's, but not exclusively. Their involvement in the chemical industry was mainly in two areas, petrochemicals and fertilizers. Their participation in fertilizers was mainly due to the excess availability of refinery hydrogen. However their attempts in this field were a failure due mainly to:- the overcapacity in the fertilizer industry (companies operated these capital intensive plants at high rates, irrespective of the demand in order to achieve lower production costs for their products); the oil companies lack of know-how in marketing fertilizers. However, the oil companies participation in the petrochemicals business was more successful as the majority of their customers were the chemical companies, the petrochemical business was much more stable than fertilizers and finally petrochemicals manufacturing was a natural addition to oil refining.

The study has also analysed the possibility of the oil companies moving deeper into chemicals and has concluded that they are expanding only in specific product areas or in product lines where they possess production or marketing advantages, such as the building blocks (e.g. ethylene, propylene, benzene, etc.), some organic intermediates and plastics. The data presented in the study together with its analysis do not support the theory that the oil companies are aggressively integrating forwards.

The study states that the chemical industry should not fear the oil companies' increasing share of the industry, it should instead consider the possibility of the oil companies pricing their petrochemicals on the basis of their feedstock costs, where they often enjoy a significant advantage.

The study states that the oil companies may be tempted to use this advantage, however their recent massive capital investments on their building-block plants may moderate their attempts to "play the role of the spoiler". The study isolates fifteen petrochemical commodities, including ethylene glycol, propylene oxide, styrene, some plastics and terephthalates where the oil companies may hinder profitability for the chemical companies.

However, the study states that the oil companies should not be solely blamed if the prices deteriorate in the future, since the majority of the chemical companies admit that they have overexpanded their production capacities.

The study concludes that the oil companies expansions of their petrochemical capacities during the 1974-1980 period may in fact be beneficial to the chemical manufacturers, when considering that the oil companies are generally net sellers of petrochemical raw materials to the chemical manufacturers and the fact that there may be over-capacity available in these products should keep chemical companies' raw material costs down.

First Boston's study is the most comprehensive and also the most relevant concerning this present study. Its findings regarding the problems of the industry during the 1960's of overcapacity and price wars, which have persisted to the present date, are very much in line with the arguments put forward in chapter 1. Its findings regarding the strategies of the oil companies in their forward integration into petrochemicals are also in line with the strategies stated by the chief executives of the oil companies presented in chapter 2. This is especially important regarding this present work as it is extremely difficult to find out about the petrochemical activities of the oil companies and the only information sources available are the chemical journals and certain published papers and reports. However, the validity of the information obtained from such sources should be thoroughly examined but in this case First Boston's study generally supports the arguments and information presented in Chapter 2. Finally it must be emphasized that this study contains much valuable statistical data.

3.2 Problem Definition

In the first chapter we presented the background to the petrochemical industry together with some of the complexities involved in the running of such business, and also discussed its most pressing problem, that of world-wide overcapacity.

At the present time the world petrochemical industry is in a serious crisis. The demand is way below on stream capacities, which are made up of very expensive plants, and under current market conditions production cost increases are leading to the erosion of profits. Forecasts made by CEFIC (Conseil Europeen des Federation de L'Industrie Chimique) towards the end of 1978 indicated that overcapacity in the main building blocks of the industry would last until 1982-1983. However, another study carried out by Eurofinance, which is a financial research organization owned by nine European and U.S. banks, during the same period made a rather gloomier forecast. The study states that the predicted investments in neighbouring countries of the EEC and the Opec countries could prolong the community's overcapacity by another 5-6 years beyond the 1982-1983 forecasted by Cefic, which would consequently mean that the industry can look forward to a period of excruciating readjustment and lasting throughout most of the 1980's (see table 3.1).

Table 3.1 Realistic Capacity to Produce Ethylene and low density Polyethylene (m. ton)

	Non-EEC Europe (1982)	EEC Europe (1982)	Middle East (1985)	Potential exports to EEC	Annual increase in EEC demand (mid 1980s)
ethylene	7.95	16.04	2.2	2.65 +0.7 =3.35	0.5
low density polyethylene	2.86	5.34	1.1	0.9 +0.35 =1.25	0.2

Note: (1) Non-EEC Europe includes the Nordic countries (excluding Denmark), Spain, Portugal, Greece, Turkey, Austria, and Eastern Europe.

(2) EEC is the Community of the Nine.

(3) Middle East is Iran, Iraq, Qatar, Kuwait and Saudi Arabia.

(4) Potential exports to EEC are assumed to be 30 per cent of production capacity.

Source: Eurofinance, 1978

However, this problem is not a static one originating from the present economic recession but a dynamic one caused by decisions made since the late 1960s. Consequently the decisions taken now or in the near future will substantially determine the future world petrochemical industry from 10 to 20 years ahead and since the general practice of the top decision makers in this industry is to limit forecasts to only 5 years ahead, there is a large gap that needs to be bridged between the customary forecasting horizon and the far reaching impacts of the decisions taken. This phenomenon is well explained by Drucker's criterion called "the futurity of decisions" : that is, how far in the future will decisions made today limit future action? The petrochemical industry is among the industries which have a long lead time of this nature.

In order to shed more light on the dynamic nature of the problem it should be mentioned that the most important causes of the industry's overcapacity are the aggressive capacity expansion programmes adopted by the companies during the late 1960s and the early 1970s based on the simplistic perception of continually increasing exponential growth of demand and also the industry's delay in perceiving the depth and duration of the economic recession, especially in OECD countries during the 1970s. During the 1967-1973 period many large companies planned on the basis of building larger plants than their competitors, outselling their competitors at cheaper prices for two or three years to push them out of the market, so as to reap profits later for their future larger plants.

However, in early 1970's the industry entered a new era in which its growth declined considerably, but the companies were unfortunately slow to recognize the extent of the changed conditions. In fact according to Eurofinance's study, mentioned earlier, the investments in the three years following 1973 were 22% higher than in the preceding years and have continued to rise, as we mentioned in chapter two.

In the past the effects of misplanning, for example of capacity expansion, used to be cured quickly because demand was fast in catching up with such overcapacity. However, in the future structural misinvestments will be equivalent to self-mutilation. Capital intensive projects, even if they make technological sense, represent a big economic risk. Underutilization requires digestion of high overhead costs on the face of product price pressure. Such depressed market conditions are bringing attention to debottlenecking Projects instead of new plant construction.

To sum up the situation, the present overcapacity of the industry is mainly, as we mentioned earlier, due to the huge orders placed for plants during the 1967-1973 period and the long lags that exist in the construction of petrochemical plants. The capital intensive nature of the industry together with the decline in the growth of demand have seriously damaged the financial performance of the industry. Concerning the future for the petrochemical industry, it is expected to be dynamic but full of risk and the main task of the companies operating in the industry would involve matching their capacities to demand and financing their varying capital expenditures.

3.3 Purpose of the Research

Our concern in this present work is in the diversification of an oil company into the petrochemical business and the exploration of the appropriate corporate strategies. As we mentioned in the previous section, the companies operating in this industry, including the chemical subsidiaries of the oil companies, have been faced with large overcapacities of production since 1974. This phenomenon in turn affects the overall corporate strategies of the oil companies towards their chemical businesses. Consequently the need for establishing a more adequate capacity acquisition policy arises which is one of the main objectives of this study. In achieving this aim, a more disciplined approach to investment is required because as we now know, the investment policies adopted by companies during the late 1960s and the early 1970s have caused the industry a great deal of harm which is expected to continue for many years to come. Therefore past history has to be examined thoroughly so that similar mistakes are not made in the future.

Further, in order to design an appropriate acquisition policy, there is a need for accurate long range planning, however there are many obstacles in doing so. The business cycles and the resulting capital investment cycles are one such obstacle which are common to capital intensive industries and according to theory and practice, are amongst the most variable components of the G.D.P. (NEDO, 1976). Long varying construction completion times also complicate the situation, because the need for long planning horizon arises which in turn affects the magnitude of the errors in the forecasting process. As we mentioned in chapter 1 and also in the previous section, badly estimated demand forecasts of the past have made certain contributions to the overcapacity problem and this suggests that significant errors are likely in forecasting the growth of demand for petrochemicals 5 years ahead.

In this study we shall put special emphasis on:-

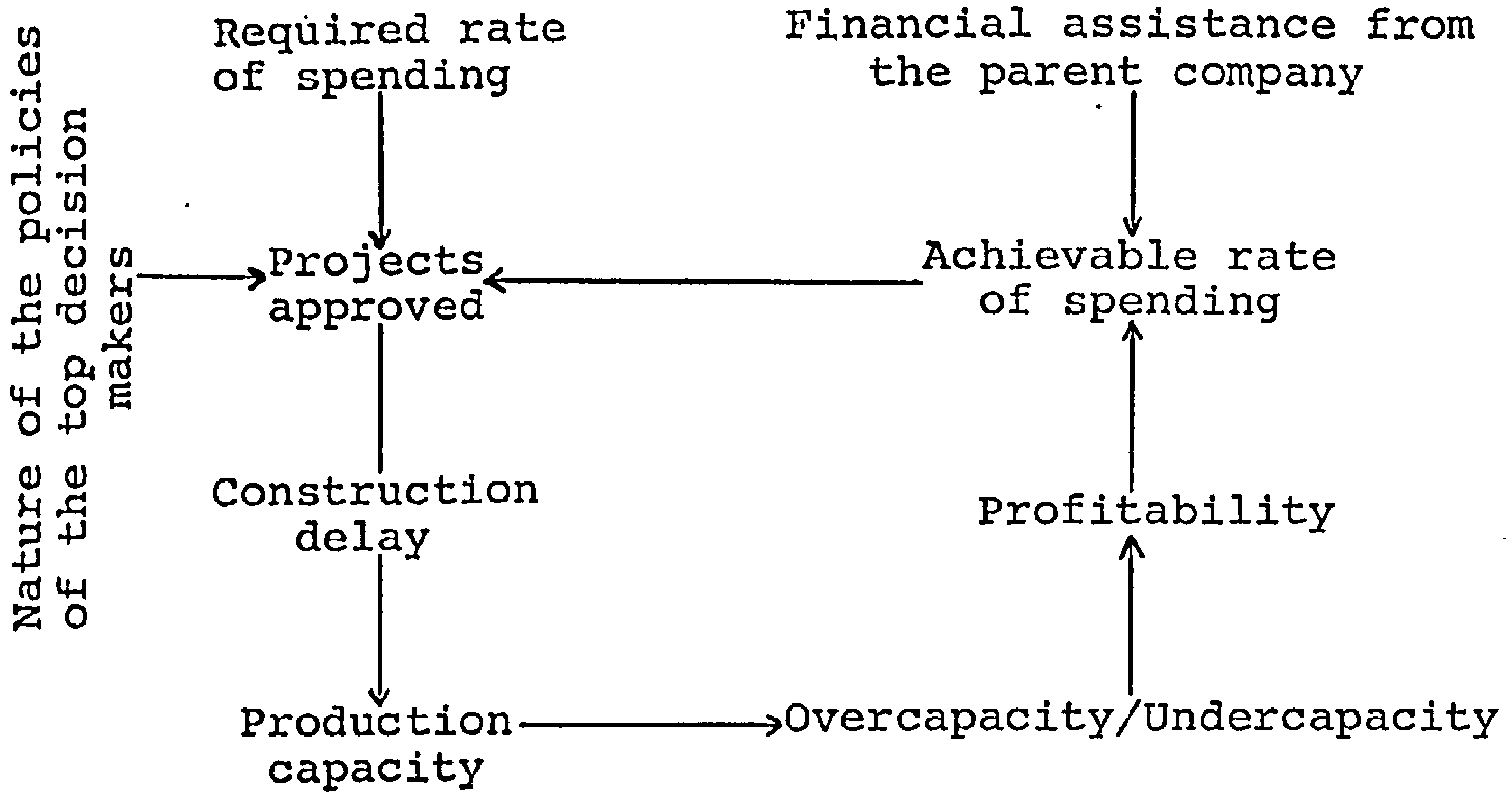
(a) Examining the seriousness of the errors in the capacity planning process, particularly concerning the forecasting of the rate of growth of demand.

(b) Exploring the interaction between the planning side of the business and the top decision making in order to see whether the resultant impact could ever amplify the exogenous shocks from the environment.

(c) Looking for any other factors, besides those mentioned earlier, which might have a significant effect on the problem.

(d) Examining the impact on the company when operating under inflationary conditions.

As we have defined the problem, it is evident that our interest lies in the possible destabilizing effects of changes in the amount of spendings required on new plants interacting with changes in the level of spendings the company could sustain under the influences of factors which were mentioned earlier and also the aggressive or conservative nature of the policies of the top decision makers towards the market. Ideally, if the intentions are to match the capacity to demand, one would really seek a "balance" between over and under reaction towards investments which would hopefully result in a "balance" between supply and demand which is necessary for the long term survival of the companies operating in the industry. This situation is very well demonstrated by the following diagram which in fact represents a feedback loop, and our purpose is to explore the implications of this loop on the behaviour of the company.



This is of course just one part of the very complex system that we are studying. However, this loop is very important due to the interactions which it represents, but the eventual solution to the problem would involve the examination of a number of endogenous and exogenous factors within the company and its environment respectively.

Before we proceed to explain the method of research, it is essential to make it clear that the solution which we hope to find should be tested, for sensitivity purposes, against the kind of errors which we described earlier and also against parameter and relationship errors which might be made when modelling the system. Coyle (1977) refers to this type of requirement as external and internal robustness. External robustness for cases in which the parameters and relationships of the outside environment are not known accurately. In our case we do know that the demand forecasts could contain a large element of error, therefore this criterion is appropriate.

Next, internal robustness for cases in which the analyst's knowledge of the internal structure of the system under study lacks in certain parts which would be consequently reflected in the modelling process. To alleviate this problem, one should ideally design the policies so that they are not too dependent on the parts which include a large element of uncertainty, and instead rely on parameters and functions which are known more precisely. This is particularly important for this present work because as we mentioned in chapter two, it has been extremely difficult to obtain all the information required due to the confidential nature of the operations of the oil companies, therefore the solution which we aim to find should be relatively robust to any aggregations and approximations made during the modelling process.

3.4 Method of Research

The enormous complexities of the problem described in the previous sections implies that probably the only possible approach to the problem is to actually construct a model of the system under study in order to be able to analyse the behaviour mode resulting from the interactions of the many interdependent sub-systems within the organization. In doing so, we need to search for a modelling method which would suit our problem. Ideally we would like to find one which could satisfy the following requirements:- our problem is basically how to control and manage the system, therefore the modelling theory should have strong links to control theory; the model should operate through time in order to have any meaning in relation to the actual company; since the system contains delays and elements of non-linearity, the model should also accommodate for these very important phenomena; it is important that for a problem of this complexity the analyst should choose a technique which is understandable by managers so that they can participate in the modelling because after all they are the ones who know the most about the system; the model should not require too much data about the past because firstly many organizations do not possess a comprehensive data base system and secondly in our case the information is very confidential and therefore difficult to obtain; it would also be advantageous to choose a technique which enables the analyst to build the model as quickly and cheaply as possible, which is usually required in a real company situation, and also permits the rapid testing of many alternatives which would be required for such a study.

Among the mathematical modelling techniques available, Industrial Dynamics (Forrester, 1962) and(Coyle, 1977) is the one which offers the most concerning the above requirements.

Forrester (1962) describes Industrial Dynamics as "a way of studying the behaviour of industrial systems to show how policies, decisions, structure, and delays are inter-related to influence growth and stability. It integrates the separate functional areas of management-marketing, investment, research, personnel, production, and accounting. Each of these functions is reduced to a common basis by recognizing that any economic or corporate activity consists of flows of money, orders, materials, personnel, and capital equipment. These five flows are integrated by an information network. Industrial dynamics recognizes the critical importance of this information network in giving the system its own dynamic characteristics."

Coyle in MSD (1977) recommends a number of criteria in order to enable the analyst to decide whether a particular managerial problem is indeed of the nature suitable for a dynamic modelling study. His recommendations are as follows:

Firstly - Is there any dynamic behaviour?
Secondly - Do the dynamics matter, and why?
Thirdly - Are there any loops?
Fourthly - Are there any alternative system structures or control policies?

The first chapter of this present research gives sufficient detail and justification to Coyle's first two criteria. Concerning the third criterion, we have already demonstrated a very important loop of the system in the previous section and the influence diagram of the whole system which will be presented later reveals many more feed-back loops, therefore the third criterion is satisfied. With respect to the last criterion, the answer must be 'yes' because otherwise the system is either very well managed, or completely paralysed and neither of these two states apply to the system under this present study. Further it is generally possible to make any alterations to the organizational structure and policies as long as they are feasible. Therefore the fourth criterion is also satisfied and we can conclude that the problem is indeed within the field of dynamic modelling.

In this study our purpose is to construct a model of the petrochemical subsidiary of an oil company in order to analyse its financial performance under the impacts of the supply and demand situation, and the capital expenditure programme commitments, which then in turn affects the supply and demand situation. Therefore we need a corporate financial model in order to analyse the top management policies regarding planning proposals. Industrial dynamics modelling through its successful application to problems concerning corporate planning and business policies of firms is thus very appropriate. Its methodology is especially suitable for the study of the management and control of large organizations, such as the one under this present study, and in particular how they grow and evolve in an uncertain future. Further it is particularly powerful in enabling the analyst to explore the way in which policy making within an organization affects its behaviour and then to design policies which would produce satisfactory behaviour if things go right in the external world, whilst at the same time protecting the organization against the worst that can happen if things go wrong. Our conclusion is thus that the technique is indeed very well suited for our problem.

3.5 System Boundaries

In a study of this nature the first and most important step prior to the construction of the model is to define a suitable selection of the boundaries of the system to be explored, according to the objectives of the research. Forrester (1962) argues that "if all the necessary components are adequately described and properly inter-related, the model system cannot do other than behave as it should". Hence great care has to be taken in order to include all the significant factors affecting the behaviour of the system under the study. Any negligence in doing so could result in the elimination of behaviour which might be of great importance to the aims of the research and hence affecting the credibility of the work undertaken. At the same time the researcher has to guard against the boundaries becoming unnecessarily extended which could result in the overshadowing of the main objectives of the study and also affecting the intended duration of the work.

Concerning this present research, after a great deal of consultation with a number of companies interviewed and also extensive research in the literature from different sources; a system boundary was derived according to the objectives of the study which is demonstrated by figure 3.1.

The next step is to translate the system boundary into an influence diagram which would include the most significant variables of the system adequately linked. Influence diagramming is very powerful in demonstrating the causal relationships among variables. The list extension technique recommended by Coyle (1977) is helpful in enabling the analyst to draw a preliminary influence diagram which would embody the most important components of the system. We employed this technique in constructing a first diagram which was then taken to a number of companies. We found the influence diagram to be an excellent tool of communication during our contacts with the executives of the companies. They gave very constructive comments on the links between the variables, suggested certain amendments and also some new links and variables of great importance. During the interviews we perceived that an influence diagram of this nature represents


General Rate of Growth of Demand
Changes in Structure of Demand for Petrochemicals
Crude Oil Price Rises
Overall Inflation Rate
Rate of Return on Investment at Balanced Supply and Demand Situation
Interest Rate on Cash Reserves
Taxation and Dividend Rate
Overall Inflation Rate
Demand
Actual Production
Working Capital
Cost
Price at Balanced Supply and Demand Situation
Profit Margin and Depreciation Charges at Balanced Supply and Demand Situation
Actual Profit and Depreciation Charges
Cash Balance
Financial Ability of the Subsidiary
Maximum Financial Assistance from the Parent Company
Capital Cost of Plants
Monetary Value of Capacity
Physical Depreciation
Overcapacity/ Undercapacity
Production Capacity
Actual Project Initiations
D
D
D
D

an intuitive model of the system which a manager, or a person who knows most about the system, has in mind hence their willingness to co-operate.

Figure 3.2 represents a simplified influence diagram of the system under this present study. The diagram does not include all the links because to do so would have meant the inclusion of hundreds of links crossing one another and thus displaying a very complex figure which would be of little use. However, it does demonstrate the very bone structure of the system embodying the most important components which are responsible for the way that the actual system behaves. The driving forces of the system together with the assumptions made in the modelling process are discussed in chapter 4.

3.6 Nature of the Organization to be Studied

In this study our concern is with the petrochemical activities of the first line oil companies (i.e. the majors known as the seven sisters). Their strategies towards the chemical business are, as we discussed in chapter two, very similar, with minor differences. The research is actually based on a hypothetical petrochemical subsidiary of a major oil company (due to the reasons given below), however it could represent the chemical activities of any of the seven companies mentioned above which is advantageous in terms of making the conclusions applicable in a wider context and also for any possible comparisons. However, the hypothetical nature of the company does imply that there is a danger of over simplifying the situation which in turn affects the

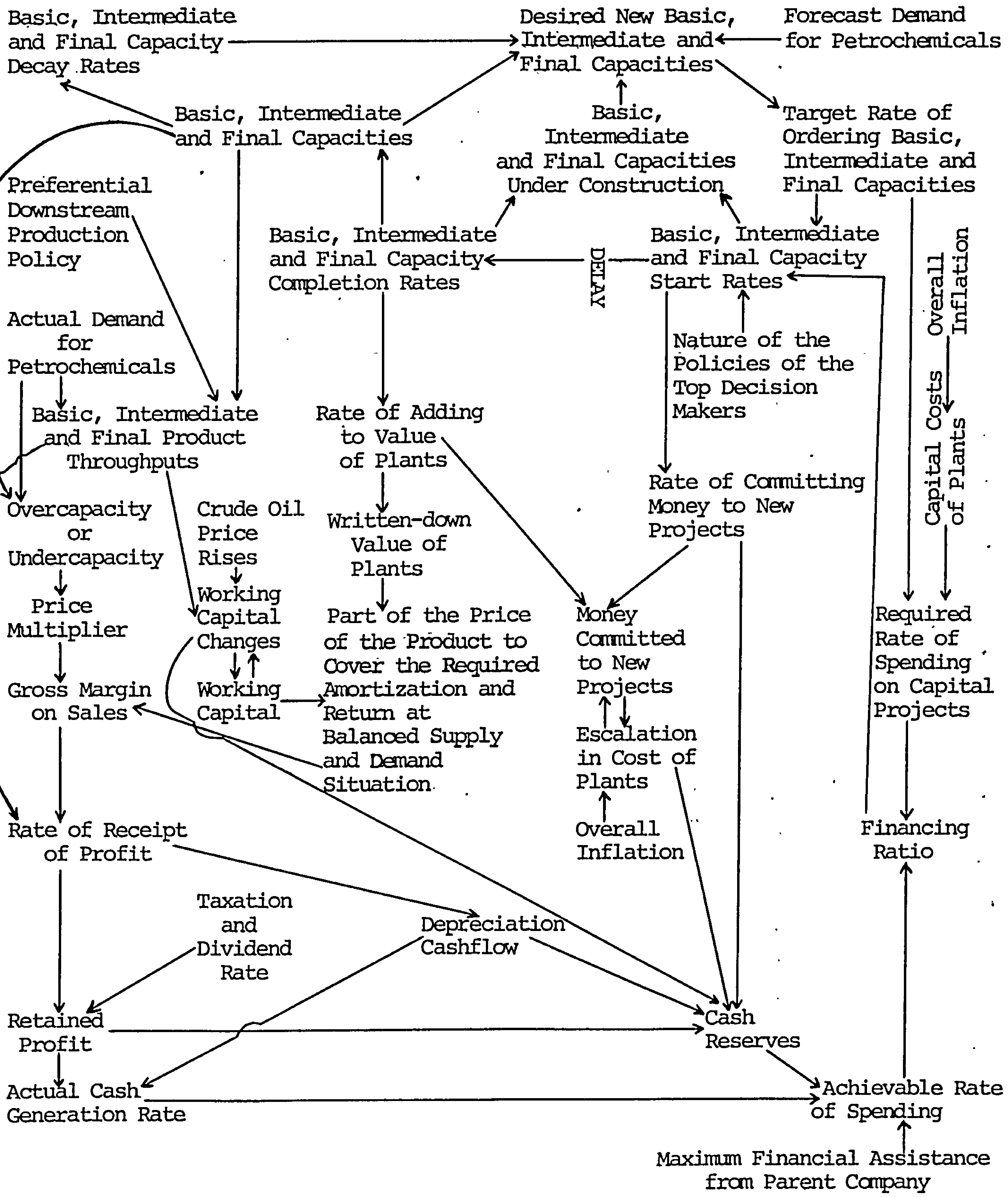


Figure 3.2 Simplified Influence Diagram of the System

credibility of the work. Consequently in order to prevent this we have tried to acquire and analyse information from as many sources as available.

3.7 'Confidential' Contacts with Major Oil and Chemical Companies

During the initial stages of the project, a number of major oil companies were contacted in order to find out about the possibility of carrying out the work on a real company. However, as we mentioned in chapter two, due to the confidential nature of the operations of the major oil companies, it proved impossible to obtain the high level of involvement necessary from the management of any of the companies approached, but after a great deal of assurances and guarantees that no names of persons or companies will be revealed in the thesis they did agree to co-operate to a certain extent. During the period of our research we have had frequent contact with the executives of a number of major oil and also chemical companies who have discussed and commented on our work and also suggested some very important factors to be included. They also provided us with some very important data and information which we were not able to obtain from the other sources. These informations are presented in the thesis, however their sources will remain undisclosed due to our promise to the companies. At this point we would like to state that the co-operation of the executives of the companies has been absolutely invaluable and crucial concerning the development and the completion of our study. Unfortunately we cannot name them but we would like to take advantage of this opportunity to give them our deepest gratitude for all the time and effort which they contributed towards our research.

3.8 Geographical Boundary

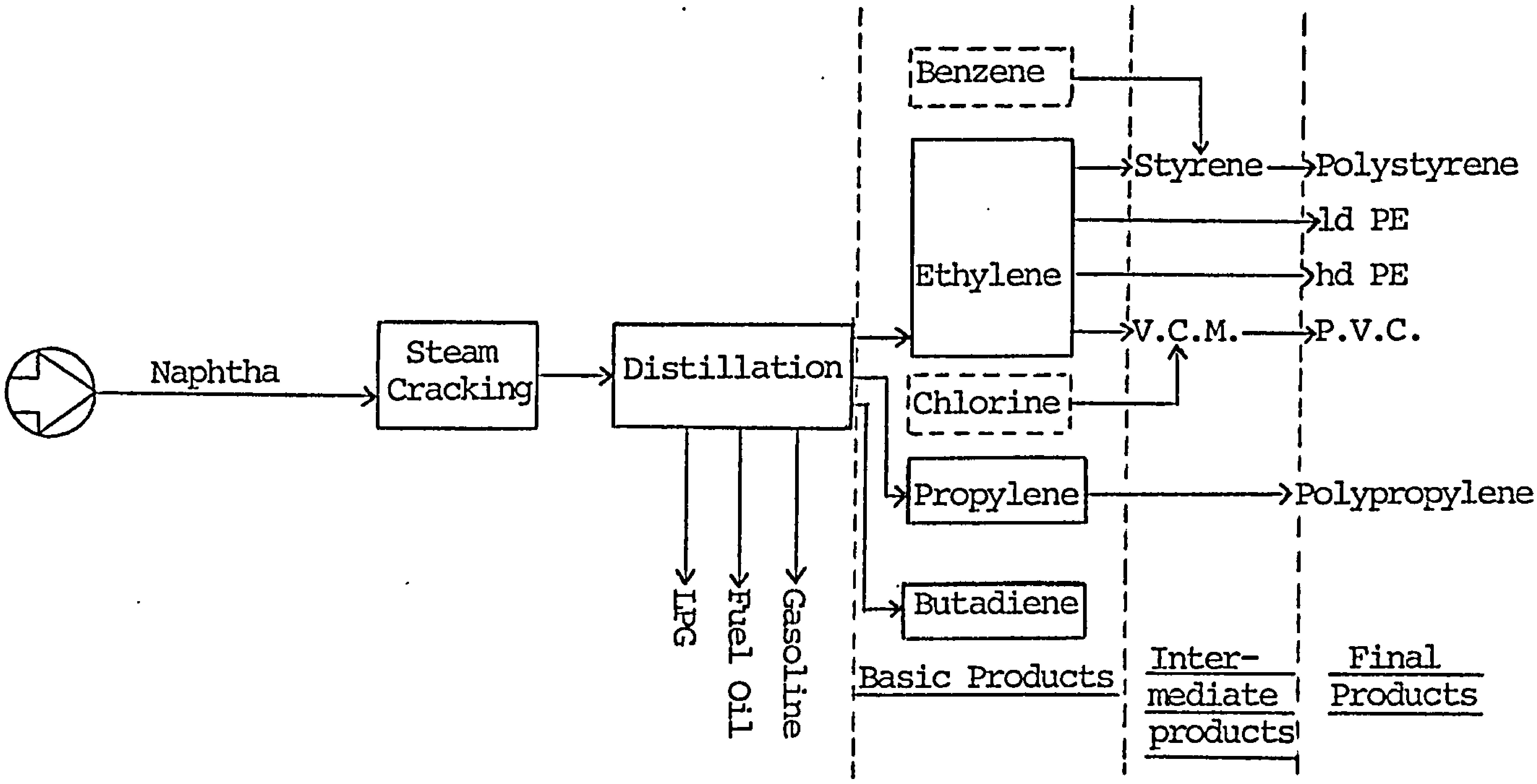
For the purposes of this present work, since the bulk of the petrochemicals are produced and consumed within the industrialized nations we decided to explore the petrochemical operations of a major oil company within an industrialised region of the world where the conditions would be fairly homogeneous. Western Europe is one such region where the petrochemical industry is mainly based on naphtha which is a product of the refining process of crude oil which is mostly imported (although there are some endogenous sources such as those of the U.K. and Norway) and the price of which is fairly similar over the region. It is also not too unrealistic to assume an average overall inflation figure for this region (as is assumed by the companies discussed in chapter 4) although there are differences from one country to another. The growth and the structure of demand for petrochemical products, and the construction completion times of the petrochemical plants are also fairly homogeneous over the region. At this point we should make it clear that the corporate planning model constructed for the purposes of this study would be of interest to the parent oil company in order to assess the overall performance of its petrochemical operations over such a region. There will of course be a number of operating companies within the countries covered by such a region which will carry out their own detailed planning according to certain strategic guidelines set out by the parent company. These guidelines would be the result of an overall strategic plan prepared by the parent company which is also the aim of our own work.

3.9 The Chemical Products Selected for the Study and the Choice of Feedstock

The major oil companies, as discussed in chapter 2, have been concentrating on the large tonnage commodity and 'commodity' type chemicals which include olefins, aromatics, plastic intermediates, fibre intermediates and plastic resins. Since this study concerns the typical chemical operations of one such company, therefore we have chosen to concentrate on the largest part of their chemical businesses which consists of olefins, plastic intermediates and plastics, which respectively fall within the basic, intermediate and final products range of the petrochemical industry. Figure 3.3 describes the selected products in detail together with the internal structure of this part of the industry.

As was mentioned in chapter 1, the European petrochemical industry has been mainly based on naphtha which is a product of the oil refining process. The United States' petrochemical industry is also switching to heavy liquid feedstocks, such as naphtha, because of the rapid exhaustion of its natural gas reserves. The feedstock situation is also generally the same in other areas. Therefore, concerning this present study we will concentrate on naphtha, of which the oil companies have plenty, as the feedstock for the production of olefins. The naphtha steam cracking process yields a number of basic petrochemical products such as Ethylene, Propylene and Butadiene and a number of energy products including Gasoline, Fuel oil and LPG.

Figure 3.3 The Internal Structure of the Selected Products



In the intermediate sector we are considering vinyl chloride for which the raw materials are Ethylene and Chlorine, and Styrene which is based on Ethylene and Benzene. However, since in this study we are not considering the aromatics and chlorine production activities of the oil company, therefore Benzene and Chlorine are treated as exogeneous inputs and we shall be assuming that the company has access to sufficient quantities of these two raw materials for its Styrene and vinyl chloride production.

CHAPTER 4

EQUATION FORMULATION OF THE MODEL

4.1 Introduction

In this chapter we shall discuss in detail the equation formulations of the model representing, quantitatively, the causal relationships existing among the variables described in the influence diagram presented in chapter 3.

There are various computer languages available for dynamic modelling, however for the purposes of this present study DYSMAP, due to its simplicity and at the same time suitability for studying the dynamic behaviour of socio-economic systems, was selected (Ratnatunga, 1979). The Dysmap compiler is very refined, incorporating many features including dimensional analyser. Coyle describes in detail the formulation of dynamic equations using DYSMAP (Coyle, 1977).

During the initial stages of the research a simple hypothetical model of the system structure of the petro-chemical subsidiary of a major oil company was constructed which was then taken to a number of major oil and chemical companies in order to verify the validity of the relationships presented in the model. These contacts, made throughout the research up to the present time, have had invaluable impact on the evolution of the model to its final form. The people interviewed assisted enormously in the adaptation of the model in relation to the workings of the actual system. They suggested certain changes to a number of relationships, recommended some very important factors to be included in the model and supplied some very valuable and otherwise inaccessible data. Therefore the values of the various parameters of the model and the structure of the system have been based upon the knowledge and experience of people who run the type of system which is under this present study. This is particularly important concerning the validity of the model which is discussed in chapter five.

The time unit of the simulation period of the model is in terms of month. The solution interval, DT, was suitably set to ½ month for reasons of stability.

The time horizon of the model extends from the year 1980 to the year 2000, so that we would have the opportunity of studying the medium-range dynamic behaviour of the system as well as that of its longer-term.

Due to the size of the model, we shall only describe the formulation of those equations which are important due to their relative complexity and the importance of the assumptions built into them. A full listing of the equations of the model is given in Appendix A.

Since in this study we have modelled the three main sectors of the petrochemical industry, i.e. basic, intermediate and the final product sectors, therefore many of the equations written for these sectors are of similar structure and if necessary we shall only describe one equation which would also define the others. We will also define the value of the parameters and the initial conditions of the equations.

Finally the corporate planning model has been built in such a way so as to be useful to both the top management and the operational staff of the company. It provides detailed physical and financial information about each individual product required by the operational staff for the running of the business as well as the broader type of strategic information required by the company's board of directors for their yearly decision making on the coming year's programme of new capital expenditure proposals. The model also gives the broader physical and financial information about the product groups of the company (i.e. basic, intermediate and final) so that the top decision makers can readily assess the overall performance of their different businesses.

4.2 The Product Demand Sector

As was discussed in chapter 2 the majority of the oil companies are involved in the production of large-tonnage plastics which they sell to plastic fabricating companies to be used as raw material for the production of a variety of industrial and household products. It was also mentioned that a few oil companies have very minor interests in the fabrication of plastics but generally they are net sellers of plastic resins to the processing industry. Therefore for the hypothetical company under this present study we have realistically assumed total non-captive demand for plastics. The company's production of plastics depends for its raw materials on the production of a number of basic and intermediate products. Therefore the oil companies retain a certain amount of their basic and intermediate production for further captive processing by their plastics divisions and sell the rest to some of the traditional chemical companies and the plastics companies who are dependent on the oil companies for the raw materials of their plastics production activities. This situation is reflected in the modelling process of the demand for the different products of the company. Briefly the demand for ethylene consists of a captive and a non-captive part. The captive part depends on the demand for vinyl chloride, styrene, low-density polyethylene and high-density polyethylene. The non captive part is the demand for ethylene by outside customers. The demand for propylene depends on the demand for company's polypropylene and the amount of propylene demanded by outside customers. The demand for butadiene is assumed to be wholly non-captive. The demand for vinyl chloride and styrene depend on the demand for company's PVC and polystyrene, and the non-captive demand for vinyl chloride and styrene respectively (see figure 3.3).

The pattern of demand (ADGF) for petrochemical products, in the model, is a function of an exogenous factor namely a scenario for general rate of growth of demand for petrochemicals in the 1980's and the 1990's. We have not considered the effect of the company lowering its products prices, compared to its competitors, in order to gain a larger market share, because during the interviews made with a number of major companies they mentioned that this type of marketing strategy is, on the long run, very damaging and does not work (as discussed in chapter 3) because other companies would also lower their prices in order to protect their market share and at the end of the day everybody would be worse off. They stated that they have learnt from their past similar mistakes particularly during the late 1960's and the early 1970's and have since built up a mutual understanding among themselves not to resort to such futile marketing strategies. It was also mentioned that the only way a company could actually increase its market share would be to acquire plants from other companies thereby not disturbing the total capacity of the industry. In this study, therefore, we have assumed that the oil companies will not in the future try to capture other companies' market shares and we have also decided, through consultation with a number of companies, not to consider increase in market share through acquisition due to the small number of such deals happening among companies.

Concerning the general rate of growth of demand for petrochemicals in the next decade, it is important to refer to Shell's study (Royal Dutch/Shell Group of Companies, 1980) which forecasts a 4% growth per year in the 1980's. This forecast is based on a 2½% growth per year forecast for industrial production which would therefore imply that the demand for petrochemicals is expected to grow at 1½% per year higher than the industrial production. However, during the interviews made with other oil and chemical companies the majority of them mentioned that the 4% growth per year was too optimistic and one company was pessimistic enough to suggest a growth of 2%. However, the majority thought that an average annual growth of 3% would be more realistic and therefore we have adopted this figure for our present research (even the 3% growth during the time horizon considered leads to significant growth in production capacity, which will be discussed in more detail in chapter 5).

Since the demand for petrochemicals like other industries such as electricity, paper, cement, etc., is highly cyclical we have introduced this phenomenon into the demand equations through the use of a sine wave function. Like many other heavy industries, the petrochemical industry experiences a business cycle with an average period of 48 months. It was revealed during our interviews with the oil companies that they plan according to a business cycle amplitude of between ± 5 and ± 6 percent. Therefore for our purposes we have chosen an average amplitude of ± 5½%.

It was also suggested by the oil companies that for planning reasons for the 1990's we can also 'safely' assume a 3% general annual growth of demand for petrochemicals.

Apart from the general growth of demand for petrochemicals, it is expected that the structure of demand for plastics in Western Europe will change significantly by 1990. This has been thoroughly explored and presented in McKinsey's study (McKinsey, 1978). The table below describes the structure of demand given by McKinsey.

Table 4.1 The eight core products will continue to account for over 80% of consumption in Western Europe .....

FORECAST CONSUMPTION IN WESTERN EUROPE BY PRODUCT, 1976-90
(%)

100%

1976		1990
24	PVC	24
23	LDPE	22
10	Polystyrene	9
8	HDPE	10
6	Polypropylene	11
10	ABS/SAN, Polyurethanes Unsaturated Polyesters	10
19	Others	14

Source: McKinsey survey of industry sources

We also asked the opinion of the oil companies about this demand structure and they all agreed with McKinsey's forecast. The impact of the structural changes of demand for plastics in Western Europe has accordingly been introduced to the demand sector of the model through a modelling device called a multiplier (e.g. LDMUL). For the purposes of our study we have assumed a straight line change of demand structure through time to 1990 due to the unavailability of the individual yearly forecast of demand structure up to the end of the decade. Also since the time horizon considered for this study extends to the 1990's and the structure of demand goes only as far as 1990, we have assumed that the structure of demand for plastics in Western Europe will remain unchanged throughout the 1990's at the 1990 figures.

We are now in a position to describe some of the most important equations constructed for the demand sector based on the information and assumptions which have so far been presented in this section. The first equation concerns the formulation of the actual petrochemical demand growth factor which when multiplied by the base level of demand (in 1980) for each product, gives the product demand at any point in time:

```
(1)    A ADGF.K = EXP(RGDM*TIME.K)*(1+AMP*SIN(6.283*
       X          (TIME.K+7)/PERD))

(1-1)  N RGDM   = .03/12

(1-2)  C AMP    = .055

(1-3)  C PERD   = 48
```

Where:

ADGF = (1) Actual petrochemical demand growth factor

RGDM = (1/M) General rate of growth of demand for petrochemicals

TIME = (M) Simulated time in model

AMP = (1) Amplitude of the business cycle

PERD = (M) Period of the business cycle

The first component of the right hand side of equation (1) reflects the exponential growth, of 3% per year, of the demand for petrochemicals discussed earlier. The second component is the sine wave representing the business cycle (it was found out from the Chemical Industries Association Ltd. that the peak in the production of petrochemicals in Western Europe was reached in May 1980, hence the inclusion of TIME.K+7 in equation (1) which is an attempt to correct the cycle accordingly). Throughout the rest of the thesis wherever division by twelve occurs in an equation (as in equation (1-1) above), it reflects the conversion of the yearly value of a variable or parameter into that of a monthly value due to our unit of simulation time.

Next we shall explain the demand equation for ethylene which would also hold as an explanation for the other demand equations:

```
(2)   A  ED.K    =  LDPED.K*ETOLD+HDPED.K*ETOHD+VCMD.K*
      X             ETOVC+SD.K*ETOS+BED*ADGF.K

(2-2) C  ETOLD   =  1.03

(2-3) C  ETOHD   =  1.02

(2-4) C  ETOVC   =  .485

(2-5) C  ETOS    =  .307

(2-6) N  BED     =  AEECU*EBCAP*EY-((LDPED*ETOLD+HDPED*ETOHD)+
      X             (VCMD*ETOVC+SD*ETOS))
```

Where:

ED = (T/M) Total demand for ethylene

LDPED = (T/M) Total demand for low-density polyethylene

ETOLD = (T/T) Amount of ethylene required to produce 1 ton of low-density polyethylene

HDPED = (T/M) Total demand for high-density polyethylene

ETOHD = (T/T) Amount of ethylene required to produce 1 ton of high-density polyethylene

VCMD = (T/M) Total demand for vinyl chloride

ETOVC = (T/T) Amount of ethylene required to produce 1 ton of vinyl chloride

SD = (T/M) Total demand for styrene

ETOS = (T/T) Amount of ethylene required to produce 1 ton of styrene

BED = (T/M) Base level of non-captive demand for ethylene in 1980

ADGF = (1) Actual petrochemical demand growth factor

AEECU = (1) Average Western European effective ethylene capacity utilization in 1979

EBcap = (T/M) Effective basic product capacity including energy products capacity

EY = (1) Ethylene yield per ton of naphtha cracked

Before explaining equation (2) we would like to stress that wherever the word 'demand' is used in the definition of the variables of the model given in the listing presented in Appendix A and also in the text of this thesis, unless otherwise stated, it would mean the demand from industry, other petrochemical manufacturers and also where appropriate the downstream product divisions of our hypothetical petrochemical subsidiary for a certain product which the hypothetical petrochemical subsidiary is actively involved in the production of.

Equation (2) describes that the total demand for ethylene depends on the amount of low-density polyethylene, high-density polyethylene, vinyl chloride, styrene and ethylene demanded from the company. Table 4.2 gives the appropriate data on material usages for petrochemicals incorporated in equation (2) and also in other demand equations. This table was supplied by one of the oil companies interviewed.

Table 4.2 Data on Material Usages for Petrochemicals

No.	Feedstock	Product	Feedstock Usage te/te Product
1	Ethylene	Styrene	0.307
2	"	VCM	0.485
3	"	LDPE	1.03
4	"	HDPE	1.02
5	Styrene	Polystyrene	1.05
6	VCM	PVC	1.01
7	Propylene	Polypropylene	1.096

Source: 'Confidential' (The Petrochemical Subsidiary of a Major Oil Company)

We will now describe equation (2-6) which works out the base level of non-captive demand for ethylene in 1980, i.e. the amount of ethylene demanded from the company by industry and other petrochemical manufacturers initially in 1980.

The base level has been set at the average Western European effective ethylene capacity utilization in 1979 multiplied by the company's initial effective ethylene capacity in 1980, less the total ethylene required for the manufacture of the initial amount of low-density polyethylene, high-density polyethylene, vinyl chloride and styrene, demanded from the company in 1980. This type of formulation implies that the company retains as much ethylene as required for its downstream operations and sells the remaining part to outside processors. The formulation in fact represents the petrochemical production strategy of the majority of the oil companies which was found out during the interviews. The oil companies would like to add as much value to the barrel of naphtha as possible, hence their preferential downstream production policies which will be discussed in greater depth in a later section. Data on the average Western European effective capacity utilization in 1979 for the products under this present study was obtained from one of the major oil companies and is presented in the table below.

Table 4.3 Average Western European Effective Petrochemical Capacity Utilization in 1979

Plant	Average Western European effective capacity utilization in 1979 %
Ethylene	90
Propylene	87
Butadiene	90
Styrene	87
VCM	90
LDPE	94
HDPE	72
PVC	93
Polypropylene	70
Polystyrene	77

Source: 'Confidential' (The Petrochemical Subsidiary of a Major Oil Company)

Having explained equations (2) and (2-6), the reader should encounter no difficulty in understanding the other demand equations and their appropriate initial values.

In the demand sector of the model there is an equation (TERP) which works out the amount of ethylene required for further processing into LDPE, HDPE, Polystyrene (via styrene) and Polyvinyl chloride (via VCM), demanded by industry and petrochemical fabricators so that in the production planning sector of the model provision for preferential allocation of raw material to the company's own downstream activities can be made.

Two other equations in the demand sector need to be explained. In this sector there is an equation for the total demand for basic petrochemical products (TBD) which consists of the demand for ethylene, propylene and butadiene. However due to the yield constraints of the products of naphtha steam cracking process (selected as the only source of olefins for this present study) and the forecast change in the structure of demand for plastics in Western Europe by 1990 (particularly concerning the near doubling of polypropylene's share compared to its 1976 share), it became necessary to devise another equation (TBDY) as well as TBD in order to work out the total demand for basic petrochemical products which would take into account the yield constraints of naphtha-based ethylene crackers. This is in effect the demand for ethylene, propylene and butadiene which the company could hope to satisfy through naphtha steam cracking process only. As will be discussed in greater depth in the production planning sector, since ethylene and propylene are the major chemical products of the naphtha steam cracking process and their yields cannot be varied much, the amounts to be produced of these two products have to be in line with their yields because otherwise the company could end up with an excess amount above the demand for one of these two products for which there would be no customer and especially due to the scale of such an operation the losses could be quite substantial.

However it was found out from the companies interviewed that they attempt to satisfy the actual demands for ethylene and propylene through the cracking of natural gases, some heavy liquid petroleum feedstocks such as gas oil, and naphtha which is their main source of olefins. The ethylene and propylene yields of heavy liquid petroleum crackers can be varied within small margins according to the demand of these two products but if after variation there is still for example a shortage of ethylene, then if the demand for LPG is strong, the company might decide to run its crackers according to the demand of ethylene and sell the excess propylene thus produced as LPG (however the sale of propylene at fuel value is not generally desirable). Further, the cracking of propane and ethane produces propylene and ethylene respectively which would alleviate any tightness in the supply situation of these two products which might not be possible to meet through the cracking of heavy liquid feedstocks only. The companies also do certain exchanges among themselves in order to alleviate any short term shortages or excesses of certain products. For instance a company might be short of propylene and another company may be in a position to help and perhaps vice-versa on another occasion.

We shall now present the equation formulation for TBDY discussed earlier:

```
(3)   A TBDY.K  = CLIP(ED.K,EPRAT*PD.K,EPRAT,ED.K/PD.K)*
      x           EPBTOE

(3-1) N EPRAT   = EY/PY

(3-2) N EPBTOE  = (EY+PY+BY)/EY
```

Where:

TBDY = (T/M) Total demand for basic petrochemical products, taking into account the yield constraints of naphtha based ethylene crackers

ED = (T/M) Total demand for ethylene

EPRAT = (1) Ratio of ethylene to propylene production or capacity permitted due to their yield constraints

PD = (T/M) Total demand for propylene

EPBTOE = (1) Ratio of the total yields of ethylene, propylene and butadiene to the yield of ethylene

The CLIP function appearing on the right hand side of equation (3) is a standard DYSMAP macro function. In this case it evaluates the ratio of the ethylene demand to that of propylene's and compares it with the ratio (EPRAT) which is feasible according to the yield constraints.

If EPRAT $\geq$ ED/PD then TBDY = ED*EPBTOE

If EPRAT $<$ ED/PD then TBDY = EPRAT*PD*EPBTOE

These relationships in fact represent the adjustment process discussed earlier.

Relationship (3-2) calculates the ratio of the total yields of ethylene, propylene and butadiene to the yield of ethylene so that when multiplied appropriately, as above, by ED or EPRAT*PD would give TBDY.

Table 4.4 obtained from one of the oil companies gives the yields of ethylene and propylene, incorporated in equations 3-1 and 3-2, as well as the yields of the other products of the naphtha steam cracking process.

Table 4.4 Approximate data on typical naphtha based steam cracker yield structure

NO.	PRODUCT	YIELD % wt
1.	Ethylene	31
2.	Propylene	16
3.	Butadiene	5
4.	SC Gasoline	21
5.	Fuel Gas	25
6.	Fuel Oil	1
7.	Loss	1
	Total	100

Source: 'Confidential' (The Petrochemical Subsidiary of a Major Oil Company)

It can be observed from table 4.4 that the yield of butadiene is very small compared to the yields of ethylene and propylene and for this reason the companies run the olefin plants according to the demands of the major chemical products (i.e. ethylene and propylene) and therefore the amount of butadiene produced is not necessarily according to the market demand. For instance, Western European petrochemical industry produces more butadiene than is locally demanded and therefore exports are made to the U.S. where there is a shortage because its olefins production (unlike Western Europe which is based mainly on naphtha) is at present based mainly on natural gases which does not offer the scope of fulfilling its total home demand for butadiene. However as was mentioned in chapter 3 the United States' petrochemical industry is switching to heavy-liquid crackers due to its dwindling natural gas reserves.

For reasons mentioned above we also decided not to consider the demand for butadiene when evaluating TBDY in equation (3) discussed earlier.

4.3 Forward Planning - Necessary Capacity Forecasts Sector

In our interviews with the petrochemical subsidiaries of a number of major oil companies, they stated that the petrochemical industry, like many other heavy industries such as electricity, cement and steel, has to go through periods of high overcapacity due to the cyclic nature of the demand which together with the long construction lags of bringing plants on stream and their long lifetimes make it impossible for the industry to match its capacity to demand at all times. This undesirable phenomenon can be highlighted even more if there are any misplannings such as those of the late 1960's and early 1970's, discussed in the previous chapters, which have since 1974 placed the industry in a period of very high overcapacity expected to last well into the 1980's.

As a matter of interest we enquired whether they would consider a capacity planning policy which would take their production capacities somewhere in between the peaks and the troughs of their business cycles so as to have less overcapacity at the expense of missing part of the peaks. They replied that this sort of policy might be adequate for small to medium sized companies, operating in certain industries, fighting for their survival. However, in the petrochemical industry where very large companies operate, a producer has always to remain competitive so as to be able to respond to any potential growth in demand because otherwise others, capable of doing so will, and thereby increase their market share. In this situation the firm which has lost some of its market share would find it extremely difficult to capture it again.

They therefore stated that, accepting that the least risk from the point of view of the companies operating in this industry is to remain always competitive, then they have to plan their capacity in order to take advantage of all the peaks in demand due to the business cycle. They further mentioned that this kind of capacity build up would of course result in significant overcapacity at the troughs of the cycle but is necessary in order to enable them to match their capacity to the peaks on time.

We have therefore adopted this capacity planning policy for our research which has required the forecasting of a necessary capacity (which is not always desired) for each product over a horizon of 5 years, which is the common time horizon for the forecasting activities of the companies interviewed. This has involved the formulation of an equation (FNCGF) that forecasts the necessary petrochemical capacity growth factor, which is structurally very similar to the equation for the actual petrochemical demand growth factor (ADGF), discussed in section

4.2, except for the required time shift, the exclusion of the sine wave function which represents the business cycle (but retaining the amplitude term AMP) and the inclusion of an error and bias term, RGDMEB, which may arise when attempting to forecast the general rate of growth of demand for petrochemicals (RGDM). Due to their similarity, it is not necessary to present here the equation for FNCGF.

The equation for FNCGF together with the appropriate multipliers representing the forecast changes in the structure of demand for plastics (e.g. PPMULP) based on McKinsey's study (discussed earlier) and the base level of demand for the different products give the necessary capacity for each product in five years time. The equations for the necessary capacities are very similar to those representing the demand of the different products, described in section 4.2, therefore we shall not give their formal presentation.

4.4 Current Production Capacity Sector

The equations in the sector are very straight forward. For example:

```
(4)     L   BCAP.K    = BCAP.J+DT*(BCCR.JK-BCDR.JK)
(4-1)   N   BCAP      = 7887E3/12
(5)     A   EBCAP.K   = BCAP.K*MFCUR
(5-1)   C   MFCUR     = .8
(6)     A   EBCAPE.K  = EBCAP.K*TYEPB
(6-1)   N   TYEPB     = EY+PY+BY
(7)     R   BCDR.KL   = BCAP.K/LTPP
(7-1)   C   LTPP      = 204
```

Where:

BCAP = (T/M) Basic product capacity

BCCR = ((T/M)/M) Rate of completion of basic product capacity

BCDR = ((T/M)/M) Rate of decay of basic product capacity

EBCAP = (T/M) Effective basic product capacity including energy products capacity

MFCUR = (1) Maximum feasible capacity utilization

EBCAPE = (T/M) Effective basic product capacity excluding energy products capacity

TYEPB = (1) Total yields of ethylene, propylene and butadiene per ton of naphtha cracked

BCDR = ((T/M)/M) Rate of decay of basic product capacity

LTPP = (M) Lifetime of petrochemical plants

Equation (4) represents the basic product capacity which increases by the amount of any new capacity completed and depletes through physical wear. The initial value of basic capacity (in 1980) given by equation (4-1) and also those of the other products do not necessarily correspond to the production capacities of a particular oil company, however they do represent capacities comparable to those of the subsidiaries of the major oil companies.

Equation (5) represents the effective basic product capacity in terms of the basic capacity and the maximum feasible capacity utilization. It was mentioned in the interviews that the effective capacity of a plant is generally lower than the capacity which is designed and claimed by the construction engineers. The companies stated that it is not usually possible to reach a utilization of more than 85 - 90% even after 'debottlenecking'. Other factors also reduce utilization including breakdowns and maintenance. The age of the plant also limits utilization. In the case of a new plant, its first year loading is about 60% of the effective capacity, 2nd year 80%, 3rd year 90-100% and full utilization in the 4th year. The utilization drops towards the end of the useful life of a plant. Having considered all these factors, the companies suggested that on average, a maximum feasible capacity utilization of 80% would be realistic, which has been adopted for this study. Equation (6) simply evaluates the effective basic capacity excluding the energy products capacity. Finally, it was mentioned by the oil companies that, for Planning purposes, they depreciate their petrochemical plants physically over a life time of 17 years, using the straight line method due to its simplicity and close correspondence to the actual decay of plants. This method of depreciation is widely used by the majority of British companies (ICAEW, 1976). Hence, equation (7) was formulated. There are averaging equations in this sector which evaluate the average rate of decay of capacities, used in the planning of future capacities. The averaging time is 3 months which is also used by the companies.

4.5 Forward Planning - Capacity Requirements Sector

The oil companies plan for their future petrochemical capacity requirements over a horizon of five years. It is necessary for them to operate on such a long horizon because the construction completion times for the plants producing the chemicals are long. For example, the average Western European construction times for olefins and plastics plants are 4 and 3 years respectively which when considering the planning horizon gives the companies 1 and 2 years respectively to make their decision on the ordering of the plants. In the interviews made with the companies, we asked them why they did not operate on a planning horizon of 4 years for plastic products since this time scale would still give them a one year decision making interval equivalent to that of olefins. It was mentioned to us that they operate on a common planning horizon for all products because otherwise, due to the interdependency of products for their raw material usage, complications would have to be built into the planning process which is undesirable. Therefore to correspond with reality we have adopted the same system. The companies' planners evaluate any desired new capacity for a certain product according to its necessary future capacity (explained in section 4.3), present capacity, physical wear of the present capacity during the decision making interval and the construction completion time (i.e. the total time of which equals the planning horizon) of the plant producing such a product, and the capacity of any such product which the company might have on order and which may be completed before the end of the planning horizon. This process has correspondingly been adopted for our planning sector. As an example, we shall present below the equation formulation for the desired new ethylene capacity which would also act as the explanation for the desired new capacities of other products.

```
(8)    A  DE.K   = (NE.K-EY*EBCAP.K)/MFCUR+EY*ABCDR.K*
       X           (DMINTB+CDELBP)-EY*BCAPOR.K

(8-1)  C  EY     =  .31

(8-2)  C  MFCUR  =  .8

(8-3)  C  DMINTB =  12

(8-4)  C  CDELBP =  43.2694
```

Where:

DE = (T/M) Desired new ethylene capacity

NE = (T/M) Necessary ehtylene capacity in 5 years time

EY = (1) Ethylene yield per ton of naphtha cracked

EBCAP = (T/M) Effective basic product capacity including energy products capacity

MFCUR = (1) Maximum feasible capacity utilization

ABCDR = ((T/M)/M) Average level of decay of basic product capacity

DMINTB = (M) Decision-making interval for basic product capacity

CDELBP = (M) Construction delay in basic product capacity additions

BCAPOR = (T/M) Basic product capacity on order but not received

Note that the construction completion time of basic (i.e. olefins) capacity presented in equation (8-4) is set at a value less than the actual time (i.e. 4 years) mentioned earlier. This is due to the behaviour of DYSMAP's DELAY3 macro function used in the modelling of the construction process which will be discussed in greater depth in the capacity construction pipeline sector.

Another equation in this sector which needs our attention concerns the evaluation of the desired new basic product capacity which is based on a similar methodology to that of equation (3) discussed in the product demand sector of this chapter. As was discussed in that section, the cracking of naphtha produces a number of petrochemical and energy products. The major chemical products are ethylene and propylene, and the rest of the products are considered as by-products. These two products have certain yields and therefore when evaluating the desired new basic product capacity, one has to consider the desired new ethylene and propylene capacity and adjust them according to their yield constraints in order to decide on the size of the new cracker required. This process is modelled through the following relationship:

(9) A DC.K = CLIP(DE.K,EPRAT*DP.K,EPRAT,DE.K/DP.K)/EY

(9-1) C EY = .31

Where:

DC = (T/M) Desired new basic product capacity

EPRAT = (1) Ratio of ethylene to propylene production or capacity permitted due to their yield constraints

DP = (T/M) Desired new propylene capacity

(definition of DE and EY were given above)

The CLIP function compares EPRAT with the ratio of DE/DP and if EPRAT $\geqslant$ DE/DP then DC=DE/EY, if EPRAT $<$ DE/DP then DC=EPRAT* DP/EY. Hence the desired new basic product capacity is either the desired new ethylene capacity (DE) or the feasible new ethylene capacity (EPRAT*DP) depending on the comparison and in each case divided by the yield of ethylene (EY) in order to convert the ethylene capacity to the corresponding basic product capacity.

The planning department, having evaluated any future capacity requirements, propose them to the board of directors at the end of each year for their approval. Given the board's approval, which depends on the company's financial position and the nature of their sanctioning policies, the planners would then be in a position to decide on the execution of the projects. However, these kinds of decisions are usually made within some time interval which we shall call the 'decision-making interval'. Hence the construction of the new plants should commence within the current interval. As mentioned earlier the decision making intervals in our case are 1 and 2 years depending on the type of plant being built. These intervals are differences between the planning horizon and the construction delays.

Based on the above arguments we are now in a position to apply a simple proportional control law which gives the target rate of ordering plants. As an example we shall present the equation for the target rate of ordering basic capacity:

(8) A TROBCAP.K = DC.K/DMINTB

(8-1) C DMINTB = 12

Where:

TROBCAP = ((T/M)/M) Target rate of ordering basic product capacity

DC = (T/M) Desired new basic product capacity

DMINTB = (M) Decision-making interval for basic product capacity

Finally we should make it clear that the capital projects which are proposed to the board would have previously undergone thorough short and long term profitability tests such as DCF and also selected according to their suitability in matching the company's corporate objectives. However this part of the planning process is not within the purpose of this present research because our main interest lies in the strategic management decision making. Therefore, we shall assume that the capital expenditure proposals put forward are all worth serious consideration by the board.

4.6 Forward Planning - Spending Requirements Sector

In this sector of the model Company's spending needs are evaluated which consist of a number of items. Any gap between the working capital required to support the planned production (WCAPR) and its actual value (WCAP) should ideally be filled as soon as it arises, hence in our case at each DT. The same degree of urgency applies to alleviating any gap between the required money to be committed to new capacity addition projects (RMCNP) and its actual value (MCNP). This gap arises because of the rises in the construction costs of plants, discussed in chapter 1. Since the company is obliged to make the required payments to the constructors as scheduled, any shortfall has to be quickly dealt with. It was discovered from the companies interviewed that when they commit money to new projects, they generally include a certain amount to cover the future cost rises of the plants. However, they also mentioned that their forecasts of the cost rises do not usually match the actual rises, due to the difficulty in estimating the future inflation level, therefore adjustments become necessary. Due to the deficiencies and complications involved in this process and also since it is not the purpose of our study to analyse such a process, we decided to adopt the methodology described earlier which enables the company to adjust MCNP according to inflation, and this is sufficient for our purposes.

Finally the required rate of spending on capital projects (RRS) is simply formulated as the target rate of ordering manufacturing capacity for a particular product (e.g. TROBCAP) multiplied by the capital cost per ton of this capacity (e.g. CCC), summed for all the different capacities to be ordered. RRS is in fact the rate at which the company should be spending money now so as to be able to meet the expected demand by the end of the planning horizon. However since the planning process is continuous, RRS will be reviewed with the passage of time.

4.7 Implementation of Planning Decisions Sector

At the end of each year the board of directors of the company meet in order to make their decision on the new capital expenditure proposals put forward to them by their corporate planners. Their decision is generally based on a comparison between the required rate of spending on new capital projects (RRS) for which approval is needed, and the achievable rate of spending which the company could sustain (ARS) through its internal cash generation and financial assistance from the parent company. RRS is the result of planning discussed in section 4.6 and ARS will be defined in section 4.13. Briefly if ARS is about the same or exceeds RRS then the company is in a firm position and therefore all the proposals would be approved. However if ARS is below RRS then the company is not in a firm position and hence the proposals have to be reduced according to the shortfall. However, it was mentioned to us by the companies interviewed that the reduction is not actually exactly proportionate to the shortfall. Further stating that, defining the ratio of ARS to RRS as the financing ratio (FRAT), if for example only 50% of the money can be foreseen (i.e. FRAT=50%) then the board might actually approve 65% of the proposals. They explained that this growth orientated investment policy stems from their access to parent company's vast financial resources and the ability to raise capital in the future if necessary. This policy in fact implies that the petrochemical subsidiaries of the oil companies would actually approve more expenditure than they can afford on the assumption that they can obtain the deficit when required.

In order to represent the foregoing argument in the model, firstly the financing ratio (FRAT) was defined accordingly. Then through adapting an approach postulated by Coyle (1977) a modelling device called the financial multiplier (FPMULT) was formulated in order to give the fraction of the planned expenditure (RRS) which is actually approved by the board, depending on the financing ratio (FRAT). However, it should be stressed that such a formulation is a model rather than a statement of actual behaviour.

```
(9)      A FRAT.K    = ARS.K/(RRS.K+clip(O,1,RRS.K,.1).)
(10)     A FPMULT.K = TABHL(TFPMULT,FRAT.K,O,2,.5)
(10-1)   N FPMULT    = 1
(10-2)   T TFPMUT    = O/.65/1/1/1
```

Where:

FRAT = (1) Ratio of achievable rate of spending and required rate

ARS = ($/M) Achievable rate of spending on capacity additions

RRS = ($/M) Required rate of spending on new capital projects

FPMULT = (1) Fraction of planned expenditure actually incurred

TFPMULT = (1) Table value for financial policy multiplier FPMULT

Figure 4.1 describes the table function (10-2) graphically.

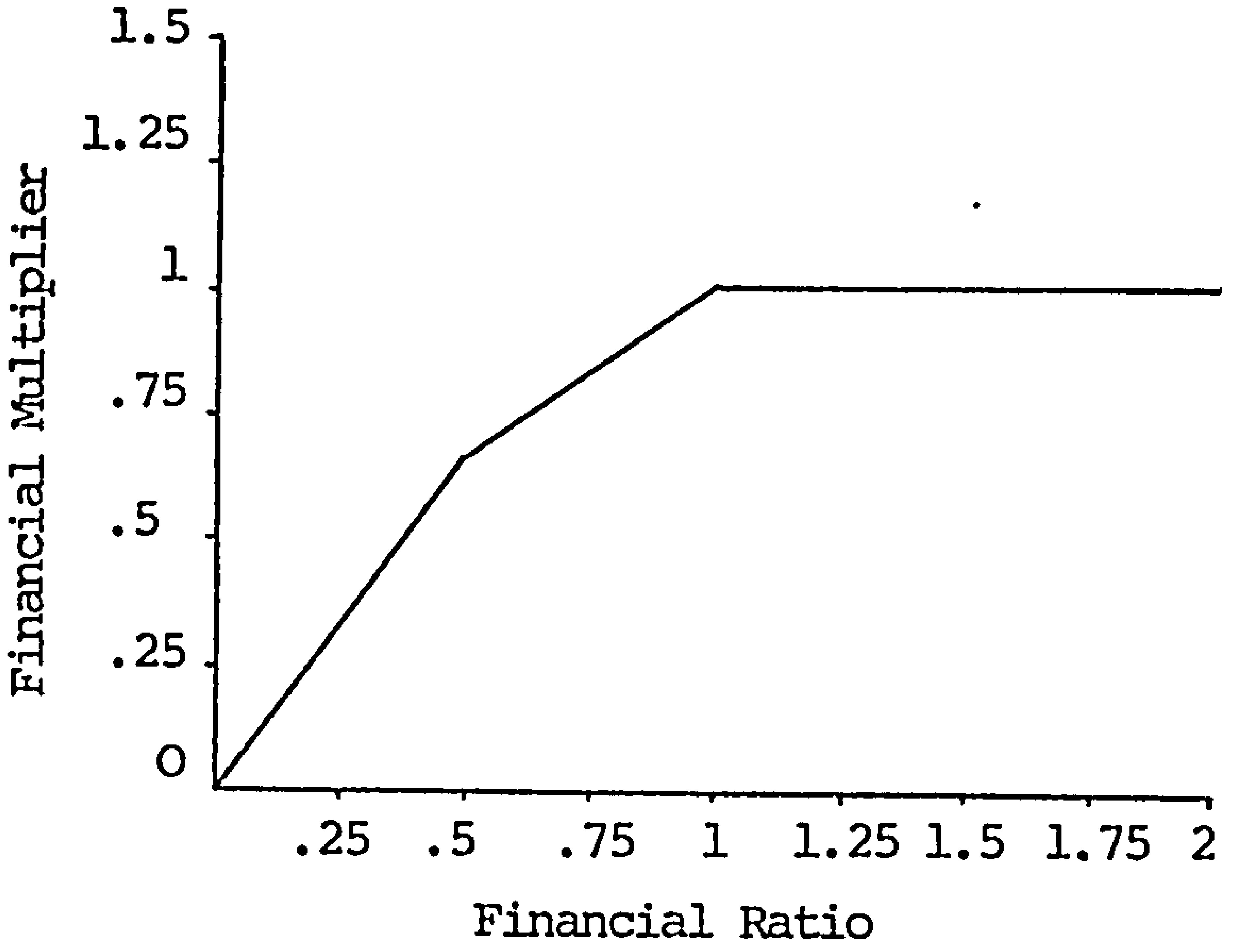


Figure 4.1 Financial Multiplier

It can be observed that the above relationship is not linear. However, it has to be stressed that the data given in the table function (10-2) which is also illustrated in figure 4.1 does not actually correspond to any particular company because the persons interviewed were not able to disclose such information and also mentioned that even if they were, it would still be very difficult to quantify the relationship accurately. Therefore the relationship presented is one possible pattern, however the important thing is that it reflects a growth orientated policy. Note that for values of FRAT higher than 1 the value of the financial multiplier (FPMULT) remains at 1, which implies that the board of directors would not approve more capital expenditure than required even if the company could afford it (this was mentioned to us during our interviews with the companies).

Besides FRAT we have also defined IFRAT which represents the subsidiary's ability to finance its capital projects through its internal cash generation. The formulation of IFRAT is basically the same as that of FRAT except for the exclusion of the financial assistance from the parent company. IFRAT is a very useful indicator of the financial performance of the subsidiary.

One other outcome of the board meeting is to decide on the need of financial assistance from the parent company. The petrochemical subsidiaries of the oil companies do not generally borrow from the money market themselves. All the borrowings for the different businesses are carried out by the parent company and are given to the subsidiary in terms of investment from the parent. However, even the major oil companies can only borrow within feasible limits, therefore they in turn have to impose limits on the amount of investments which they can allow for their subsidiaries. This phenomenon has been incorporated in the model through a relationship that works out the actual rate of the parent company's monthly investment in its petrochemical subsidiary (RIPC) which depends on the difference between the subsidiary's actual and feasible spending rates (SCDIFF) and also the parent company's maximum monthly allowable investment in its petrochemical subsidiary.

After the board meeting if the amount of capital expenditure approved is below the required level, then the planners have to carry out the detailed work of deciding which projects are to go through and which are to be shelved for the time being. Hence in the model, the availability of funds to pay for the target rate of ordering capacity (e.g. TROBCAP) could restrict the ordering decision (e.g. BCSR) through the financial policy multiplier (FPMULT).

(11) R BCSR.KL = TROBCAP.K*FPMULT.K

Where:

BCSR = ((T/M)/M) Rate of commencement of basic product capacity

TROBCAP = ((T/M)/M) Target rate of ordering basic product capacity

FPMULT = (1) Fraction of planned expenditure actually incurred

However if FPMULT = 1 then there is no restriction.

Consequently the rate of committing money to new projects (RCMTNP) has been formulated as the rate of commencement of each kind of capacity (e.g. BCSR) multiplied by its appropriate construction cost (e.g. CCC), and summed for all the different capacities.

Finally due to the importance of having sufficient working capital in order to support the company's production activities, the target rate of growth in working capital (TIWC) is wholly approved at all times, because otherwise the level of production would have to be cut and this is not generally desirable in a highly competitive industry. Therefore, working capital additions take priority over capital expenditure requirements on new plants.

4.8 Capacity Construction Pipeline Sector

In this sector we have formulated a number of relationships that represent the amount of each different product capacity which the company has under construction but not yet completed. The relationships are simply an accumulation of the difference between the rates of commencement and completion of each type of capacity. The initial values of these relationships have been evaluated by simple mathematical manipulation of certain appropriate equations. For example, in order to establish the initial value of the amount of styrene capacity on order but not yet received (SCAPOR), first of all we assume that the rate of commencement of styrene capacity (SCSR) is intially equal to its target value (TROSCAP) and also that SCAPOR would initially be equal to the initial value of SCSR multiplied by the construction delay in styrene capacity additions (CDELS). Now all that is left is to substitute in the relationships representing TROSCAP and SCAPOR their equivalents defined above so as to be able to obtain a relationship which would give the initial value of SCSR in terms of other known variables. This in turn would give the initial value of SCAPOR, i.e. SCAPOR = SCSR*CDELS.

In order to represent the construction process in the model, we have made use of DYSMAP's DELAY3 macro function which is a third order delay having a spread which approximately resembles the actual completion of the different stages of the project during its construction period (i.e. the start up, the main progress and the finishing touches). However, it has to be made clear that the construction process modelled in such a way does not correspond to the exact real life process which is generally quite complicated and not within the purpose of this present research which is concerned with the overall strategic management decision-making process. At this level we are more concerned with the overall physical and financial implications of the construction process for the company rather than the detailed work involved in the progress of the construction activities.

The following relationship gives as an example the rate of completion of styrene capacity:

(12) R SCCR.KL = DELAY3(SCSR.JK,CDELS)

(12-1) C CDELS = 31.6729

Where:

SCCR = ((T/M)/M) Rate of completion of styrene capacity

SCSR = ((T/M)/M) Rate of commencement of styrene capacity

CDELS = (M) Construction delay in styrene capacity additions

Note that the construction delay in styrene capacity additions given by relationship (12-1) is less than the actual value (i.e. 36 months). In fact all the construction completion times used within the simulated model are less than their actual values. This is due to the fact that the delay time (e.g. CDELS) incorporated in a DELAY3 macro function is not the same as the actual construction completion time. The DELAY3 macro function is designed in order to give a reasonable spread of plant completion times and in doing so the spread becomes rather large. Therefore, at the end of the delay time (e.g. CDELS) there is still a certain percentage of the capacity which is not yet complete. Coyle (1978) in Equations for Systems has investigated the behaviour of the DELAY3 macro very thoroughly and also suggests a number of remedies concerning the problem of the spread of the delay.

In our study we have accordingly reduced the delay times (e.g. CDELS) in order to make sure that any capacity ordered is completed within the actual construction completion time. The delay times are given in the appropriate sector of the model presented in Appendix A.

4.9 Prices, Amortization and Return, and Production Costs Sector

In this sector of the model we generate the prices of the different petrochemical products, under this present study, in Western Europe. These prices are at balanced supply and demand situation, therefore at any point in time according to the industry being in a position of overcapacity or undercapacity the actual prices will fall or rise above the generated prices respectively. The effect of capacity utilization on gross profit margin will be discussed in section 4.12.

In generating the equilibrium prices of the products we have made use of a table of relationships presented in UNIDO's study on the petrochemical industry (UNIDO/ICIS, 1978). This table gives information concerning the shares of the 1978 (the year the study was undertaken) prices of a number of petrochemical products expected to vary with the price of crude oil and the shares which are expected to vary with overall inflation. This information is presented in table 4.5. It can be observed that the impact of the crude oil price is less further down the stream (i.e. as we move down the table), as was also discussed in chapter 1. Conversely the impact of overall inflation increases further down the stream. This is because further processing of chemicals requires more and more manpower, utilities, plant and machinery, thereby increasing the weight of overall inflation.

We checked on the validity of this information and its applicability concerning the 1980 (the initial year of the simulation period of the model constructed for this study) prices through the interviews made with the oil companies and also enquired whether these relationships could be used for the projection of the equilibrium prices mentioned earlier. They did agree with the information and its applicability to the 1980 conditions and stated that these relationships would also apply to the equilibrium prices. Further, since the UNIDO's study does not give the relationships for vinyl chloride, high-density polyethylene, PVC and polypropylene, the companies kindly supplied us with their estimates which are included in table 4.5.

In order to project the equilibrium prices, one would also require their base levels. Therefore we asked the companies what the prices of a certain number of petrochemical and energy products would have been, if today (i.e. 1980) the supply and demand situation for these products were balanced in Western

Table 4.5 Estimated petrochemical price trends (based on current prices)

	Share of present price expected to vary with crude oil price %	Share of present price expected to vary with overall inflation %
Ethylene	50	50
Propylene	50	50
Butadiene	50	50
Benzene	50	50
Oxylene	50	50
P. Xylene	50	50
Styrene	40	60
VCM	35	65
Acrylonitrile	33	67
DMT	30	70
Ld Polyethylene	29	71
Hd Polyethylene	29	71
Polypropylene	29	71
PVC	28	72
Polystyrene	28	72

Source: UNIDO/ICIS, First World-Wide study on the Petrochemical Industry : 1975-2000, December 1978.

Europe. They replied that in a balanced situation the petrochemical industry could probably achieve a return of about 6% per year in real value. Further stating that since they work on an average Western European inflation rate of about 11% for the foreseeable future, therefore the real value of 6% would correspond to an inflated value of 17%. The companies are also allowed to depreciate the value of their plants over a period of 10 years (for more details please see section 4.13). The depreciation cashflow is a very important source of funds to the companies concerning their future capital investment programmes. Based on the above information one of the companies supplied us with the possible equilibrium prices of a number of petrochemical products presented in table 4.6.

Table 4.6 Possible Prices of a Number of Petrochemical and Energy Products if their Supply and Demand were Balanced in Western Europe in 1980

PRODUCT	PRICE $/TON
Ethylene	900
Propylene	648
Butadiene	792
Gasoline	384
LPG	360
Fuel oil	192
Vinyl Chloride Monomer	792
Styrene	1008
High-density Polyethylene	1584
Low-density Polyethylene	1512
Polyvinyl Chloride	1272
Polystyrene	1440
Polypropylene	1512

Source: 'Confidential' (The Petrochemical Subsidiary of a Major Oil Company)

Concerning the future price rises of crude oil, the companies stated that they expect the OPEC countries to increase their prices by at least the average inflation level so as to preserve their buying power. They suggested rises between 10-12%, however there was consensus on an average of 11% which corresponds to their forecast average inflation level in Western Europe.

The following relationships based on the foregoing discussion are worth noting:

```
(13)    A PE.K      = BPE*(FE*COPI.K+(ONE-FE)*OII.K)

(13-1)  C BPE       = 900

(13-2)  C FE        = .5

(13-3)  C ONE       = 1

(14)    A PPE.K     = ETOEP*(FWDV*(WDVC.K+AWCAPRB.K)+DEPPC*WDVC.K)/
        X             (EBCAP.K*EY)

(14-1)  N ETOEP     = EY/(EY+PY)

(14-2)  N FWDV      = .17/12

(14-3)  C EY        = .31

(14-4)  A CPTE.K    = PE.K+DIFF.K-PPE.K

(15)    A DIFF.K    = BY*(PB.K-MKTPB.K)/(EY+PY)

(15-1)  C BY        = .05

(16)    L COPI.K    = COPI.J+DT*(COPI.J*COPR)

(16-1)  N COPI      = 1

(16-2)  N COPR      = .11/12

(17)    L OII.K     = OII.J+DT*(OII.J*OIR)

(17-1)  N OII       = 1

(17-2)  N OIR       = .11/12
```

Where:

PE = ($/T) Price of ethylene when supply and demand are balanced

BPE = ($/T) Base price of ethylene in 1980

FE = (1) Share of ethylene price expected to vary with crude oil price

COPI = (1) Crude oil price index

ONE = (1) Number 1

OII = (1) Overall inflation index

PPE = ($/T) Part of the price of ethylene which covers the required amortization and return on investment when supply and demand are balanced

ETOEP = (1) Ratio of the yield of ehtylene to the total yields of ethylene and propylene

FWDV = (1/M) Fraction of written down value of plants to cover the required return on investment when supply and demand are balanced

WDVC = ($) Written down value of naphtha crackers

AWCAPRB = ($) Average WCAPRB

EBCAP = (T/M) Effective basic product capacity including energy products capacity

EY = (1) Ethylene yield per ton of naphtha cracked

CPTE = ($/T) Cost per ton of ethylene produced

DIFF = ($/T) Loss or gain of the sale of butadiene to be added to or subtracted from the price of ethylene and propylene

COPR = (1/M) Forecast average rate of crude oil price rises

OIR = (1/M) Forecast average rate of increase of overall inflation in Western Europe

Ethylene and propylene are the major chemical products of the naphtha steam cracking process which also yields a number of by-products including butadiene, gasoline, LPG and fuel oil. The balanced supply and demand prices of ethylene and propylene, given in table 4.6, are reached by deducting the balanced supply and demand values (i.e. prices) of the by-products of the cracking process from the total manufacturing costs, hence the rest of the costs would have to be recovered through the selling prices of ethylene and propylene. Due to this costing system the required amortization and return on investment (at balanced supply and demand) is distributed equally within the balanced prices of ethylene and propylene. Hence, relationship (14) simply evaluates this portion of ethylene's price (PPE).

Further due to the above costing system and also the crackers being run according to the demands of ethylene and propylene only (i.e. no control on the amount of by-products produced) if the supply and demand situation is not balanced for the by-products then the cost of ethylene and propylene could increase or decrease accordingly. However since it is not within the boundary of this present research to consider the variation of the prices of the energy products due to the business cycle and seasonal factors, therefore we have only considered the fluctuations of the market price of butadiene (MKTPB) about its balanced price (PB) which is equally distributed on the costs of ethylene and propylene and is defined by the relationship (15).

For working capital requirements, which will be discussed in section 4.1, it became necessary to formulate three relationships in order to generate the average prices of the energy products (neglecting the effects of business cycle and seasonal variations). It was mentioned to us by the companies that the energy products price rises are 100% related to crude oil price rises. Based on this information and the base prices of the products, given in table 4.6, the above formulations were made possible and are given in the appropriate sector of the model presented in Appendix A.

Relationships (16) and (17) simply give the crude oil and overall inflation indexes required for generating the prices of the products.

4.10 Production Planning Sector

The oil companies interviewed, all stated that their production planning policy is based on further processing, as much as is demanded and is possible, of petrochemicals which they produce and then selling the remainder to other manufacturers. Their reason for this policy is to add as much value to the barrel of naphtha as possible. Therefore we have fully taken into account this preferential downstream production planning strategy in our research.

The companies actually use very large L.P. models to schedule their production activities, however our work does not require such detailed planning because we are really concerned with the overall strategic behaviour of the sub-systems of the organization interacting together. Therefore, for this sector of the model we have formulated a number of very simple rules by which the overall production strategies of the companies will be reflected and we shall rely on the companies' planners to work out the detailed 'optimum' production plans (for instance by using L.P.).

The formulation of the relationship giving the throughput in basic product sector (BTPUT) is very similar to relationship (3) discussed in sector 4.2. The level is set according to the demands of ethylene and propylene, (making sure that no excess quantity of any of these two products is produced) and is limited by the effective capacity. Hence the capacity utilization in the basic product sector is defined as the ratio of the total throughput in this sector to the total effective basic product capacity. The capacity utilizations in the other sectors are defined in a similar manner.

In the intermediate product sector it is worth discussing, as an example, the relationship defining the vinyl chloride monomer throughput (VCTPUT):

```
(18)    A VCTPUT.K = Min(CLIP(VCMD.K,CLIP(PVCD.K*VCTOPV+(BVCMD*
        x            ETOVC/(BVCMD*ETOVC+BSD*ETOS))*(BTPUT.K*
        x            EY-TERP.K)/ETOVC, ((PVCD.K*VCTOPV*ETOVC/
        x            TERP.K)*BTPUT.K*EY)/ETOVC, BTPUT.K*EY,
        x            TERP.K), BTPUT.K*EY, ED.K-BED*ADGF.K),
        x            EVCCAP.K)

(18-1)  C VCTOPV   = 1.01

(18-2)  C ETOVC    = .485

(18-3)  C ETOS     = .307

(18-4)  C EY       = .31
```

Where:

VCTPUT = (T/M) Vinyl Chloride monomer throughput

VCMD = (T/M) Total demand for vinyl chloride

PVCD = (T/M) Total demand for polyvinyl chloride

VCTOPV = (T/T) Amount of vinyl chloride required to produce 1 ton of polyvinyl chloride

BVCMD = (T/M) Base level of non-captive demand for vinyl chloride in 1980

ETOVC = (T/T) Amount of ethylene required to produce 1 ton of vinyl chloride

BSD = (T/M) Base level of non-captive demand for styrene in 1980

ETOS = (T/T) Amount of ethylene required to produce 1 ton of styrene

BTPUT = (T/M) Throughput in basic product sector

EY = (1) Ethylene yield per ton of naphtha cracked

TERP = (T/M) Total ethylene required for further processing into plastics by the company's plastics division

ED = (T/M) Total demand for ethylene

BED = (T/M) Base level of non-captive demand for ethylene in 1980

ADGF = (1) Actual petrochemical demand growth factor

EVCCAP = (T/M) Effective vinyl chloride capacity

Equation (18) might appear complicated, however it is not and its size is purely due to the interdependencies of the petrochemical products. Basically VCTPUT depends on raw material availability, demand for vinyl chloride and the company's effective production capacity of this product. The raw materials for the production of vinyl chloride are ethylene and chlorine. Production of chlorine is not considered within this present study, hence it is considered as an exogenous factor and we shall assume that the company can always secure a sufficient quantity of this product for its vinyl chloride production. Therefore the raw material constraint becomes only that of ethylene's, hence the importance of the yield of ethylene from the throughput in basic product sector (i.e. BTPUT*EY). The demand for vinyl chloride (VCMD), bearing in mind that the company wishes to process as much of its petrochemicals further down the stream as is possible and demanded and then selling the remainder to other processors, consists of the part (that takes priority) which is needed by the company's plastics division to be converted into PVC and the part which is demanded from the company by other downstream processors.

The production of styrene is dependent on ethylene and benzene. Since benzene is also not included in this study, it is treated exogenously and the company is assumed to always be able to secure a sufficient quantity of this chemical for its styrene production. Therefore, styrene's raw material constraint becomes only that of ethylene's.

In the final product sector (i.e. polymers) we shall discuss, as an example, the evaluation of the polyvinyl chloride throughput (PVTPUT):

(19) A PVTPUT.K = MIN(MIN(VCTPUT.K/VCTOPV,PVCD.K),EPVCAP.K)

(19-1) C VCTOPV = 1.01

Where:

PVTPUT = (T/M) Polyvinyl chloride throughput

EPVCAP = (T/M) Effective polyvinyl chloride capacity
(See equation (18) for the rest of the definitions)

Again PVTPUT is limited by the three factors mentioned earlier (i.e. raw material availability, demand for polyvinyl chloride and the company's effective production capacity of this product).

As we discussed in chapter 2 the oil companies are net sellers of polymers and very few are actually involved in their fabrication. We have accordingly adopted this strategy, therefore the whole of the polymer production is sold to the outside customers.

We have incorporated a checking system (CHECKM) in this sector of the model to make sure that the throughputs of the major basic products (i.e. ethylene and propylene) equal their non-captive sales and the amounts retained for further processing by the subsidiary. Hence ensuring that there is no leakage or creation of materials within the model.

4.11 Working Capital Sector

The value of working capital employed in the business (WCAP) has been defined as the accumulation of the difference between the addition rate to working capital (ARWC) and the rate of reducing working capital if it exceeds requirements (RRWC). The initial value of WCAP, in 1980, has been set at its required level.

Working capital required to support the planned level of production (WCAPR) is the cost per ton of each product (except for the energy products and butadiene) multiplied by its planned level of throughput and also the cover of production cost required (COVER) and this is then summed for all the different products (the required cover for the sector of industry under this present study is 2 months). For energy products, their average prices are adopted and for butadiene its market price. These exceptions are due to the costing system discussed in section 4.10. If WCAP is below WCAPR then the gap has to be filled quickly, as was mentioned in section 4.5, because otherwise the planned level of production would be affected. Conversely if the ratio of the actual working capital to its required (WCRAT) level exceeds 1 and reaches a critical value (WCRCV), reductions become necessary over a certain period (TRWC). In our case the limit has been set at 1.2, with an adjustment period of 3 months, over which the excess working capital is liquidated and added to the cash reserves of the company.

4.12 Sales, Profit and Cashflow Sector

Concerning the sales of chemicals it is important to emphasize that the oil companies' strategy is to process as much of their petrochemicals further down the stream as possible and then sell the remainder to other processors. We have therefore adopted this policy when formulating the relationships which give the chemical sales of the company.

The sales equations are very simple, for example, the amount of ethylene which is sold to other petrochemical manufacturers (Esold) is whatever is left, if any, when the total ethylene requirements of the planned level of throughputs of LDPE, HDPE, VCM and styrene are deducted from the planned level of ethylene throughput (i.e. BTPUT*EY).

Having discussed the sales of the products, we shall now discuss the effect of capacity utilization on the profitability of the company. However in doing so, due to the size of the hypothetical company under this present study (representing the petrochemical subsidiary of a major oil company) and its competitiveness, we shall be assuming that the company's profitability would reflect that of the petrochemical industry's average.

During the interviews made with a number of companies, they mentioned that they do not allow sales of chemicals at prices below their direct costs even when there is very significant overcapacity in the market. They further stated that they can overlook the portion of the price covering the required depreciation charges and profits but the direct costs have to be covered in order for their businesses to at least remain operational. It was explained to us that the decline of prices according to the overcapacity situation differs for the various products of the industry. This situation is best explained by grouping the products according to the behaviour of their prices:

Group A : these are products which are not easily transportable, hence there is insignificant trade of these products internationally. Ethylene falls within this group which is generally produced in complexes including further processing plants that use ethylene as their raw material to for example produce vinyl chloride which in turn is converted into PVC. On a national scale there is movement of ethylene by pipelines but due to this logistic constraint, insignificant international trade and also the good relationship between the producers and the customers of this product established through long years of reliable contracts, the price does not fall rapidly during periods of overcapacity.

Group B : these are products which unlike group A are easily transportable (hence free competition). Therefore during periods of overcapacity due to the special subsidies protecting this type of industry in some countries, the favourable cost of raw materials in certain regions and anticipation of full utilization, large quantities of these products become available on the international market and due to the fierce competition the prices fall very rapidly. Styrene, butadiene and benzene fall within this group.

Group C : these products, which include polymers, are generally produced in complexes, for example PVC which is produced from ethylene via VCM. Again the supplier-customer relationship is very important and since the customer, through years of trade, has been satisfied with the quality of the products he has received, will be unwilling to change to another supplier whose products he will not be familiar with. Therefore in a situation of overcapacity the prices of these products drop slowly but not as slowly as those of group A.

Group D : these products, which include propylene and vinyl chloride, are of such a nature that their prices do not fall rapidly during overcapacity periods, however they do decline faster than those of group C.

To quantify the deterioration of the prices of these four product groups according to the overcapacity situation is not an easy task. However, one of the companies interviewed kindly helped us by suggesting approximate patterns of the deterioration of that portion of the price of products, which covers the required depreciation charges and profits, according to the overcapacity situation. We have expressed these patterns by a modelling device called the price multiplier whose value is dependent on the ratio of demand to capacity (not the effective capacity).

The patterns suggested to us are displayed in figure 4.2, which expresses the relationship between the price multiplier and the ratio of demand over capacity.

Curves A, B, C and D represent the price multipliers of the four product groups discussed earlier in relation to the ratio of their demands over their capacities. We have approximated each curve by three straight lines in order to simplify their inclusions within the model, however they do still reflect the general pattern of the deterioration of prices displayed by curves A, B, C and D. We should also state that these curves do by no means represent the real value of deteriorations and that they only display their possible shapes, therefore our own approximations using straight lines are adequate enough for the purposes of this present research.

The relationships given in figure 4.2 demonstrates that if

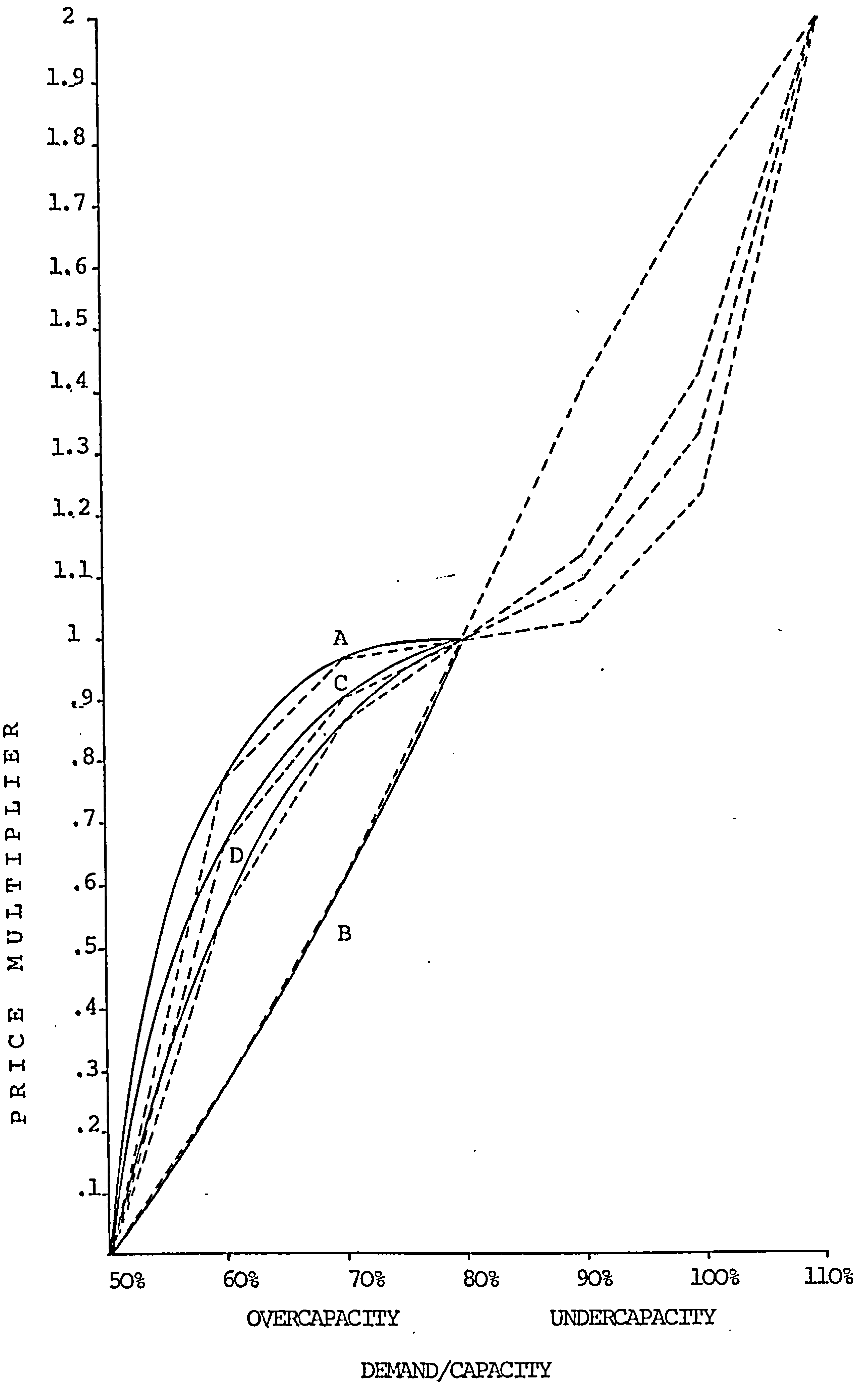


Figure 4.2 PRICE MULTIPLIER

the ratio of demand over capacity (not the effective capacity, effective capacity = .8 x capacity) for a certain product is 80% (i.e. balanced supply and demand situation) then the price multiplier is 1, however if the ratio falls to 50% then the price multiplier drops to zero. The 50% figure is by no means accurate and just serves as an estimate. The price multipliers are used to determine the gross margin on sales of the different chemicals. We shall present, as an example, the formulation of the price multiplier for ethylene (PME) and its consequent use in evaluating the gross margin on ethylene sales (GME).

```
(20)   A PME.K = TABHL(TPME,(TBDY.K*EY/TYEPB)/(BCAP.K*EY),
       X         5,1.1,.1)

(20-1) T TPME  = 0/.77/.97/1/1.03/1.23/2

(20-2) C EY    = .31

(21)   A GME.K = PPE.K*PME.K
```

Where:

PME = (1) Price multiplier for ethylene

TPME = (1) Table values of PME

TBDY = (T/M) Total demand for basic petrochemical products, taking into account the yield constraints of naphtha based ethylene crackers

TYEPB = (1) Total yields of ethylene, propylene and butadiene per ton of naphtha cracked

BCAP = (T/M) Basic product capacity

EY = (1) Ethylene yield per ton of naphtha cracked

GME = ($/T) Gross margin on ethylene sales

PPE = ($/T) Part of the price of ethylene which covers the required amortization and return on investment when supply and demand are balanced

Relationship (20) gives the appropriate price multiplier for ethylene (PME) in accordance with the ratio of the demand for ethylene (taking into account the yield constraints) to its capacity. This multiplier is in turn used in equation (21) in order to establish what the gross margin is on ethylene sales. In section 4.9 we discussed the formulation of a number of relationships that evaluate the part of the price of each product which covers the required amortization and return on investment when supply and demand are balanced (e.g. PPE). However in reality the supply and demand are rarely balanced, therefore the margin which the company can obtain on top of the direct costs through the selling price per ton of the product is not equal to its balanced value (e.g. PPE). The price multiplier (e.g. PME) reflects this imbalance between supply and demand, and hence appropriately adjusts the balanced portion of the amortization and return (e.g. PPE) in order to give the actual gross margin on sales of chemicals (e.g. GME).

Figure 4.2 also demonstrates the possible values of the price multipliers in a situation of undercapacity, which lie to the right of the 80% Demand/Capacity ratio (i.e. balanced supply and demand). The lines drawn in the undercapacity part of the graph are related to the lines in the overcapacity sector, because we have assumed that the price multipliers would increase slowly (in a situation of undercapacity) in the case of product groups A, C and D due to the importance of the supplier-customer relationships (i.e. the supplier would not raise its prices too high for its contract customers) and logistic constraints (in the case of some of these products the producer is connected to its customers through pipelines, therefore it would be difficult for the supplier to change its customers and vice-versa). Conversely, in the case of product group B which are easily transportable (and hence free competition) the price multipliers are assumed to increase very rapidly if there is a shortage on the market of such products.

Finally we should mention that the table values of the price multiplier for butadiene (TPMB) are somewhat different from the other table values. This is because during our interviews with the oil companies, they mentioned that they expect the market price of butadiene to vary about ± 20% of its balanced value, given in table 4.6 section 4.9, in the future according to the supply and demand situation. Therefore based on this information and also the pattern of behaviour presented for product group B in figure 6.2, we have formed the table values of the price multiplier for butadiene which vary between 0.8 and 1.2 according to the supply and demand, and when this is applied to the balanced price of butadiene (PB) we obtain its market price (MKTPB).

Having discussed how we arrive at gross margins on the sales of chemicals, we are now in a position to evaluate the rate of receipt of profit from production and also the company's cash resources (PR). This is simply the level of throughput of each product (e.g. BTPUT*EY) multiplied by the appropriate gross margin per ton of sales (in this case GME) summed for all the different product sales, plus the interest which the company earns on its cash reserves (CASH) and also the money which is committed to new capacity addition projects but not yet paid for (MCNP) and hence kept in the bank. The oil companies interviewed mentioned that, assuming an average

Western European inflation rate of 11% for the forseeable future, then an average interest rate of 2% higher than this level (to cover the risks) would probably result. Therefore we have adopted this value for our study. A three month exponential smooth of PR gives the average profit level (APL).

In order to evaluate how much of the profits are actually retained by the company for future investments (RP), it is necessary to know what proportion is paid in taxes and dividends. During an interview with one of the companies, it was mentioned to us that if the company is investing heavily then the portion is very small because the company offset plant allowances of 100% against tax. However if the company is not investing, then the portion could be up to 52%. Since including this criteria within the model would have meant a certain amount of complications not necessary for the purposes of this study, we have instead assumed (having consulted the companies) that on average 30% of the profits will be paid in taxes and dividends. Therefore, the retained profit is equal to 70% of the rate of receipt of profit, having deducted from it the depreciation charges (DCFL). A three month exponential smooth of RP gives the average retained profit (ARP).

4.13 Cash Generation Sector

In this sector of the model a number of very simple relationships enable us to assess the company's spending capacity:

```
(22)   A DCFL.K = MAX(0,CLIP(DEPPC*WDV.K,PR.KL,PR.KL-DEPPC*
       x          WDV.K,0))

(22-1) N DEPPC  = 1/120
```

(23) L CDCFL.K = CDCFL.J+DT*(DEPPC*WDV.J-DCFL.J)

(23-1) N CDCFL = 0

(24) A ACGR.K = ARP.K+ADCFL.K

(25) A ARS.K = (MAXIPC.K+FREXP.K)-(ARWC.K+ECP.K)

(25-1) C PHOR = 60

(26) A MAXIPC.K = MAXIPC80*OII.K

(26-1) N MAXIPC80 = 5E8/12

(27) A MINCASH.K = PC*WCAPR.K

(27-1) C PC = .3

Where:

DCFL = ($/M) Depreciation cash flow

DEPPC = (1/M) Fraction of value of plant allowable for depreciation

WDV = ($) Written down value of capital plants

PR = ($/M) Rate of receipt of profit from production and cash resources

CDCFL = ($) Cumulative depreciation cashflow unfulfilled

ACGR = ($/M) Actual cash generation rate

ARP = ($/M) Average retained profit

ADCFL = ($/M) Average depreciation cashflow

APL = ($/M) Average profit level

ARS = ($/M) Achievable rate of spending on capacity additions

MAXIPC = ($/M) Parent company's maximum monthly investment in its petrochemical subsidiary

CASH = ($) Cash reserves of company

MINCASH = ($) The level below which the company's cash reserves should not fall

ARWC = ($/M) Addition rate to working capital

ECP = ($/M) Escalation in cost of plants under construction due to inflation

MAXIPC80 = ($/M) Base level of parent company's maximum monthly investment in its petrochemical subsidiary in 1980

OII = (1) Overall inflation index

PC = (1) The proportion of the value of the working capital to be kept in cash by the company

Even though the companies depreciate the plants physically over a lifetime of 17 years, due to inflation of the capital cost of plants they are allowed to depreciate the value of the plants over 10 years (accelerated depreciation) and hence this is deducted from their profits before they are taxed. However if the profits are lower than the allowable depreciation charges, then all that the company has for its depreciation cashflow is the actual profit*. The depreciation cashflow (DCFL) is thus simply defined by equation (22). A three month exponential smooth of DCFL gives the average depreciation cashflow (ADCFL). In order to balance the books we have formulated relationship (23) which accumulates any unfulfilled depreciation charges, discussed above. Average depreciation cashflow together with the average retained profit give the actual cash generation (ACGR) of the company. As was discussed in section 4.7 the petrochemical subsidiary of an oil company has also access to the cash generation of its parent company, however according to a certain limit. Since the petrochemical industry has reached its maturity and is expected to grow in the future according to the whole economy, we have assumed that the yearly investments of the oil companies in their subsidiaries have also reached their peak. Hence we have set the criterion

---

*For a thorough analysis of this criterion please see Robert K. Jaedicke and Robert T. Sprouse, "Accounting Flows: Income and Cash", Englewood Cliffs, N.J.; Prentice-Hall Inc., 1965,pp80-86 that the parent company's maximum monthly investment in its petrochemical subsidiary would be according to its maximum level in 1980 multiplied by an overall inflation index in order to preserve the value of the investment at its 1980 value (see relationship (26)). We assumed an initial value of half a billion dollars per year which does not relate to any particular company but is probably in the region of what they can afford to give to their chemical subsidiaries. In our interviews with the companies they mentioned that it is important for them not to allow their cash reserves to fall below a certain level which is in turn related to their working capital requirements. This requirement has been formulated by relation (27) which sets the minimum cash level at 30% of the value of the required working capital.

We are now in a position to assess the company's achievable rate of spending on capacity additions (ARS) in terms of the maximum monthly financial assistance which the parent company is able to give to its subsidiary, the rate of expenditure which could be sustained through the subsidiary's internal funds, and finally the addition rate to working capital and escalation in cost of plants under construction (due to inflation) which have to be paid for no matter what, and hence take priority over spendings on new projects (see relationship (25)).

4.14 Capital Cost of Plants Sector

As was discussed in section 1.6, the installed cost (per ton) of petrochemical plants decreases as larger capacities are ordered. The drop is not linear and varies according to a power function whose exponent is 0.7 up to capacities of about 200000 tons/year and approaches 1 for capacities of more than 400000 tons/year, indicating little if any economy of scale. It was found out during our interviews with the companies that they are only interested in the larger capacities due to lower investment costs per ton of product and the spreading of overheads and semivariable costs, hence resulting in a lower manufacturing cost per ton of product, which is absolutely essential in such a competitive industry. In section 4.18 the typical plant sizes which the companies are interested in (see table 4.7) are presented. Hence in this study the capacities ordered are of these particular sizes. The capital costs, given in this sector of the model, are for 1980 conditions. However as we discussed in chapter 1 the capital costs of the petrochemical plants are expected to increase in the future according to the overall inflation. Therefore the capital costs in 1980 multiplied by the appropriate overall inflation index (OII) give the capital costs of the plants at any time in the future.

4.15 Valuation of The Company Sector

The total liabilities of the petrochemical subsidiary (TL) is simply the sum of the parent company's total investment (to date) in its petrochemical subsidiary and the subsidiaries cumulative retained profits. The parent company's total investment (IPC) is the accumulation of its past investments. The initial value (i.e. in 1980) of IPC has been chosen in such a way as to balance the books. Cumulative retained profits (CRP) is the accumulation of the profits retained in the past. Again the initial value (i.e. in 1980) of CRP has been selected so as to balance the books.

Money committed to new capacity addition projects (MCNP) is a composite of the rate of committing money to new projects (RCMTNP), escalation in cost of plants under construction due to inflation (ECP) and the rate of adding to value of petrochemical plants (RAVP).

The required money to be committed to new capacity addition projects is simply the amount of capacity which the company has on order (but not yet received) for each product multiplied by its appropriate capital cost and summed for all the different capacities.

Written down value of the plants are simply a composite of the rate of adding to value of plants and the rate of financial depreciation of plants.

Rate of adding to value of plants has been formulated as the rate of completion of capacity multiplied by the appropriate capital cost (per ton) prevailing at the time of completion (and not the cost at time of ordering).

4.16 Balance Sheet Sector

The equations formulated for this sector of the model are very simple and standard representing the accounts of the company, therefore we shall only discuss them briefly (see the listing in Appendix A for their exact forms).

The feasible rate of expenditure which could be sustained through the company's internal funds (FREXP) is the sum of the actual cash generation (ACGR) and the excess cash (if any) which could be spread and spent over the planning horizon.

The rate at which the company spends cash (RSC) is the total of the rate of committing money to new projects (RCMTNP), the addition rate to working capital (ARWC) and the escalation in cost of plants under construction due to inflation (ECP).

The cash reserves of the company (CASH) is a composite of the inflow and the outflow of money. The inflow consists of the profits retained (RP), depreciation cashflow (DCF1), rate of reducing working capital if it exceeds requirements (RRWC) and the actual rate of the parent company's monthly investment in the subsidiary (RIPC). The outflow is simply the rate at which the company spends cash (RSC). The initial value of cash (in 1980) has been set at the difference between the total liabilities of the company (TL) and total of the written down value of plants (WDV), working capital employed (WCAP) and the money committed to new capacity addition projects (MCNP).

The difference between the rate at which the subsidiary spends cash (RSC), and that which it has available (FREXP) determines whether there is any need for financial assistance from the parent company.

The total assets of the company (TA) consists of the written-down value of its capital plants (WDV), working capital employed (WCAP), money committed to new capacity addition projects (MCNP) and cash reserves of the company (CASH).

We have incorporated a checking system (CHECKF) in this sector of the model to make sure that the account books balance, that is the total assets of the company plus the cumulative depreciation cashflow unfulfilled (CDCFL) equals the total liabilities of the company.

4.17 Performance Index Sector

One of the most common performance indexes in the commercial environment is the return on investment which is simply the ratio of the average profit level of the company to its total assets. Hence in this sector we have formulated a relationship that gives the subsidiary's return on investment (ROI) which is the ratio of its average profit level after depreciation charges (i.e. APL-ADCFL) to its total assets (TA).

4.18 Amendments Necessary to the Basic Model to Assess the Capacity Build up Process, Under the Effects of the Economic Size Constraints, if Joint Ventures were not to be Formed

As was discussed in chapter 1, the running of reasonably large plants is essential in this internationally competitive industry in order to produce the products as cheaply as possible. Concerning the basic model constructed for this study, whose sixteen sectors were discussed in this chapter, it is assumed that if the desired new capacity of a product is less than the economic size of such a capacity then the company would form a joint venture with other companies in the same situation so as to take advantage of the economies of scale (the reason and justification for this assumption is discussed in detail in chapter 5). Table 4.7, obtained from confidential oil company sources, presents the typical plant sizes which they are interested in, together with their appropriate capital costs. However it must be made clear that these economic sizes are from the point of view of the oil companies, therefore for other concerns they might be different.

In order to assess the capacity build up process (under the effects of the economic size constraints) if joint ventures were not to be formed, three sectors of the basic model were amended accordingly. The sectors are 4.5, 4.7 and 4.8 which are given in appendix B. The changes made to sectors 4.5 and 4.7 basically concern the target rate of ordering capacity (e.g. TROBCAP) and the rate of commencement of capacity (e.g. BCSR), upon which the economic size constraints are imposed. Further, these two rates are kept constant (during every twelve months period) at levels determined as a result of the company's yearly board meeting, for reasons of consistency in the ordering process. These changes were facilitated through the use of DYSMAP's SAMPLE and INT functions.

Finally in section 4.8 the initial values of the amount of each different type of capacity under construction have been set at levels which are in multiples of the appropriate economic sizes. The simulated result of the amended version is discussed in chapter 5.

Table 4.7 Approximate Data on Battery Limits Plant Costs*

(1980 Index Construction Values)

NO.	PLANT	TYPICAL PLANT SIZE '000 te/a	APPROXIMATE BLP COST per te Product $/te capacity
1	Steam Cracker (Naphtha)	450	640
2	Styrene Monomer	300	230
3	VCM	300	330
4	LDPE	100	500
5	HDPE	100	500
6	PVC	120	380
7	Polypropylene	100	830
8	Polystyrene	100	400

* i.e. Excluding offsites, utilities plant etc.

Source: 'Confidential' (The Petrochemical Subsidiary of a Major Oil Company)

CHAPTER 5

VALIDITY OF THE BASIC MODEL

Having built the model the next step, prior to making any further analysis, is to establish whether or not the model is valid. However this is not an easy task, especially since there is no general agreement among management scientists on a set of criteria which could be used to test the validity of a model. The managers of the industry, on the other hand, have a more pragmatic type of approach towards the issues concerning the credibility of such a model. The manager's concern is to observe whether the model is well structured, embodies all the important factors (from his point of view because after all it is he who is supposed to know most about the system) and finally, useful in fulfilling its purposes.

In the field of System Dynamics, Forrester (1961) and Coyle (1977) have acknowledged the complexities surrounding the issue of credibility of models and have therefore, based on the pragmatic managerial approach, common sense and scientific methods, put forward a set of guidelines to assess the validity of a model. Coyle refers to model validation as meaning the "process by which we establish sufficient confidence in a model to be prepared to use it for some particular purpose".

The guide lines put forward are as follows:

(i) Does the model relate to questions and behaviour that are of importance to the success of the organization?

(ii) Is the system boundary right?

(iii) Does the model contain an effective choice of variables, properly related according to those of real life?

(iv) Are the parameter values correct?

(v) Does the model contain any gross technical errors?

(vi) Does the model generate behaviour characteristics similar to those of the real system?

These guide lines put forward by the authors mentioned above seem adequate to serve as tests for establishing the validity of the model constructed for the purposes of this present research. Therefore, in the following paragraphs we shall discuss how our model compares in relation to the above requirements, and hence its validity.

(i) During our interviews with the oil companies, they repeatedly stated that their main problems during the 1970's have been the increasing material prices coupled with overcapacity (since 1974) and the resulting deterioration of the prices of petrochemicals which in turn affects their profitability, and thus their corporate strategies towards the chemical business. They also mentioned that they expect the overcapacity situation to continue well into the 1980's. In this present research we are addressing these very same problems, which we discussed in great depth in chapters one and three, that are of great importance to the future performance of the companies. We also discussed, in chapter 3, a number of very important questions related to the purpose of the research. In the next chapter we shall employ the model to provide answers to these questions. Thus we can safely state that the first requirement has been fulfilled.

(ii) In chapter 3 we carefully selected the boundaries of the system in relation to the objectives of this present work. In doing so we only included those factors which are believed to be of significant importance in determining the dynamic behaviour of the system and enabling us to answer the questions drawn from the purpose of the research. For example, in chapter four it was explained that since our concern is with corporate planning issues we did not think that it was necessary to employ an L.P. model to handle the production planning sector of the research which would have involved great detail and effort, not required for our purposes. However it should be made clear that we are by no means implying that there are inadequacies in L.P. as a modelling technique. Indeed it is widely used in this industry for scheduling the detailed production activities but for our purposes we do not need a very detailed and sophisticated manufacturing planning sector, particularly since the dynamics involved would be too short for the time scale chosen for this study.

(iii) In chapter 4 we discussed in detail the formulation of most of the relationships incorporated in the model presented in appendix A. Some of these relationships are standard physical and accounting relationships. A large number of them are based on our findings during the interviews made with a number of companies, during which we also checked on the reality of the other relationships. For example, the central decision-making process for the approval of the yearly capital expenditure proposals, the preferential downstream production planning policy and the different patterns of the deterioration of the prices of the petrochemical products according to the overcapacity situation were discovered during the interviews and included in the model. In the cases where relationships were difficult to quantify (such as the deterioration of the prices mentioned above) and only rough estimates were supplied to us, we tested the model (see chapter 6) with a reasonable range of values for these relationships in order to detect any significant change in the dynamic behaviour of the system. Based on the judgment and skill of the executives of the companies interviewed, whose co-operation has been invaluable concerning the formulation of the relationships, and our safeguards against areas of less certainty, we believe that the mechanisms of the model could closely resemble those of the real system.

(iv) Most of the parameter values of the model were obtained from confidential company sources and also from published sources after thorough research. System Dynamics models are not generally very sensitive to the values of most of their parameters and they may be selected anywhere within a plausible range. The few sensitive parameters will be identified through the appropriate model testings (see chapter 6).

(v) We have carried out a series of tests in order to make sure that the model does not contain any errors:

(a) The model has been tested by DYSMAP's Dimensional Analyser in order to make sure that the resultant dimension of the right hand side of each relationship is the same as that of its left hand side.

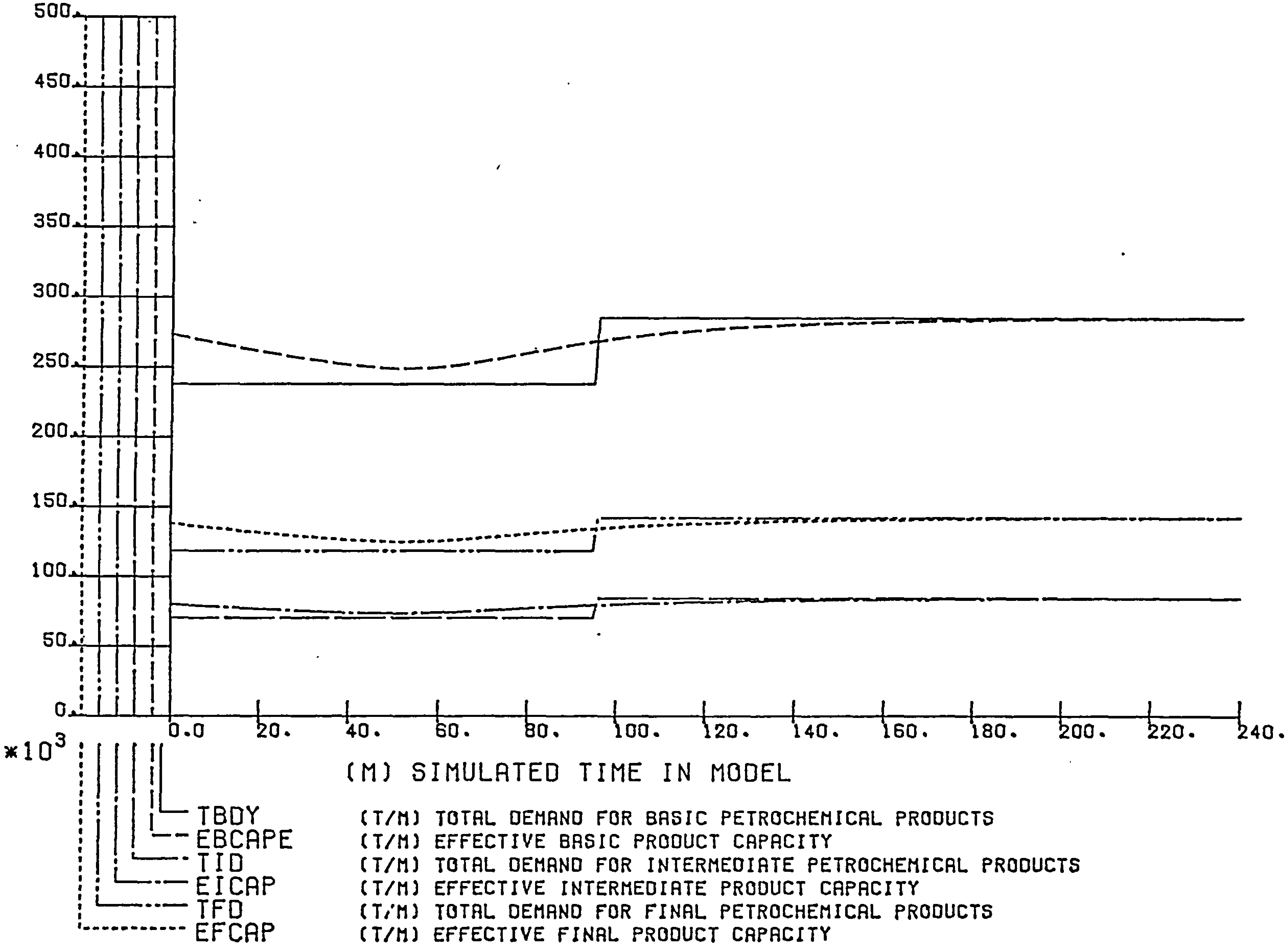
(b) The outputs of the simulation runs of the model have been thoroughly checked in order to make sure that the values of the variables are within realistic ranges.

(c) In order to comply with the Balance Sheet rule that the total assets of the company should equal its total liabilities we have accordingly devised a checking system (CHECKF) in the model which computes the difference between the two, so as to make sure that the model does not leak or create any money. The value of CHECKF was found to be negligible throughout the simulation which in effect confirms that the accounting equations of the model are correct. There is also another check, CHECKM, in order to make sure that the model does not leak or create any petrochemical material, which in turn confirms the correctness of the production equations of the model.

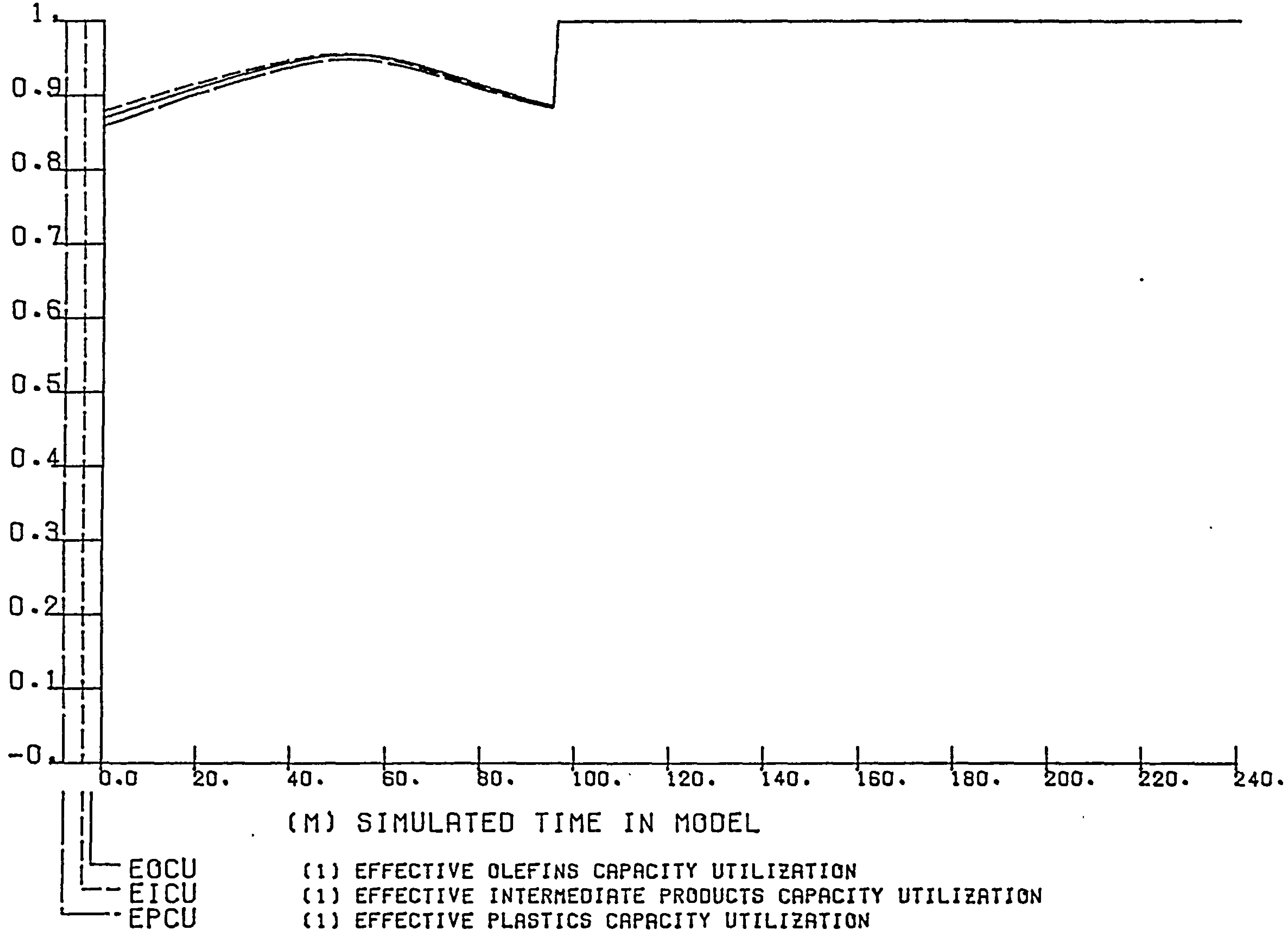
(d) In order to make sure that the model does not produce any false dynamics particularly with respect to improper initial conditions, it was subjected to a standard STEP input. This involved the running of the model under constant demand for products for the first 96 months and then a sudden 20% STEP increase in the demand of products. The model forecasts the increase in demands 60 months in advance. Therefore the model would be free of any false dynamics if its state variables demonstrate steady behaviour (except those which are not expected to do so) during the first 36 months. Figure 5.1 (a, b and c) demonstrates this test and confirms the non-existence of false dynamics.

(vi) Finally concerning the question of whether or not the model generates behaviour characteristics similar to those of the real system, this can be generally approached through qualitative and/or quantitative comparisons between the simulated and the real performances of the organization. However since in our research we are not modelling any specific company it is not possible to perform any detailed statistical fit test. Even in the case when the analyst is modelling a particular organization and has access to the company's confidential data, it is still extremely difficult to do so because the information systems are not generally sufficiently comprehensive, do not go back in time far enough and do not indicate all the policies and the changes made to them through time, and many other practical obstacles.

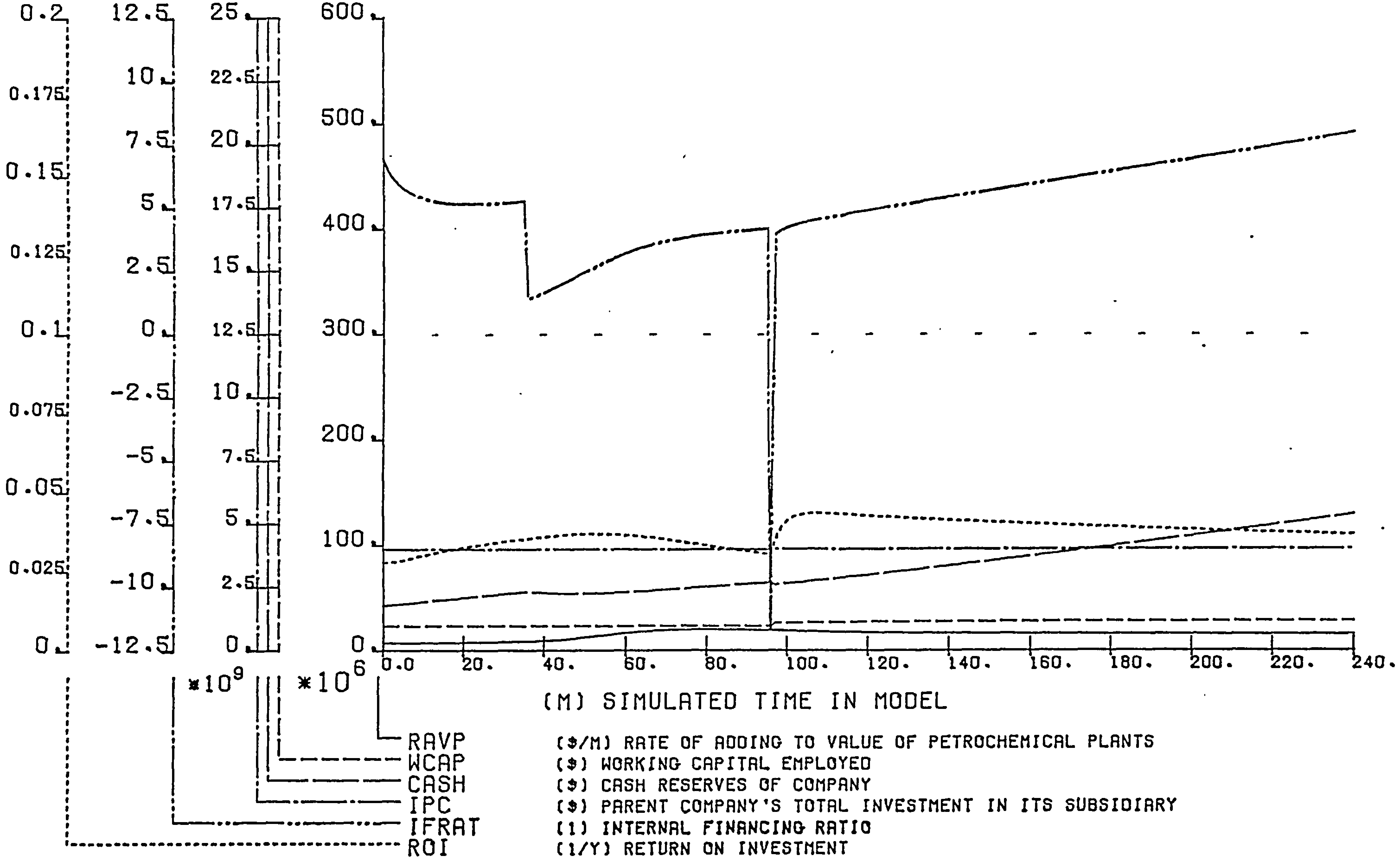
Further since our aim is to explore the appropriate corporate strategies to be pursued by the company during the 1980's and the 1990's, we would gain very little by spending a great deal of effort in getting the model to reproduce the past performance of the company.



a) FIG 5.1 BASIC MODEL WITH 'STEP' TEST
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY



b) FIG 5.1 BASIC MODEL WITH 'STEP' TEST
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY



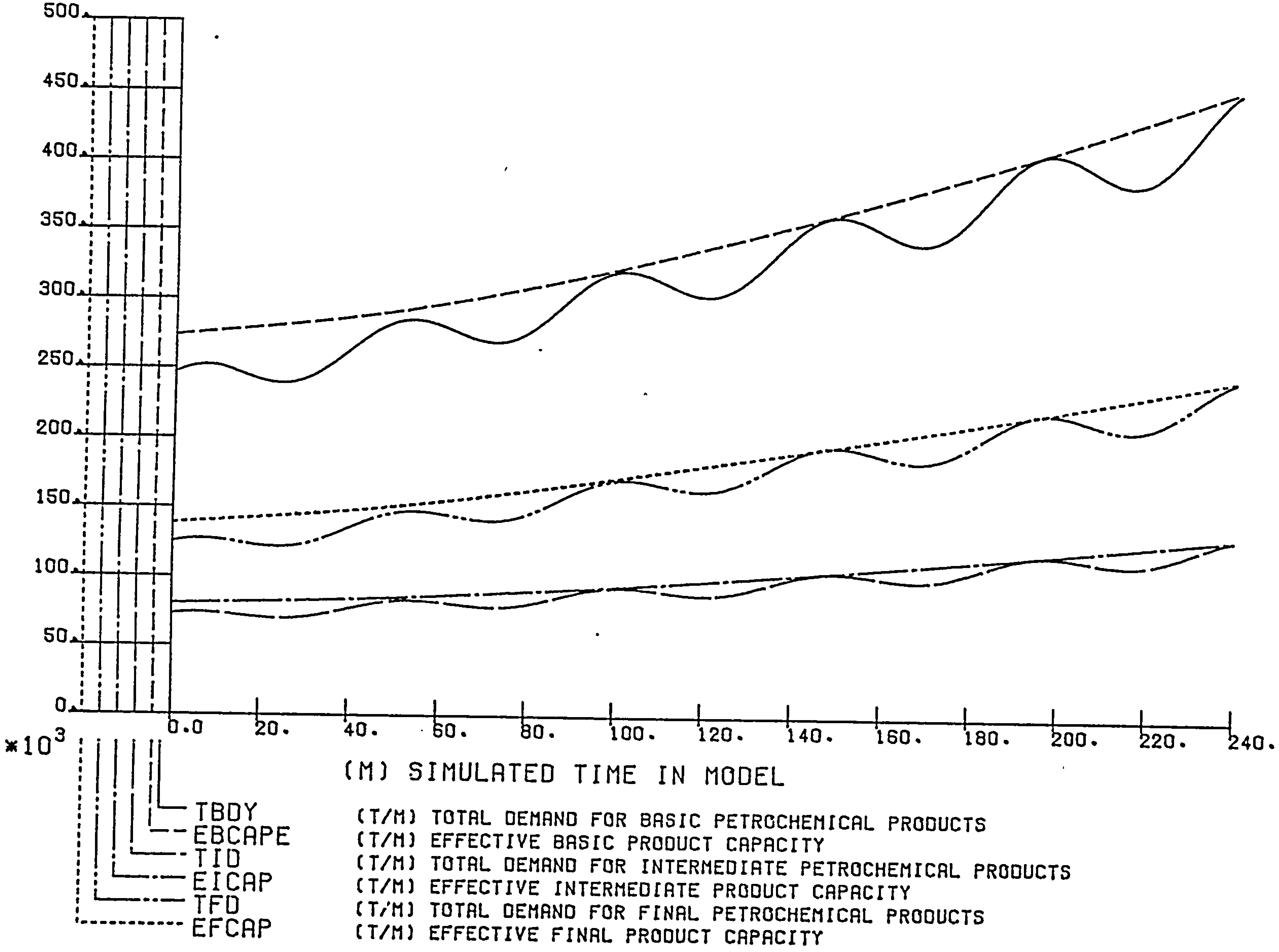
c) FIG 5.1 BASIC MODEL WITH 'STEP' TEST
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

However, having said this, it is important to know as much about the past history of the organization as possible in order to be able to design its appropriate future strategies. Therefore it can be concluded that in our case quantitative comparisons of behaviour are neither possible nor appropriate and hence we will spend our effort in establishing whether or not the simulated behaviour corresponds qualitatively with that expected from the real system. Forrester and Coyle argue that if the model contains all the necessary components adequately described and properly interconnected, and has captured the causes of the actual system's difficulties, then the model cannot do other than produce the same basic characteristics and trouble symptoms as the actual system. Forrester further argues that "once the general qualitative nature of a particular phenomenon is present in a model and approximately correct, it can usually be adjusted to any desired value by changing system parameters without moving these parameters outside the range compatible with our knowledge of their values in the actual system". However both authors acknowledge that a perfect fit of the model to the actual system does not really help in designing a better system. The above arguments put forward by the two authors encourages us even more in adopting the qualitative approach for comparing the simulated and expected future behaviour of the system under this present study.

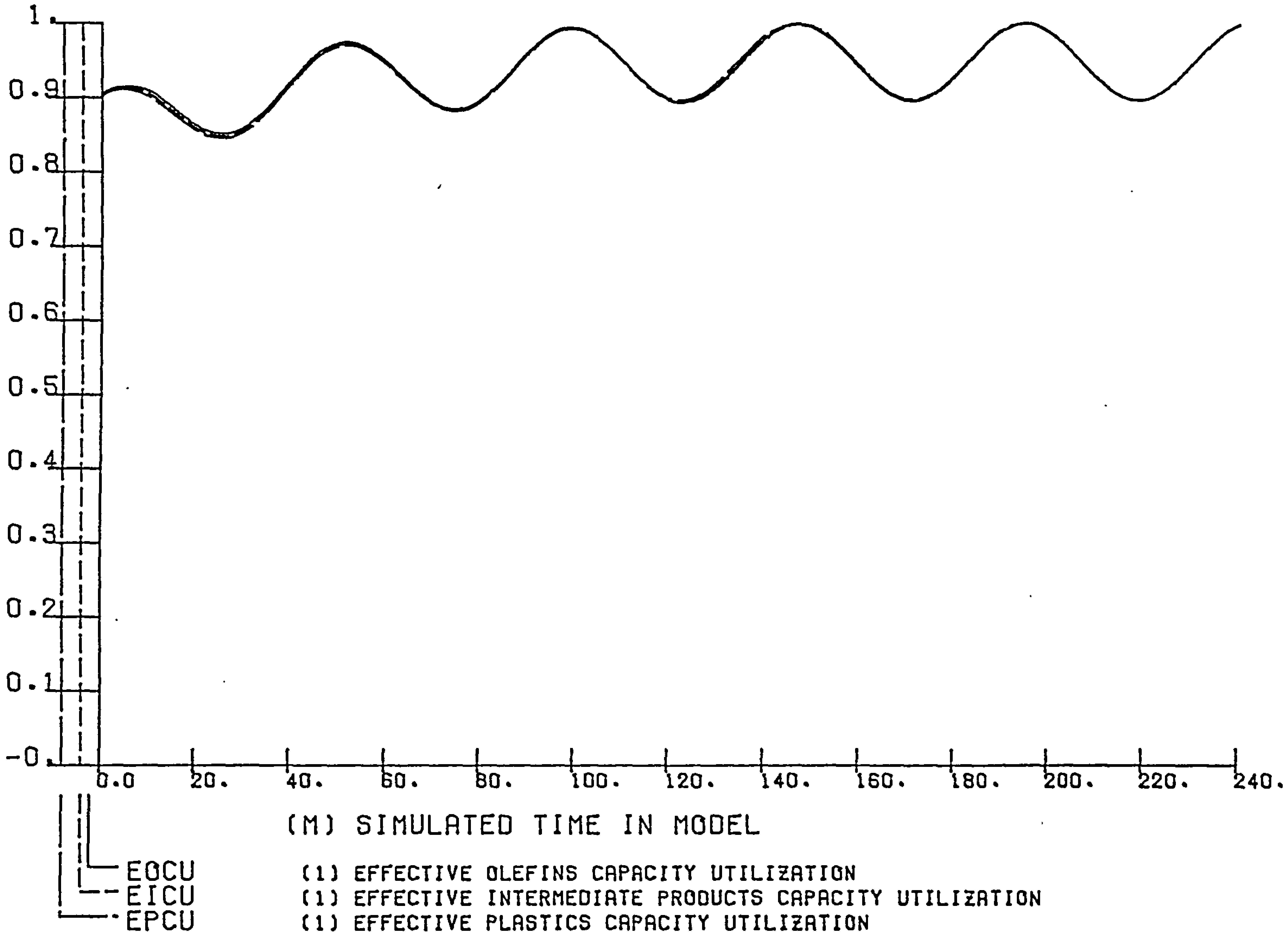
Examining figures 5.2 (a, b and c) it can be observed that the model indeed demonstrates behaviour mode which is qualitatively similar to that expected from the real system. (The horizontal axis of the figures corresponds to that of time which is in terms of months. Months zero and 240 correspond respectively to January 1980 and January 2000).

The basic, intermediate and final product capacity build ups enable the petrochemical subsidiary to take advantage of all the peaks in demand which, as was discussed in chapter 4, is the objective of the companies. As can be observed the company initially (i.e. in 1980) has significant excess capacity in all three product sectors, corresponding to the average overcapacity in Western European petrochemical industry given in section 4.2, which take nearly 10 years to be absorbed into the system hence resulting in a balance between the actual and the necessary capacity. This time span is known as the settling time of the system. It is useful for managers to be aware of its magnitude in order to appreciate the long term effects of their decisions and changed circumstances.

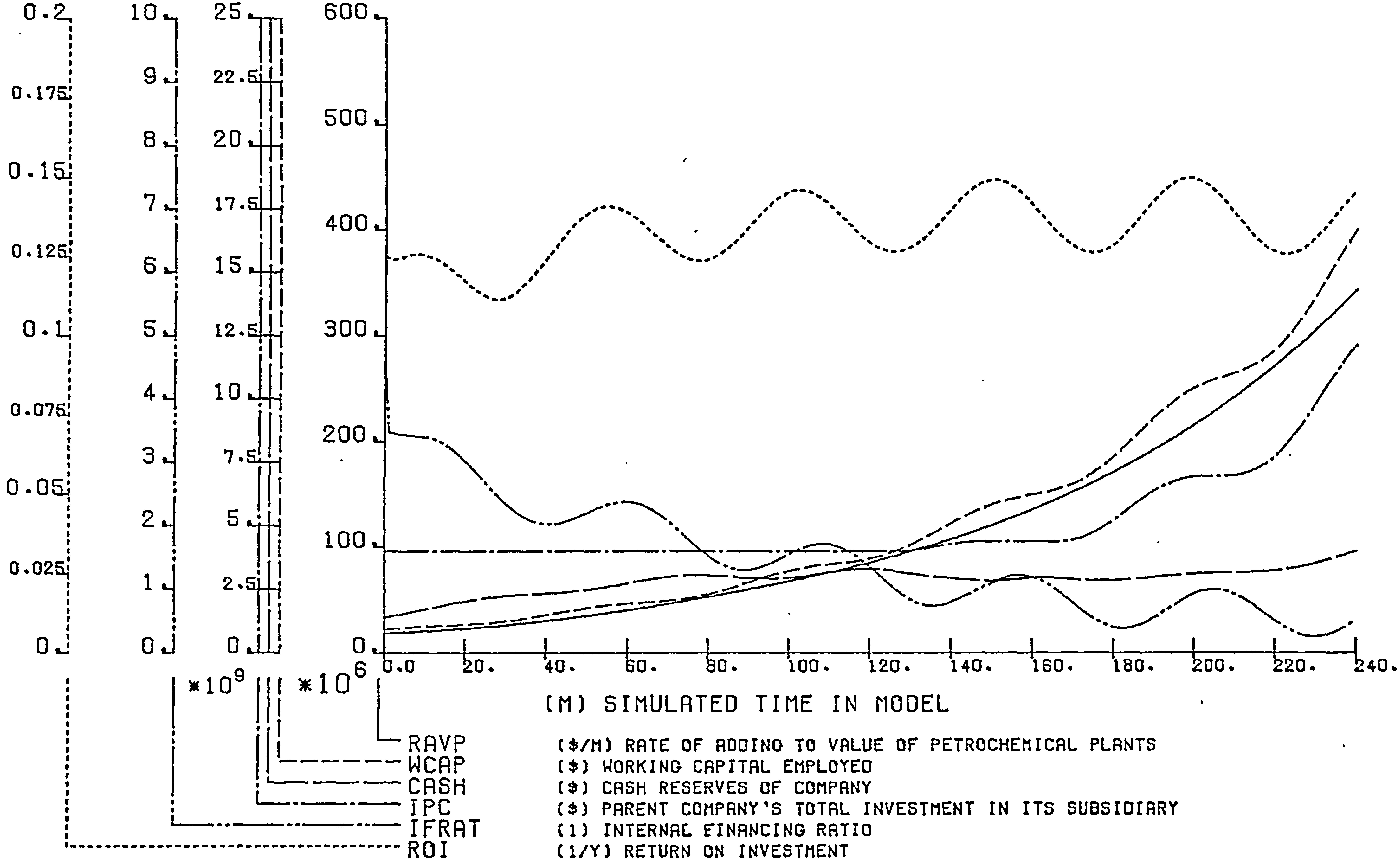
The effective capacity utilization, after initial low levels, settles at a sustained oscillatory mode fluctuating between 90-100%, according to the position of the 4-year business cycle. The excess capacity during the troughs of the cycle is very undesirable, since it leads to the erosion of the prices and hence the profitability of the industry. However it cannot be helped, due to the impracticalities of significant stockpiling for long periods. If stocking was feasible then the producers could have maintained a lower level of capacity than in our case and would still have been



a) FIG 5.2 BASIC MODEL
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY



b) FIG 5.2 BASIC MODEL
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY



c) FIG 5.2 BASIC MODEL
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

able to meet the peaks in demand through stockpiling during the troughs of the cycle which would have in turn resulted in high utilization of plants at all times. We believe that the capacity acquisition process designed for this study is probably the most adequate as it leads to minimum overcapacity during the troughs of the cycle, given the constraints concerning the objective of the company, the long construction duration of the plants and the impracticalities of massive stock holding. However as will be demonstrated in chapter 6, the process is sensitive to errors in demand forecasts.

Concerning the financial performance of the company, it can be observed that the ability of the petrochemical subsidiary to finance its capital projects (i.e. Internal Financing Ratio (IFRAT)) declines through time even with ample initial cash reserves. Consequently in the latter half of the 1990's the subsidiary becomes heavily dependent on financial assistance from the parent company which is both alarming and undesirable concerning the long term viability of such a business. In order to assess the financial situation of the company more thoroughly we have extracted values from the tabular output and for the sake of brevity we use the initial and final values of the selected variables as in table 5.1.

The decline in IFRAT, from 4.62 in 1980 to 0.25 by the year 2000, is basically due to two factors. Firstly, the growth in demand during the time horizon considered which leads to significant growth in the effective basic, intermediate and final product capacities (67.3%, 64.7% and 78.1% respectively) involving massive investments, and the financing of working capital increases required to sustain growth in production. Secondly the rises in overall inflation and

Table 5.1 Summary of the Performance of the Basic Model

		Time	
		0 ($x9)	240 ($x9)
Balance Sheet Items			
Investment by Parent Company	IPC	4	9.576
Cumulative Retained Profits	CRP	2	35.156
Total Liabilities	TL	6	44.732
Cash	CASH	1.386	3.513
Working Capital	WCAP	.919	13.873
Written-down Value of Plants	WDV	2.995	15.557
Money Committed to New Projects	MCNP	.7	11.789
Total Assets	TA	6	44.732
Other Variables			
Cumulative Pretax Gross Profits	CPGP	0	66.18
Cumulative Actual Cash Generation	CACG	0	43.656
Cumulative Required Spending on Capital Projects	CRS	0	26.758
Cumulative Escalation in Cost of Plants	CECP	0	8.566
Internal Financing Ratio	IFRAT(1)	4.62	0.25
Changes			
Growth in TL less increase in IPC			33.156

the price of oil. The overall inflation is directly responsible for the escalation in cost of plants which in our case places an enormous burden on the company as can be observed from the growth in the values of WDV, MCNP and CECP given in table 5.1. The crude oil price rises also necessitate huge increases (from $0.919 billion in 1980 to $13.873 billion by the year 2000) in the value of the working capital employed (WCAP).

It can be observed from table 5.1 that the company indeed generates large amounts of cash, as demonstrated by the growth of total liabilities less increase in investment by the parent company. However, due to the increasing demand (and hence the increasing capacity requirements) and inflation, the subsidiary would have to obtain financial assistance from the parent company from the second half of the 1990's onwards which by the year 2000 reaches a total of $5.576 billion. In the next chapter we shall attempt to analyse the financial problems more thoroughly through careful investigation and simulation experiments.

The behaviour mode discussed above was that of the Basic Model, in which it has been assumed that if the desired new capacity of a product is less than the economic size of such a capacity then the company would form a joint venture with other companies in the same situation, so as to take advantage of the economies of scale.

In order to observe, in particular, the pattern of capacity build up (under economic size constraints) in a scenario in which joint ventures would not be formed, the model was modified accordingly (details of which were discussed in section 4.18). Figure 5.3 demonstrates the simulated behaviour in such a case.

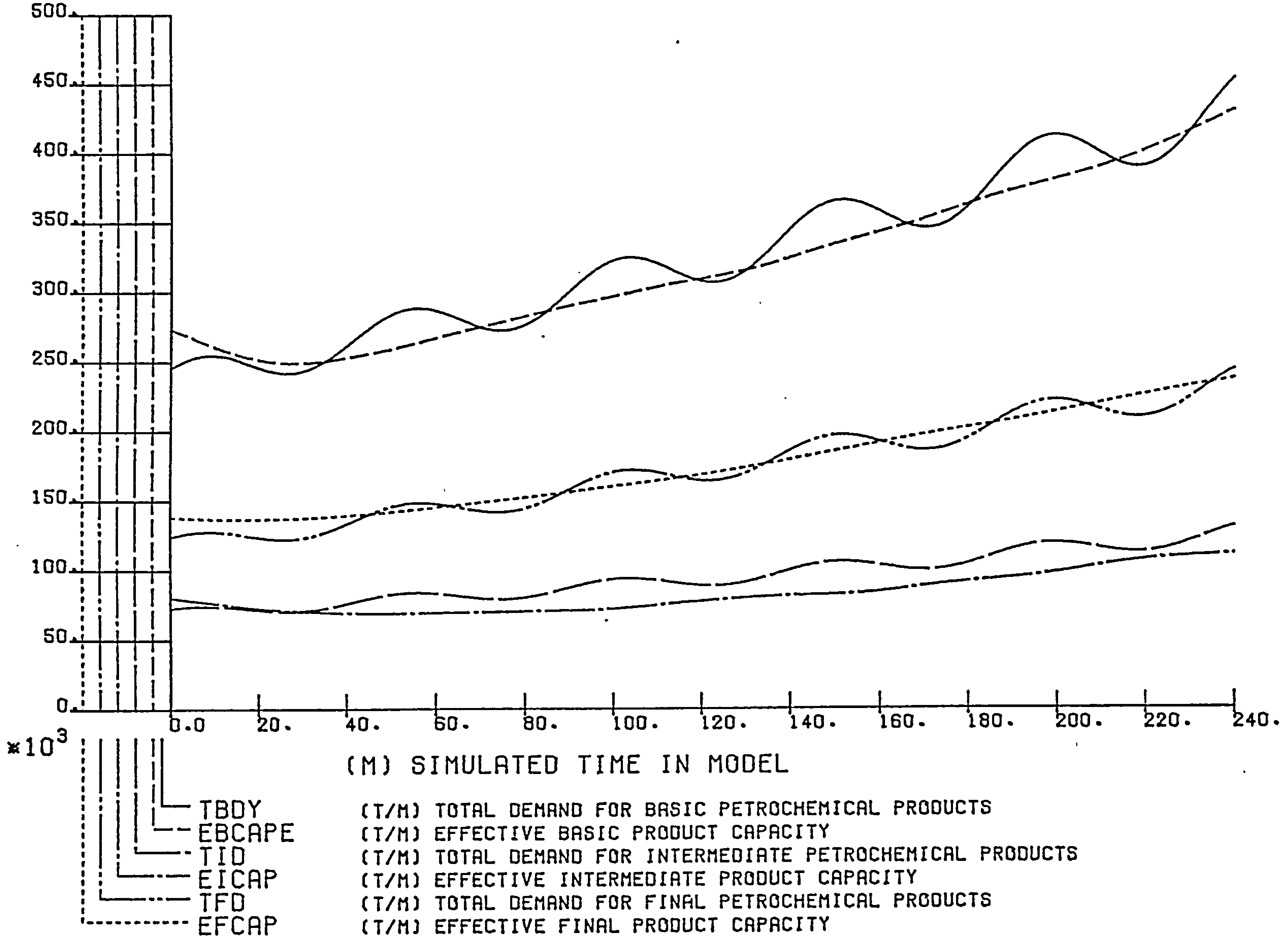


FIG 5.3 EFFECT OF ECONOMIC PLANT SIZE CONSTRAINT
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

As can be observed, after the initial years during which the overcapacity is absorbed, the capacity planning process is no longer capable of enabling the company to take advantage of the peaks in demand. In fact, in the case of the intermediate products (i.e. Styrene and VCM), the production capacity falls even below the troughs of the business cycle, due to the large economic sizes of the plants producing these products. This pattern of capacity build up proved to be undesirable when discussed during our interviews with the companies, since it did not achieve their aim. However this deficiency is purely due to the imposition of the economic size constraints when ordering new capacity, since in the Base Case (discussed earlier) the company could meet all the peaks in demand. There are two ways of alleviating the shortfall in capacity. Firstly, to order a plant of minimum economic size when only a part of its capacity is required, however this strategy would threaten other manufacturers' market shares. It was mentioned to us in our contacts with the companies that during recent years they have built up a mutual understanding among themselves not to resort to such a strategy which would lead to overexpansion by all manufacturers in order to preserve their market shares and result in overcapacity and the deterioration of prices.

The second option which is feasible and open to a company is to go into joint venture with other companies in the same situation. As was discussed in chapter 2, in recent years a large number of joint ventures have been formed between the oil and chemical companies and also among oil companies themselves. Among the reasons given for these joint ventures are the chemical companies' desire to secure feedstock supply through oil company partners, and the huge capital costs of the petrochemical plants. It is our belief that the low level of growth in demand compared to the past, coupled with the large economic sizes of the petrochemical plants together with the mutual understanding among the companies in keeping to their own market shares will force them to go into joint ventures in the future. Of course the other reasons mentioned earlier would make the joint ventures even more attractive; however the factors mentioned above will be the dominating ones. In the case of a chemical company wishing to increase its basic product capacity (i.e. Olefins) there will most probably be the need for an oil company partner, rather than a chemical company due to the co-production of a large quantity of energy products for which only an oil company has the required marketing logistics.

The need for joint ventures due to the market share consensus among the companies is well reflected by the Shell-Esso cracker project at Moss Morran approved by the U.K. government in 1979 (European Chemical News, 1979). As was discussed in chapter 3, McKinsey had predicted that the U.K. will require new petrochemical capacity a few years before the rest of the EEC, hence the approval of Moss Morran. However the important factor concerning the above joint venture is that, the major oil companies have very large cash generations, for example in 1980 Shell and BP declared profits in terms of billions of dollars. Therefore they do have the ability of financing a whole petrochemical plant on their own, and there is really no other factor to stop them doing so other than the mutual market agreement among themselves.

In our interviews with the companies, we discussed the above findings and they did mention that they could be true, however they were generally unwilling to comment any further on the matter. We believe that their unwillingness was because the market share consensus and the consequent joint ventures would in effect imply a 'Cartel' among the companies.

In the next chapter all our experiments will be on the base case, in which it has been assumed that the petrochemical subsidiary will go into joint ventures with other companies if its capacity requirement for any of the products under this present research is less than the economic size.

CHAPTER 6

MODEL ANALYSIS

6.1 Analysis of the Company's Financial Problems

In chapter 5 we concluded that the decline in the financial ability of the subsidiary was due to the growth in demand (and hence the growing investment requirements) and inflation. Ideally a company as such, in a mature industry should, under the right economic climate be capable of generating enough cash so as to finance internally its capital projects. However this is not so in our case. In order to substantiate our conclusion about the impact of growth and inflation on the financial performance of the system, we shall in this section employ the model to explore the effect of each of these two factors.

As an initial experiment it would be interesting to see how the system would perform if there was to be no growth in demand and no inflationary measures. However, we have already conducted an experiment in chapter 5 which can also equally serve for this purpose (see figure 5.1 (a, b and c)). In that experiment, in order to make sure that the model did not produce any false dynamics, it was run under constant demand for the first 96 months and then a sudden 20% STEP increase in the demand of products was injected and from there onwards the demand was maintained at this level. This run also did not include any inflationary measures (i.e. OIR = 0, COPR = 0, IR = .02/12, DEPPC = 1/LTPP (i.e. financial depreciation of the value of plant according to its physical lifetime (i.e. LTPP) and not the accelerated depreciation), FWDV = .06/12). It can be observed from figures 5.1 (a, b and c) that under constant demand RAVP, WCAP and IPC remain constant, as we would expect. The cash reserves (CASH) grow very rapidly due to the retained earnings and consequently so does the financial ability of the company (IFRAT). Note that the value of IFRAT goes negative for a short while at time 96 due to the heavy required increase in the value of WCAP triggered by the STEP increase in demand. The ROI falls continuously, due to the continuous increase in liquid assets (i.e. CASH) which earn a low return in the bank, compared to that earned on physical assets (i.e. on WDV and WCAP). Our conclusion from this experiment is that, with no growth and no inflation, the company would indeed become more and more wealthy and would have no problem other than finding a more profitable way of utilizing its vast liquid assets kept in the bank.

In the next scenario we considered the possibility of constant demand but with an imposed business cycle, and an inflation level the same as that of the base case. As can be observed from figure 6.1 RAVP and WCAP grow steadily due to inflation. The cash reserves grow very rapidly mainly due to the healthy profit level. The value of IFRAT declines somewhat, due to the increasing investment requirements, stemming from the high inflation level (i.e. 11% annually). However even at the end of the simulation period its value is at a very comfortable level indeed. Due to the healthy financial performance the value of IPC remains at its initial value all through the simulation period.

Our next scenario concerns the case in which there is growth in demand according to the base case, but no inflationary measures. Figure 6.2 demonstrates the financial performance of this experiment. It can be observed that

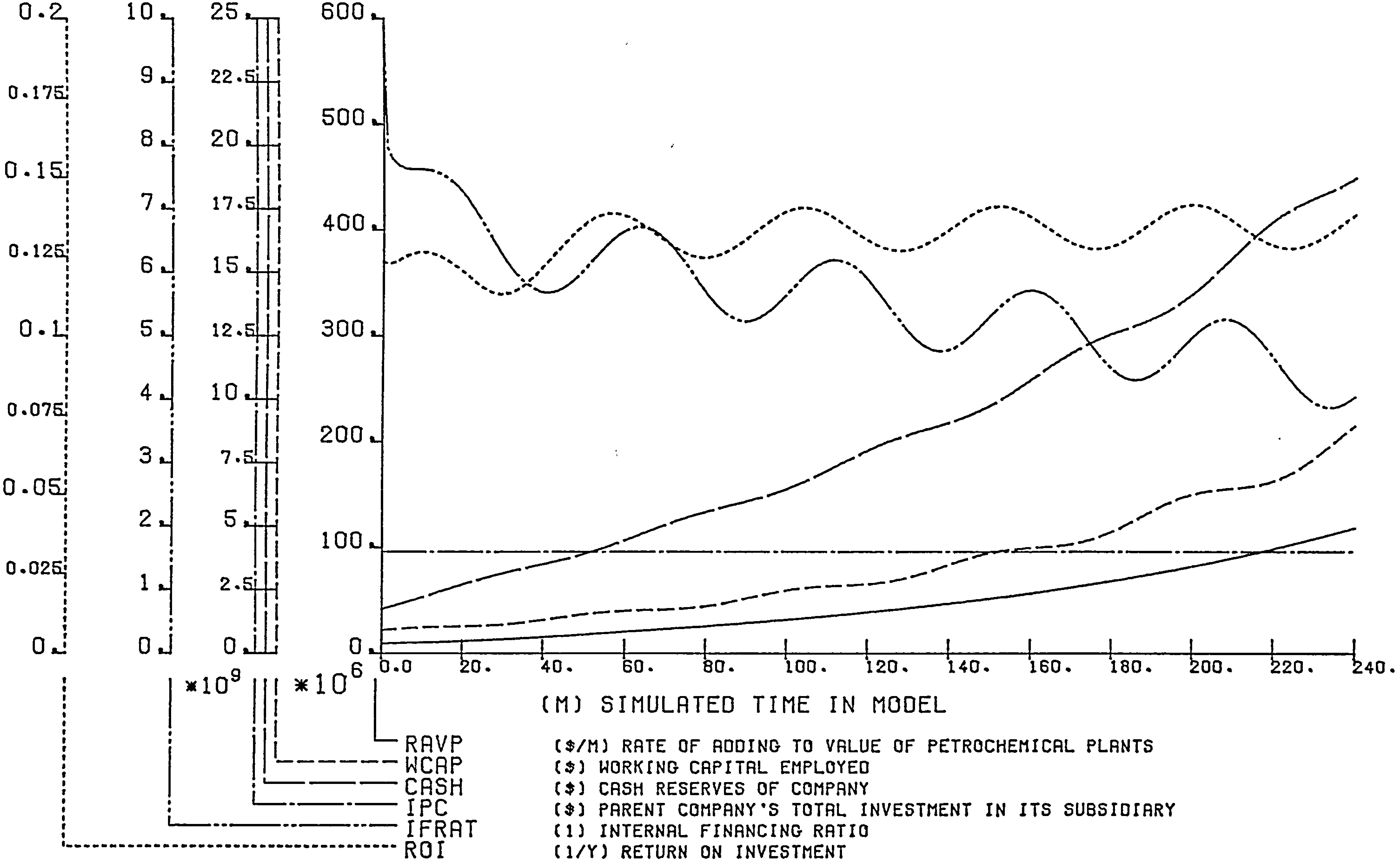


FIG 6.1 NO REAL GROWTH IN DEMAND
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

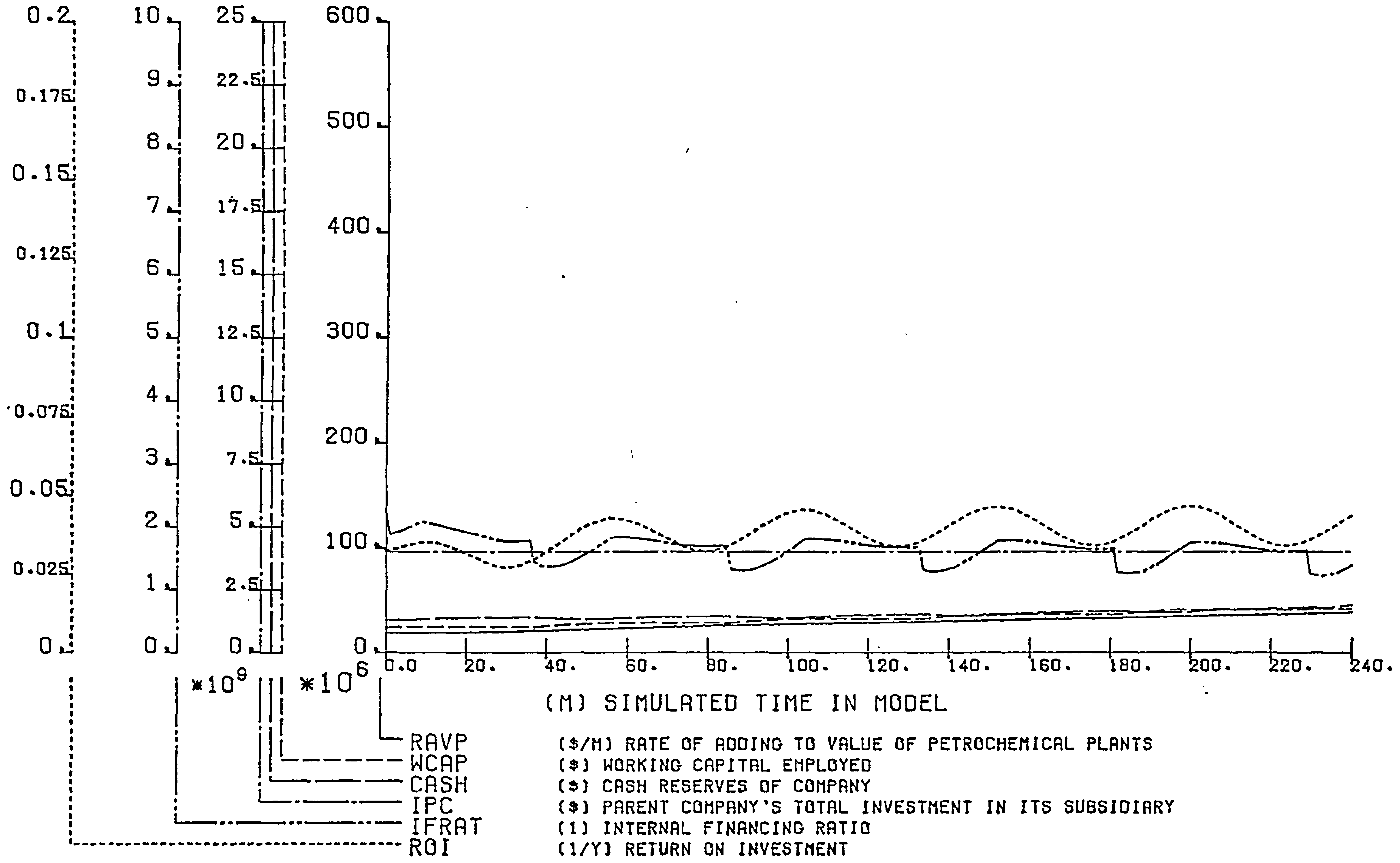


FIG 6.2 CONSTANT REAL MATERIAL PRICES
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

RAVP, WCAP and CASH grow steadily and slowly according to the demand pattern. The subsidiary manages to finance all its capital projects from internal cash generation, hence there is no investment by the parent company (IPC). The internal financing ratio (IFRAT) starts to settle at a sustained oscillatory mode, towards the end of the simulation time, with a minimum value which is over 1. Return on investment also follows a sustained oscillatory mode. Our overall conclusion from this scenario is that the company would have no problem in providing the required investment for the 3% annual growth in demand as in the base case, provided that there is no inflation in the economy and the price of raw materials.

In the next scenario we considered the possibility of the inflation level being half that of the base case (i.e. OIR =.055/12, COPR = .055/12, FWDV = .115/12, IR = .075/12, DEPPC = 1/120). Figure 6.3 demonstrates the financial performance of the company under this level of inflation. As can be observed, RAVP and WCAP grow significantly due to the inflation and growth. Consequently due to the increasing investment requirements the value of IFRAT declines and towards the very end of the simulation period the subsidiary becomes dependent on financial assistance from the parent company (i.e. when IFRAT falls below 1). Comparing this scenario to the two previous ones, it is evident that the reason for the poor financial performance of the company is the coupled effect of inflation and growth which gradually exhaust its internal financial resources.

In the next scenario we increased the level of inflation to one and a half times that of the base case (i.e. OIR =.165/12,

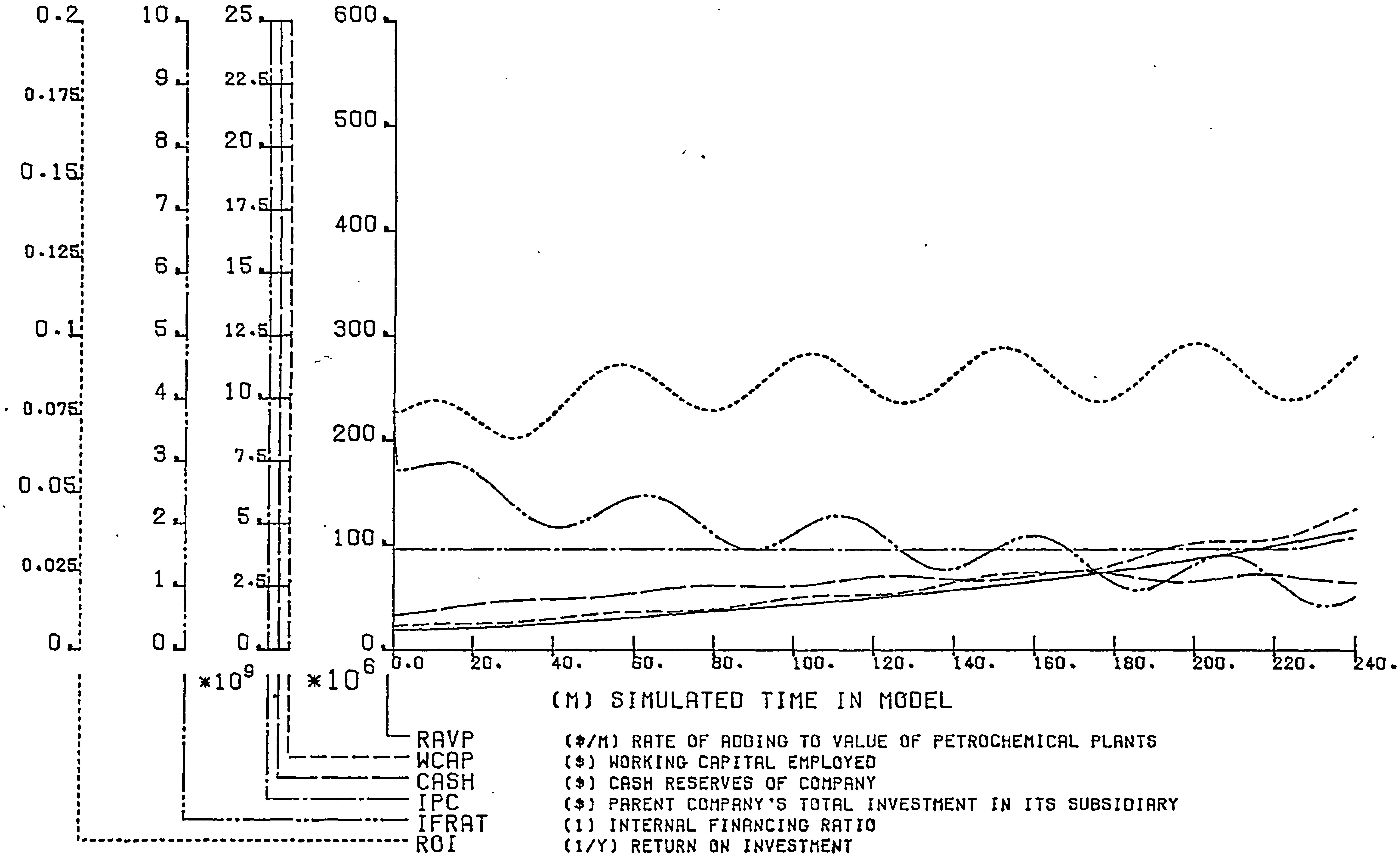


FIG 6.3 5.5% INFLATION IN REAL MATERIAL PRICES
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

COPR = .165/12, IR = .185/12, FWDV = .225/12). Figure 6.4 demonstrates this experiment. It can be observed that the result is devastating for the company. RAVP and WCAP grow enormously. Due to the massively increasing investment requirements the subsidiary becomes heavily dependent on financial assistance from the parent company all through the 1990's. The internal financing ratio, IFRAT, reaches extremely low levels towards the end of the simulation run which is very alarming.

Our overall conclusion from the experiments described in this section is that the financial performance of the company and hence its long term viability is very much affected by the rate of growth of demand and the inflation level. Indeed the system was found to be extremely sensitive to these two parameters. In the case of constant demand and no inflation the financial performance of the company was extremely good. With constant demand and an inflation level the same as the base case, the company's performance was satisfactory. In the case of growing demand but no inflation the company still managed to cope reasonably well. With growing demand and an inflation rate half that of the base case, the performance was rather poor and towards the end of the simulation period the subsidiary became financially dependent on the parent company. However this performance was comparatively much better than the base case. With a higher inflation level than the base case the financial performance was extremely poor and alarming. Hence we would like to state confidently that if in the future demand grows at a rate of 3%, then an inflation level of even 5.5% would lead to a decline in the ability of

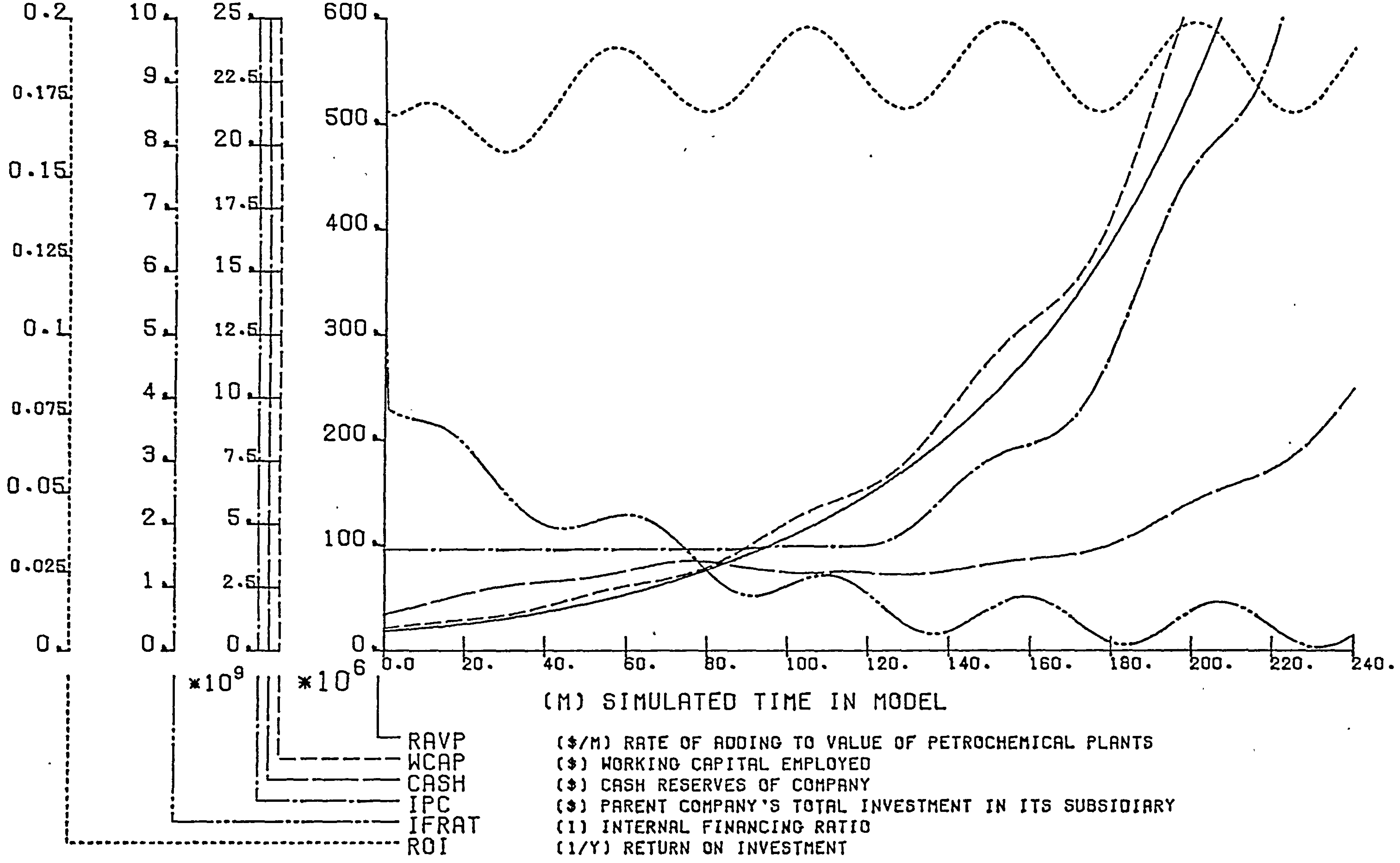


FIG 6.4 16.5% INFLATION IN REAL MATERIAL PRICES
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

the company to finance its capital projects. The system simply cannot cope under the coupled effect of growth in demand and high inflation. According to the experiments carried out, there is most probably a limit within the 0-5.5% inflation level, beyond which the system would commence to exhibit poor financial performance. It is possible through simulation to find the limit but due to the time consuming nature of the exercise, it was decided not to spend a great deal of effort in doing so. Anyway, the important thing is that we have demonstrated the effect of inflation and the range within which its plausible value would lie. We further believe that the value probably lies in the lower half of the range.

Generally in a System Dynamics study, if the system produces poor performance it is usually possible through loop analysis of the structure of the system to identify the trouble areas with poor control mechanisms and then improve the controllability and performance through the design of suitable and practical policies. However in our case the system would have behaved satisfactorily if it was not for the high inflation level. Hence the remedy is either a reduction in the level of inflation, which is not controllable by the company and depends on the whole economy or, as has been investigated by Elbedeiwy (1979) to adopt accounting policies which would calculate the depreciation charges on the replacement cost of plants when operating under inflationary conditions, and not according to the historical cost accounting which has been employed in this study and is the general practice in the industry. It is not within the scope of this present study to employ Elbedeiwy's sophisticated accounting method to assess the changes in performance. Therefore it remains as a possible area of research for the future. In the next section we shall discuss the robustness of the model and identify some sensitive parameters of the system, the values of which when altered within a plausible range could lead to a certain level of improvement in the financial performance of the system, but not to the extent of complete improvement.

6.2 Robustness of the Model

Concerning Coyle's (1977) criterion of external robustness, we have already tested the model with a STEP increase in demand, in chapter 5. This demonstrated that the system is capable of responding adequately to such a shock and then settling at the required level after a certain time span. Further, in the base case with exponential growth in demand and an imposed business cycle the system again responded suitably by achieving its objective of matching the capacity to that necessary for growth. In the previous section we also tested the model against different rates of inflation (which is an exogenous input) and it was discovered that the system is indeed very sensitive to inflationary measures.

In this section we shall spend some time on checking the external robustness of the model against other factors of importance, such as the errors in the forecasts, and also check for internal robustness against errors in the estimation of parameters, table functions etc. This is most easily done through performing a sensitivity analysis which would enable us to identify the critical factors, which involves the variation of the values of the parameters (one at a time) within a plausible range so as to observe any changes in the overall performance of the system.

In chapters three and four we stated that some of the parameters and functional relationships employed in the model, although within a plausible range, could not be estimated accurately due to the difficulties of quantification and also the confidentiality of information. The sensitivity testing has been most helpful in exposing those factors which are of a sensitive nature. Due to the size of the model, in order to prevent spending a great deal of effort and time on such a process, we have limited ourselves to the testing of those parameters which are believed to be of significant importance concerning the purpose of the study.

6.2.1 Sensitivity Testing

The results of the sensitivity analysis are represented in Table 6.1 which also includes the result of the Base Case for reasons of comparison. A certain number of important performance indicators were selected in order to highlight any significant changes in the overall performance of the system when the value of a parameter was altered. These are given in the table and their definitions are as follows:

1) Cash Reserves of Company (CASH)
2) Parent Company's Total Investment in its Petrochemical Subsidiary (IPC)
3) Ratio of Achievable Rate of Spending and Required Rate (FRAT)
4) Internal Financing Ratio (IFRAT)
5) Return on Investment (ROI)
6) Effective Basic Product Capacity Excluding Energy Products Capacity (EBCAPE)

Run No.	Variables / Parameters	CASH ($x10^8)		IPC ($x10^9)	FRAT		IFRAT		ROI		EBCAPE at TIME 240
		MAX	MIN		MAX	MIN	MAX	MIN	MAX	MIN	
	BASE CASE	39.79	13.83	12.06	6.84	1.26	4.62	.25	.15	.113	457442
1	DMINTB 6 DMINTIF 12 18 36	38 41.98	13.54 14.03	14.21 10.11	6.53 7.07	1.19 1.34	4.4 4.78	.2 .3	.143 .153	.111 .114	465514 449685
2	CDELBP 48	39.55	13.1	12.08	6.89	1.27	4.63	.25	.151	.113	451331
3	RGDM .02/12 .04/12	61.98 45.05	13.83 13.83	10.83 14.24	34.53 81.7	1.02 1.07	17.9 16.01	.43 .19	.159 .146	.113 .094	433425 490531
4	LTPP 300	48.2	15.59	8.79	9.34	1.49	6.34	.22	.15	.113	---
5	TAXDIV .2 .4	75.56 35.88	13.83 13.83	5.54 18.17	7.17 6.51	1.67 1.09	4.95 4.29	.66 .075	.148 .15	.113 .113	--- ---
6	FWDV .15/12 .19/12	37.09 48.65	13.71 13.94	15.7 8.53	6.63 7.05	1.15 1.42	4.41 4.82	.14 .41	.137 .161	.104 .121	--- ---
7	MAXIPC80 $\$4x10^8/12$ $\$6x10^8/12$	39.79 39.79	13.83 13.83	12.06 12.06	6.4 7.29	1.06 1.46	4.62 4.62	.25 .25	.15 .15	.113 .113	--- ---
8	PC .2 .4	33.09 48.61	13.83 13.83	11.5 12.63	6.92 6.76	1.28 1.25	4.7 4.54	.27 .23	.15 .149	.113 .113	--- ---
9	DEPPC 1/60	44.43	14.26	10.41	8.03	1.31	5.81	.297	.148	.106	---
10	TPME 0/.67/.87/1 1.13/1.33/2	38.15	13.83	14.19	6.66	1.18	4.44	.17	.149	.101	---

Table 6.1 Results of the Sensitivity Analysis

6.2.1.1

In the first run of the sensitivity analysis the duration of the decision making intervals for basic (i.e. DMINTB), intermediate and final product capacities (i.e. DMINTIF) were decreased and then increased by half respectively in order to assess the consequent impacts on the system.

In the case of the decisions on the capital expenditure proposals being made within an interval half that of the base case, there was at the end of the simulation period an excess EBCAPE of 8072 tons/month compared to the base case (see table 6.1). The shorter DMINTB and DMINTIF increased the financial requirements. Consequently the value of IPC increased significantly (i.e. the subsidiary became more financially dependent on the parent company), and as expected the values of CASH, FRAT, IFRAT and ROI decreased.

A longer decision making interval, expectedly, led to a shortfall in EBCAPE of 7757 tons/month compared to the base case, and hence a lower IPC. The financial position of the company improved due to lower capital expenditure.

Our conclusion from Run 1 is that the overcapacity and undercapacity resulting from altering the decision making interval is not really significant (about 1.7% of the capacity in the base case). However the financial performance, particularly the change in the level of IPC, is significant.

6.2.1.2

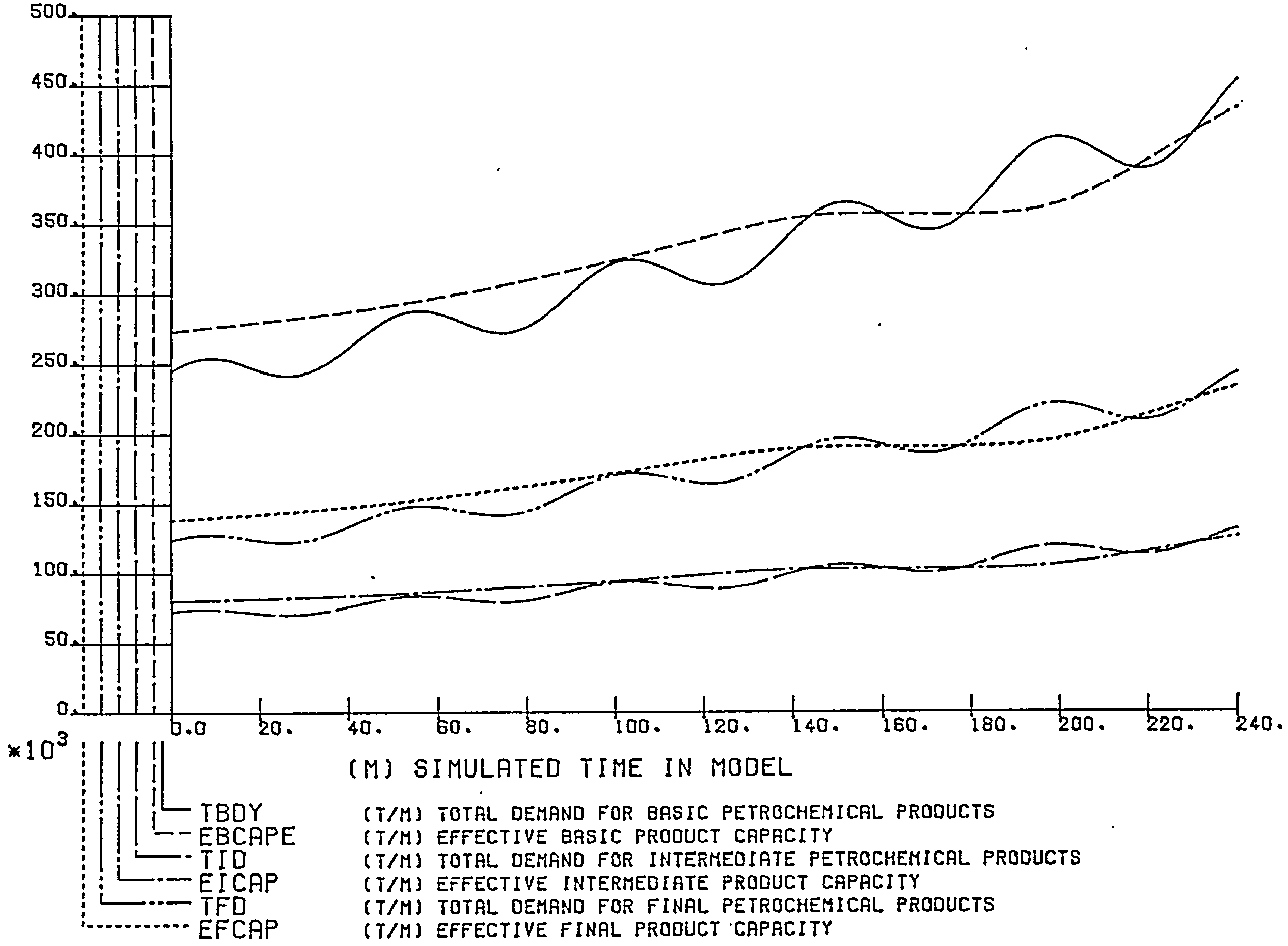
In Run 2 the construction delay for basic plants, and for intermediate and final plants was increased to 48 and 36 months respectively in order to assess the overall change in the performance of the company. Longer construction delays do happen and it is worthwhile to study their impacts.

As expected there is a shortfall of 6111 tons/month in EBCAPE compared to the base case, however this is not at all significant. The financial performance is very much the same as the base case. Hence we can safely conclude that the system is highly robust concerning the construction duration time of the plants.

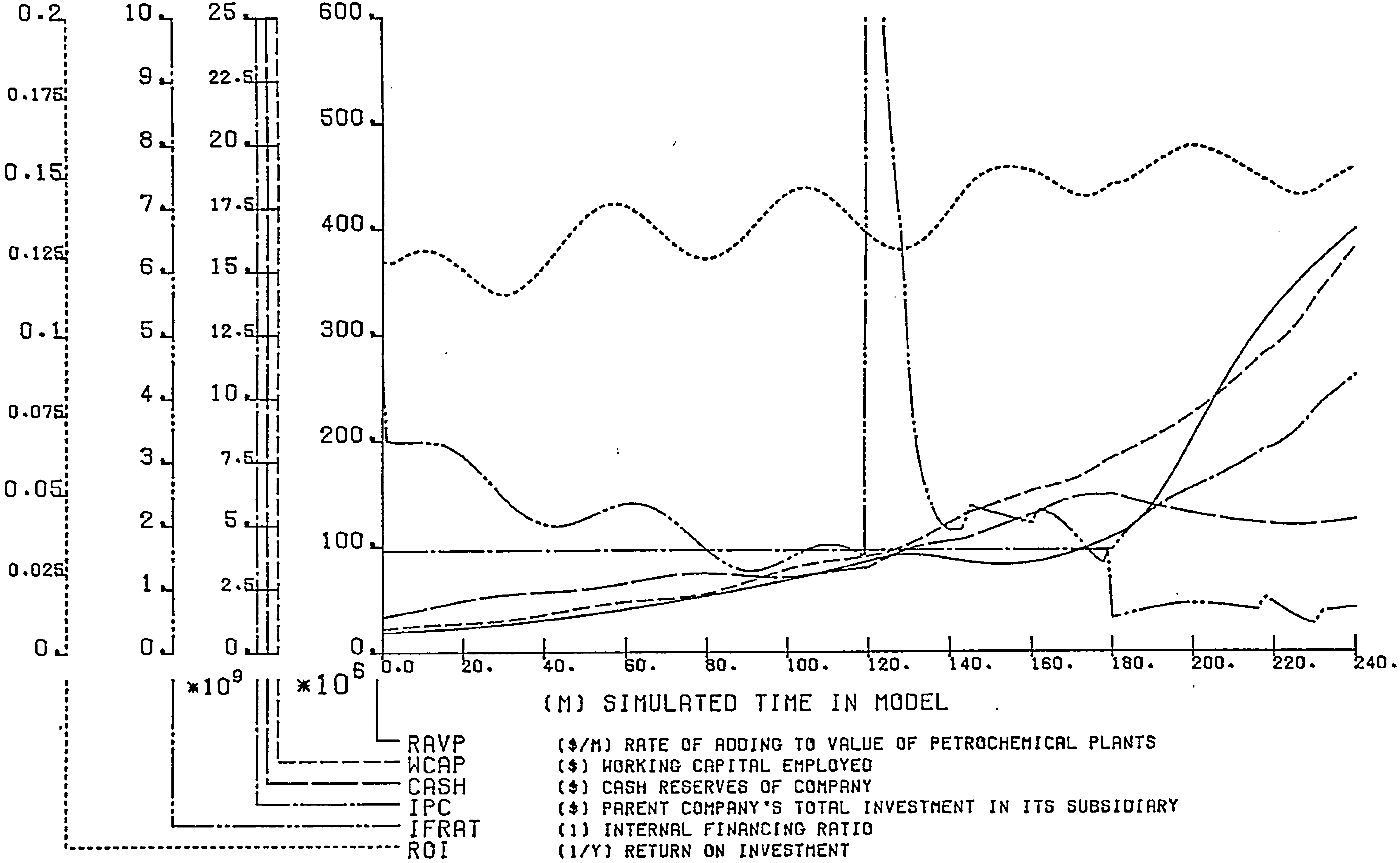
6.2.1.3

As was explained in chapters 1, 3 and 4 the petrochemical industry has in the past blamed the errors in the forecasting processes of demand for the problems which the industry has faced since 1974. Hence in Run 3 we tested this phenomenon by supposing that from 1990-1995 the industry forecasts the growth of demand between 1995-2000 to be 2% in one scenario and 4% per year in the next (in the base case it is 3%) and we also assumed that the actual growth in demand between 1995-2000 turns out to be 3% per year. These experiments enable us to find out about the impacts on the system of pessimistic and optimistic forecasting respectively.

Figures 6.5 (a and b) demonstrate the performance of the system (see also table 6.1) under pessimistic forecasts. As can be observed there is significant shortfall in capacity during time 145-240, particularly at about time 195. At the end of the simulation period there is 24017 tons/month less EBCAPE than the base case. Concerning the financial performance, the value of IFRAT at time 120 goes sky high (out of our own scales) due to the very low spending requirements stemming from the low growth of demand forecasted for the year 1995 and which continues up to the year 2000. At time 180 IFRAT drops significantly due to the increasing spending requirements arising from



a) FIG 6.5 PESSIMISTIC FORECASTS OF DEMAND
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

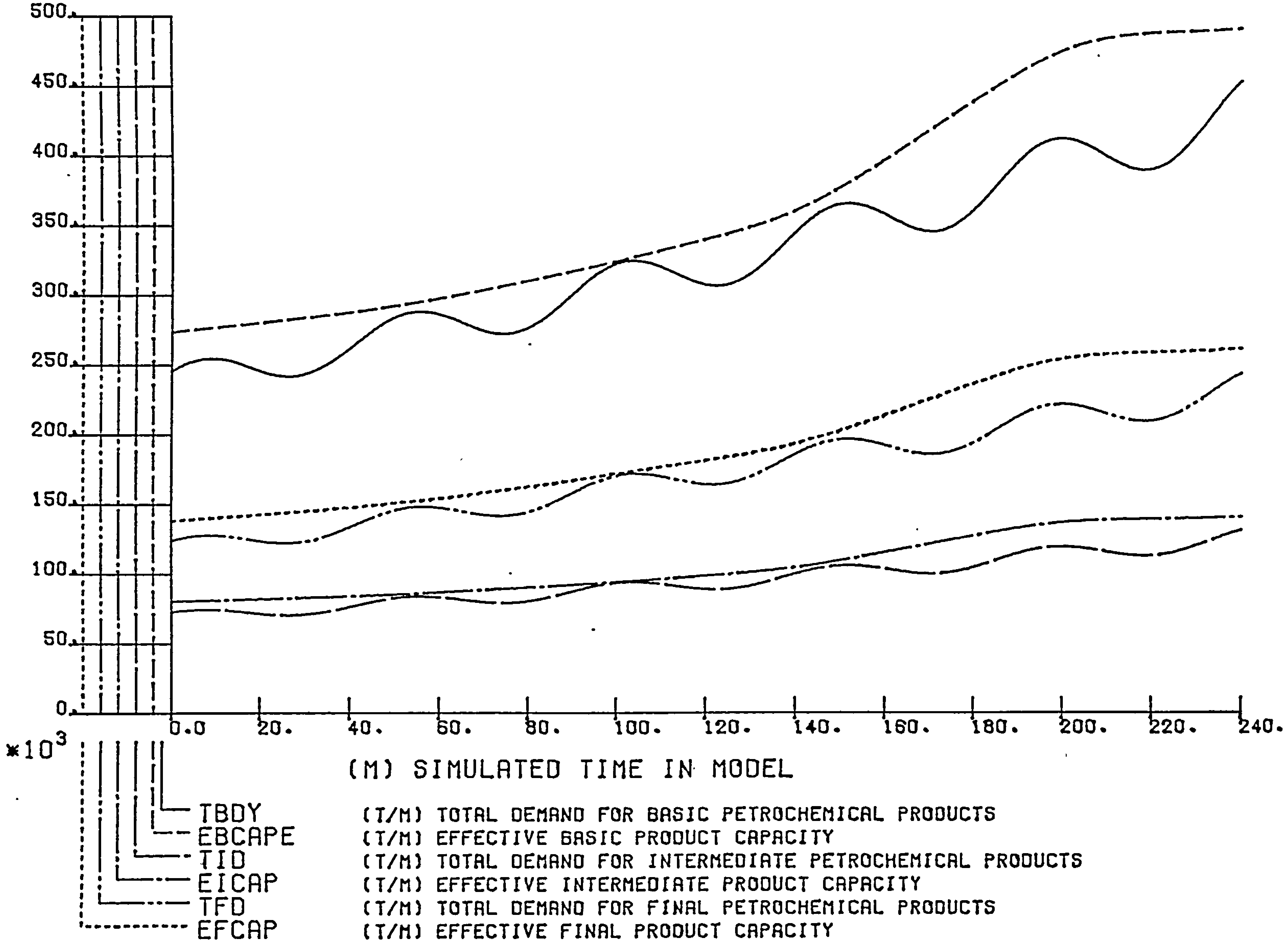


b) FIG 6.5 PESSIMISTIC FORECASTS OF DEMAND
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

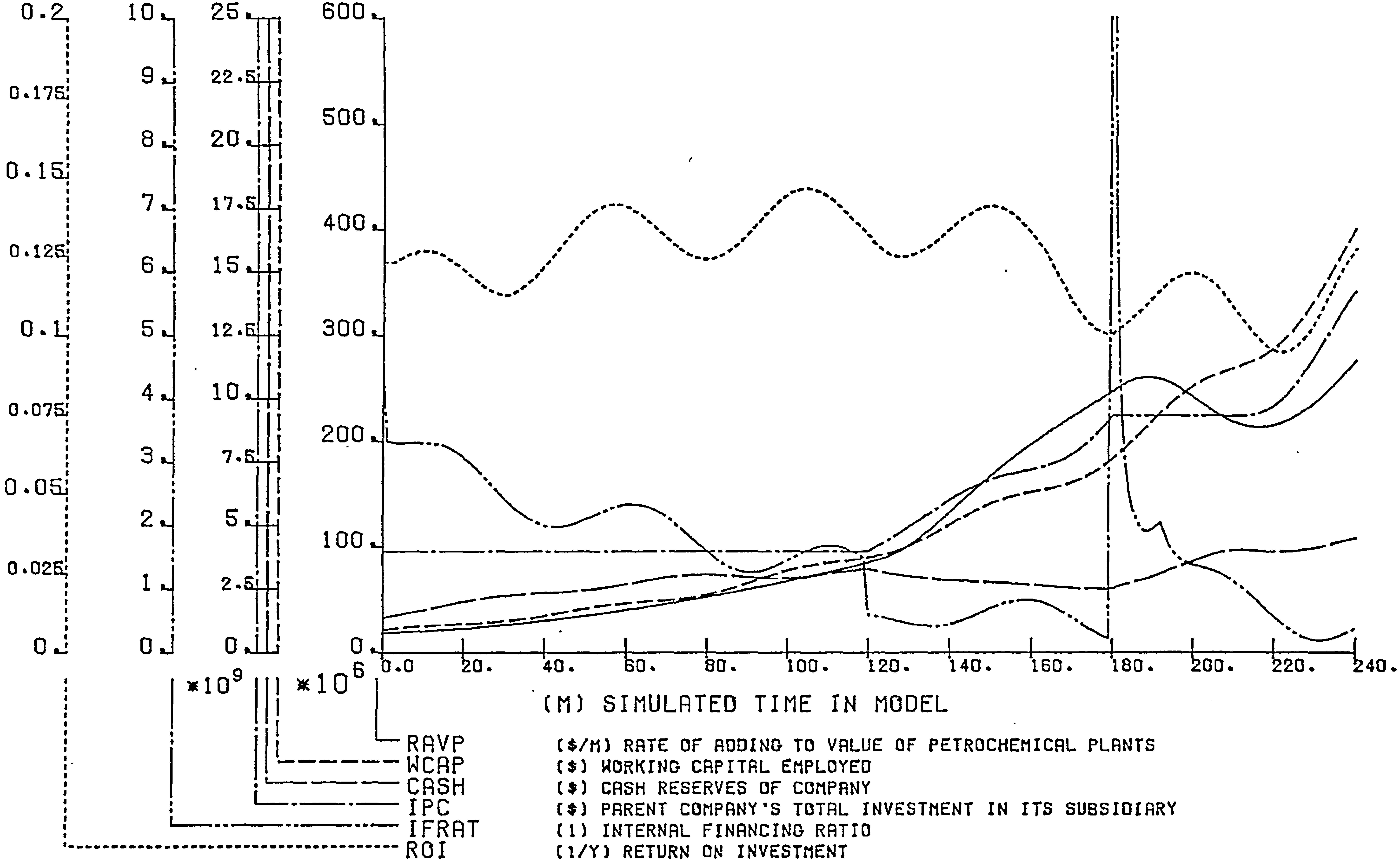
the growth of demand commencing to be forecasted at its original higher value (i.e. 3%). Due to the decrease in investment requirements during 1990-1995 the cash level goes up enormously and IPC, expectedly, decreases. ROI improves due to the higher utilization of capacity and the resulting high values of price multipliers.

Figures 6.6 (a and b) demonstrate the performance of the system with optimistic forecasting (see also table 6.1). Significant overcapacity occurs during time 145–240, reaching a peak at about time 218. The value of IFRAT falls significantly at time 120, due to the heavy financial requirements triggered by the higher growth of demand forecasted for time 180, which continues up to time 240. At time 180, the value of IFRAT shoots up significantly due to the very low spending requirements stemming from the lower growth of demand (i.e. 3%) being forecasted for time 240 onwards. The final level of Cash is higher than the base case due to the lower level of investments needed during the period 180-240. IPC increases due to the heavy investments made by the subsidiary during time 120-180. ROI declines due to the lower utilization of the plants which depresses profits.

Our overall conclusion concerning Run 4 is that errors in the forecasting process and the period of misplanning do indeed have a great impact on the system (as also concluded by the UNIDO (1978) study). They can cause, as was demonstrated, significant overcapacity or undercapacity with very important financial implications for the company. If we accept the fact that there is bound to be some degree of uncertainty about the forecasts of future demands for petrochemicals, then in order to protect the company from the impacts of such undesirable phenomenon, it becomes necessary to attempt to re-design the capacity acquisition



a) FIG 6.6 OPTIMISTIC FORECASTS OF DEMAND
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY



b) FIG 6.6 OPTIMISTIC FORECASTS OF DEMAND
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

process in order to desensitise it against such errors. However an undertaking of this nature would itself entail a major study. Therefore it remains as a future area of research.

6.2.1.4

In an article in the Chemical Age Journal (Joseph, 1979) it was predicted that in the future due to the high cost of replacing a plant, it would become more economic to extend its physical lifetime up to 25 years, rather than to replace it when fully depreciated after a lifespan of ten years. Hence we put this scenario to the test, through Run 4, to observe its financial implications for the company (see table 6.1). Due to the longer lifetime (LTPP) the spending requirements declined, resulting in a very significant increase in the level of CASH and also a marked decline in IPC. The value of ROI is very much the same as the base case. Hence our conclusion is that the increase in LTPP indeed makes the company richer, however the qualitative behaviour of the system remains the same.

6.2.1.5

In section 4.12 we mentioned that the companies pay very little in taxes and dividends (TAXDIV) when investing heavily (through offsetting plant allowances of 100% against tax), otherwise they pay up to 52%. For the purposes of our study an average value of 30% was adopted. In Run 5 we tested the sensitivity of the model, by paying a TAXDIV of 20% and 40% respectively.

In the case when the company pays only 20% in taxes and dividends, the financial performance improves significantly. The level of CASH is nearly double that of the base case through larger retained earnings. IPC is less than half. The minimum value of IFRAT is more than doubled. ROI is lower than the Base Case due to the high level of liquid assets.

When the company pays a higher portion of its profits in taxes and dividends the financial performance deteriorates significantly and the value of IPC increases by 50%. IFRAT reaches an alarming minimum level of .075.

Our conclusion on Run 5 is that the variation of TAXDIV has indeed very significant implications for the company. The less the company pays in taxes and dividends, the better it is for its long term survival. Most probably, due to the heavy future investment requirements, the company would be able to give away very little in taxation and hence a figure of 20% for TAXDIV might well be plausible.

6.2.1.6

In Run 6 we varied the fraction of the written down value of plants and working capital to cover the required return on investment when supply and demand are balanced (FWDV) at about its original value of .17/12 per month. The values selected were .15/12 and .19/12 per month (see table 6.1).

In the case of FWDV = .15/12 the financial performance of the system is quite poor. IPC increases due to the low level of internal profit generation. Hence the minimum value of IFRAT reaches a value significantly lower than that of the base case. ROI also declines considerably.

In the scenario when the industry somehow manages to increase its return expectations (i.e. FWDV = .19/12) the financial performance, as one would expect, improves markedly. Due to the high internal profit generation, the level of CASH increases significantly and IPC drops to nearly two thirds of that of the base case (which is desirable by the subsidiary).

The minimum value of IFRAT also improves considerably in comparison and there is also a much improved ROI.

Our conclusion on Run 7 is that, if the industry manages to demand a higher return on its assets, then its long term viability would be improved but not to the extent of alleviating all together its financial problems. This may seem surprising to those industrialists who believe that adequate ROI would lead to financial stability, underestimating the effects of operating under high inflationary conditions which require suitable accounting policies (Elbedeiwy, 1979) that would take account of the rising replacement costs of plants.

6.2.1.7

Next we considered altering the base level of the parent company's maximum monthly investment in its petrochemical subsidiary in 1980 (MAXIPC80) to \$33.33 million and \$50 million respectively. The financial performance in both cases is very much the same as the base case, as we would expect, except the decline and improvement in FRAT respectively. Hence we can safely conclude that the system is robust concerning variations in MAXIPC80.

In Run 9 the proportion of the value of the working capital to be kept in cash by the company (PC) was varied about its original value of 0.3. The values selected were .2 and .4. The performance of the system did not change significantly except for a decrease and an increase in the level of cash. Hence the model is robust to the variations in PC.

6.2.1.8

In the next Run we tested the model against increasing the fraction of the value of plants allowable for depreciation (DEPPC). In the base case the value of the plant was depreciated over a lifespan of 10 years (i.e. DEPPC = 1/120 per month) whereas in this run it was depreciated over 5 years (i.e. DEPPC = 1/60 per month). The results of this run did not show any significant changes in the qualitative behaviour of the system in comparison with the base case, although the level of cash improved and there was a decline in IPC. There was also a slight improvement in the minimum value of IFRAT. Hence our conclusion is that the financial ability of the company cannot be improved significantly by increasing the depreciation rate when operating under high inflationary conditions (as has been investigated by Elbedeiwy (1979)).

6.2.1.8

As was discussed in section 4.12, the relationship between the deterioration of prices and the magnitude of overcapacity is very difficult to quantify and we stated that the relationships represented in figure 4.2 only highlighted the shape of the deterioration and were by no means accurate in numerical terms. Hence in Run 11 we lowered the curves (i.e. faster deterioration of prices during periods of overcapacity and hence faster price rises during periods of undercapacity). In table 6.1 only table values of price multiplier for ethylene (TPME) are noted due to the scarcity of space, however we will now present the table values of the other price multipliers:

$$\left.\begin{array}{l}\text{TPMP}\\ \text{TPMVCM}\end{array}\right\} = 0/.47/.77/1/1.23/1.53/2$$

TPMB = .8/.834/.9/1/1.1/1.166/1.2

TPMS = 0/.17/.5/1/1.5/1.83/2

$$\left.\begin{array}{l}\text{TPMLDPE}\\ \text{TPMHDPE}\\ \text{TPMPVC}\\ \text{TPMPS}\\ \text{TPMPP}\end{array}\right\} = 0/.57/.8/1/1.2/1.43/2$$

Although the curves were lowered by a small margin, the financial position of the company declined to a certain degree. Due to the lower internal profit generation, the subsidiary became more financially dependent on the parent company than the base case, by borrowing more than two billion dollars more. The cash level also declined significantly. The minimum value of IFRAT was .17 compared to the .25 of the base.

Our conclusion on Run 10 is that the system has shown a certain degree of sensitivity towards the values of the price multipliers and due to our limited knowledge about these relationships, it is necessary, as a future area for research, to investigate and quantify as plausibly as possible the relationships represented by figure 6.2.

Our overall conclusion can thus be stated that, although the quantitative results of the performance indicators were relatively sensitive to a number of parameters, the most important matter, from the robustness point of view, is that the qualitative mode of the financial performance of the company remains unchanged, no matter what. That is, the declining financial capability of the company to finance its capital expenditure requirements. This phenomenon highlights the relative robustness of the system.

6.3 Model Experiments

In this section we shall run the model as a conventional 'what would happen if' type of simulation. In the previous section it was discovered, as suspected, that the financial performance of the model was relatively sensitive to TAXDIV, LTPP, MAXIPC80 and FWDV, and in particular to the value of the first parameter. Hence we thought that it would be interesting to find out about the combined effect of these parameters, set at their desirable values (highlighted by the sensitivity analysis), on the financial performance of the company.

Among the four parameters mentioned above, the changing of FWDV (the return which the petrochemical industry and hence the company can expect on its assets at equilibrium supply and demand) is not really feasible by the company, since it requires a collective approach by all the producers and also depends on the overall state of the economy. However the values of the other three parameters could be altered, from the point of view of the company, within a plausible range. Hence in our first scenario we considered the combined effects of these three parameters (with TAXDIV = .2, LTPP = 300, and MAXIPC80 = $\$6\times10^8/12$ per month) on the system, and then in the next scenario we added to this combination the desirable value of FWDV (i.e. .19/12 per month). However, before carrying out the simulation runs concerning these two scenarios, we would like to state that we do not expect significant qualitative changes in the financial performance of the system because its deteriorating behaviour mode, as was discussed in section 6.1, is very much determined by the level of inflation.

The first scenario is more achievable, from the company's point of view, and its results are demonstrated by figure 6.7. Due to the favourable values of the three parameters, particularly

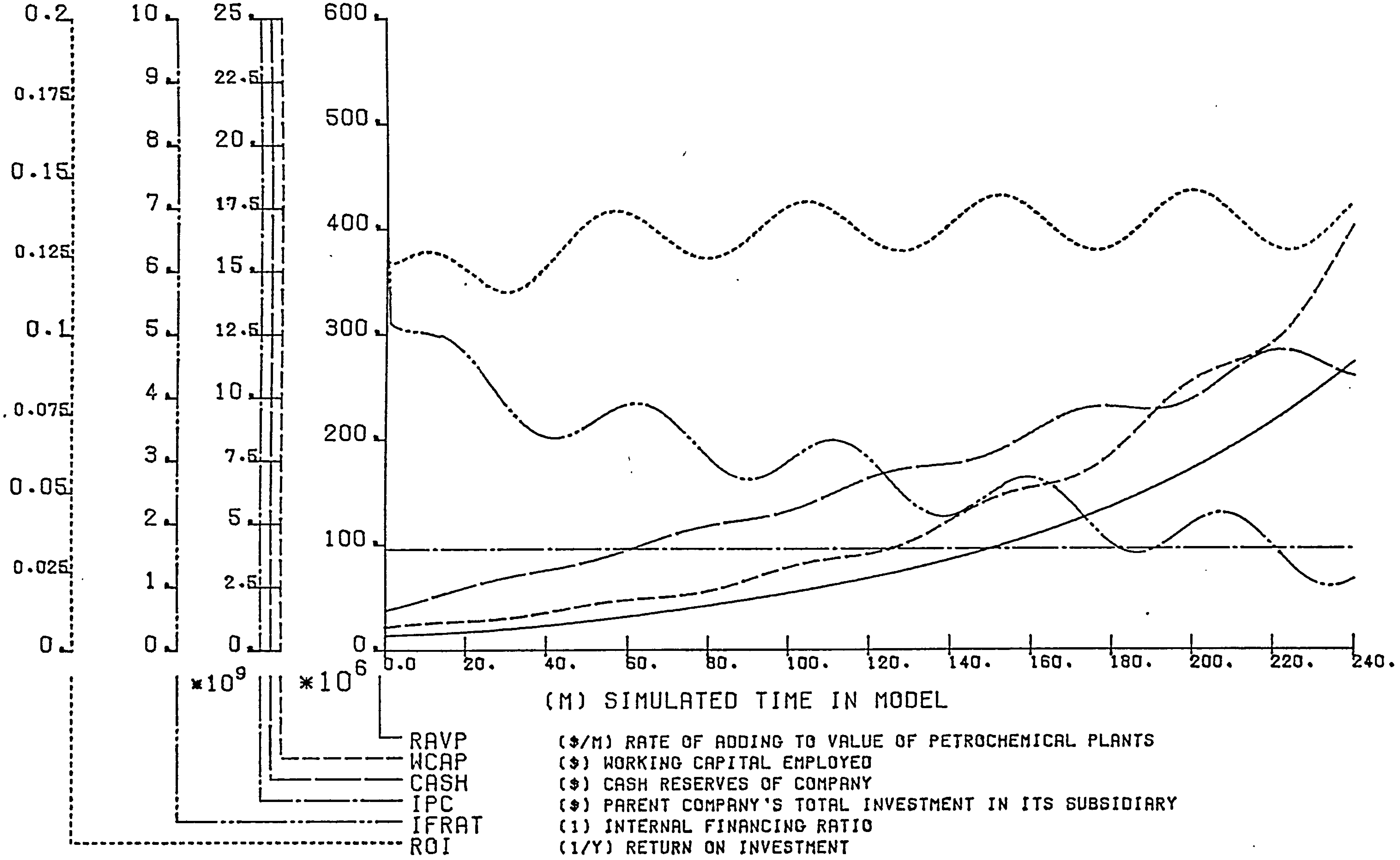


FIG 6.7 LTPP=300,TAXDIV=.2,MAXIPC80=6E8/12
A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY

the low level of payment in taxation and dividends which leads to higher retained earnings and the longer lifetime of plants which decreases the investment requirements, the company's cash reserves grow enormously to about three times as much as the base case. The minimum value of IFRAT is just above 1 which is four times that of the base level and hence IPC remains at its original value all throughout the simulation period (i.e. the subsidiary survives on its own cash generation up to the time 240 but after this period, which is not within our time span, it will become financially dependent on the parent company).

The second scenario is probably less achievable in the near future due to the overall state of the economy, nevertheless we shall demonstrate its impact on the system. As can be observed from figure 6.8, under this scenario the cash reserves grow even more significantly than in the first scenario for basically the same reasons together with the added effect of higher FWDV. The minimum value of IFRAT is about 1.69 which is more than 6 times larger than that of the base case. However the value of ROI is not much higher than the base level, due to the significant level of liquid assets and their low return.

Our overall conclusion on the results of the scenarios investigated within this section is that quantitatively these two scenarios lead to significantly better financial performance than the base case. However, the qualitative behaviour which we believe is more important in the long term, and which is dictated by the overall inflation, is basically unchanged.

CHAPTER 7

CONCLUSION AND FUTURE RESEARCH

7.1 Conclusion

As was discussed in chapter 1, prior to 1967 the petrochemical industry mainly consisted of small production units and therefore those manufacturers capable of using large single stream units were happy to let the smaller manufacturers set a "price umbrella" under which they themselves acquired huge profits, without endangering the interests of their competitors. During this 'golden era' the industry was experiencing very rapid growth, which was facilitated by the low cost of its feedstocks, the cost of which was going down, even in real value. Hence the prices of petrochemical products were very competitive against those of the natural products resulting in their ever increasing substitution.

However, from 1967 the number of larger production plants (which could produce the products at substantially lower costs, due to the economies of scale) increased rapidly due to the aggressive approach of the producers to the market, and also the ease of entry into the industry, which encouraged the penetration of companies in other industries. During this era many companies planned on the simple basis of building a larger plant than their competitors, outselling the competitors at lower prices for a few years in the hope of capturing their market shares and then reaping the profits later for the next larger plants. Fortunately for the companies, such misplannings did not cause significant overcapacity during this period because demand was quick to catch up.

However, at some point in the early 1970's the petrochemical industry entered a new era of maturity in which the faster substitution phase for most products started to tail off; the benefits of plant economies of scale reached their peak and the feedstock costs started to move up. The sudden quadrupling of oil prices in 1973 affected the slow-down of the industry further. Due to the misplannings of the late sixties and early seventies, the industry has, since 1974, been faced with large overcapacity and the resulting low prices for its products. This undesirable phenomenon together with the high inflation level in material prices which the industry has had to operate under during the 1970's (and which hardly existed in the earlier periods) have very much threatened the long term survival of the chemical companies.

Having explored the evolution of the industry, the study then concentrates firstly on examining the implications of an oil company's diversification into the petrochemical business, in the way of exploring the past and present history of the oil companies' participation in order to find out about their reasons for doing so and also their strategies. We also isolated those product areas in which the oil companies' diversifications failed (and the reasons for their failures) and further, those in which they were successful and have since been concentrating on.

In the second stage we concentrated on exploring the corporate strategies to be followed by the petrochemical subsidiary of a major oil company, operating under the effects of the undesirable factors discussed earlier. In order to fulfil this purpose we constructed a Corporate Planning Model which could be used for decision-making in such a company. In doing so we have tried to include all the important factors and policies inherent in this kind of system, most of which were discovered through the much appreciated co-operation of the executives of a number of major oil and chemical companies. Since it is the interactions between these factors and policies which determine the dynamic behaviour of the company through time, and our aim is to analyse the outcome of the interactions in order to shed more light on the appropriate corporate strategies for the organization, we believe that System Dynamics offers a strong methodology for this type of analysis.

Hence we employed SD to construct a Basic Model which could be simulated in order to produce the expected dynamic behaviour of the company during the 1980's and the 1990's, the results of which were discussed in chapter 5. As was discussed in that chapter, the simulated behaviour corresponds closely to that expected from the real system. The effect of the 4-year business cycle on the capacity utilization and hence on the profitability of the company is very well demonstrated, as is the decline in the financial ability of the company to finance its capital projects from internal sources (which is very unlike the 'golden days' when the industry was able to finance its rapid growth through its own large internal cash generation) and hence its increasing dependence on financial assistance from the parent company in the 1990's.

In chapter 6 we analysed the decline in the financial ability of the company (IFRAT) and proved that it was due to the coupled effect of growth and inflationary measures. The system is exogenously driven by an expected general rate of growth of demand (i.e. 3% per year) and an inflation level of 11% per year. Even a 3% increase per year, which is very low compared to that experienced in the past, leads to significant increase in the company's productive capacity by the end of the 1990's, requiring heavy investments together with the financing of the increasing working capital requirements. The high inflation level of material prices exacerbates the situation by increasing the financial burden on the company, hence resulting in the decline in its financial status. We demonstrated that the system could cope with either the growth in demand or the inflation, but not with both at the rates assumed for this study (i.e. 3% and 11% per year respectively). Through sensitivity testing we observed that the system eventually ran into financial problems, hence dependence on finance from the parent company, even with a 5.5% inflation level. Therefore, we concluded that there must be an inflation level between the 0-5.5% range, probably in the lower end of the range, beyond which the financial ability of the company would decline to the extent of eventual dependence on financial rescue by the parent company. It is therefore quite clear that the system simply cannot cope with inflation levels of large magnitudes. If the average inflation level in Western Europe persists, as expected, at a level close to that forecasted for the purposes of this study, then besides a number of options open to the company, which can improve its financial performance to some degree (which will be discussed later) but not to the extent of complete financial stability, the company should somehow effectively take account of the inflation in the replacement costs of physical assets. In chapter 6 we mentioned that Elbedeiwy's (1979) accounting method of revaluing the physical assets at their current replacement costs and their depreciation according to this value might well be appropriate and lead to adequate financial stability for the company. However, this has to be explored thoroughly, as a future area of research.

In chapter 5 we explored the impact of economic plant size constraints on the Basic Model, having taken out the assumption that the subsidiary would go into joint ventures with other companies if its desired new capacity for a product falls below the economic size of such a capacity. We observed that the growth in capacity did not enable the company to take advantage of all the peaks in demand which is the main objective of the companies. Even though the hypothetical company under this present study is of the size of major companies operating in this industry, (hence possessing substantial market share) due to the rate of growth of demand and the large economic sizes of the plants, its capacity falls short of the peaks in demand. We also discussed in that chapter the consensus among the companies not to attempt to capture each others market share which would mean that a company cannot order a plant when only a part of its capacity is required. Hence, the only way that the company could reach its objective is to go into joint ventures with other companies in the same situation. We have given many examples of joint ventures, in chapters 2 and 5, and believe that in the future the main reason for their formations will be the market share consensus among the companies. Although other factors such as the huge capital costs of the plants would make such undertakings even more attractive.

In chapter 6 we tested the external and the internal robustness of the model. It was discovered that the system is sensitive to the errors in the demand forecasting process which could result in substantial overcapacity or undercapacity. Hence, as a future area of research, it would be extremely worthwhile to attempt to re-design the capacity acquisition process in order to desensitise it against such errors.

The effect of increasing the depreciation rate of the value of the plants was also investigated and we observed that under inflationary conditions such a policy would not, as might have been expected, lead to significant improvement in the financial stability of the company.

The system was found to be quite sensitive to the varying portion of profits paid in taxes and dividends. The lengthening of the physical lifetime of plants also led to some degree of improvement in the financial performance of the company. The varying of the limit of financial assistance from the parent company, expectedly, plays a decisive role during the periods when the subsidiary is under heavy financial burden.

It was also discovered that if the industry as a whole could raise its return expectation on assets, then the company's financial performance would improve to a certain extent.

The relationship between the deterioration of prices and the magnitude of the overcapacity proved to be sensitive to some degree. However further thorough research in this area is required.

Our overall conclusion on the robustness of the model is that, although the system is relatively sensitive, concerning quantitative performance, to a number of factors, it is quite robust qualitatively since there is no significant change in the overall behaviour mode regardless of variations in the parameters.

Based on our detailed conclusions, we would now like to propose the appropriate corporate strategies to be followed by the petrochemical subsidiary during the next two decades. Accepting the fact that the company would have to sustain a certain degree of growth, and also operate under high inflation levels for the foreseeable future, then the company should explore the possibility of adopting, where possible, a depreciation policy which would take account of current replacement costs (as recommended by Elbedeiwy (1979)) in preference to the historical cost accounting.

There are also a number of options open to the subsidiary by which its financial performance could be improved, which in turn affects its long term viability and survival:

a) to pay out as little in taxes and dividends as possible, which when considering that the subsidiary is allowed plant allowances of 100% against tax and also being wholly owned by the parent company, should not be too difficult.

b) to extend the physical lifetime of the plants to their practical limits.

Finally the parent company should be prepared to come to the financial rescue of its subsidiary during the periods when its internal cash generation is not large enough to cover its expenditures.

7.2 The Scope for Future Research

This present work has opened the path to other interesting areas of research for the future.

Naphtha has been the main source of petrochemicals in Western Europe and is expected to remain the dominant feedstock for the foreseeable future. We therefore chose this raw material as the source of the company's petrochemical products. However, due to the heavy increase in the demand of the lighter end of the barrel, it is expected that the companies would build plants which could use other varieties of feedstocks such as LPG and gas oil in order to alleviate the feedstock supply problem. The model has been built in such a way as to facilitate the use of other raw materials. Hence it would be interesting to extend the model accordingly to consider the case of a company which uses a variety of feedstocks for its petrochemical operations.

In the model we have not attempted to forecast the company's cash generation in the future. Hence, the decisions on capital expenditure programmes are based wholly on the level of cash generation prevailing at about the time when the decisions are taken. It would be interesting to explore the impact of the forecast on the decision-making process.

In chapter 4 we mentioned that the relationship between the price and the demand/supply situation is very difficult to quantify, and that the relationships presented were of the right behavioural pattern, but by no means accurate in numerical values. Later, in chapter 6, we tested the model against errors in the quantification of these relationships, and the system was found to be sensitive to some degree. Therefore, it is our belief that it would be quite worthwhile to attempt to quantify the relationships as accurately as possible.

The model has been built with the flexibility of including other product ranges so that if the company intends to diversify into other areas, it can explore its implications prior to making firm commitments.

Finally, concerning the operation of the company under inflationary measures, as was discussed in chapters 5 and 6, the escalation in cost of plants is very substantial indeed which places an enormous burden on the company. Elbedeiwy (1979) has thoroughly investigated this matter and developed an accounting policy which depreciates the value of the plants according to their current replacement costs in preference to the historical cost accounting (employed in our study which is also the general practice in the industry). He has applied the technique to a hypothetical textile firm and observed significant improvement in its financial stability. Hence, as a future area of research it would be extremely interesting to apply such a technique to the system under this present study in order to observe the changes in its overall performance.

Finally the capacity acquisition process was found to be sensitive to errors in the demand forecasts. Therefore, it would be extremely worthwhile to attempt to re-design the process in order to desensitise it against such errors.

APPENDIX A

LIST OF COMPUTER PROGRAMME OF THE BASIC MODEL

```
DOC
DIM
* A CORPORATE MODEL FOR A PETROCHEMICAL COMPANY
NOTE
NOTE
NOTE FILE NAME ANSARI
NOTE A COPY OF THIS MODEL IS STORED IN THE ARCHIVE OF
NOTE SYSTEM DYNAMICS RESEARCH GROUP ,
NOTE UNIVERSITY OF BRADFORD , MANAGEMENT CENTRE ,
NOTE EMM LANE , BD9 4JL , TEL 42299 STD 0274
NOTE
NOTE
NOTE ******************************************************************
NOTE PRODUCT DEMAND SECTOR
NOTE ******************************************************************
NOTE
NOTE
A ADGF,K=EXP(RGDM*TIME,K)*(1+AMP*SIN(6,283*(TIME,K+7)/PERD))
N RGDM=,03/12
C AMP=,055
C PERD=48
A TERP,K=LDPED,K*ETOLD+HDPED.K*ETOHD+PSD,K*STOPS*ETOS+PVCD,K*VCTOPV
X        *ETOVC
A ED,K=LDPED,K*ETOLD+HDPED,K*ETOHD+VCMD,K*ETOVC+SD,K*ETOS+BED*ADGF,K
N BED=AEECU*EBCAP*EY-((LDPED*ETOLD+HDPED*ETOHD)+(VCMD*ETOVC+SD*ETOS))
C AEECU=,9
A PD,K=PPD,K*PTOPP+BPRD*ADGF.K
N BPRD=AEPCU*EBCAP*PY-PPD*PTOPP
C AEPCU=,87
A BD,K=BBD*ADGF,K
N BBD=AEBCU*EBCAP*BY
C AEBCU=,9
A TBD,K=ED,K+PD,K+BD,K
A TBDY,K=CLIP(ED,K,EPRAT*PD.K,EPRAT,ED,K/PD,K)*EPBTOE
N EPBTOE=(EY+PY+BY)/EY
A VCMD,K=PVCD,K*VCTOPV+BVCMD*ADGF,K
N BVCMD=AEVCU*EVCCAP-PVCD*VCTOPV
C AEVCU=,9
A SD,K=PSD,K*STOPS+BSD*ADGF.K
N BSD=AESCU*ESCAP-PSD*STOPS
C AESCU=,87
A TID,K=VCMD,K+SD.K
A LDPED,K=BLDPED*LDMUL,K*ADGF,K
N BLDPED=AELDCU*ELDCAP
C AELDCU=,94
A LDMUL,K=TABHL(TLDMUL,TIME.K,0,132,132)
T TLDMUL=1/.9655
A HDPED,K=BHDPED*HDMUL.K*ADGF.K
N BHDPED=AEHDCU*EHDCAP
C AEHDCU=.72
A HDMUL,K=TABHL(THDMUL,TIME.K,0,132,132)
T THDMUL=1/1,1865
A PVCD,K=BPVCD*PVMUL,K*ADGF,K
N BPVCD=AEPVCU*EPVCAP
C AEPVCU=,93
A PVMUL,K=TABHL(TPVMUL,TIME.K,0,132,132)
T TPVMUL=1/1
```

```
A PSD.K=BPSD*PSMUL,K*ADGF.K
N BPSD=AEPSCU*EPSCAP
C AEPSCU=,77
A PSMUL,K=TABHL(TPSMUL,TIME.K,0,132,132)
T TPSMUL=1/.9197
A PPD.K=BPPD*PPMUL,K*ADGF.K
N BPPD=AEPPCU*EPPCAP
C AEPPCU=,7
A PPMUL,K=TABHL(TPPMUL,TIME.K,0,132,132)
T TPPMUL=1/1,5556
A TFD.K=LDPED,K+HDPED.K+PVCD.K+PSD,K+PPD.K
NOTE
NOTE
NOTE *********************************************************
NOTE FORWARD PLANNING -NECESSARY CAPACITY FORECASTS SECTOR
NOTE *********************************************************
NOTE
NOTE
A FNCGF,K=EXP(RGDM*RGDMEB*(PHOR+TIME,K))*(1+AMP)
C RGDMEB=1
A NE,K=NLD,K*ETOLD+NHD.K*ETOHD+NVC,K*ETOVC+NS.K*ETOS+BED*
X       FNCGF,K
A NP,K=NPP.K*PTOPP+BPRD*FNCGF.K
A NVC.K=NPV.K*VCTOPV+BVCMD*FNCGF.K
A NS,K=NPS.K*STOPS+BSD*FNCGF.K
A NLD.K=BLDPED*LDMULP.K*FNCGF.K
A LDMULP.K=TABHL(TLDMUL,TIME.K+PHOR,0,132,132)
A NHD.K=BHDPED*HDMULP.K*FNCGF.K
A HDMULP,K=TABHL(THDMUL,TIME.K+PHOR,0,132,132)
A NPV,K=BPVCD*PVMULP,K*FNCGF.K
A PVMULP,K=TABHL(TPVMUL,TIME.K+PHOR,0,132,132)
A NPS.K=BPSD*PSMULP,K*FNCGF.K
A PSMULP,K=TABHL(TPSMUL,TIME.K+PHOR,0,132,132)
A NPP.K=BPPD*PPMULP,K*FNCGF.K
A PPMULP,K=TABHL(TPPMUL,TIME.K+PHOR,0,132,132)
C PHOR=60
NOTE
NOTE
NOTE *********************************************************
NOTE CURRENT PRODUCTION CAPACITY SECTOR
NOTE *********************************************************
NOTE
NOTE
L BCAP,K=BCAP,J+DT*(BCCR,JK-BCDR,JK)
N BCAP=7887E3/12
A EBCAP,K=BCAP.K*MFCUR
A EBCAPE,K=EBCAP,K*TYEPB
N TYEPB=EY+PY+BY
R BCDR,KL=BCAP,K/LTPP
C LTPP=204
L ABCDR,K=ABCDR.J+(DT/TAPCDR)*(BCDR.JK-ABCDR.J)
N ABCDR=BCDR
C TAPCDR=3
L VCCAP,K=VCCAP.J+DT*(VCCCR.JK-VCCDR.JK)
N VCCAP=375E3/12
A EVCCAP.K=VCCAP,K*MFCUR
R VCCDR,KL=VCCAP,K/LTPP
```

```
L AVCCDR,K=AVCCDR.J+(DT/TAPCDR)*(VCCDR,JK-AVCCDR,J)
N AVCCDR=VCCDR
L SCAP,K=SCAP,J+DT*(SCCR.JK-SCDR.JK)
N SCAP=830E3/12
A ESCAP,K=SCAP.K*MFCUR
R SCDR.KL=SCAP,K/LTPP
L ASCDR,K=ASCDR.J+(DT/TAPCDR)*(SCDR.JK-ASCDR,J)
N ASCDR=SCDR
A ICAP,K=VCCAP,K+SCAP.K
A EICAP,K=ICAP,K*MFCUR
R ICDR.KL=ICAP,K/LTPP
L LDCAP.K=LDCAP,J+DT*(LDCCR.JK-LDCDR,JK)
N LDCAP=1005E3/12
A ELDCAP,K=LDCAP.K*MFCUR
R LDCDR,KL=LDCAP,K/LTPP
L ALDCDR,K=ALDCDR.J+(DT/TAPCDR)*(LDCDR,JK-ALDCDR.J)
N ALDCDR=LDCDR
L HDCAP.K=HDCAP.J+DT*(HDCCR.JK-HDCDR,JK)
N HDCAP=215E3/12
A EHDCAP,K=HDCAP,K*MFCUR
R HDCDR,KL=HDCAP,K/LTPP
L AHDCDR,K=AHDCDR.J+(DT/TAPCDR)*(HDCDR,JK-AHDCDR.J)
N AHDCDR=HDCDR
L PVCAP,K=PVCAP,J+DT*(PVCCR.JK-PVCDR.JK)
N PVCAP=325E3/12
A EPVCAP,K=PVCAP,K*MFCUR
R PVCDR.KL=PVCAP,K/LTPP
L APVCDR,K=APVCDR.J+(DT/TAPCDR)*(PVCDR,JK-APVCDR,J)
N APVCDR=PVCDR
L PSCAP,K=PSCAP,J+DT*(PSCCR.JK-PSCDR,JK)
N PSCAP=130E3/12
A EPSCAP,K=PSCAP,K*MFCUR
R PSCDR,KL=PSCAP.K/LTPP
L APSCDR,K=APSCDR.J+(DT/TAPCDR)*(PSCDR,JK-APSCDR,J)
N APSCDR=PSCDR
L PPCAP.K=PPCAP.J+DT*(PPCCR.JK-PPCDR,JK)
N PPCAP=397E3/12
A EPPCAP.K=PPCAP,K*MFCUR
R PPCDR,KL=PPCAP.K/LTPP
L APPCDR,K=APPCDR.J+(DT/TAPCDR)*(PPCDR,JK-APPCDR,J)
N APPCDR=PPCDR
A FCAP,K=LDCAP,K+HDCAP.K+PVCAP.K+PSCAP,K+PPCAP,K
A EFCAP,K=FCAP,K*MFCUR
R FCDR,KL=FCAP,K/LTPP
NOTE
NOTE
NOTE ********************************************************************
NOTE FORWARD PLANNING -CAPACITY REQUIREMENTS SECTOR
NOTE ********************************************************************
NOTE
NOTE
N EPTOE=(EY+PY)/EY
C EY=,31
C PY=,16
C BY=,05
C GY=,21
C LPGY=,25
```

```
C FY=.01
C LOSS=,01
C ETOS=,307
C ETOVC=,485
C ETOLD=1.03
C ETOHD=1,02
C VCTOPV=1,01
C STOPS=1,05
C PTOPP=1,096
A DE,K=(NE.K-EY*EBCAP.K)/MFCUR+EY*ABCDR.K*(DMINTB+CDELBP)-EY*BCAPOR.K
A DP,K=(NP.K-PY*EBCAP.K)/MFCUR+PY*ABCDR.K*(DMINTB+CDELBP)-PY*BCAPOR.K
C MFCUR=,8
C DMINTB=12
A DC,K=CLIP(DE.K,EPRAT*DP.K,EPRAT,DE.K/DP.K)/EY
N EPRAT=EY/PY
A DVC.K=(NVC.K-EVCCAP.K)/MFCUR+AVCCDR.K*(DMINTIF+CDELVC)-VCCAPOR.K
C DMINTIF=24
A DS,K=(NS.K-ESCAP.K)/MFCUR+ASCDR.K*(DMINTIF+CDELS)-SCAPOR.K
A DLD.K=(NLD.K-ELDCAP.K)/MFCUR+ALDCDR.K*(DMINTIF+CDELLD)-LDCAPOR.K
A DHD.K=(NHD.K-EHDCAP.K)/MFCUR+AHDCDR.K*(DMINTIF+CDELHD)-HDCAPOR.K
A DPV.K=(NPV.K-EPVCAP.K)/MFCUR+APVCDR.K*(DMINTIF+CDELPV)-PVCAPOR.K
A DPS.K=(NPS.K-EPSCAP.K)/MFCUR+APSCDR.K*(DMINTIF+CDELPS)-PSCAPOR.K
A DPP.K=(NPP.K-EPPCAP.K)/MFCUR+APPCDR.K*(DMINTIF+CDELPP)-PPCAPOR.K
A TROBCAP.K=DC.K/DMINTB
A TROVCCAP.K=DVC.K/DMINTIF
A TROSCAP.K=DS.K/DMINTIF
A TROICAP.K=TROVCCAP.K+TROSCAP.K
A TROLDCAP.K=DLD.K/DMINTIF
A TROHDCAP.K=DHD.K/DMINTIF
A TROPVCAP.K=DPV.K/DMINTIF
A TROPSCAP.K=DPS.K/DMINTIF
A TROPPCAP.K=DPP.K/DMINTIF
A TROFCAP.K=TROLDCAP.K+TROHDCAP.K+TROPVCAP.K+TROPSCAP.K+TROPPCAP.K
NOTE
NOTE
NOTE ********************************************************************
NOTE FORWARD PLANNING -SPENDING REQUIREMENTS SECTOR
NOTE ********************************************************************
NOTE
NOTE
A TIWC.K=MAX(0,(WCAPR.K-WCAP.K)/TAWC)
N TAWC=DT
A ECP.K=(RMCNP.K-MCNP.K)/TIMR
N TIMR=DT
L CECP.K=CECP.J+DT*ECP.J
N CECP=0
A RRSB.K=TROBCAP.K*EY*CCC*OII.K
A RRSI.K=(TROVCCAP.K*CCVCMC+TROSCAP.K*CCSC)*OII.K
A RRSF.K=(TROLDCAP.K*CCLDPEC+TROHDCAP.K*CCHDPEC+TROPVCAP.K*
X         CCPVCC+TROPSCAP.K*CCPSC+TROPPCAP.K*CCPPC)*OII.K
A RRS.K=RRSB.K+RRSI.K+RRSF.K
L CRS.K=CRS.J+DT*RRS.J
N CRS=0
NOTE
NOTE
NOTE ********************************************************************
NOTE IMPLEMENTATION OF PLANNING DECISIONS SECTOR
```

```
NOTE *******************************************************************
NOTE
NOTE
A FRAT.K=ARS.K/(RRS.K+CLIP(0,1,RRS.K,.1))
A FPMULT.K=TABHL(TFPMULT,FRAT.K,0,2,.5)
N FPMULT=1
T TFPMULT=0/.65/1/1/1
A IFRAT.K=(FREXP.K-ARWC.K-ECP.K)/RRS.K
A ARWC.K=TIWC.K
R RIPC.KL=MAX(MIN(SCDIFF.K,MAXIPC.K),0)
R BCSR.KL=TROBCAP.K*FPMULT.K
R VCCSR.KL=TROVCCAP.K*FPMULT.K
R SCSR.KL=TROSCAP.K*FPMULT.K
R ICSR.KL=VCCSR.KL+SCSR.KL
R LDCSR.KL=TROLDCAP.K*FPMULT.K
R HDCSR.KL=TROHDCAP.K*FPMULT.K
R PVCSR.KL=TROPVCAP.K*FPMULT.K
R PSCSR.KL=TROPSCAP.K*FPMULT.K
R PPCSR.KL=TROPPCAP.K*FPMULT.K
R FCSR.KL=LDCSR.KL+HDCSR.KL+PVCSR.KL+PSCSR.KL+PPCSR.KL
A RCMTNP.K=(BCSR.KL*EY*CCC
X          +(SCSR.KL*CCSC+VCCSR.KL*CCVCMC)
X          +(LDCSR.KL*CCLDPEC+HDCSR.KL*CCHDPEC+PVCSR.KL*CCPVCC
X          +PSCSR.KL*CCPSC+PPCSR.KL*CCPPC))*OII.K
NOTE
NOTE
NOTE *******************************************************************
NOTE CAPACITY CONSTRUCTION PIPELINE SECTOR
NOTE *******************************************************************
NOTE
NOTE
L BCAPOR.K=BCAPOR.J+DT*(BCSR.JK-BCCR.JK)
N BCAPOR=(((NE-EY*EBCAP)/MFCUR+EY*ABCDR*(DMINTB+CDELBP))/
X        (EY*(DMINTB+CDELBP)))*CDELBP
R BCCR.KL=DELAY3(BCSR.JK,CDELBP)
C CDELBP=43.2694
L VCCAPOR.K=VCCAPOR.J+DT*(VCCSR.JK-VCCCR.JK)
N VCCAPOR=(((NVC-EVCCAP)/MFCUR+AVCCDR*(DMINTIF+CDELVC))/
X         (DMINTIF+CDELVC))*CDELVC
R VCCCR.KL=DELAY3(VCCSR.JK,CDELVC)
C CDELVC=31.6288
L SCAPOR.K=SCAPOR.J+DT*(SCSR.JK-SCCR.JK)
N SCAPOR=(((NS-ESCAP)/MFCUR+ASCDR*(DMINTIF+CDELS))/
X        (DMINTIF+CDELS))*CDELS
R SCCR.KL=DELAY3(SCSR.JK,CDELS)
C CDELS=31.6729
A ICAPOR.K=VCCAPOR.K+SCAPOR.K
R ICCR.KL=VCCCR.KL+SCCR.KL
L LDCAPOR.K=LDCAPOR.J+DT*(LDCSR.JK-LDCCR.JK)
N LDCAPOR=(((NLD-ELDCAP)/MFCUR+ALDCDR*(DMINTIF+CDELLD))/
X         (DMINTIF+CDELLD))*CDELLD
R LDCCR.KL=DELAY3(LDCSR.JK,CDELLD)
C CDELLD=31.6794
L HDCAPOR.K=HDCAPOR.J+DT*(HDCSR.JK-HDCCR.JK)
N HDCAPOR=(((NHD-EHDCAP)/MFCUR+AHDCDR*(DMINTIF+CDELHD))/
X         (DMINTIF+CDELHD))*CDELHD
R HDCCR.KL=DELAY3(HDCSR.JK,CDELHD)
```

```
C CDELHD=31.5143
L PVCAPOR.K=PVCAPOR.J+DT*(PVCSR.JK-PVCCR.JK)
N PVCAPOR=(((NPV-EPVCAP)/MFCUR+APVCDR*(DMINTIF+CDELPV))/
X          (DMINTIF+CDELPV))*CDELPV
R PVCCR.KL=DELAY3(PVCSR.JK,CDELPV)
C CDELPV=31.6372
L PSCAPOR.K=PSCAPOR.J+DT*(PSCSR.JK-PSCCR.JK)
N PSCAPOR=(((NPS-EPSCAP)/MFCUR+APSCDR*(DMINTIF+CDELPS))/
X          (DMINTIF+CDELPS))*CDELPS
R PSCCR.KL=DELAY3(PSCSR.JK,CDELPS)
C CDELPS=31.8529
L PPCAPOR.K=PPCAPOR.J+DT*(PPCSR.JK-PPCCR.JK)
N PPCAPOR=(((NPP-EPPCAP)/MFCUR+APPCDR*(DMINTIF+CDELPP))/
X          (DMINTIF+CDELPP))*CDELPP
R PPCCR.KL=DELAY3(PPCSR.JK,CDELPP)
C CDELPP=31.2262
A FCAPOR.K=LDCAPOR.K+HDCAPOR.K+PVCAPOR.K+PSCAPOR.K+PPCAPOR.K
R FCCR.KL=LDCCR.KL+HDCCR.KL+PVCCR.KL+PSCCR.KL+PPCCR.KL
NOTE
NOTE
NOTE *******************************************************************
NOTE PRICES ,AMORTIZATION AND RETURN , AND PRODUCTION COSTS SECTOR
NOTE *******************************************************************
NOTE
NOTE
A DIFF.K=BY*(PB.K-MKTPB.K)/(EY+PY)
A PE.K=BPE*(FE*COPI.K+(ONE-FE)*OII.K)
C BPE=900
C ONE=1
C FE=.5
A PPE.K=ETOEP*(FWDV*(WDVC.K+AWCAPRB.K)+DEPPC*WDVC.K)/(EBCAP.K*EY)
N ETOEP=EY/(EY+PY)
A CPTE.K=PE.K+DIFF.K-PPE.K
A PPR.K=BPP*(FP*COPI.K+(ONE-FP)*OII.K)
C BPP=648
C FP=.5
A PPPR.K=(ONE-ETOEP)*(FWDV*(WDVC.K+AWCAPRB.K)+DEPPC*WDVC.K)/(EBCAP.K*PY
X         )
A CPTP.K=PPR.K+DIFF.K-PPPR.K
A PB.K=BPB*(FB*COPI.K+(ONE-FB)*OII.K)
C BPB=792
C FB=.5
A MKTPB.K=PB.K*PMB.K
A APG.K=BPG*COPI.K
C BPG=384
A APLPG.K=BPLPG*COPI.K
C BPLPG=360
A APF.K=BPF*COPI.K
C BPF=192
A PVCM.K=BPVCM*(FVCM*COPI.K+(ONE-FVCM)*OII.K)
C BPVCM=792
C FVCM=.35
A PPVCM.K=(FWDV*(WDVVCM.K+ACPTVC.K*VCTPUT.K*COVER)+DEPPC*WDVVCM.K)
X          /EVCCAP.K
N PPVCM=(FWDV*(WDVVCM+PVCM*VCTPUT*COVER)+DEPPC*WDVVCM)
X        /(EVCCAP+FWDV*VCTPUT*COVER)
A CPTVCM.K=PVCM.K-PPVCM.K
```

```
L ACPTVC,K=ACPTVC.J+(DT/TAC)*(CPTVCM,J-ACPTVC,J)
N ACPTVC=CPTVCM
C TAC=2
A PST,K=BPS*(FS*COPI,K+(ONE-FS)*OII.K)
C BPS=1008
C FS=.4
A PPST,K=(FWDV*(WDVS,K+ACPTS.K*STPUT,K*COVER)+DEPPC*WDVS,K)
X        /ESCAP.K
N PPST=(FWDV*(WDVS+PST*STPUT*COVER)+DEPPC*WDVS)
X      /(ESCAP+FWDV*STPUT*COVER)
A CPTS,K=PST,K-PPST.K
L ACPTS,K=ACPTS,J+(DT/TAC)*(CPTS,J-ACPTS.J)
N ACPTS=CPTS
A PLDPE,K=BPLDPE*(FLDPE*COPI.K+(ONE-FLDPE)*OII,K)
C BPLDPE=1512
C FLDPE=,29
A PPLDPE,K=(FWDV*(WDVLDPE.K+ACPTLD,K*LDTPUT,K*COVER)+DEPPC*WDVLDPE.K)
X          /ELDCAP,K
N PPLDPE=(FWDV*(WDVLDPE+PLDPE*LDTPUT*COVER)+DEPPC*WDVLDPE)
X        /(ELDCAP+FWDV*LDTPUT*COVER)
A CPTLDPE,K=PLDPE.K-PPLDPE.K
L ACPTLD,K=ACPTLD.J+(DT/TAC)*(CPTLDPE,J-ACPTLD.J)
N ACPTLD=CPTLDPE
A PHDPE,K=BPHDPE*(FHDPE*COPI.K+(ONE-FHDPE)*OII,K)
C BPHDPE=1584
C FHDPE=,29
A PPHDPE,K=(FWDV*(WDVHDPE.K+ACPTHD,K*HDTPUT,K*COVER)+DEPPC*WDVHDPE.K)
X          /EHDCAP,K
N PPHDPE=(FWDV*(WDVHDPE+PHDPE*HDTPUT*COVER)+DEPPC*WDVHDPE)
X        /(EHDCAP+FWDV*HDTPUT*COVER)
A CPTHDPE,K=PHDPE.K-PPHDPE,K
L ACPTHD,K=ACPTHD.J+(DT/TAC)*(CPTHDPE,J-ACPTHD,J)
N ACPTHD=CPTHDPE
A PPVC,K=BPPVC*(FPVC*COPI.K+(ONE-FPVC)*OII,K)
C BPPVC=1272
C FPVC=,28
A PPPVC,K=(FWDV*(WDVPVC.K+ACPTPV.K*PVTPUT.K*COVER)+DEPPC*WDVPVC,K)
X         /EPVCAP.K
N PPPVC=(FWDV*(WDVPVC+PPVC*PVTPUT*COVER)+DEPPC*WDVPVC)
X       /(EPVCAP+FWDV*PVTPUT*COVER)
A CPTPVC,K=PPVC,K-PPPVC.K
L ACPTPV,K=ACPTPV.J+(DT/TAC)*(CPTPVC,J-ACPTPV,J)
N ACPTPV=CPTPVC
A PPS.K=BPPS*(FPS*COPI.K+(ONE-FPS)*OII,K)
C BPPS=1440
C FPS=,28
A PPPS,K=(FWDV*(WDVPS.K+ACPTPS.K*PSTPUT,K*COVER)+DEPPC*WDVPS.K)
X        /EPSCAP,K
N PPPS=(FWDV*(WDVPS+PPS*PSTPUT*COVER)+DEPPC*WDVPS)
X      /(EPSCAP+FWDV*PSTPUT*COVER)
A CPTPS,K=PPS,K-PPPS,K
L ACPTPS,K=ACPTPS.J+(DT/TAC)*(CPTPS.J-ACPTPS,J)
N ACPTPS=CPTPS
A PPP.K=BPPP*(FPP*COPI.K+(ONE-FPP)*OII,K)
C BPPP=1512
C FPP=,29
A PPPP,K=(FWDV*(WDVPP.K+ACPTPP.K*PPTPUT,K*COVER)+DEPPC*WDVPP,K)
```

```
X        /EPPCAP,K
N PPPP=(FWDV*(WDVPP+PPP*PPTPUT*COVER)+DEPPC*WDVPP)
X      /(EPPCAP+FWDV*PPTPUT*COVER)
A CPTPP,K=PPP,K-PPPP.K
L ACPTPP,K=ACPTPP.J+(DT/TAC)*(CPTPP,J-ACPTPP,J)
N ACPTPP=CPTPP
L COPI,K=COPI,J+DT*(COPI,J*COPR)
N COPR=,11/12
N COPI=1
L OII.K=OII.J+DT*(OII.J*OIR)
N OIR=,11/12
N OII=1
N FWDV=,17/12
NOTE
NOTE
NOTE *********************************************************************
NOTE PRODUCTION PLANNING SECTOR
NOTE *********************************************************************
NOTE
NOTE
A BTPUT,K=MIN(CLIP(ED.K,EPRAT*PD,K,EPRAT,ED,K/PD,K)/EY,EBCAP,K)
A EOCU,K=TYEPB*BTPUT,K/EBCAPE.K
A VCTPUT,K=MIN(CLIP(VCMD,K,CLIP(PVCD,K*VCTOPV+(BVCMD*ETOVC/(BVCMD*
X           ETOVC+BSD*ETOS))*(BTPUT.K*EY-TERP,K)/ETOVC,((PVCD,K*
X           VCTOPV*ETOVC/TERP.K)*BTPUT,K*EY)/ETOVC,BTPUT,K*EY,
X           TERP,K),BTPUT.K*EY,ED,K-BED*ADGF,K),EVCCAP,K)
A STPUT,K=MIN(CLIP(SD.K,CLIP(SD,K*STOPS+(BSD*ETOS/(BVCMD*ETOVC+
X          BSD*ETOS))*(BTPUT.K*EY-TERP,K)/ETOS,((PSD,K*STOPS*
X          ETOS/TERP,K)*BTPUT.K*EY)/ETOS,BTPUT.K*EY,TERP,K),
X          BTPUT,K*EY,ED,K-BED*ADGF.K),ESCAP,K)
A ITPUT,K=VCTPUT.K+STPUT.K
A EICU,K=ITPUT.K/EICAP,K
A LDTPUT,K=MIN(MIN((LDPED.K*ETOLD/TERP,K)*BTPUT.K*EY/ETOLD,
X           LDPED.K),ELDCAP.K)
A HDTPUT,K=MIN(MIN((HDPED.K*ETOHD/TERP,K)*BTPUT,K*EY/ETOHD,
X           HDPED.K),EHDCAP.K)
A PVTPUT,K=MIN(MIN(VCTPUT.K/VCTOPV,PVCD.K),EPVCAP.K)
A PSTPUT,K=MIN(MIN(STPUT.K/STOPS,PSD.K),EPSCAP.K)
A PPTPUT,K=MIN(MIN(BTPUT,K*PY/PTOPP,PPD.K),EPPCAP,K)
A FTPUT,K=LDTPUT,K+HDTPUT.K+PVTPUT,K+PSTPUT.K+PPTPUT,K
A EPCU,K=FTPUT.K/EFCAP,K
A CHECKM,K=(BTPUT.K*EY-(ESOLD.K+VCSOLD,K*ETOVC+SSOLD,K*ETOS+LDTPUT.K
X          *ETOLD+HDTPUT.K*ETOHD+PVTPUT.K*VCTOPV*ETOVC+PSTPUT.K*
X          STOPS*ETOS))+(BTPUT.K*PY-(PSOLD,K+PPTPUT,K*PTOPP))
NOTE
NOTE
NOTE *********************************************************************
NOTE WORKING CAPITAL AND ACTUAL PRODUCTION SECTOR
NOTE *********************************************************************
NOTE
NOTE
L WCAP.K=WCAP,J+DT*(ARWC.J-RRWC.JK)
N WCAP=WCAPR
A WCAPRB,K=(CPTE,K*EY+CPTP,K*PY+MKTPB,K*BY
X         +APG,K*GY+APLPG.K*LPGY+APF.K*FY)*BTPUT.K*COVER
N WCAPRB=((EY*(PE+DIFF)+PY*(PPR+DIFF)-WDVC*(FWDV+DEPPC)/EBCAP
X        +MKTPB*BY+APG*GY+APLPG*LPGY+APF*FY)*BTPUT*COVER)/(1+
```

```
X        FWDV*BTPUT*COVER/EBCAP)
L AWCAPRB,K=AWCAPRB.J+(DT/TAW)*(WCAPRB,J-AWCAPRB,J)
N AWCAPRB=WCAPRB
C TAW=2
A WCAPR,K=WCAPRB,K+((CPTVCM.K*VCTPUT,K+CPTS.K*STPUT.K)+(CPTLDPE.K
X         *LDTPUT.K+CPTHDPE.K*HDTPUT,K+CPTPVC,K*PVTPUT.K+
X         CPTPS,K*PSTPUT.K+CPTPP.K*PPTPUT.K))*COVER
C COVER=2
A WCRAT,K=WCAP,K/WCAPR.K
R RRWC,KL=((WCAP,K-WCAPR.K)/TRWC)*CLIP(ONE,0,WCRAT,K,WCRCV)
C WCRCV=1,2
C TRWC=3
NOTE
NOTE
NOTE **********************************************************************
NOTE SALES, PROFIT AND CASHFLOW SECTOR
NOTE **********************************************************************
NOTE
NOTE
A ESOLD,K=MAX(0,BTPUT.K*EY-(LDTPUT.K*ETOLD+HDTPUT.K*
X          ETOHD+VCTPUT.K*ETOVC+STPUT,K*ETOS))
A PSOLD,K=MAX(0,BTPUT.K*PY-PPTPUT,K*PTOPP)
A VCSOLD,K=MAX(0,VCTPUT,K-PVTPUT.K*VCTOPV)
A SSOLD,K=MAX(0,STPUT.K-PSTPUT.K*STOPS)
A PME.K=TABHL(TPME,(TBDY,K*EY/TYEPB)/(BCAP,K*EY),.5,1.1,,1)
T TPME=0/,77/,97/1/1,03/1.23/2
A PMP,K=TABHL(TPMP,(TBDY.K*PY/TYEPB)/(BCAP,K*PY),,5,1,1,,1)
T TPMP=0/,57/,87/1/1,13/1.43/2
A PMB.K=TABHL(TPMB,(TBDY,K*BY/TYEPB)/(BCAP.K*BY),.5,1.1,,1)
T TPMB=,8/,854/,92/1/1.08/1.146/1,2
A PMVCM,K=TABHL(TPMVCM,VCMD.K/VCCAP.K,,5,1,1,,1)
T TPMVCM=0/.57/,87/1/1,13/1.43/2
A PMS.K=TABHL(TPMS,SD.K/SCAP.K,,5,1,1,,1)
T TPMS=0/,27/,6/1/1,4/1.73/2
A PMLDPE,K=TABHL(TPMLDPE,LDPED.K/LDCAP,K,.5,1,1,,1)
T TPMLDPE=0/.67/,9/1/1.1/1.33/2
A PMHDPE,K=TABHL(TPMHDPE,HDPED.K/HDCAP,K,.5,1,1,,1)
T TPMHDPE=0/,67/,9/1/1.1/1.33/2
A PMPVC,K=TABHL(TPMPVC,PVCD.K/PVCAP.K,,5,1.1,,1)
T TPMPVC=0/,67/,9/1/1.1/1.33/2
A PMPS,K=TABHL(TPMPS,PSD.K/PSCAP.K,,5,1,1,,1)
T TPMPS=0/,67/,9/1/1,1/1.33/2
A PMPP,K=TABHL(TPMPP,PPD.K/PPCAP.K,.5,1,1,,1)
T TPMPP=0/.67/.9/1/1,1/1.33/2
A GME,K=PPE.K*PME.K
A GMP.K=PPPR,K*PMP.K
A GMVCM,K=PPVCM.K*PMVCM.K
A GMS.K=PPST,K*PMS,K
A GMLDPE,K=PPLDPE.K*PMLDPE,K
A GMHDPE,K=PPHDPE.K*PMHDPE,K
A GMPVC,K=PPPVC.K*PMPVC.K
A GMPS,K=PPPS,K*PMPS,K
A GMPP,K=PPPP,K*PMPP,K
R PR,KL=BTPUT,K*EY*GME.K+BTPUT.K*PY*GMP.K+VCTPUT,K*GMVCM,K+
X       STPUT,K*GMS.K+LDTPUT.K*GMLDPE,K+HDTPUT.K*GMHDPE.K+PVTPUT.K*
X       GMPVC,K+PSTPUT.K*GMPS.K+PPTPUT,K*GMPP.K+IR*(CASH,K+MCNP,K)
N IR=.13/12
```

```
L CPGP,K=CPGP,J+DT*PR.JK
N CPGP=0
L APL.K=APL,J+(DT/TAP)*(PR.JK-APL,J)
N APL=PR
C TAP=3
A RP,K=MAX(0,(ONE-TAXDIV)*(PR.KL-DCFL.K))
C TAXDIV=.3
L ARP.K=ARP,J+(DT/TARP)*(RP.J-ARP,J)
N ARP=RP
C TARP=5
NOTE
NOTE
NOTE ******************************************************************
NOTE CASH GENERATION SECTOR
NOTE ******************************************************************
NOTE
NOTE
A DCFL,K=MAX(0,CLIP(DEPPC*WDV.K,PR,KL,PR.KL-DEPPC*WDV,K,0))
N DEPPC=1/120
L CDCFL,K=CDCFL.J+DT*(DEPPC*WDV,J-DCFL,J)
N CDCFL=0
L ADCFL,K=ADCFL,J+(DT/TADCFL)*(DCFL.J-ADCFL.J)
N ADCFL=DCFL
C TADCFL=3
A ACGR,K=ARP.K+ADCFL.K
L CACG,K=CACG,J+DT*ACGR,J
N CACG=0
A ARS.K=(MAXIPC.K+FREXP.K)-(ARWC.K+ECP,K)
A MAXIPC,K=MAXIPC80*OII.K
N MAXIPC80=5E8/12
A MINCASH,K=PC*WCAPR,K
C PC=,3
NOTE
NOTE
NOTE ******************************************************************
NOTE CAPITAL COST OF PLANTS SECTOR
NOTE ******************************************************************
NOTE
NOTE
C CCC=7680
C CCVCMC=3960
C CCSC=2760
C CCLDPEC=6000
C CCHDPEC=6000
C CCPVCC=4560
C CCPSC=4800
C CCPPC=9960
NOTE
NOTE
NOTE ******************************************************************
NOTE VALUATION OF THE COMPANY SECTOR
NOTE ******************************************************************
NOTE
NOTE
A TL,K=IPC.K+CRP,K
L IPC,K=IPC,J+DT*RIPC.JK
N IPC=4E9
```

```
L CRP.K=CRP,J+DT*RP,J
N CRP=2E9
L MCNP,K=MCNP,J+DT*(RCMTNP.J+ECP.J-RAVP.JK)
N MCNP=RMCNP
A RMCNP,K=(BCAPOR.K*EY*CCC+(VCCAPOR.K*CCVCMC+SCAPOR,K*CCSC)+
X          (LDCAPOR.K*CCLDPEC+HDCAPOR.K*CCHDPEC+PVCAPOR.K*CCPVCC
X          +PSCAPOR.K*CCPSC+PPCAPOR.K*CCPPC))*OII.K
A WDV.K=WDVC.K+WDVVCM.K+WDVS.K+WDVLDPE.K+WDVHDPE.K+WDVPVC.K
X       +WDVPS.K+WDVPP.K
R RAVP,KL=RAVC,KL+RAVVCMP.KL+RAVSP.KL+RAVLDPEP.KL+RAVHDPEP,KL+
X          RAVPVCP.KL+RAVPSP.KL+RAVPPP.KL
L WDVC,K=WDVC,J+DT*(RAVC,JK-WDVC,J*DEPPC)
N WDVC=BCAP*EY*CCC
R RAVC,KL=BCCR.KL*EY*CCC*OII.K
L WDVVCM.K=WDVVCM.J+DT*(RAVVCMP,JK-WDVVCM.J*DEPPC)
N WDVVCM=VCCAP*CCVCMC
R RAVVCMP.KL=VCCCR.KL*CCVCMC*OII.K
L WDVS.K=WDVS.J+DT*(RAVSP.JK-WDVS,J*DEPPC)
N WDVS=SCAP*CCSC
R RAVSP,KL=SCCR.KL*CCSC*OII.K
L WDVLDPE.K=WDVLDPE.J+DT*(RAVLDPEP.JK-WDVLDPE,J*DEPPC)
N WDVLDPE=LDCAP*CCLDPEC
R RAVLDPEP.KL=LDCCR.KL*CCLDPEC*OII.K
L WDVHDPE.K=WDVHDPE.J+DT*(RAVHDPEP.JK-WDVHDPE,J*DEPPC)
N WDVHDPE=HDCAP*CCHDPEC
R RAVHDPEP.KL=HDCCR.KL*CCLDPEC*OII.K
L WDVPVC.K=WDVPVC.J+DT*(RAVPVCP.JK-WDVPVC.J*DEPPC)
N WDVPVC=PVCAP*CCPVCC
R RAVPVCP.KL=PVCCR.KL*CCPVCC*OII.K
L WDVPS.K=WDVPS.J+DT*(RAVPSP.JK-WDVPS,J*DEPPC)
N WDVPS=PSCAP*CCPSC
R RAVPSP,KL=PSCCR.KL*CCPSC*OII.K
L WDVPP.K=WDVPP.J+DT*(RAVPPP.JK-WDVPP,J*DEPPC)
N WDVPP=PPCAP*CCPPC
R RAVPPP,KL=PPCCR.KL*CCPPC*OII.K
NOTE
NOTE
NOTE *****************************************************************
NOTE BALANCE SHEET SECTOR
NOTE *****************************************************************
NOTE
NOTE
A FREXP.K=ACGR.K+(CASH.K-MINCASH.K)/PHOR
R RSC.KL=RCMTNP.K+ARWC.K+ECP.K
L CASH.K=CASH.J+DT*(RP.J+DCFL.J+RRWC.JK+RIPC.JK-RSC.JK)
N CASH=TL-(WDV+WCAP+MCNP)
A SCDIFF.K=RSC.KL-FREXP.K
A TA.K=WDV.K+WCAP.K+CASH.K+MCNP.K
A CHECKF.K=TA.K+CDCFL.K-TL.K
NOTE
NOTE
NOTE *****************************************************************
NOTE PERFORMANCE INDEX SECTOR
NOTE *****************************************************************
NOTE
NOTE
A ROI.K=((APL.K-ADCFL.K)*MPY)/TA.K
```

```
C MPY=12
NOTE
NOTE
NOTE ******************************************************************
NOTE OUTPUT CONTROL SECTOR
NOTE ******************************************************************
NOTE
NOTE
A PRTPER.K=1+STEP(9,11)
SPEC DT=.5/LENGTH=240/PLTPER=1
PLOT TBDY=6,EBCAPE=1,TID=5,EICAP=I,TFD=5,EFCAP=F(0,5E5)
PLOT EOCU=E,EICU=I,EPCU=C(0,1)
PLOT RAVP=R(0,6E8)/WCAP=W,CASH=C,IPC=I(0,25E9)/IFRAT=F(0,10)
X    /ROI=%(0,.2)
PRINT 1)TBD,TBDY,EBCAPE,BTPUT,EBCAP,BCAP,DE,DP,TROBCAP,BCSR,
X        BCCR,BCDR,BCAPOR,TID,ITPUT,EICAP,ICAP,TROICAP
PRINT 2)ICSR,ICCR,ICDR,ICAPOR,TFD,FTPUT,EFCAP,FCAP,TROFCAP,FCSR
X        ,FCCR,FCDR,FCAPOR
PRINT 3)PR,APL,RP,DCFL,ACGR,ROI,ARS,RRS,FRAT,FPMULT,RCMTNP,ECP,RMCNP,
X        ,MCNP,FREXP,RSC,SCDIFF,RIPC
PRINT 4)WCAP,WCAPR,RRWC,ARWC,WCRAT,IPC,CRP,TL,WDV,RAVP,CASH,CHECKF
PRINT 5)ESOLD,PSOLD,VCSOLD,SSOLD,LDTPUT,HDTPUT,PVTPUT,PSTPUT,PPTPUT,ED,
X        PD,BD,VCMD,SD,LDPED
PRINT 6)CPTE,PPE,GME,PME,CPTP,PPPR,GMP,PMP,PB,MKTPB,DIFF,PMB,CPTVCM,
X        PPVCM,GMVCM,PMVCM,CPTS,PPST
PRINT 7)GMS,PMS,CPTLDPE,PPLDPE,GMLDPE,PMLDPE,CPTHDPE,PPHDPE,GMHDPE,
X        PMHDPE,CPTPVC,PPPVC,GMPVC,PMPVC,CPTPS,PPPS,GMPS,PMPS
PRINT 8)CPTPP,PPPP,GMPP,PMPP,CECP,CRS,CACG,CPGP,IFRAT,CHECKM
RUN BASIC MODEL
NOTE
NOTE
NOTE ******************************************************************
NOTE VARIABLE DEFINITIONS
NOTE ******************************************************************
NOTE
NOTE
D ABCDR=((T/M)/M) AVERAGE RATE OF DECAY OF BASIC PRODUCT CAPACITY
D ACGR=($/M) ACTUAL CASH GENERATION RATE
D ACPTHD=($/T) AVERAGE CPTHDPE
D ACPTLD=($/T) AVERAGE CPTLDPE
D ACPTPP=($/T) AVERAGE CPTPP
D ACPTPS=($/T) AVERAGE CPTPS
D ACPTPV=($/T) AVERAGE CPTPVC
D ACPTS=($/T) AVERAGE CPTS
D ACPTVC=($/T) AVERAGE CPTVCM
D ADCFL=($/M) AVERAGE DEPRECIATION CASHFLOW
D ADGF=(1) ACTUAL PETROCHEMICAL DEMAND GROWTH FACTOR
D AEBCU=(1) AVERAGE WESTERN EUROPEAN EFFECTIVE BUTADIENE CAPACITY
X           UTILIZATION IN 1979
D AEECU=(1) AVERAGE WESTERN EUROPEAN EFFECTIVE ETHYLENE CAPACITY
X           UTILIZATION IN 1979
D AEHDCU=(1) AVERAGE WESTERN EUROPEAN EFFECTIVE HIGH-DENSITY
X            POLYETHYLENE CAPACITY UTILIZATION IN 1979
D AELDCU=(1) AVERAGE WESTERN EUROPEAN EFFECTIVE LOW-DENSITY
X            POLYETHYLENE CAPACITY UTILIZATION IN 1979
D AEPCU=(1) AVERAGE WESTERN EUROPEAN EFFECTIVE PROPYLENE CAPACITY
X           UTILIZATION IN 1979
```

```
D BSD=(T/M) BASE LEVEL OF NON-CAPTIVE DEMAND FOR STYRENE IN 1980
D BTPUT=(T/M) THROUGHPUT IN BASIC PRODUCT SECTOR
D BVCMD=(T/M) BASE LEVEL OF NON-CAPTIVE DEMAND FOR VINYL CHLORIDE IN
X           1980
D BY=(1) BUTADIENE YIELD PER TON OF NAPHTHA CRACKED
D CACG=($) CUMULATIVE ACTUAL CASH GENERATION
D CASH=($) CASH RESERVES OF COMPANY
D CCC=($/(T/M)) CAPITAL COST OF NAPHTHA CRACKER IN 1980
D CCHDPEC=($/(T/M)) CAPITAL COST OF HIGH-DENSITY POLYETHYLENE PLANT
X                   IN 1980
D CCLDPEC=($/(T/M)) CAPITAL COST OF LOW-DENSITY POLYETHYLENE PLANT
X                   IN 1980
D CCPPC=($/(T/M)) CAPITAL COST OF POLYPROPYLENE PLANT IN 1980
D CCPSC=($/(T/M)) CAPITAL COST OF POLYSTYRENE PLANT IN 1980
D CCPVCC=($/(T/M)) CAPITAL COST OF POLYVINYL CHLORIDE PLANT IN 1980
D CCSC=($/(T/M)) CAPITAL COST OF STYRENE PLANT IN 1980
D CCVCMC=($/(T/M)) CAPITAL COST OF VINYL CHLORIDE PLANT IN 1980
D CDCFL=($) CUMULATIVE DEPRECIATION CASHFLOW UNFULFILLED
D CDELBP=(M) CONSTRUCTION DELAY IN BASIC PRODUCT CAPACITY ADDITIONS
D CDELHD=(M) CONSTRUCTION DELAY IN HIGH-DENSITY POLYETHYLENE CAPACITY
X            ADDITIONS
D CDELLD=(M) CONSTRUCTION DELAY IN LOW-DENSITY POLYETHYLENE CAPACITY
X            ADDITIONS
D CDELPP=(M) CONSTRUCTION DELAY IN POLYPROPYLENE CAPACITY ADDITIONS
D CDELPV=(M) CONSTRUCTION DELAY IN POLYVINYL CHLORIDE CAPACITY ADDITION
D CDELPS=(M) CONSTRUCTION DELAY IN POLYSTYRENE CAPACITY ADDITIONS
D CDELS=(M) CONSTRUCTION DELAY IN STYRENE CAPACITY ADDITIONS
D CDELVC=(M) CONSTRUCTION DELAY IN VINYL CHLORIDE CAPACITY ADDITIONS
D CECP=($) CUMULATIVE ESCALATION IN COST OF PLANTS UNDER CONSTRUCTION
X          DUE TO INFLATION
D CHECKF=($) DIFFERENCE BETWEEN TOTAL ASSETS AND TOTAL LIABILITIES
D CHECKM=(T/M) CHECK TO MAKE SURE THAT THE MODEL DOES NOT LEAK OR
X              CREATE ANY PETROCHEMICAL MATERIAL
D COPI=(1) CRUDE OIL PRICE INFLATION INDEX
D COPR=(1/M) FORECAST AVERAGE RATE OF CRUDE OIL PRICE RISES
D COVER=(M) COVER OF PRODUCTION COST REQUIRED
D CPGP=($) CUMULATIVE PRETAX GROSS PROFITS
D CPTE=($/T) COST PER TON OF ETHYLENE PRODUCED
D CPTHDPE=($/T) COST PER TON OF HIGH-DENSITY POLYETHYLENE PRODUCED
D CPTLDPE=($/T) COST PER TON OF LOW-DENSITY POLYETHYLENE PRODUCED
D CPTP=($/T) COST PER TON OF PROPYLENE PRODUCED
D CPTPP=($/T) COST PER TON OF POLYPROPYLENE PRODUCED
D CPTPS=($/T) COST PER TON OF POLYSTYRENE PRODUCED
D CPTPVC=($/T) COST PER TON OF POLYVINYL CHLORIDE PRODUCED
D CPTS=($/T) COST PER TON OF STYRENE PRODUCED
D CPTVCM=($/T) COST PER TON OF VINYL CHLORIDE PRODUCED
D CRP=($) CUMULATIVE RETAINED PROFITS
D CRS=($) CUMULATIVE REQUIRED SPENDING ON NEW CAPITAL PROJECTS
D DC=(T/M) DESIRED NEW BASIC PRODUCT CAPACITY
D DCFL=($/M) DEPRECIATION CASH FLOW
D DE=(T/M) DESIRED NEW ETHYLENE CAPACITY
D DEPPC=(1/M) FRACTION OF VALUE OF PLANT ALLOWABLE FOR DEPRECIATION
D DHD=(T/M) DESIRED NEW HIGH-DENSITY POLYETYLENE CAPACITY
D DLD=(T/M) DESIRED NEW LOW-DENSITY POLYETHYLENE CAPACITY
D DIFF=($/T) LOSS OR GAIN OF THE SALE OF BUTADIENE TO BE ADDED TO
X            OR SUBTRACTED FROM THE PRICE OF ETHYLENE AND PROPYLENE
D DMINTB=(M) DECISION MAKING INTERVAL FOR BASIC PRODUCT CAPACITY
```

```
D DMINTIF=(M) DECISION-MAKING INTERVAL FOR INTERMEDIATE AND
X             FINAL PRODUCT CAPACITY
D DP=(T/M) DESIRED NEW PROPYLENE CAPACITY
D DPS=(T/M) DESIRED NEW POLYSTYRENE CAPACITY
D DPP=(T/M) DESIRED NEW POLYPROPYLENE CAPACITY
D DPV=(T/M) DESIRED NEW POLYVINYL CHLORIDE CAPACITY
D DS=(T/M) DESIRED NEW STYRENE CAPACITY
D DT=(M) SOLUTION INTERVAL IN SIMULATION CALCULATIONS
D DVC=(T/M) DESIRED NEW VINYL CHLORIDE CAPACITY
D EBCAP=(T/M) EFFECTIVE BASIC PRODUCT CAPACITY INCLUDING ENERGY PRODUCTS
X             CAPACITY
D EBCAPE=(T/M) EFFECTIVE BASIC PRODUCT CAPACITY EXCLUDING ENERGY
X              PRODUCTS CAPACITY
D ECP=($/M) ESCALATION IN COST OF PLANTS UNDER CONSTRUCTION DUE TO
X         INFLATION
D ED=(T/M) TOTAL DEMAND FOR ETHYLENE
D EFCAP=(T/M) EFFECTIVE FINAL PRODUCT CAPACITY
D EHDCAP=(T/M) EFFECTIVE HIGH-DENSITY POLYETHYLENE CAPACITY
D EICAP=(T/M) EFFECTIVE INTERMEDIATE PRODUCT CAPACITY
D EICU=(1) EFFECTIVE INTERMEDIATE PRODUCTS CAPACITY UTILIZATION
D ELDCAP=(T/M) EFFECTIVE LOW-DENSITY POLYETHYLENE CAPACITY
D EOCU=(1) EFFECTIVE OLEFINS CAPACITY UTILIZATION
D EPBTOE=(1) RATIO OF THE TOTAL YIELDS OF ETHYLENE , PROPYLENE AND
X            BUTADIENE TO THE YIELD OF ETHYLENE
D EPCU=(1) EFFECTIVE PLASTICS CAPACITY UTILIZATION
D EPPCAP=(T/M) EFFECTIVE POLYPROPYLENE CAPACITY
D EPRAT=(1) RATIO OF ETHYLENE TO PROPYLENE PRODUCTION OR CAPACITY
X           PERMITTED DUE TO THEIR YIELD CONSTRAINTS
D EPSCAP=(T/M) EFFECTIVE POLYSTYRENE CAPACITY
D EPTOE=(1) RATIO OF THE TOTAL YIELD OF ETHYLENE AND PROPYLENE TO
X           THE YIELD OF ETHYLENE
D EPVCAP=(T/M) EFFECTIVE POLYVINYL CHLORIDE CAPACITY
D ESCAP=(T/M) EFFECTIVE STYRENE CAPACITY
D ESOLD=(T/M) PART OF THE ETHYLENE PRODUCTION WHICH IS SOLD TO OTHER
X             PETROCHEMICAL MANUFACTURERS
D ETOEP=(1) RATIO OF THE YIELD OF ETHYLENE TO THE TOTAL YIELDS OF
X           ETHYLENE AND PROPYLENE
D ETOHD=(T/T) AMOUNT OF ETHYLENE REQUIRED TO PRODUCE 1 TON OF
X             HIGH-DENSITY POLYETHYLENE
D ETOLD=(T/T) AMOUNT OF ETHYLENE REQUIRED TO PRODUCE 1 TON OF
X             LOW-DENSITY POLYETHYLENE
D ETOS=(T/T) AMOUNT OF ETHYLENE REQUIRED TO PRODUCE 1 TON OF
X            STYRENE
D ETOVC=(T/T) AMOUNT OF ETHYLENE REQUIRED TO PRODUCE 1 TON OF
X             VINYL CHLORIDE
D EVCCAP=(T/M) EFFECTIVE VINYL CHLORIDE CAPACITY
D EY=(1) ETHYLENE YIELD PER TON OF NAPHTHA CRACKED
D FB=(1) SHARE OF BUTADIENE PRICE EXPECTED TO VARY WITH CRUDE
X        OIL PRICE
D FCAP=(T/M) FINAL PRODUCT CAPACITY
D FCAPOR=(T/M) FINAL PRODUCT CAPACITY ON ORDER BUT NOY RECEIVED
D FCCR=((T/M)/M) RATE OF COMLETION OF FINAL PRODUCT CAPACITY
D FCDR=((T/M)/M) RATE OF DECAY OF FINAL PRODUCT CAPACITY
D FCSR=((T/M)/M) RATE OF COMMENCEMENT OF FINAL PRODUCT CAPACITY
D FE=(1) SHARE OF ETHYLENE PRICE EXPECTED TO VARY WITH CRUDE
X        OIL PRICE
D FHDPE=(1) SHARE OF HIGH-DENSITY POLYETHYLENE PRICE EXPECTED TO
```

```
X          VARY WITH CRUDE OIL PRICE
D FLDPE=(1) SHARE OF LOW-DENSITY POLYETHYLENE PRICE EXPECTED TO
X          VARY WITH CRUDE OIL PRICE
D FNCGF=(1) FORECAST NECESSARY PETROCHEMICAL CAPACITY GROWTH FACTOR
D FP=(1) SHARE OF PROPYLENE PRICE EXPECTED TO VARY WITH CRUDE
X       OIL PRICE
D FPMULT=(1) FRACTION OF PLANNED EXPENDITURE ACTUALLY INCURRED
D FPP=(1) SHARE OF POLYPROPYLENE PRICE EXPECTED TO VARY WITH
X        CRUDE OIL PRICE
D FPS=(1) SHARE OF POLYSTYRENE PRICE EXPECTED TO VARY WITH CRUDE
X        OIL PRICE
D FPVC=(1) SHARE OF POLYVINYL CHLORIDE PRICE EXPECTED TO VARY WITH
X         CRUDE OIL PRICE
D FRAT=(1) RATIO OF ACHIEVABLE RATE OF SPENDING AND REQUIRED RATE
D FREXP=($/M) FEASIBLE RATE OF EXPENDITURE WHICH COULD BE SUSTAINED
X            THROUGH COMPANY'S INTERNAL FUNDS
D FS=(1) SHARE OF STYRENE PRICE EXPECTED TO VARY WITH CRUDE
X       OIL PRICE
D FTPUT=(T/M) THROUGHPUT IN FINAL PRODUCT SECTOR
D FVCM=(1) SHARE OF VINYL CHLORIDE PRICE EXPECTED TO VARY
X         WITH CRUDE OIL PRICE
D FWDV=(1/M) FRACTION OF WRITTEN DOWN VALUE OF PLANTS AND WORKING
X            TO COVER THE REQUIRED RETURN ON INVESTMENT WHEN SUPPLY
X            AND DEMAND ARE BALANCED
D FY=(1) FUEL OIL YIELD PER TON OF NAPHTHA CRACKED
D GY=(1) GASOLINE YIELD PER TON OF NAPHTHA CRACKED
D GME=($/T) GROSS MARGIN ON ETHYLENE SALES
D GMHDPE=($/T) GROSS MARGIN ON HIGH-DENSITY POLYETHYLENE SALES
D GMLDPE=($/T) GROSS MARGIN ON LOW-DENSITY POLYETHYLENE SALES
D GMP=($/T) GROSS MARGIN ON PROPYLENE SALES
D GMPP=($/T) GROSS MARGIN ON POLYPROPYLENE SALES
D GMPS=($/T) GROSS MARGIN ON POLYSTYRENE SALES
D GMPVC=($/T) GROSS MARGIN ON POLYVINYL CHLORIDE SALES
D GMS=($/T) GROSS MARGIN ON STYRENE SALES
D GMVCM=($/T) GROSS MARGIN ON VINYL CHLORIDE SALES
D HDCAP=(T/M) HIGH-DENSITY POLYETHYLENE CAPACITY
D HDCAPOR=(T/M) HIGH-DENSITY POLYETHYLENE CAPACITY ON ORDER BUT NOT
X              RECEIVED
D HDCCR=((T/M)/M) RATE OF COMPLETION OF HIGH DENSITY POLYETHYLENE
X                CAPACITY
D HDCDR=((T/M)/M) RATE OF DECAY OF HIGH-DENSITY POLYETHYLENE CAPACITY
D HDCSR=((T/M)/M) RATE OF COMMENCEMENT OF HIGH-DENSITY POLYETHYLENE
X                CAPACITY
D HDMUL=(1) MULTIPLIER TO REFLECT THE FORECAST CHANGE IN HIGH-DENSITY
X          POLYETHYLENE'S SHARE OF TOTAL PLASTICS CONSUMPTION DURING
X          1980-1990
D HDMULP=(1) HDMUL VALUE AT THE END OF PLANNING HORIZON
D HDPED=(T/M) TOTAL DEMAND FOR HIGH DENSITY POLYETHYLENE
D HDTPUT=(T/M) HIGH-DENSITY POLYETHYLENE THROUGHPUT
D ICAP=(T/M) INTERMEDIATE PRODUCT CAPACITY
D ICAPOR=(T/M) INTERMEDIATE PRODUCT CAPACITY ON ORDER BUT NOT RECEIVED
D ICCR=((T/M)/M) RATE OF COMPLETION OF INTERMEDIATE PRODUCT CAPACITY
D ICDR=((T/M)/M) RATE OF DECAY OF INTERMEDIATE PRODUCT CAPACITY
D ICSR=((T/M)/M) RATE OF COMMENCEMENT OF INTERMEDIATE PRODUCT CAPACITY
D IFRAT=(1) INTERNAL FINANCING RATIO
D IPC=($) PARENT COMPANY'S TOTAL INVESTMENT IN ITS PETROCHEMICAL
X        SUBSIDIARY
```

```
D IR=(1/M) AVERAGE WESTERN EUROPEAN INTEREST RATE ON CASH RESOURCES
D ITPUT=(T/M) THROUGHPUT IN INTERMEDIATE PRODUCT SECTOR
D LDCAP=(T/M) LOW-DENSITY POLYETHYLENE CAPACITY
D LDCAPOR=(T/M) LOW-DENSITY CAPACITY ON ORDER BUT NOT RECEIVED
D LDCCR=((T/M)/M) RATE OF COMPLETION OF LOW-DENSITY POLYETHYLENE
X                 CAPACITY
D LDCDR=((T/M)/M) RATE OF DECAY OF LOW-DENSITY POLYETHYLENE CAPACITY
D LDCSR=((T/M)/M) RATE OF COMMENCEMENT OF LOW-DENSITY POLYETHYLENE
X                 CAPACITY
D LDMUL=(1) MULTIPLIER TO REFLECT THE FORECAST CHANGE IN LOW-DENSITY
X           POLYETHYLENE'S SHARE OF TOTAL PLASTICS CONSUMPTION DURING
X           1980-1990
D LDMULP=(1) LDMUL VALUE AT THE END OF PLANNING HORIZON
D LDPED=(T/M) TOTAL DEMAND FOR LOW-DENSITY POLYETHYLENE
D LDTPUT=(T/M) LOW-DENSITY POLYETHYLENE THROUGHPUT
D LENGTH=(M) SIMULATED PERIOD
D LOSS=(1) LOSS PER TON OF NAPHTHA CRACKED
D LPGY=(1) LPG YIELD PER TON OF NAPHTHA CRACKED
D LTPP=(M) LIFETIME OF PETROCHEMICAL PLANTS
D MAXIPC=($/M) PARENT COMPANY'S MAXIMUM MONTHLY INVESTMENT IN
X              ITS PETROCHEMICAL SUBSIDIARY
D MAXIPC80=($/M) BASE LEVEL OF PARENT COMPANY'S MAXIMUM MONTHLY
X                INVESTMENT IN ITS PETROCHEMICAL SUBSIDIARY IN 1980
D MCNP=($) MONEY COMMITTED TO NEW CAPACITY ADDITION PROJECTS
D MESC=(T/M) ECONOMIC SIZE OF A NAPHTHA STEAM CRACKER
D MESHD=(T/M) ECONOMIC SIZE OF A HIGH-DENSITY POLYETHYLENE PLANT
D MESLD=(T/M) ECONOMIC SIZE OF A LOW-DENSITY POLYETHYLENE PLANT
D MESPP=(T/M) ECONOMIC SIZE OF A POLYPROPYLENE PLANT
D MESPS=(T/M) ECONOMIC SIZE OF A POLYSTYRENE PLANT
D MESPV=(T/M) ECONOMIC SIZE OF A POLYVINYL CHLORIDE PLANT
D MESS=(T/M) ECONOMIC SIZE OF A STYRENE PLANT
D MESV=(T/M) ECONOMIC SIZE OF A VINYL CHLORIDE PLANT
D MFCUR=(1) MAXIMUM FEASIBLE CAPACITY UTILIZATION
D MINCASH=($) THE LEVEL BELOW WHICH THE COMPANY'S CASH RESERVES
X             SHOULD NOT FALL
D MKTPB=($/T) MARKET PRICE OF BUTADIENE
D MPY=(M/Y) MONTHS PER YEAR
D NE=(T/M) NECESSARY ETHYLENE CAPACITY IN 5 YEARS TIME
D NHD=(T/M) NECESSARY HIGH-DENSITY POLYETHYLENE CAPACITY IN 5 YEARS
X           TIME
D NLD=(T/M) NECESSARY LOW-DENSITY POLYETHYLENE CAPACITY IN 5 YEARS
X           TIME
D NP=(T/M) NECESSARY PROPYLENE CAPACITY IN 5 YEARS TIME
D NPP=(T/M) NECESSARY POLYPROPYLENE CAPACITY IN 5 YEARS TIME
D NPS=(T/M) NECESSARY POLYSTYRENE CAPACITY IN 5 YEARS TIME
D NPV=(T/M) NECESSARY POLYVINYL CHLORIDE CAPACITY IN 5 YEARS TIME
D NS=(T/M) NECESSARY STYRENE CAPACITY IN 5 YEARS TIME
D NVC=(T/M) NECESSARY VINYL CHLORIDE CAPACITY IN 5 YEARS TIME
D OII=(1) OVERALL INFLATION INDEX
D OIR=(1/M) FORECAST AVERAGE RATE OF INCREASE OF OVERALL INFLATION IN
X           WESTERN EUROPE
D ONE=(1) NUMBER 1
D PB=($/T) PRICE OF BUTADIENE WHEN SUPPLY AND DEMAND ARE BALANCED
D PC=(1) THE PROPORTION OF THE VALUE OF THE WORKING CAPITAL TO
X        BE KEPT IN CASH BY THE COMPANY
D PD=(T/M) TOTAL DEMAND FOR PROPYLENE
D PE=($/T) PRICE OF ETHYLENE WHEN SUPPLY AND DEMAND ARE BALANCED
```

```
D PERD=(M) PERIOD OF THE BUSINESS CYCLE
D PHOR=(M) PLANNING HORIZON
D PHDPE=($/T) PRICE OF HIGH-DENSITY POLYETHYLENE WHEN SUPPLY AND DEMAND
X             ARE BALANCED
D PLDPE=($/T) PRICE OF LOW-DENSITY POLYETHYLENE WHEN SUPPLY AND DEMAND
X             ARE BALANCED
D PLTPER=(M) PLOTTING INTERVAL
D PMB=(1) PRICE MULTIPLIER FOR BUTADIENE
D PME=(1) PRICE MULTIPLIER FOR ETHYLENE
D PMHDPE=(1) PRICE MULTIPLIER FOR HIGH-DENSITY POLYETHYLENE
D PMLDPE=(1) PRICE MULTIPLIER FOR LOW-DENSITY POLYETHYLENE
D PMP=(1) PRICE MULTIPLIER FOR PROPYLENE
D PMPP=(1) PRICE MULTIPLIER FOR POLYPROPYLENE
D PMPS=(1) PRICE MULTIPLIER  FOR POLYSTYRENE
D PMPVC=(1) PRICE MULTIPLIER FOR POLYVINYL CHLORIDE
D PMS=(1)`PRICE MULTIPLIER FOR STYRENE
D PMVCM=(1) PRICE MULTIPLIER FOR VINYLCHLORIDE
D PPCAP=(T/M) POLYPROPYLENE CAPACITY
D PPCAPOR=(T/M) POLYPROPYLENE CAPACITY ON ORDER BUT NOT RECEIVED
D PPCCR=((T/M)/M) RATE OF COMPLETION OF POLYPROPYLENE CAPACITY
D PPCDR=((T/M)/M) RATE OF DECAY OF POLYPROPYLENE CAPACITY
D PPCSR=((T/M)/M) RATE OF COMMENCEMENT OF POLYPROPYLENE CAPACITY
D PPD=(T/M) TOTAL DEMAND FOR POLYPROPYLENE
D PPMUL=(1) MULTIPLIER TO REFLECT THE FORECAST CHANGE IN POLYPROPYLENE'S
X           SHARE OF TOTAL PLASTICS CONSUMPTION DURING 1980-90
D PPMULP=(1) PPMUL VALUE AT THE END OF PLANNING HORIZON
D PPE=($/T) PART OF THE PRICE OF ETHYLENE WHICH COVERS THE REQUIRED
X           AMORTIZATION AND RETURN ON INVESTMENT WHEN SUPPLY AND DEMAND
X           ARE BALANCED
D PPHDPE=($/T) PART OF THE PRICE OF HIGH-DENSITY POLYETHYLENE WHICH
X              COVERS THE REQUIRED AMORTIZATION AND RETURN ON INVESTMENT
X              WHEN SUPPLY AND DEMAND ARE BALANCED
D PPLDPE=($/T) PART OF THE PRICE OF LOW-DENSITY POLYETHYLENE WHICH
X              COVERS THE REQUIRED AMORTIZATION AND RETURN ON INVESTMENT
X              WHEN SUPPLY AND DEMAND ARE BALANCED
D PPP=($/T) PRICE OF POLYPROPYLENE WHEN SUPPLY AND DEMAND ARE BALANCED
D PPPP=($/T) PART OF THE PRICE OF POLYPROPYLENE WHICH COVERS THE
X            REQUIRED AMORTIZATION AND RETURN ON INVESTMENT WHEN
X            SUPPLY AND DEMAND ARE BALANCED
D PPPR=($/T) PART OF THE PRICE OF PROPYLENE WHICH COVERS THE REQUIRED
X            AMORTIZATION AND RETURN ON INVESTMENT WHEN SUPPLY AND DEMAND
X            ARE BALANCED
D PPPS=($/T) PART OF THE PRICE OF POLYSTYRENE WHICH COVERS THE REQUIRED
X            AMORTIZATION AND RETURN ON INVESTMENT WHEN SUPPLY AND
X            DEMAND ARE BALANCED
D PPPVC=($/T) PART OF THE PRICE OF POLYVINYL CHLORIDE WHICH COVERS
X             THE REQUIRED AMORTIZATION AND RETURN ON INVESTMENT WHEN
X             SUPPLY AND DEMAND ARE BALANCED
D PPS=($/T) PRICE OF POLYSTYRENE WHEN SUPPLY AND DEMAND ARE BALANCED
D PPST=($/T) PART OF THE PRICE OF STYRENE WHICH COVERS THE REQUIRED
X            AMORTIZATION AND RETURN ON INVESTMENT WHEN SUPPLY AND
X            DEMAND ARE BALANCED
D PPR=($/T) PRICE OF PROPYLENE WHEN SUPPLY AND DEMAND ARE BALANCED
D PPTPUT=(T/M) POLYPROPYLENE THROUGHPUT
D PPVC=($/T) PRICE OF POLYVINYL CHLORIDE WHEN SUPPLY AND DEMAND ARE
X            BALANCED
D PPVCM=($/T) PART OF THE PRICE OF VINYL CHLORIDE WHICH COVERS THE
```

```
X             REQUIRED AMORTIZATION AND RETURN ON INVESTMENT WHEN SUPPLY
X             AND DEMAND ARE BALANCED
D PR=($/M) RATE OF RECEIPT OF PROFIT FROM PRODUCTION AND CASH
X          RESOURCES
D PRTPER=(M) PRINTING INTERVAL FOR OUTPUT
D PSCAP=(T/M) POLYSTYRENE CAPACITY
D PSCAPOR=(T/M) POLYSTYRENE CAPACITY ON ORDER BUT NOT RECEIVED
D PSCCR=((T/M)/M) RATE OF COMPLETION OF POLYSTYRENE CAPACITY
D PSCDR=((T/M)/M) RATE OF DECAY OF POLYSTYRENE CAPACITY
D PSCSR=((T/M)/M) RATE OF COMMENCEMENT OF POLYSTYRENE CAPACITY
D PSD=(T/M) TOTAL DEMAND FOR POLYSTYRENE
D PSMUL=(1) MULTIPLIER TO REFLECT THE CHANGE IN POLYSTYRENE'S SHARE OF
X           TOTAL PLASTICS CONSUMPTION DURING 1980-90
D PSMULP=(1) PSMUL VALUE AT THE END OF PLANNING HORIZON
D PSOLD=(T/M) PART OF PROPYLENE PRODUCTION WHICH IS SOLD TO OTHER
X             PETROCHEMICAL MANUFACTURERS
D PST=($/T) PRICE OF STYRENE WHEN SUPPLY AND DEMAND ARE BALANCED
D PSTPUT=(T/M) POLYSTYRENE THROUGHPUT
D PTOPP=(T/T) AMOUNT OF PROPYLENE REQUIRED TO PRODUCE 1 TON OF
X             POLYPROPYLENE
D PVCAP=(T/M) POLYVINYL CHLORIDE CAPACITY
D PVCAPOR=(T/M) POLYVINYL CHLORIDE CAPACITY ON ORDER BUT NOT RECEIVED
D PVCCR=((T/M)/M) RATE OF COMPLETION OF POLYVINYL CHLORIDE CAPACITY
D PVCDR=((T/M)/M) RATE OF DECAY OF POLYVINYL CHLORIDE CAPACITY
D PVCSR=((T/M)/M) RATE OF COMMENCEMENT OF POLYVINYL CHLORIDE CAPACITY
D PVCD=(T/M) TOTAL DEMAND FOR POLYVINYL CHLORIDE
D PVCM=($/T) PRICE OF VINYL CHLORIDE WHEN SUPPLY AND DEMAND ARE BALANCED
D PVMUL=(1) MULTIPLIER TO REFLECT THE FORECAST CHANGE IN POLYVINYL
X           CHLORIDE'S SHARE OF TOTAL PLASTICS CONSUMPTION DURING
X           1980-90
D PVMULP=(1) PVMUL VALUE AT THE END OF PLANNING HORIZON
D PVTPUT=(T/M) POLYVINYL CHLORIDE THROUGHPUT
D PY=(1) PROPYLENE YIELD PER TON OF NAPHTHA CRACKED
D RAVC=($/M) RATE OF ADDING TO VALUE OF NAPHTHA CRACKERS
D RAVHDPEP=($/M) RATE OF ADDING TO VALUE OF HIGH-DENSITY POLYETHYLENE
X                PLANTS
D RAVLDPEP=($/M) RATE OF ADDING TO VALUE OF LOW-DENSITY POLYETHYLENE
X                PLANTS
D RAVP=($/M) RATE OF ADDING TO VALUE OF PETROCHEMICAL PLANTS
D RAVPPP=($/M) RATE OF ADDING TO VALUE OF POLYPROPYLENE PLANTS
D RAVPSP=($/M) RATE OF ADDING TO VALUE OF POLYSTYRENE PLANTS
D RAVPVCP=($/M) RATE OF ADDING TO VALUE OF POLYVINYL CHLORIDE PLANTS
D RAVSP=($/M) RATE OF ADDING TO VALUE OF STYRENE PLANTS
D RAVVCMP=($/M) RATE OF ADDING TO VALUE OF VINYL CHLORIDE PLANTS
D RCMTNP=($/M) RATE OF COMMITTING MONEY TO NEW PROJECTS
D RGDM=(1/M) GENERAL RATE OF GROWTH OF DEMAND FOR PETROCHEMICALS
X            IN THE 1980'S AND THE 1990'S
D RGDMEB=(1) MULTIPLIER TO REFLECT ERROR AND BIAS IN FORECASTING
X            RATE OF GROWTH OF DEMAND FOR PETROCHEMICALS
D RIPC=($/M) ACTUAL RATE OF PARENT COMPANY'S MONTHLY INVESTMENT
X            IN ITS PETROCHEMICAL SUBSIDAIRY
D RMCNP=($) REQUIRED MONEY TO BE COMMITTED TO NEW CAPACITY ADDITION
X           PROJECTS
D ROI=(1/Y) RETURN ON INVESTMENT
D RP=($/M) RETAINED PROFIT
D RRS=($/M) REQUIRED RATE OF SPENDING ON NEW CAPITAL PROJECTS
D RRSB=($/M) REQUIRED RATE OF SPENDING ON NEW BASIC PRODUCT CAPACITY
```

```
D RRSF=($/M) REQUIRED RATE OF SPENDING ON NEW FINAL PRODUCT CAPACITY
D RRSI=($/M) REQUIRED RATE OF SPENDING ON NEW INTERMEDIATE PRODUCT
X            CAPACITY
D RRWC=($/M) RATE OF REDUCING WORKING CAPITAL IF IT EXCEEDS REQUIREMENTS
D RSC=($/M) RATE OF SPENDING CASH
D SCAP=(T/M) STYRENE CAPACITY
D SCAPOR=(T/M) STYRENE CAPACITY ON ORDER BUT NOT RECEIVED
D SCCR=((T/M)/M) RATE OF COMPLETION OF STYRENE CAPACITY
D SCDIFF=($/M) DIFFERENCE BETWEEN  ACTUAL  AND FEASIBLE SPENDING RATES
D SCDR=((T/M)/M) RATE OF DECAY OF STYRENE CAPACITY
D SCSR=((T/M)/M) RATE OF COMMENCEMENT OF STYRENE CAPACITY
D SD=(T/M) TOTAL DEMAND FOR STYRENE
D SSOLD=(T/M) PART OF STYRENE PRODUCTION WHICH IS SOLD TO OTHER
X           PETROCHEMICAL MANUFACTURERS
D STOPS=(T/T) AMOUNT OF STYRENE REQUIRED TO PRODUCE 1 TON OF
X             POLYSTYRENE
D STPUT=(T/M) STYRENE THROUGHPUT
D TA=($) TOTAL ASSETS OF THE COMPANY
D TAC=(M) TIME TO AVERAGE COST PER TON OF PRODUCT PRODUCED
D TADCFL=(M) TIME TO AVERAGE DEPRECIATION CASHFLOW
D TAP=(M) TIME TO AVERAGE PROFIT LEVEL
D TAPCDR=(M) TIME TO AVERAGE RATE OF DECAY OF PETROCHEMICAL CAPACITY
D TARP=(M) TIME TO AVERAGE RETAINED PROFIT
D TAW=(M) TIME TO AVERAGE WCAPRB
D TAWC=(M) TIME TO ADJUST WORKING CAPITAL POSITION
D TAXDIV=(1) PROPORTION OF PROFIT FLOW LOST IN TAXATION AND DIVIDEND
X            PAYMENTS
D TBD=(T/M) TOTAL DEMAND FOR BASIC PETROCHEMICAL PRODUCTS
D TBDY=(T/M) TOTAL DEMAND FOR BASIC PETROCHEMICAL PRODUCTS ,TAKING
X            INTO ACCOUNT THE YIELD CONSTRAINTS OF NAPHTHA-BASED
X            ETHYLENE CRACKERS
D TERP=(T/M) TOTAL ETHEYLENE REQUIRED FOR FURTHR PROCESSING INTO
X            PLASTICS BY THE COMPANY'S PLASTICS DIVISION
D TFD=(T/M) TOTAL DEMAND FOR FINAL PETROCHEMICAL PRODUCTS
D TFPMULT=(1) TABLE VALUE FOR FINANCIAL POLICY MULTIPLIER FPMULT
D THDMUL=(1) TABLE VALUES OF HDMUL
D TID=(T/M) TOTAL DEMAND FOR INTERMEDIATE PETROCHEMICAL PRODUCTS
D TIME=(M) SIMULATED TIME IN MODEL
D TIMR=(M) TIME TO INCREASE MCNP WHEN IT FALLS BELOW THE RMCNP
D TIWC=($/M) TARGET RATE OF GROWTH IN WORKING CAPITAL
D TL=($) TOTAL LIABILITIES OF THE COMPANY
D TLDMUL=(1) TABLE VALUES OF LDMUL
D TPMB=(1) TABLE VALUES OF PMB
D TPME=(1) TABLE VALUES OF PME
D TPMHDPE=(1) TABLE VALUES OF PMHDPE
D TPMLDPE=(1) TABLE VALUES OF PMLDPE
D TPMP=(1) TABLE VALUES OF PMP
D TPMPP=(1) TABLE VALUES OF PMPP
D TPMPS=(1) TABLE VALUES OF PMPS
D TPMPVC=(1) TABLE VALUES OF PMPVC
D TPMS=(1) TABLE VALUES OF PMS
D TPMVCM=(1) TABLE VALUES OF PMVCM
D TPPMUL=(1) TABLE VALUES OF PPMUL
D TPSMUL=(1) TABLE VALUES OF PSMUL
D TPVMUL=(1) TABLE VALUES OF PVMUL
D TROBCAP=((T/M)/M) TARGET RATE OF ORDERING BASIC PRODUCT CAPACITY
D TROFCAP=((T/M)/M) TARGET RATE OF ORDERING FINAL PRODUCT CAPACITY
```

```
D TROHDCAP=((T/M)/M) TARGET RATE OF ORDERING HIGH-DENSITY POLYETHYLENE
X                    CAPACITY
D TROICAP=((T/M)/M) TARGET RATE OF ORDERING INTERMEDIATE PRODUCT
X                   CAPACITY
D TROLDCAP=((T/M)/M) TARGET RATE OF ORDERING LOW-DENSITY POLYETHYLENE
X                    CAPACITY
D TROPPCAP=((T/M)/M) TARGET RATE OF ORDERING POLYPROPYLENE CAPACITY
D TROPSCAP=((T/M)/M) TARGET RATE OF ORDERING POLYSTYRENE CAPACITY
D TROPVCAP=((T/M)/M) TARGET RATE OF ORDERING POLYVINYL CHLORIDE
X                    CAPACITY
D TROSCAP=((T/M)/M) TARGET RATE OF ORDERING STYRENE CAPACITY
D TROVCCAP=((T/M)/M) TARGET RATE OF ORDERING VINYL CHLORIDE CAPACITY
D TRWC=(M) TIME TO REDUCE WORKING CAPITAL WHEN IT EXCEEDS REQUIREMENTS
D TYEPB=(1) TOTAL YIELDS OF ETHYLENE , PROPYLENE AND BUTADIENE
X           PER TON OF NAPHTHA CRACKED
D VCCAP=(T/M) VINYL CHLORIDE CAPACITY
D VCCAPOR=(T/M) VINYL CHLORIDE CAPACITY ON ORDER BUT NOT RECEIVED
D VCCCR=((T/M)/M) RATE OF COMPLETION  OF VINYL CHLORIDE CAPACITY
D VCCDR=((T/M)/M) RATE OF DECAY OF VINYL CHLORIDE CAPACITY
D VCCSR=((T/M)/M) RATE OF COMMENCEMENT OF VINYL CHLORIDE CAPACITY
D VCMD=(T/M) TOTAL DEMAND FOR VINYL CHLORIDE
D VCSOLD=(T/M) PART OF VINYL CHLORIDE PRODUCTION WHICH IS SOLD TO OTHER
X              PETROCHEMICAL MANUFACTURERS
D VCTOPV=(T/T) AMOUNT OF VINYL CHLORIDE REQUIRED TO PRODUCE 1
X              TON OF POLYVINYL CHLORIDE
D VCTPUT=(T/M) VINYL CHLORIDE MONOMER THROUGHPUT
D WCAP=($) WORKING CAPITAL EMPLOYED
D WCAPR=($) WORKING  CAPITAL REQUIRED TO SUPPORT PLANNED PRODUCTION
D WCAPRB=($) WORKING CAPITAL REQUIRED TO SUPPORT PLANNED BASIC
X            PRODUCTION
D WCRAT=(1) RATIO OF ACTUAL WORKING CAPITAL TO THAT REQUIRED TO SUSTAIN
X           THE PLANNED LEVEL OF PRODUCTION
D WCRCV=(1) CRITICAL VALUE OF WORKING CAPITAL RATIO , WCRAT , ABOVE
X           WHICH REDUCTIONS IN WORKING CAPITAL WILL BE MADE
D WDV=($) WRITTEN DOWN VALUE OF CAPITAL PLANTS
D WDVC=($) WRITTEN DOWN VALUE OF NAPHTHA CRACKERS
D WDVHDPE=($) WRITTEN DOWN VALUE OF HIGH-DENSITY POLYETHYLENE PLANTS
D WDVLDPE=($) WRITTEN DOWN VALUE OF LOW-DENSITY POLYETHYLENE PLANTS
D WDVPP=($) WRITTEN DOWN VALUE OF POLYPROPYLENE PLANTS
D WDVPS=($) WRITTEN DOWN VALUE OF POLYSTYRENE PLANTS
D WDVPVC=($) WRTTEN DOWN VALUE OF POLYVINYL CHLORIDE PLANTS
D WDVS=($) WRITTEN DOWN VALUE OF STYRENE PLANTS
D WDVVCM=($) WRITTEN DOWN VALUE OF VINYL CHLORIDE PLANTS
+
****

↑******************************************************************************
```

APPENDIX B

LIST OF COMPUTER PROGRAMME OF THE AMENDED SECTORS OF THE BASIC MODEL

```
NOTE
NOTE
NOTE *****************************************************************
NOTE FORWARD PLANNING -CAPACITY REQUIREMENTS SECTOR
NOTE *****************************************************************
NOTE
NOTE
N EPTOE=(EY+PY)/EY
C EY=.31
C PY=,16
C BY=,05
C GY=.21
C LPGY=,25
C FY=,01
C LOSS=,01
C ETOS=,307
C ETOVC=,485
C ETOLD=1,03
C ETOHD=1.02
C VCTOPV=1,01
C STOPS=1,05
C PTOPP=1,096
A DE,K=(NE,K-EY*EBCAP.K)/MFCUR+EY*ABCDR,K*(DMINTB+CDELBP)-EY*BCAPOR.K
A DP,K=(NP,K-PY*EBCAP.K)/MFCUR+PY*ABCDR.K*(DMINTB+CDELBP)-PY*BCAPOR.K
C MFCUR=,8
C DMINTB=12
A DC,K=CLIP(DE.K,EPRAT*DP.K,EPRAT,DE,K/DP.K)/EY
N EPRAT=EY/PY
A DVC.K=(NVC.K-EVCCAP.K)/MFCUR+AVCCDR,K*(DMINTIF+CDELVC)-VCCAPOR.K
C DMINTIF=24
A DS,K=(NS.K-ESCAP.K)/MFCUR+ASCDR,K*(DMINTIF+CDELS)-SCAPOR.K
A DLD.K=(NLD,K-ELDCAP.K)/MFCUR+ALDCDR,K*(DMINTIF+CDELLD)-LDCAPOR,K
A DHD.K=(NHD.K-EHDCAP.K)/MFCUR+AHDCDR.K*(DMINTIF+CDELHD)-HDCAPOR.K
A DPV,K=(NPV,K-EPVCAP.K)/MFCUR+APVCDR,K*(DMINTIF+CDELPV)-PVCAPOR,K
A DPS.K=(NPS,K-EPSCAP.K)/MFCUR+APSCDR,K*(DMINTIF+CDELPS)-PSCAPOR,K
A DPP.K=(NPP.K-EPPCAP.K)/MFCUR+APPCDR.K*(DMINTIF+CDELPP)-PPCAPOR.K
A TROBCAP,K=SAMPLE((INT(DC.K/MESC)*MESC)/DMINTB,DMINTB,10081)
A TROVCCAP,K=SAMPLE((INT(DVC.K/MESV)*MESV)/DMINTIF,DMINTB,0)
A TROSCAP.K=SAMPLE((INT(DS.K/MESS)*MESS)/DMINTIF,DMINTB,0)
A TROICAP,K=TROVCCAP,K+TROSCAP.K
A TROLDCAP.K=SAMPLE((INT(DLD.K/MESLD)*MESLD)/DMINTIF,DMINTB,694.42)
A TROHDCAP.K=SAMPLE((INT(DHD.K/MESHD)*MESHD)/DMINTIF,DMINTB,0)
A TROPVCAP,K=SAMPLE((INT(DPV.K/MESPV)*MESPV)/DMINTIF,DMINTB,416.67)
A TROPSCAP.K=SAMPLE((INT(DPS.K/MESPS)*MESPS)/DMINTIF,DMINTB,0)
A TROPPCAP.K=SAMPLE((INT(DPP.K/MESPP)*MESPP)/DMINTIF,DMINTB,347.21)
A TROFCAP.K=TROLDCAP,K+TROHDCAP.K+TROPVCAP.K+TROPSCAP.K+TROPPCAP.K
NOTE
NOTE
NOTE *****************************************************************
NOTE IMPLEMENTATION OF PLANNING DECISIONS SECTOR
NOTE *****************************************************************
NOTE
NOTE
A FRAT,K=ARS.K/(RRS.K+CLIP(0,1,RRS,K,.1))
A FPMULT.K=TABHL(TFPMULT,FRAT.K,0,1,.5)
N FPMULT=1
T TFPMULT=0/.65/1
```

```
A ARWC,K=TIWC,K
R RIPC,KL=MAX(MIN(SCDIFF.K,MAXIPC.K),0)
R BCSR,KL=SAMPLE((INT(DC.K*FPMULT.K/MESC)*MESC)/DMINTB
X         ,DMINTB,10081)
C MESC=120.967E3
R VCCSR,KL=SAMPLE((INT(DVC.K*FPMULT.K/MESV)*MESV)/DMINTIF
X          ,DMINTB,0)
C MESV=25E3
R SCSR,KL=SAMPLE((INT(DS.K*FPMULT.K/MESS)*MESS)/DMINTIF
X         ,DMINTB,0)
C MESS=25E3
R ICSR,KL=VCCSR.KL+SCSR.KL
R LDCSR,KL=SAMPLE((INT(DLD.K*FPMULT.K/MESLD)*MESLD)/DMINTIF
X          ,DMINTB,694,42)
C MESLD=8,333E3
R HDCSR,KL=SAMPLE((INT(DHD.K*FPMULT.K/MESHD)*MESHD)/DMINTIF
X          ,DMINTB,0)
C MESHD=8,333E3
R PVCSR,KL=SAMPLE((INT(DPV.K*FPMULT.K/MESPV)*MESPV)/DMINTIF
X          ,DMINTB,416,67)
C MESPV=10E3
R PSCSR,KL=SAMPLE((INT(DPS.K*FPMULT.K/MESPS)*MESPS)/DMINTIF
X          ,DMINTB,0)
C MESPS=8.333E3
R PPCSR,KL=SAMPLE((INT(DPP.K*FPMULT.K/MESPP)*MESPP)/DMINTIF
X          ,DMINTB,347,21)
C MESPP=8.333E3
R FCSR,KL=LDCSR,KL+HDCSR,KL+PVCSR,KL+PSCSR.KL+PPCSR,KL
A RCMTNP,K=(BCSR,KL*EY*CCC
X          +(SCSR.KL*CCSC+VCCSR.KL*CCVCMC)
X          +(LDCSR.KL*CCLDPEC+HDCSR.KL*CCHDPEC+PVCSR.KL*CCPVCC
X          +PSCSR.KL*CCPSC+PPCSR.KL*CCPPC))*OII,K
NOTE
NOTE
NOTE ********************************************************************
NOTE CAPACITY CONSTRUCTION PIPELINE SECTOR
NOTE ********************************************************************
NOTE
NOTE
L BCAPOR,K=BCAPOR.J+DT*(BCSR.JK-BCCR.JK)
N BCAPOR=((INT((((NE-EY*EBCAP)/MFCUR+EY*ABCDR*(DMINTB+CDELBP))/
X        (EY*(DMINTB+CDELBP)))*DMINTB/MESC)*MESC)/DMINTB)*CDELBP
R BCCR,KL=DELAY3(BCSR.JK,CDELBP)
N BCSR=0
C CDELBP=43.2694
L VCCAPOR.K=VCCAPOR.J+DT*(VCCSR.JK-VCCCR.JK)
N VCCAPOR=((INT((((NVC-EVCCAP)/MFCUR+AVCCDR*(DMINTIF+CDELVC))/
X          (DMINTIF+CDELVC))*DMINTIF/MESV)*MESV)/DMINTIF)*CDELVC
R VCCCR,KL=DELAY3(VCCSR.JK,CDELVC)
C CDELVC=31.6288
L SCAPOR,K=SCAPOR.J+DT*(SCSR.JK-SCCR.JK)
N SCAPOR=((INT((((NS-ESCAP)/MFCUR+ASCDR*(DMINTIF+CDELS))/
X        (DMINTIF+CDELS))*DMINTIF/MESS)*MESS)/DMINTIF)*CDELS
R SCCR,KL=DELAY3(SCSR.JK,CDELS)
C CDELS=31.6729
A ICAPOR.K=VCCAPOR,K+SCAPOR.K
R ICCR,KL=VCCCR.KL+SCCR.KL
```

```
L LDCAPOR.K=LDCAPOR.J+DT*(LDCSR.JK-LDCCR.JK)
N LDCAPOR=((INT((((NLD-ELDCAP)/MFCUR+ALDCDR*(DMINTIF+CDELLD))/
X          (DMINTIF+CDELLD))*DMINTIF/MESLD)*MESLD)/DMINTIF)*CDELLD
R LDCCR,KL=DELAY3(LDCSR.JK,CDELLD)
C CDELLD=31,6794
L HDCAPOR.K=HDCAPOR.J+DT*(HDCSR.JK-HDCCR.JK)
N HDCAPOR=((INT((((NHD-EHDCAP)/MFCUR+AHDCDR*(DMINTIF+CDELHD))/
X          (DMINTIF+CDELHD))*DMINTIF/MESHD)*MESHD)/DMINTIF)*CDELHD
R HDCCR,KL=DELAY3(HDCSR.JK,CDELHD)
C CDELHD=31.5143
L PVCAPOR.K=PVCAPOR.J+DT*(PVCSR.JK-PVCCR.JK)
N PVCAPOR=((INT((((NPV-EPVCAP)/MFCUR+APVCDR*(DMINTIF+CDELPV))/
X          (DMINTIF+CDELPV))*DMINTIF/MESPV)*MESPV)/DMINTIF)*CDELPV
R PVCCR,KL=DELAY3(PVCSR.JK,CDELPV)
N PVCSR=0
C CDELPV=31,6572
L PSCAPOR.K=PSCAPOR.J+DT*(PSCSR.JK-PSCCR.JK)
N PSCAPOR=((INT((((NPS-EPSCAP)/MFCUR+APSCDR*(DMINTIF+CDELPS))/
X          (DMINTIF+CDELPS))*DMINTIF/MESPS)*MESPS)/DMINTIF)*CDELPS
R PSCCR,KL=DELAY3(PSCSR.JK,CDELPS)
C CDELPS=31.8529
L PPCAPOR.K=PPCAPOR.J+DT*(PPCSR.JK-PPCCR.JK)
N PPCAPOR=((INT((((NPP-EPPCAP)/MFCUR+APPCDR*(DMINTIF+CDELPP))/
X          (DMINTIF+CDELPP))*DMINTIF/MESPP)*MESPP)/DMINTIF)*CDELPP
R PPCCR,KL=DELAY3(PPCSR.JK,CDELPP)
N PPCSR=0
C CDELPP=31.2262
A FCAPOR,K=LDCAPOR,K+HDCAPOR.K+PVCAPOR,K+PSCAPOR,K+PPCAPOR.K
R FCCR,KL=LDCCR.KL+HDCCR.KL+PVCCR.KL+PSCCR.KL+PPCCR.KL
```

BIBLIOGRAPHY

Champion, N.	"Structural changes and their effect in the Organic Chemical Industry: Some Perspective Views", *Chemistry and Industry*, 7 January 1978.
Chemical Week	August 1979, pp. 19 and 32.
Coyle, R. G.	Management System Dynamics, John Wiley and Sons, 1977.
Coyle, R. G.	Equations for Systems, Preliminary Edition, University of Bradford, 1978.
Davis, J. C.	"Are Bigger Plants Better? No small debate", News features, *Chemical Engineering*, 22 May 1978.
Elbedeiwy, M. A.	Accounting Policies and Corporate Survival Under Inflation: A System Dynamics Study, Ph.D. Thesis, University of Bradford, 1979.
European Chemical News	"Government approves Shell-Esso cracker project at Moss Morran", August 20/27 1979.
First Boston Corporation	"The myth and realities of the oil companies' aggressive move into the chemical business", May 1976.
Forrester, J. W.	Industrial Dynamics, MIT Press, 1962.
Institute of Chartered Accountants	Survey of Published Accounts, I.C.A.E.W., 1976.
Joseph, J.	"OECD forecast: outlook bleak for new plant financing, with a depression settling over prices", *Chemical Age*, 9 March 1979
Lurie, M.	"Oil and Chemicals Era of peaceful co-existence?" *Chemical Week*, 17 October 1979.
McKinsey & company, Inc.	Strategy options for the plastics materials industry in the United Kingdom, A report for the petrochemicals SWP, November 1978.

Moslehshirazi, A.	The Dynamics of Corporate Diversification, PhD Thesis, University of Bradford, 1979.
National Economic Development Office	Cyclical Fluctuations in the United Kingdom Economy, NEDO, 1976.
Ratnatunga A. K.	DYSMAP Users Manual, University of Bradford, 1979.
Royal Dutch/Shell Group of Companies	Financial and Operational Information, 1969-1978.
Royal Dutch/Shell Group of Companies	Annual Report, 1978.
Royal Dutch/Shell Group of Companies	The Financial Times, 3 March 1980.
Taylor, A. W.	"The Petrochemical Industry : Some Perspective Views", *Chemistry and Industry*, 1 January 1977.
Thomson, W. C.	"Oil and/or Chemical refineries?" *Hydrocarbon Processing*, February 1978
UNIDO/ICIS	First World-Wide Study on the Petrochemical Industry : 1975-2000, 12 December 1978.
Von der Heyde, R.	"The Organic Chemical Industry and its development: A Commercial.Viewpoint", *Chemistry and Industry*, 7 January 1978.