OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

18218

Distr.
LIMITED

PPD.157(SPEC.)
18 April 1990

ORIGINAL: ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

PROJECT PROFILE FOR THE ESTABLISHMENT OF DIOCTYL PHTHALATE (DOP) PRODUCTION PLANTS IN THE ARAB WORLD*

Prepared by

Taitaba International Business
Consulting Office (TIBCO)

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. Mention of firm names and commercial products does not imply the endorsement of UNIDO. This document has not been edited.

V.90-83850

TABLE OF CONTENTS

LIST OF TABLES

DIOCTYL PHTHALATE (DOP)

INTRODUCTION

Plasticizers are very important materials because they are widely used during the processing operations of chemical polymers to achieve the following:

1. Improvement of the flexibility and consequently the workability of the polymers.
2. Production of the polymer's end products with certain predetermined specific properties and characteristics.

Dioctyl Phthalate (DOP) is an important member of the plasticizers group.

If the purpose is only to achieve flexibility, the plasticizer is then considered as a "processing aid" and does not perform any further function after the fabrication is completed. On the other hand, if the aim is to achieve both flexibility and production of various end products with specific properties, then the plasticizer becomes an important functional component of the resulting end product's composition.

An illustrative example of the effect of plasticizers on polymers is the processing of polyvinyl chloride (PVC). Without a plasticizer, fabrication of PVC through a hot two-roll mill results in producing brittle and corrosive sheets having brown to black color. If, on the other hand, a plasticizer such as dioctyl phthalate is added to the polyvinyl chloride, the resulting sheets will be clear, colorless to faintly yellow, noncorrosive and semi-rigid

to very flexible depending on the amounts of the plasticizers (dioctyl phthalate) used*.

It is a well recognized industrial fact that the amount of dioctyl phthatle plasticizer in processing a polyvinyl chloride compound will greatly affect the overall performance properties of the plasticized compound. Such performance properties include the hardness, elongation, surface characteristics and the electric and dielectric ones.

Most of the plasticizers used in the various industrial applications are produced in the main three industrialized regions of the world, namely Western Europe, United States of America and Japan. West Europe is considered the leader in this field. Production of plasticizers in the developing countries is stil very limited but is expected to steadily increase relative to the production and the consumption of polyvinyl chloride. Some of the developing countries are planning to establish plasticizers' production plants, while others are presently constructing such plants and/or are already producing plasticizers. These countries include India, Korea, Mexico and Brazil.

In the Arab countries, production and consumption of PVC have jumped to reach over 500 thousand tons and over 550 thousand tons respectively. The growth rates of both production and consumption are expected to continuously increase through the decade of the nineties.

Dioctyl phthalate is definitely accepted as the most effective and suitable plasticizer for the PVC industry. Therefore, the need

*Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 16, p.111, 1981

for the Arab World to plan seriously for the establishment of DOP production facilities becomes very apparent. The main raw materials needed to produce DOP are phthalic anhydride and octyl alcohol. The feedstocks needed to produce these two materials are basically available in some Arab oil producing countries.

The object of this report is to prepare a Project Profile for the production of DOP in any economically suitable location in the Arab World. This profile will include the following:

1. Supply/Demand of Plasticizers
2. Possible Plant Locations
3. Technical Study to consist of the manufacturing process and its required raw materials, utilities and manpower.
4. Economic Evaluation to include the total investment and the profitability of the project.

SUPPLY/DEMAND OF PLASTICIZERS

Plasticizers are mostly produced in the three industrialized regions of the world; namely West Europe, United States of America and Japan. West Europe takes the leading role as it produces nearly 50% of the total world plasticizers production.

The West European plasticizers capacities, production and consumption at the end of 1988 are listed in Table 1 and are presented graphically in Figure 1. In addition, the producers in West Europe and their respective capacities are shown in Figure 2.

Table 1. Production Capacity and Consumption of Plasticizers in West Europe* (000' MT)

Year	Production	Capacity	Consumption
1988	1120	1620	955
1989	1140	1620	980
1990	1160	1640	1000
1991	1180	1670	1050
1993	1200	1670	1080
1995	1215	1670	1095

*Chemie Linz, Linz, Austria - data obtained through personal contact during a business visit

It should be noted that capacity utilization is approximately 70%. Therefore, no new major plants with the possible exceptions of replacement of depreciated ones, are expected to be established during the coming ten years. This is because the present available capacity will be more than sufficient to satisfy the demand during this period

A sizeable portion of the amounts of plasticizers presented in Table 1 are consumed in processing polymers, mostly polyvinyl chloride. Phthalate esters dominate the plasticizers production and technology not only in Western Europe but also in the other two industrial regions particularly in the United States of America.

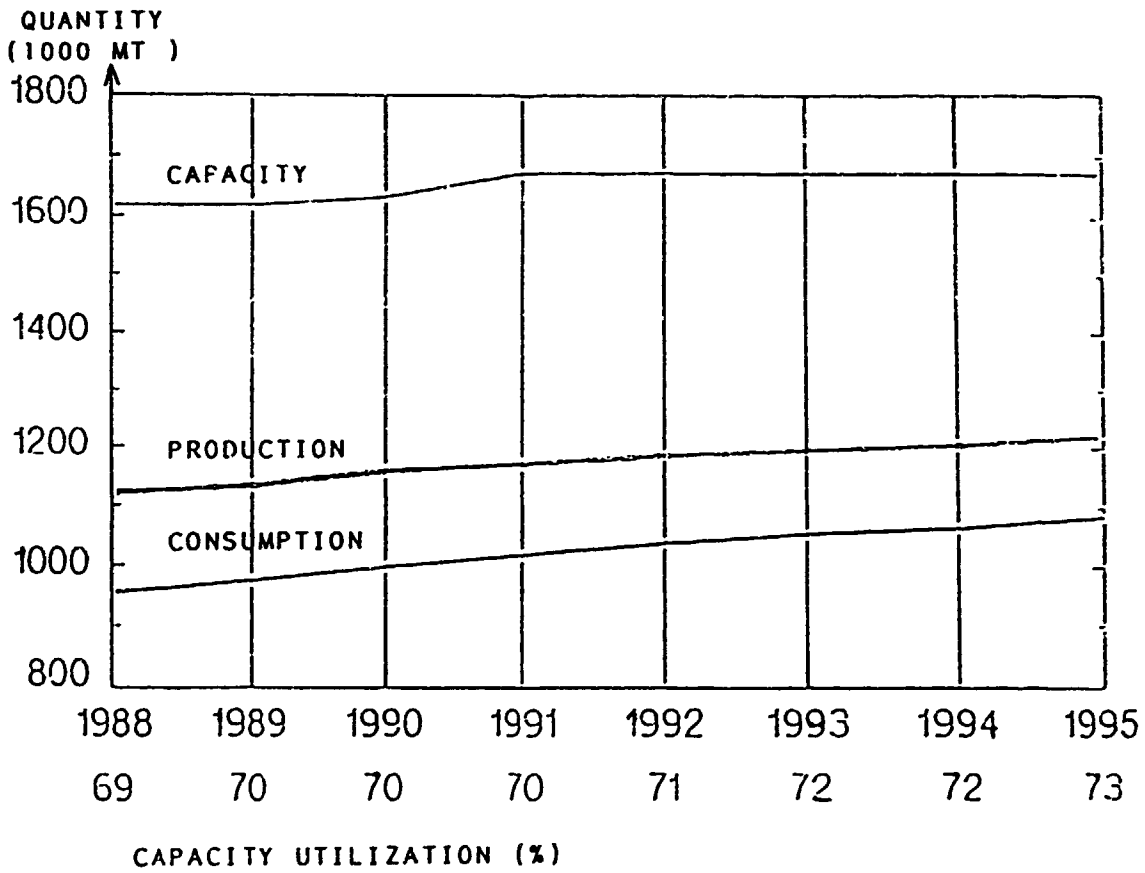


Figure 1. Capacity, Production and Consumption of Plasticizers in Western Europe

(Source: Chemie Linz, Linz, Austria)

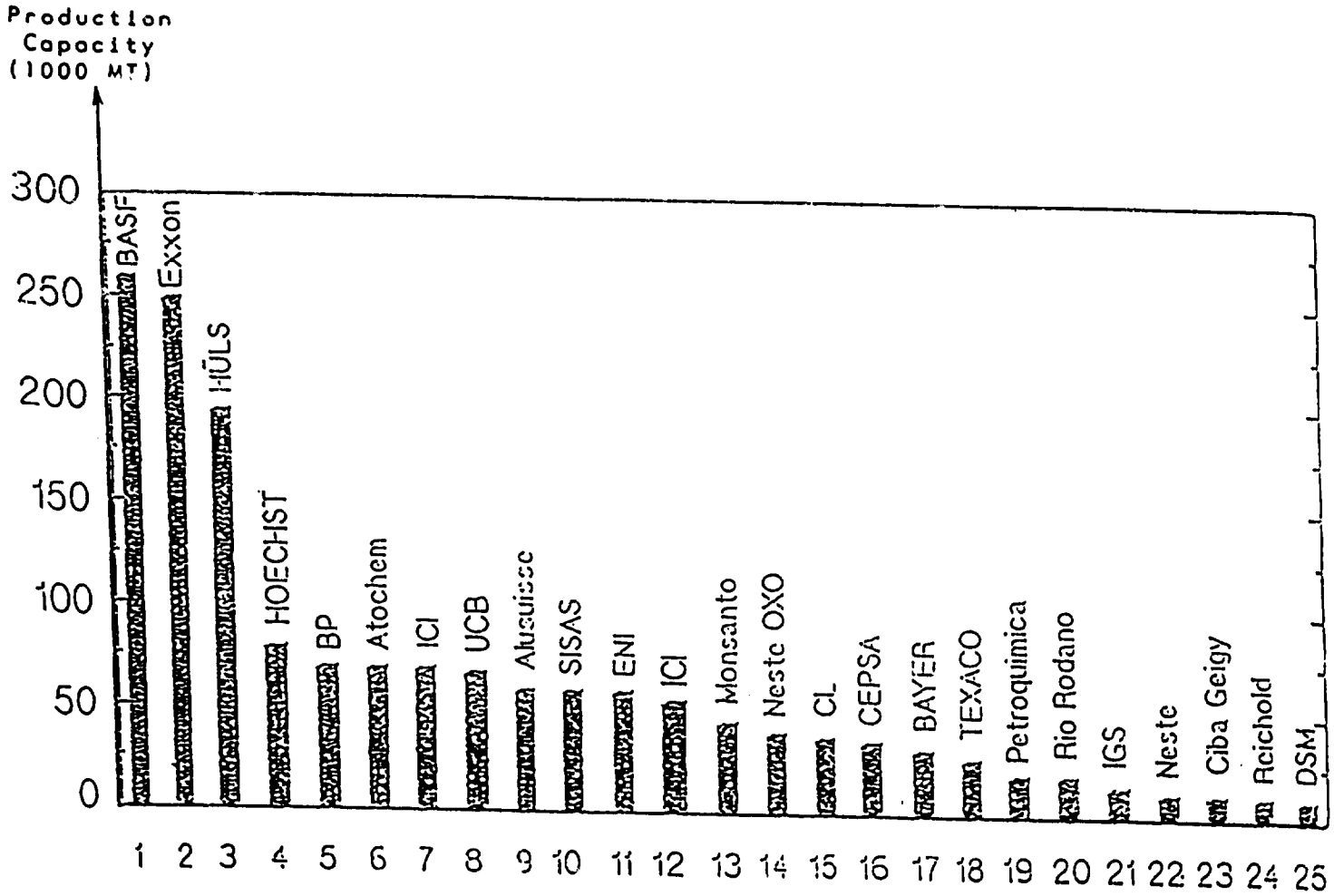


Figure 2. Plcsticizers Production Capocities of West European Producers.
(Source: Chemie Linz, Linz, Austrio)

The phthalate esters account for nearly 70% of the total plasticizers production. Dioctyl phthalate (DOP) which accounts for approximately 25 percent of the phthalate esters is basically considered as the industry standard for a general purpose plasticizer for polyvinyl chloride and is a benchmark for comparison of other plasticizers.

This is so because of its excellent all-around performance resulting from factors such as compatibility with the PVC resin, efficiency in flexibilizing, low volatility, and stability after processing the polymer to produce the end product.

The future growth of dioctyl phthalate is directly related to that of the plasticized PVC products. During 1987, the production and consumption of plasticizers in the United States and in Western Europe were four to five percent higher than 1986. But, within the next five to ten years, it is expected that the average annual growth will be between 1% and 3% through 1995 even though a growth rate of better than 3% was achieved during the decade ending in 1988.

DIOCTYL PHTHALATE SITUATION IN THE ARAB WORLD

As stated previously, plasticizers help in providing flexibility to facilitate the processing of polymers. One of its main outstanding uses is in the production of flexible PVC products where the weight ratio of plasticizers (e.g. DOP) to the PVC is 35% to 65% respectively.

When this ratio is viewed together with the increase in the production of PVC during the last ten years in the Arab World, one sees the definite need to consider local production of plasticizers.

Until recently, flexible PVC production in the Arab countries accounted for about 20% of the total processed PVC. This ratio is expected to increase with time. If one is to assume a trend similar to that in Western Europe, the production of flexible PVC compounds could possibly double in the not too distant future.

The Gulf Organization for Industrial Consulting* estimated the total Arab World Consumption of DOP in 1985 and presented their forecast up to 2010, based on three different scenarios as indicated in Table 2.

Table 2: Arab Consumption Forecast for DOP in Metric Tons

	1985	1990	1995	2000	2005	2010
High Scenario	35343	49292	59011	67656	75536	82655
Medium Scenario	32467	32513	32677	32874	33154	33504
Low Scenario	32467	32293	32205	32268	32394	32572

*GOIC/AIDO, Production of Aromatic Compounds in the Arab Countries

Since the emphasis in PVC production in the Arab countries has been on manufacturing rigid PVC and with the anticipation of higher growth rates in the flexible PVC products, one can easily see that a realistic consummption figure will be higher than the medium/low scenarios but not necessarily as high as the high scenario figures. Assuming a fifty percent increase in the flexible PVC demand, one observes that a consumption of 50,000 - 60,000 tons of DOP per year is a realistic figure.

GOIC reported the actual DOP capacity which existed in 1986 and the additional capacity potential expected to be on stream by the year 2010 as indicated in Table 3 below:

Table 3: Production Capacity of DOP in the Arab World 1986 vs. 2010* (000'MT)

Product	Actual Capacity in 1986	Capacity Potential expected by 2010	Total Expected Capacity by 2010
Dioctyl Phthalate	28	60	88

*GOIC/AIDO, Production of Aromatic Compounds in the Arab countries, Table VI. 2, p. II.148, 1988

The annual production capacities of the actual West European producers of plasticizers including DOP reveals that they range between 12,000 - 120,000 MT/Year. A sizeable number of these producers operate plants with capacities of 20,000 - 60,000 MT/year.

Considering this and an estimated future Arab consumption of 60,000 MT/year and the existing production capacity of 28,000 MT/Y, it is recommended to establish the project with an annual production capacity of 40,000 MT/year. This capacity will be geared to basically satisfy the Arab market as the export market trend does not encourage higher capacity.

It should be pointed out that the concept of "Minimum Economic Capacity" is not necessarily applicable for a dioctyl phthalate production plant. This is because many producers of plasticizers plan to produce different types including dioctyl phthalate in the same plant. As such the design capacity for a particular type of plasticizer is basically of a limited analytical value with regard to the economics of the project.

POSSIBLE PLANT LOCATION

In general, the following factors must be considered in selecting tha plant location:

1. Availability of infrastructures including services, roads, ports ...etc.
2. Availability of experienced manpower and their cost.
3. Availability of raw materials and their prices delivered to the plant.
4. Nature of site and its effect on cost of civil works.
5. Products' local consumption and export distribution costs.
6. Atmospheric and weather conditions which may affect the project.
7. Other related factors.

Because of the nature of this report, the above mentioned factors have not been studied in details as this should be done while carrying out the more detailed future studies for the project. But, a quick review of these factors reveals that the plant can be located in Saudi Arabia, Iraq, Egypt or Algeria. This is so because of the availability of the local market, manpower and the assumption that some of the needed raw materials such as phthalic anhydride will become locally available.

For the purpose of economic calculations, the plant site will be assumed to be in Al Jubail, Saudi Arabia where phthalic anhydride is expected to be produced.

If the preliminary results of this report point to an economic viable project, then the feasibility study will thoroughly evaluate

TECHNICAL STUDY

In this section, the following will be presented and discussed:

I. Manufacturing Technology

II. Raw Materials Requirements and Costs

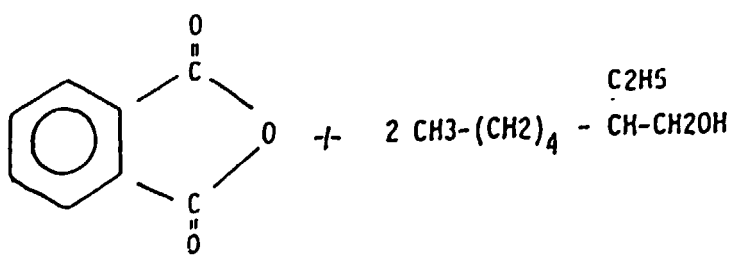
III. Process Utilities Requirements and Costs

IV. Manpower Requirements and Costs

I. Manufacturing Technology

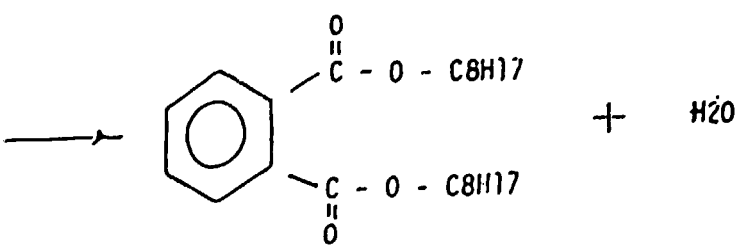
The basic technological concepts including the batch operation as well as the raw materials and their catalytical chemical reaction from seventy years ago are still being used nowadays. The main modifications revolve around the high automation of the plants which permits continuous operations.

Dioctyl phthalate is produced by simple catalytical esterification reaction of phthalic anhydride and octyl alcohol as indicated below:



Phthalic Anhydride

2-Ethylhexanol



Dioctyl Orthophthalate (DOP)

Both the batch and the continuous processes are presently in use by the producers of plasticizers. The general characteristics of these processes are described as follows:

1. The esterification reaction is carried out in the liquid phase using stirred vessel reactors.
2. Facilities to heat up the reaction vessel are necessary as the reaction takes place between 160 °C to 215 °C.
3. Reaction is speeded up by an esterification catalyst such as sulfuric acid or p-toluene sulfonic acid. These acids are normally removed later in a washing step.
4. Water, as a by-product, is normally removed as an alcohol azeotrope by refluxing the reaction solution.
5. Following the reaction, the resulting solution is cooled and scrubbed with caustic soda and then with water to eliminate the monoester and catalyst.
6. Excess alcohol is normally introduced to the reaction vessel. After the reaction is completed, the excess alcohol is removed by distillation and steam stripping and then recycled to the feed to the plant.
7. The yield is 97 % on both the phthalic anhydride and the octyl alcohol.

The main differences between both the batch and the continuous processes are:

1. The batch process operates at atmospheric pressure while the other at high pressure.
2. The batch process yields products with color which is removed by passing the solution over activated carbon at

about 200°C. On the other hand, the products of the continuous process are colorless because of the high temperature and pressure processing operation.

3. The continuous process operates economically at much higher production capacities

BASF, a main international plasticizer producer operating in Europe and the USA, developed the BASF Continuous Process. They are operating at high capacities and are producing other plasticizers such as adipates and maleates. On the other hand, Chemische Werke Huls of West Germany developed the Huls Batch Process which is still widely used in West Europe.

The major producers of phthalate plasticizers in the three industrialized regions include:

USA: BASF, Exxon, Aristech, Eastman and Monsanto.

W.Europe: BASF, Exxon, Hoechst AG and Huls Aktiengesellschaft (see Figure 2)

Japan: Kyowa Yuka Co., Mitsubishi-Monsanto Chem.Co., Sekisui Che.Co

As stated above, both the batch and continuous processes are currently being used by international DOP producers. However, the continuous process is always utilized for the production of high DOP capacities. Therefore, taking the proposed Arab DOP plant capacity into consideration, it becomes evident that the batch is more suitable for this project. As such it will be suggested for the project, and the estimation of the fixed capital will be made accordingly.

II. Raw Materials and Costs

Based on a plant capacity of 40,000 MT/year, the required raw materials and their costs are estimated and presented in Table 4.

Table 4: Raw Materials and their Costs*

Product	Consumption* per MT DOP	Quantity (MT)	Price** ($/MT)	Total Cost (000'$)
Phthalic Anhydride*	.40 Ton	16,000	680	10,880
Octyl Alcohol*	.69 "	27,600	880	24,288
Caustic Soda	$ 3/Ton DOP			120
Activated Carbon	$.75/Ton DOP			30
Catalyst & Additives	$1.5/Ton DOP			60
			Total	35,378

* Personal Contact with European Producer and Technical Literature.
**-Chemical Marketing Reporter - several issues, 1989.
-Average Prices for past five years.

III. Process Utilities, Requirements and Costs

The utilities needed for the operation of a 40,000 MT annual capacity plant are estimated as tabulated in Table 5.

Table 5: Process Utilities and their Costs

Utility	Consumption* per MT DOP	Total Annual Consumption	Price** ($/Unit)	Total Annual Cost ($)
Electricity	35 KWH	1.40 MM KWH	0.0143	20,000
Steam	0.5 Tons	20,000 MT	11	220,000
Cooling Water	30 m^3	1.20 MM m^3	0.03	36,000
			Total	276,000

* -Personal communication with a European producer
-Technical literature survey
** GOIC/AIDO, Production of Aromatic Compounds in the Arab Countries, 1988

IV. Manpower Requirements and Costs

The manpower requirements and their costs are estimated as presented in Table 6.

Table 6: Manpower Requirements and Costs

Category	Number Required	Salary/ Month ($)	Total Annual Costs ($)
Plant Manager	1	3,800	45,600
Production Manager	1	3,200	38,400
Operators	16	600	307,200
Laboratory Control	3	3,000	108.000
Supporting Staff	6	1,000	72,000
Total	27		571,200

ECONOMIC EVALUATION

This section provides the estimates of the investment requirements and the expected operating costs for the establishment of a manufacturing plant to produce 40.000 metric tons dioctyl phthalate per year.

In calculating the profitability, it will be assumed that customs duties and taxes will not be levied on equipment, machinery or imported raw materials.

The following items will be estimated and/or calculated:

A. Fixed Capital

B. Annual Operating Costs

C. Working Capital

D. Total Investment

E. Finance

F. Depreciation

G. Total Annual Production Cost

H. Project Fixed and Variable Costs

I. Estimation of Sales Revenue

J. Calculation of Annual Net Profit

K. Calculation of Rate of Return

L. Calculation of Pay-back Period

M. Determination of Break-even Point

N. Summary of Project Economics

A. Fixed Capital

The costs' estimates of the Battery Limits and the Off-sites for a plant with an annual production capacity of 40,000 metric tons dioctyl phthalate were mainly based on figures provided by a European DOP producer for a plant located in West Europe. These estimates were then adjusted for a Saudi Arabian site using a location factor of 1.3. The resulting figures are as indicated below:

	Estimated Costs (000'$)
Battery Limits	7,410
Off-sites	5,200
	12,610
Contingency 20 %	2,520
Total Fixed Capital	15,130

The estimated required land area is 2800 m^2. It is assumed that it will be rented at nominal rates.

B. Annual Operating Costs

The expected operating costs are estimated as follows:

	Cost (000'$)
1. Raw Materials	35,378
2. Utilities	276
3. Salaries and Wages	571
4. Maintenance - 3% of errected plant cost for materials and labor	454
5. Insurance - 0.5% of errected plant cost	76
6. General Expenses	200
7. Packaging and handling	800
Total	37,755

C. Working Capital

	Value (000'$)
Imported Raw Materials (3 months)	8,845
Utilities (3 months)	69
Wages and Salaries (3 months)	143
Total	9,057

D. Total Investment

	Amount (000'$)
Fixed Capital	15,130
Working Capital	9,057
Total Investment	24,187

E. Finance

It is assumed that the project will be established on a 100% of equity financing.

F. Depreciation

Assuming a useful lifetime of 12 years for the plant, the yearly depreciation will be as follows:

Fixed Capital = US $ 15,130,000

Depreciation = US $ 1,261,000

G. Total Annual Production Costs

	Cost (000'$)
Annual Operating Costs	37,755
Annual Depreciation	1,261
Total	39,016

H. Project Fixed and Variable Costs

a) Fixed Costs

	Annual Amount (000'$)
Annual Depreciation	1,261
Maintenance	454
Insurance	76
Salaries*	286
Total Fixed Costs	2,077

*Assume 50% of the salaries/wages as fixed costs and the other 50% as variable costs.

b) Variable Costs

	Annual Amount (000'$)
Raw Materials	35,378
Utilities	276
General Expenses	200
Labor Cost	286
Packaging and Handling	800
Total Variable Cost	36,940

I. Estimation of Sales Revenue

The estimated ex-works selling price is U.S. $1,010 per metric ton. This price is based on:

1) Figures received from a DOP producer in Europe.

2) Chemical Marketing Reporter, November 24, 1989.

3) Average Prices for past five years.

Total Sales Value = 40,000 x 1,010 =	U.S.	$40,400,000
Loss 2%	U.S. $	808,000
Total Net Sales Value	U.S.	$39,592,000

J. Calculation of Annual Profit

	Amount (000'$)
Total Net Sales Value	39,592
Total Production Cost	39,016
Total Annual Profit (Assuming no taxes)	576

K. Calculation of Annual Rate of Return

Assuming a plant operation at full production capacity starting the first year, the rate of return is calculated as follows:

$$\text{Rate of Return}^{*} = \frac{\text{Annual Profit}}{\text{Total Investment}}$$

$$= \frac{576{,}000}{24{,}187{,}000}$$

$$= 2.4\%$$

L. Calculation of Pay-back Period

$$\text{Pay-back Period} = \frac{\text{Total Investment}}{\text{Annual Profit + Depreciation}}$$

$$= \frac{24{,}187{,}000}{1{,}837{,}000}$$

$$= 13 \text{ years}$$

M. Calculation of Break-even Point (BEP)

The Breakeven Point is the point at which the project income is equal to the total expenses and thus the project produces no profits or losses. The Break-even Point is calculated as shown below and determined graphically as indicated in Figure 3.

$$\text{BEP} = \frac{\text{Average Fixed Costs}}{\text{Net Sales Value - Average Variable Costs}}$$

$$= \frac{2{,}077{,}000}{39{,}592{,}000 - 36{,}940{,}000}$$

$$= 78\%$$

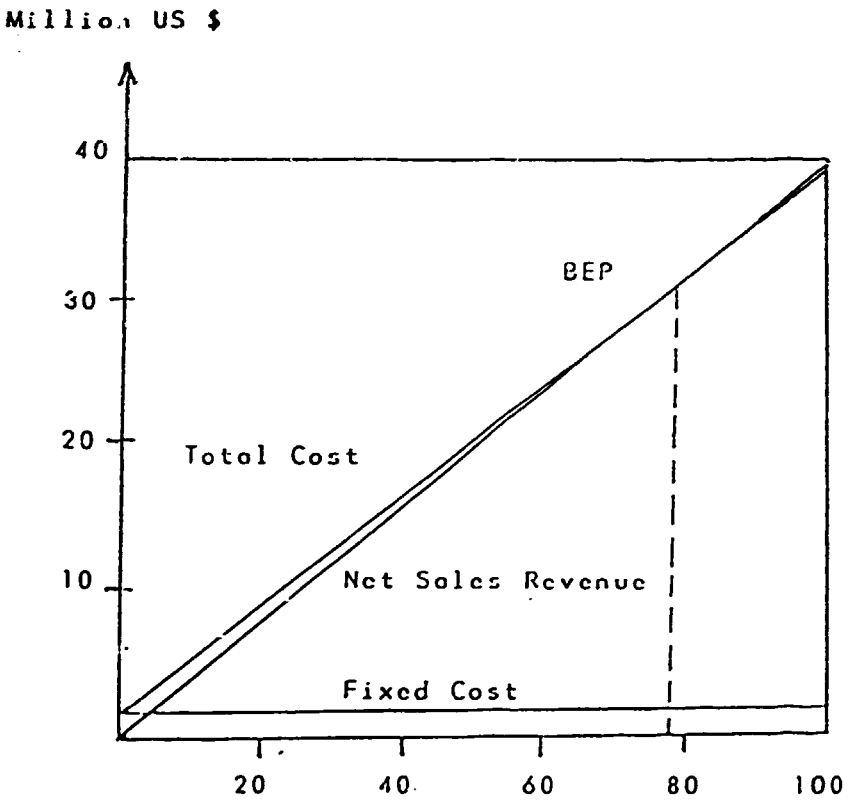


Figure 3. Determination of Break-even Point

N. Summary of Project Economics

Production Capacity	40,000 MT/Year
Total Investment	U.S.$ 24,187,000
Working Capital	9,057,000
Production Cost	39,016,000
Raw Materials Cost	35,378,000
Cost of Utilities	276,000
Salaries and Wages	571,000
Depreciation	1,261,000
Fixed Costs	2,077,000
Variable Costs	36,940,000
Net Sales Revenue	39,592,000
Annual Profit	576,000
Rate of Return	2.4%
Pay-back Period	13 years
Break-even Point	78%
Total Manpower	27
Land Area Required	2,800 m^2

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

a) Most of the Arab World demand for dioctyl phthalate is presently fulfilled by imports from other countries.

b) The international overall demand for polymeric plasticizers is expected to grow at an annual rate of 2% which should basically be in line with the demand for flexible PVC.

c) The production cost, and consequently the profitability of the project, is heavily dependent on the cost of raw materials (90%). As such, an integrated complex in which the feedstocks and the dioctyl phthalate are produced may yield better economical results.

d) The results of this profile indicate that the profitability of establishing the project is rather very tight but possibly can be improved with the establishment of the integrated complex mentioned in Item C above.

2. Recommendations

a) The results of the study indicate that the economic viability of the operation of such a project based on the existing raw materials prices is not financially rewarding. Therefore it is not recommended to establisha the project with the aim to import the raw materials from other countries during the useful life of the project.

b) Because of the direct significant effect of the raw materials prices on the production cost, it is recommended to prepare a study for the establishment of an integrated complex to produce the required raw materials and dioctyl phthalate (DOP). It is reasonable to assume the profitability will be improved.