Plant Location Factors in the Petrochemical Industry in Louisiana.

Robert Nance Mcmichael
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IN LOUISIANA

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Management and Marketing

by

Robert Nance McMichael
B.S., Louisiana Polytechnic Institute, 1948
M.B.A., Louisiana State University, 1958
August, 1961

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ABSTRACT

The petrochemical industry has grown at a tremendous rate since the end of World War II. The major portion of this growth has taken place along the Louisiana-Texas Gulf Coast, which now boasts 70 to 80 percent of the nation's productive capacity in petrochemicals.

The objectives of this study are to determine the factors influencing location of the Gulf Coast petrochemical industry, to compare Louisiana with Texas as a location site for petrochemical plants, and to evaluate the location factors in view of certain economic theories of location. A final objective is that of predicting the outlook for Louisiana's petrochemical industry.

Information was obtained by means of interviews with representatives of seven major petrochemical firms operating plants in Louisiana. Information was obtained from other petrochemical firms by way of correspondence and indirect means. Valuable information was obtained through interviews and correspondence with government agencies, trade associations, chambers of commerce, utility companies, and private research agencies.

Petrochemical plants are primarily raw material oriented. Thus, raw material availability is the chief location factor. The other principal factors were found to be water availability and complete transportation facilities.
Texas and Louisiana rank first and second respectively in the United States in the production of crude oil and natural gas. The two states combined yield more than 50 percent of the crude oil and about 70 percent of the natural gas produced in the nation.

Approximately 50 percent of domestic petrochemicals are derived from petroleum refinery by-products, with the remaining half divided about equally between natural gas and liquefied petroleum gases as the source. Louisiana ranks third in the nation in crude oil refining capacity and fourth in production of liquefied petroleum gases. A shortage of petrochemical building blocks has resulted from the lack of processing facilities for crude oil and natural gas in relation to production of these resources in Louisiana.

Louisiana has ample water resources. The nation's largest fresh water source, the Mississippi River, provides inducement for development along its banks from Baton Rouge to the Gulf. Surface water is not so plentiful in the southwestern part of the state because of salt water invasion.

A complete transportation system is provided in the Gulf Coast section of Louisiana. Domestic transportation may be handled by barge, rail, or motor truck, whereas international trade is facilitated by deep water ports at Baton Rouge, Lake Charles, and New Orleans.

The plants surveyed were generally located at the point of least production costs although there was not unanimity in this location choice. This reasoning fits into the least-cost theory of location. The maximum-profit theory of location, which includes the idea of spatial monopoly for a given market, seems to describe recent plant
location in the ammonia industry. The locational interdependence theory of plant location seems to lack applicability in the location of basic and intermediate petrochemical plants.

The specter of political instability and high taxes have created an unfavorable reputation for Louisiana. It seems that, relative to other states, this unfavorable image is more imaginary than real. Nevertheless, the image remains to be overcome.

Expansion of the petrochemical industry in Louisiana is most likely for chemicals derived from natural gas and natural gas liquids. Chemicals from methane, ethane, propane, and butanes fall in this group. However, facilities must be built to convert these petroleum fractions into petrochemical building blocks if a satisfactory basis for expansion is to be provided.

A noticeable current trend to a market area location, plus over-capacity in some products, will cause a slackening of the previous pace of petrochemical expansion on the entire Gulf Coast.
CHAPTER I
INTRODUCTION

The petrochemical story, which was begun in 1916,¹ has primarily had the Louisiana-Texas Gulf Coast as its stage. Presently, about seventy-five percent of the petrochemical producing capacity of the United States lies along the Gulf Coast.² Other recent estimates indicate that the Gulf Coast boasts more than eighty percent of the petrochemical productive capacity in the United States.³ Even though there may be some slight differences of opinion as to the exact proportion of productive capacity on the Gulf Coast, there is complete unanimity among all authorities that the Gulf Coast is the largest petrochemical complex in the world.

The Gulf Coast description refers specifically to the area about 700 miles long between Brownsville, Texas, and New Orleans, Louisiana, and running approximately one hundred miles inland from the coast.


Ponder and Evans, op. cit., XXXVIII (1959), 186.
This region has been described, perhaps more eloquently, as the "Golden Crescent."^4

Although petrochemicals were discovered in the research laboratories during World War I, they remained, for the most part, of little commercial significance until World War II. Indeed, these new substances were so little known that prior to World War II the word was not even listed in the dictionary.

For the purpose of this paper petrochemicals are defined as "chemicals derived from petroleum and more specifically substances or materials manufactured from a component of crude oil or natural gas."^5 This definition includes both organic and inorganic chemicals derived from petroleum or natural gas components.^6

The total investment in plant and equipment of the petrochemical industry in the coastal area is in excess of $3.5 billion.7 Approximately 50,000 people are employed in the Gulf Coast petrochemical industry. Of the approximately 80 major petrochemical plants located on the Gulf Coast, almost 60 percent are found in the Houston and Beaumont areas. There are eight specific locations on the Gulf Coast where the petrochemical industry has thrived. These are shown in Figure 1. They are, in order of size as measured by the number of plants:

---


^6Almost all petrochemicals are organic, containing carbon atoms, such as ethylene, C2H4. However, ammonia, made from natural gas is an inorganic, or non carbon, chemical substance having the formula NH3.

^7King, loc. cit.
FIGURE 1

PETROCHEMICAL CENTERS OF THE CONTINENTAL UNITED STATES

Location of Petrochemical Plants

Source: Business Week

PETROCHEMICAL PLANT LOCATIONS OF THE GULF COAST

Key to Plant Location Areas

1. Brownsville
2. Corpus Christi
3. Freeport
4. Houston
5. Beaumont
6. Lake Charles
7. Baton Rouge
8. New Orleans

Source: Petroleum Engineer

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1. Houston-Pasadena-Texas City-Baytown Area
2. Beaumont-Port Arthur-Orange Area
3. Baton Rouge Area
4. New Orleans Area, Corpus Christi Area (tie)
5. Lake Charles Area, Freeport Area (tie)
6. Brownsville Area

Louisiana's economy has benefited greatly by the growth of the petrochemical industry in the state even though only about one-fourth of the major Gulf Coast plants are located in Louisiana. In the years 1956 through 1958 approximately $600 million was invested in new and expanding petrochemical plants. This amounted to about 60 percent of total plant investment expenditures in the state for that period.\(^8\)

One characteristic of the petrochemical industry, however, is the high rate of investment per employee. Thus, with more than 60 percent of the investment, the petrochemical industry contributed less than 40 percent of the new jobs created by manufacturing expansion over the period 1956-1958.

The rate of expansion of the petrochemical industry in Louisiana has not continued at its 1956-1958 level through 1959 and 1960. However, the state has maintained the number two position in chemical plant construction outlay for the period 1958 through 1960 with $470 million for total chemical plant construction over the period.\(^9\)

\(^8\)From testimony of Curt Siegelin, Executive Director, Louisiana Department of Commerce and Industry before the U. S. Senate Committee Investigating Unemployment Problems, Baton Rouge, Louisiana, December 14, 1959.

The volume of petrochemical production in the United States has grown from 140 million pounds in 1930 to an estimated 56 billion pounds in 1960.\(^{10}\) While this amount is only 30 percent of the total volume of chemicals produced, their sales contribute 60 percent of the total sales value of chemicals and allied products.

In Louisiana, the value of output of the chemical industry was $52 million prior to World War II in 1939.\(^{11}\) In 1947 this value had increased to $217 million and by 1958 had grown to $584 million. The 1958 value shows a more than tenfold increase since the pre-war period. The average annual increase in value of production for the Louisiana chemical industry in the post-war period 1947 through 1958 has been 9.4 percent.

**Purpose**

Because of the recent rapid growth of the petrochemical industry in Louisiana and the Gulf Coast region generally it was felt that a study of the reasons for location in this area could serve several needs. The objectives of this study are:

1. To determine and evaluate the factors which have caused the phenomenal growth of the petrochemical industry in the Gulf Coast area.
2. To evaluate the development of this industry in light of certain economic theories of industrial location.
3. To determine specifically what factors have influenced the growth of this industry in Louisiana and to discover what special conditions have favored a greater growth in Texas.
4. To predict the potential of the petrochemical industry in the Gulf Coast area; particularly Louisiana.


\(^{11}\)"Louisiana Industry," reprinted from the *Manufacturers Record*, 1959, p. 2.

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Method of Collecting Data

A search of existing literature was made to determine what general factors influence the location of industry. In the writings of economists several theories on the location of economic activity have been advanced over the years. Certain theories of this group are explored in Chapter II of this work.

The problems of plant location are also very important to persons in the areas of management and engineering. Thus, books and periodical literature in these areas have provided a source of supply of background material. Because of the nature of the industry studied and its rather recent rise of importance, most of the material applying to this specific area is to be found in periodic literature written in the last decade.

Since it was decided to emphasize location factors in Louisiana, contact was made with nineteen companies thought to have petrochemical operations in the Louisiana Gulf Coast area. Of these, three stated that they were not in the petrochemical business. A questionnaire was sent to each of the eleven companies agreeing to supply information concerning plant location factors in the petrochemical industry. A problem in defining companies operations developed because of the interrelationships among companies in this industry. Thus, one company interviewed could supply answers for more than one of the original companies written. Seven of the companies completed questionnaires, and the others, except one, agreed to give information, but not in questionnaire form. The questionnaire used is shown in Appendix A.

In addition to the data obtained from the companies in the petrochemical industry, much valuable information has been obtained from government agencies, trade associations, Chambers of Commerce, power
companies, gas transmission companies, and private research agencies. This information has been collected both by personal interview and written communication.

Papers presented at the Forty-fourth National Meeting and First Petrochemical and Refining Exposition of the American Institute of Chemical Engineers have been of special value in providing information for this study. This meeting was held in New Orleans, February 26-March 1, 1961.

Extent and Limitations

This study was made solely for the purpose of discovering industrial location factors for the petrochemical industry. However, it is quite obvious that many of the factors which apply to the petrochemical industry may be applied to other industries in making location decisions. Nevertheless, no attempt was made to relate these factors to any industry other than petrochemicals.

The original information collected for this report was from petrochemical manufacturers in Louisiana having investments of $10 million or more in plant and equipment. Some of the companies had operations both in Louisiana and Texas. A trip was made to Texas to collect additional information. However, the data on operations in Texas was of a much more general nature than that collected for Louisiana. For comparative purposes, plant location considerations in areas outside the Gulf Coast will be covered to some extent.

None of the data presented in this report is associated with any specific company. At the request of the contributing companies, they are not identified even in an acknowledgment.
Method of Presentation

This paper is presented in six parts. The first part deals with certain economic theories of plant location. In this section, the more modern writings of Greenhut and Isard have been given emphasis. These, however, do not overlook the earlier works of Von Thunen, Weber, Losch, and others.

The following four sections deal with plant location factors. A wheel-type arrangement of factors influencing industrial plant location is shown in Figure 2. Although the factors used in this report are not exactly the same as those in Figure 2, this arrangement shows in unique form the general considerations in plant site decisions.

The first chapter on the factors of location in the petrochemical industry deals with the most significant factors in the Gulf Coast location. This chapter deals with the abundant raw material resources of the Gulf Coast area. In addition to the basic petrochemical resources of petroleum and natural gas, other important raw materials such as salt and sulphur are considered.

The third section covers several factors which have been combined. The four factors considered are land, labor, water and power. Probably the most important of these factors is water.

The next chapter deals with markets, transportation and industrial complex growth. The market for petrochemicals is perhaps the primary factor which is unfavorable to the continued development of the petrochemical industry on the Gulf Coast. The methods of transportation commonly used in the petrochemical industry are covered. These are water, railway, pipeline, and highway. Petrochemical plants have tended to grow in bunches, or complexes with one plant feeding off of the other. Chapter five considers this characteristic of complex growth.
FIGURE 2
LOCATION FACTOR WHEEL

SOURCE: Vilbrandt, *Chemical Engineering Plant Design*
The final chapter on plant location factors considers the more intangible factors of political and social influences on plant location. These factors are very difficult to weigh objectively but are significant in the plant location decision. Also such factors as climate and housing are included in this chapter.

The final chapter of this paper evaluates applicability of location theory to the petrochemical industry. A comparison is made of how well the actual plant location decisions in the petrochemical industry follow the general theories of plant location presented in the early part of this study.

The concluding chapter also summarizes the influence of various factors on plant location in Louisiana in the petrochemical industry. Conclusions are drawn concerning the past growth and potential of the petrochemical industry in Louisiana.
CHAPTER II

THE ECONOMIC THEORIES OF PLANT LOCATION

This chapter deals with certain selected economic theories of plant location. Many economists have written on the subject of plant location theory, varying from vague mentionings to entire books concerning this topic. Others too (geographers, engineers, and executives of industrial organizations) have written books and articles dealing with plant location.

The location theories considered in this chapter are those of least cost, locational interdependence, maximum profit, and a general theory of location set forth by Walter Isard who is probably the most outstanding current authority in the field of location theory. Analytical techniques used in plant location analysis are also discussed in this chapter plus some results of earlier plant location surveys.

In order to get a better idea of the general problems of a specific location decision before going into the location theories, the best thing to do is to consider a simplified model. Let us suppose that in a very large area there is one predominant city, A, which is the center of culture and population. This city has been covered by a market research agency acting in behalf of a company seeking additional markets for its new product X. Product X is well received in A. The company has practically no excess capacity in its existing factory. In addition, it wants
to establish a new factory to use modern methods of manufacturing product X near newer market developments.

The company immediately starts looking about in the area surrounding A to seek a suitable plant site. It is determined that the only source of the major raw material for product X is at a small town, B, located some distance from A. The company then has two location possibilities; (1) locate at the raw material source, (2) locate at the market place.

In such a situation a basic principle is applicable. If the product gains weight in processing, it is cheaper to locate the plant at the market to save on transportation charges. If the product loses weight in processing it will be cheaper to locate at the raw material source to save on transportation costs. In the case of ubiquitous materials, the market place would be the obvious location choice.

Several complicating factors have been ignored in the above analysis. For example, the rent factor or cost of land has been assumed to be constant in both areas, whereas, in actuality, it would seem certain that the land or rent cost at A would exceed the cost or rent of land at B.

Other complicating factors have not yet been mentioned. One of these could be a special tax or building inducement. Suppose that community C has the benefit of a very optimistic city council which has stirred the local citizenry to the advantages of attracting industry to supplement their primarily agricultural economy. The people in this area about C may be willing to float a local bond issue to raise capital to offer the manufacturer of product X a low-rent building for his plant. The city may also offer special tax advantages to the company and offer to sell them the building under very attractive terms.
In addition to the above location alternative, others such as special labor conditions, special power facilities, etc., make the location decision more difficult. In general, the labor, tax, power, and building advantages are most favorably considered when they are on a direct transportation route between the raw material source and the market place. All these factors, and others, must be considered before making the location decision. We shall now consider some of the work of plant location theorists.

**Least Cost Location Theory**

One of the earlier theorists dealing with the location of economic activity was Von Thunen.\(^1\) Von Thunen wrote about the location of agricultural activity, evidently due to the fact that this was the principal factor in the economy at the time and place of his writing. Von Thunen based his decision for the location of agricultural enterprise upon choosing from among alternative sites that one which would yield the least total cost of production.\(^2\)

Von Thunen makes the simplifying assumptions that capital and labor have equal costs and productivity everywhere. Von Thunen further assumes that all land is equal in fertility and that there is only one consuming center. He then sees the location decision as resolving into minimizing the two cost considerations: (1) land rent and (2) costs of transportation.\(^3\)

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Alfred Weber, another German economist, followed Von Thunen's work with a book containing a general theory of industrial location in 1909 which was later translated into English.\(^4\) Weber, like Von Thunen, followed the least-cost approach.

Weber, in his analysis, assumes varying deposits of fuel and raw materials, labor of varying quality and costs, and more than one consuming center. These assumptions then give Weber a much more realistic basis upon which to operate than Von Thunen allowed himself. However, Weber bypasses the problem of demand by the simplifying assumption that in any situation the market for any product would always be greater than the aggregate output of all suppliers.\(^5\) Weber also overlooks any influence of taxes and interest.

The cost factors to be considered in making a location decision are those of labor, transportation and agglomerating (or deglomerating) forces.\(^6\) The agglomerating forces include marketing advantages, proximity to auxiliary enterprises or industries, and economies of scale. A deglomerating force is land rent. As industries are drawn together the cost of land rises thus causing some industries to seek cheaper land away from the industrial concentration. Industries may be drawn closer together or scattered depending upon the power of the agglomerating or deglomerating forces.


\(^5\) Greenhut, *op. cit.*, p. 256.

A plant location theory having a more market oriented approach than that of the least cost theory is the locational interdependence theory.

**Locational Interdependence Theory**

The locational interdependence theory was developed under the influence of Fetter, Hotelling, Lerner and Singer, Smithies, Chamberlin, and others. This theory assumes the cost of production to be the same at all sites and that the objective of location in a certain place is to gain control over the largest possible market area. Each seller then becomes a spatial monopolist in his relations with a certain group of buyers.

Following this theory, the only cost which would affect the price to the buyer would be that of transportation. If we should assume a straight-line, negatively-sloping total demand curve for the industry and if we should further assume a linear dispersion of buyers with equal density in every portion of the market, then the most advantageous location for a seller with one plant would be at the center position, A, in

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12Greenhut, *op. cit.*, p. 258.

13 Ibid.
Figure 3. The location at A would provide the best one-point control of the market XY. This conclusion assumes that the cost of transportation remains constant per unit of weight per unit of distance.

A given seller could obtain greater sales by locating two plants in this market at points B and B' rather than one plant at A. These are the first and third quartile positions. Plant B would supply the market XA and plant B' would supply the market AY. Total sales would increase since transportation charges would be less per unit allowing a reduction in selling price and stimulating increased demand. A further market expansion could be achieved by location of plants at the first, third, and fifth sextiles, etc. The tendencies of sellers toward dispersion vary with the height of freight costs, the elasticity of demand and the characteristics of marginal costs.

Now we may suppose a competitive situation in which Company A establishes its one plant at A, then Company B establishes plants at B and B'. Company A originally had the entire market XY but with B's plants at the quartile positions, B may offer lower prices to three-fourths of the total market because of lower transport costs. Company A would then be left with price advantage only in the market ZZ', which lies one-half the distance between A and B and one-half the distance between A and B'.

Ibid., pp. 260-262.
The major disadvantage of this approach to the location of industry is that it overlooks varying costs of production at different locations. A theory which avoids the disadvantages of the locational interdependence and least cost location theories is presented next.

**Maximum-Profit Theory**

The maximum-profit theory was offered by Greenhut as a general theory of plant location which had a superior basis to those previously offered. This theory does not avoid consideration of varying cost and demand factors which were limitations of the previous theories presented.

"The inclusion of cost and demand factors in one model points out the need for a broader statement of the determinants of plant location than one which concludes that firms seek the location of least cost, or one which holds that firms seek the location offering the largest market area. This need is fulfilled by the concept of the maximum profit location, which by definition may be referred to as that site from which a given number of buyers (whose purchases are required for the greatest possible profits) can be served at the lowest total costs. While the lowest of average production cost at this site may be higher than that existing at alternative ones, the monopolistic control gained over larger numbers of buyers (spread over a market area) makes it the maximum-profit location at the optimum output."\(^{15}\)

An earlier writer, August Losch, in analyzing the theories of location stated that neither the least-cost nor the largest market should be the determinant of plant location.\(^{16}\) His conclusion regarding the best plant location site was, "In a free economy, the correct location of the individual enterprise lies where the net profit is greatest."\(^{17}\)

\(^{15}\)Ibid., p. 262.


\(^{17}\)Ibid., p. 27.
There seems to be some overlap in the thinking of Losch and Greenhut regarding the maximum profit location. The reason for Greenhut's not giving more consideration to this earlier work is probably due to the fact that Losch's book was written in Germany during World War II and was not translated into English until 1954, which was after much of Greenhut's analytical work was completed. Greenhut thus did not have full advantage of the English translation of Losch's, *The Economics of Location*. However, Greenhut did consider Losch's work in its original German form.

Professor Walter Isard is probably the most prolific and outstanding authority currently writing in the field of location economics. A brief summary of his principal work in location theory is presented next.

**Isard's General Theory**

Isard has established a broad general location theory which incorporates and refines many narrower earlier concepts. This broad theory encompasses a wide range of economic activities, giving attention to spatial variations in prices and costs and the distribution of inputs and outputs. The substitution approach has been used as the key to this spatial analysis.

The concept of transport inputs, defined as the movement of a unit weight over a unit distance, has been linked with the substitution

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approach. This method has been used to reformulate earlier (primarily Weberian) transport orientation doctrine. The problem of determining the transport optimal point resolves to that of locating the proper substitution points between pairs of transport inputs.\textsuperscript{19}

However, the location site may not always be at the point of minimum transport costs. For example, a point or points of cheap labor may exist which would be the cause of a movement from the point of minimum transport outlay.\textsuperscript{20} We may plot labor outlay against transport outlay for each of several low labor cost sites. This is done in Figure 4, which follows a pattern used by Isard.

Point A has been determined as the site of minimum transport outlay, but it may also be seen as the point of maximum labor outlay of all the points on the chart. Points B, C, D and F are all points of successively lower labor outlay but higher transport outlays. The negatively sloping diagonal lines are iso-outlay lines which indicate total outlay costs per unit of output.

It may be seen that Point C would represent the site of least total outlay rather than A, which would now become the second choice. Further inspection of Figure 4 would indicate that total outlay costs for site B and site D would be equal. If the initial location were at A, a move to C would cause a substitution of transport outlays for labor outlays.\textsuperscript{21}

\textsuperscript{19}Ibid., p. 255.
\textsuperscript{20}Ibid., p. 127.
\textsuperscript{21}Ibid., p. 129.
FIGURE 4
ISO-OUTLAY CURVES SHOWING LEAST-COST LOCATION

Labor Outlay
($ per unit of output)

Transport Outlay
($ per unit of output)
Similar analysis could also apply to any site which might have cheaper power, lower taxes, or less rent. The plant site may be shifted from the optimal transport location to any other point where sufficient savings may be obtained on any type production outlay to justify the move.\textsuperscript{22}

Alfred Weber emphasized three basic forces in location analysis. Two of these were transport cost differentials and labor cost differentials. The third thing he emphasized was the effect of agglomerating (or deglomerating) forces.

Isard follows E. M. Hoovers classification of factors of agglomeration:\textsuperscript{23}

1. Large-scale economies--Growth of the firm at one location.
2. Localization economies--Growth of one industry at a particular location.
3. Urbanization economies--Growth of all industries at a particular location to a larger total economic size at that place.

Economies of scale may be realized as a substitution of transport outlays for various production outlays as these production factors become cheaper with growth of the individual firm. This concept follows the pattern shown in Figure 4.

Localization economies are different from economies of scale in that they are external to the firm rather than internal to the firm as the economies of scale. Localization economies result in lower cost service inputs. Some firm or firms will move to be able to substitute

\textsuperscript{22}Ibid., p. 259.

\textsuperscript{23}Ibid., p. 172.
transport outlays for production outlays at the place where the localiza-
tion economies exist.\textsuperscript{24}

Urbanization economies are those which occur with the growth of
total economic size of a multi-commodity area. This growth may result
in the reduction in cost of certain facilities as power, port costs,
etc. When this condition occurs there is a substitution of transport
outlays for these various production outlays which are cheaper as a
result of economies arising from urbanization.

Agricultural location, which Isard brings into his general theory
following Von Thunen's work, is not covered in this study.\textsuperscript{25} Isard
also discusses the interrelations of location theory and trade theory
in Chapter 9 of his book.

In presenting summaries of the work of location theorists, graphical
presentation has been held to a minimum and mathematical analysis has
been omitted entirely. While this is in keeping with the limited scope
of this summary, it should be pointed out that the location theorists
mentioned made extensive use of graphical and mathematical methods in
their presentations.

\textbf{Analytical Techniques in Industrial Location Studies}

Methods of modern plant location studies have developed along
several lines. One of these has been the use of regional input-output

\textsuperscript{24} Ibid., p. 267.

\textsuperscript{25} Ibid., see Chapter 8.
analysis. By such a method the amounts of various inputs required per unit of output of a given commodity are calculated for the regions under consideration. The region in which the total input cost would be lowest per unit value of output would be the most desirable.

Another approach to industrial location determination has been made through the use of the technique of linear programming. Lefeber has written on this type analysis applied to industrial location. In the linear programming some objective function may be maximized such as profits or minimized such as costs. Problems arise due to the necessity of being able to quantify all the factors and state their relationships following a linear pattern.

Comparative cost studies have been used in plant location analysis. Isard and Schooler in their study of the petrochemical potential of the Arkansas, White, and Red river basins considered transport costs and production costs for varying size plants. This was a part of an overall economic development study of the Arkansas, White, and Red river basins participated in by the Area Development Division of The Office of Technical Services in the Department of Commerce. Extensive transportation cost analyses were made for two points in the Arkansas, White, and Red river basins and one Gulf Coast point, Houston. This analysis was made primarily on chemicals based on methane, ethylene, and acetylene. This

---


limitation was imposed because natural gas is the principal raw material in the area considered. Petrochemicals based on heavier hydrocarbons are derived from crude petroleum, which is not widely available in the Arkansas, White, and Red river basins.

A second volume using the comparative cost approach was written by Joseph Airov. This study of the synthetic fiber industry uses an interregional comparative cost analysis. This study by Airov is concerned with plant location for enterprises making such products as nylon, Orlon, Dacron, and other fibers made from petrochemical intermediates. There were three types of regions studied: raw material areas, market areas, and a low labor-cost area, Puerto Rico.

Yet another method, that of industrial complex analysis, has been presented in another recent book by Isard, Schooler and Vietorisz. This book is a case study of a proposed refinery, petrochemical, fertilizer and fiber complex in Puerto Rico. This study, along with the previously mentioned study by Airov, was supported by the Social Science Research Center of the University of Puerto Rico in seeking methods of economic development for that underdeveloped region. The industrial complex analysis approach was used in order to give maximum consideration to economies achieved through the action of forces of agglomeration.

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Professor Walter Isard and his associates have written, thus far, four books in a series of Regional Science Studies. The first was Isard's book of theory, Location and Space Economy. The second was Airov's The Location of the Synthetic Fiber Industry. The third in the series is the book on industrial complex analysis by Isard, Schooler, and Vietorisz. The fourth, Methods of Regional Analysis, which was published late in 1960, deals with analytical techniques of regional analysis.

A different mathematical approach to the plant location problem was developed by a geography professor, Chauncy D. Harris. Harris takes the view that the major determinant in plant location is the position of the market. He has developed a formula for market potential (P) in terms of the markets accessible to a point (M) and the distances of the market from that point (d). The formula then would be:

\[ P = \sum_{d} (M^i_d) \]

The best plant location then would occur at the point where P is a maximum.

Harris also recognized the importance of minimizing total transportation costs (T) which are found by the formula:

\[ P = \sum (Md) \]

where (M) represents the markets within reach of a city and (d) the distance in transport costs to each unit.

Numerous plant location surveys have been made, some to test new analytical techniques and others for various reasons. The results of some of the previous surveys are related in the next section.

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30 "Mathematics of Plant Location," The University of Chicago Reports, IV (1954) 1-2.
Results of Previous Location Surveys

In addition to the intensive plant location studies by Isard and associates which were recorded in the previous section, a study was conducted by Greenhut in connection with his work Plant Location in Theory and in Practise. Greenhut's study was made to determine why certain manufacturing plants chose their particular location.

The survey conducted by Greenhut covered eight small manufacturing firms in Alabama. In five of the eight cases, personal consideration was given as a primary factor in selecting the location of the plant, and it was listed as a secondary factor in a sixth case. These situations were principally due to the influence of personal contacts in obtaining loans, materials, or sales, or some combination of these factors. However, in two of the six cases, the personal considerations reflected an appeal of psychic income rather than the more tangible cost or sales advantages.31

Maurice Fulton, an industrial development specialist, notes that in many instances the wives of key company personnel will strongly influence a plant location decision, other things being relatively equal. Women tend to place more emphasis on climate, schools, housing, churches and people rather than raw materials, markets and transportation costs.32

31Greenhut, op. cit., p. 277.

32Joyce Schuller, "Plant Location Often Decided by Wife's Taste," Baton Rouge State-Times, CXVIII (July 21, 1960) 6-D.
A recently conducted survey reported by Greenhut and Jackson gives an account of the problems involved in community relations by various sized companies.³³

In this survey covering 752 Florida-located firms primary emphasis was placed on the satisfaction with community factors such as attitudes, fire and police protection, local labor relations, effectiveness of local government, etc. This survey indicated that the smaller firms (less than 100 employees) and the larger firms (more than 500 employees) had relatively few community problems, while the intermediate sized companies of 100 to 500 employees seemed to have the most difficulties in settling problems of community relations.

The Fantus Factory Locating Service, which has made about 1800 plant location recommendations, makes an initial decision as to whether the plant should be market, raw material or labor oriented and then works from there.³⁴ After this basic decision has been made, depending on the company's type of operations, the decision must be made on location from the several sites available. One very important factor which influences the ultimate decision is the psychological climate of the various communities. Psychological climate deals with the community attitude toward health and recreational facilities, conditions of homes, streets and public buildings, and very significantly, the educational system including vocational training provisions. After


all possible conditions have been considered, the location recommendation is made.

Now we will consider some qualitative factors which have influenced petrochemical plant location in Louisiana.
CHAPTER III

RAW MATERIALS OF THE PETROCHEMICAL INDUSTRY

With no exception the companies included in this study indicated availability of raw materials as a primary factor in the location of their petrochemical plants in Louisiana. These responses simply add further confirmation to the generally acknowledged fact that the Gulf Coast petrochemical industry is strongly raw material oriented.¹ Now we shall consider what principal raw materials have had such a pronounced effect on the location of the majority of the United States petrochemical plants. Special attention will be given to the occurrence of these raw materials in Louisiana. Comparisons will be made among Louisiana, Texas, and the total United States for these raw materials.

The chief raw material requirement in the petrochemical industry is the availability of adequate supplies of certain hydrocarbon fractions from petroleum or natural gas. Petroleum, or crude oil, is a dark brown or greenish liquid which contains varying quantities of pentanes, hexanes,


heptanes, octanes, and heavier hydrocarbons. It is very seldom that the oil from two different fields will yield the same analysis. In addition to the above mentioned hydrocarbons, some non-hydrocarbon elements may be found in crude oil such as sulfur, oxygen, and nitrogen. The amounts of these components are usually small, however.

Natural gas, which frequently, but not necessarily, is found with crude oil in the same reservoir, is composed of the more volatile hydrocarbons. Large deposits of natural gas may be found independently of crude oil. The principal constituents of natural gas are methane, ethane, propane, and butanes with a small amount of pentanes and heavier hydrocarbons. Natural gas may also contain non-hydrocarbons, usually in small amounts, such as carbon dioxide, nitrogen, and helium.

The various hydrocarbons are named according to the number of carbon atoms in each molecule. The system of naming is shown in Table I.

<table>
<thead>
<tr>
<th>Name of Hydrocarbon</th>
<th>Number of Carbon Atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>1</td>
</tr>
<tr>
<td>Ethane</td>
<td>2</td>
</tr>
<tr>
<td>Propane</td>
<td>3</td>
</tr>
<tr>
<td>Butanes</td>
<td>4</td>
</tr>
<tr>
<td>Pentanes</td>
<td>5</td>
</tr>
<tr>
<td>Hexanes</td>
<td>6</td>
</tr>
<tr>
<td>Heptanes</td>
<td>7</td>
</tr>
<tr>
<td>Octanes</td>
<td>8</td>
</tr>
<tr>
<td>Nonanes</td>
<td>9</td>
</tr>
<tr>
<td>Decanes</td>
<td>10</td>
</tr>
</tbody>
</table>

---


Naturally occurring hydrocarbons found in petroleum may be of three broad types. These are the paraffins, naphthenes, and aromatics. Before going further it would be well to briefly discuss these hydrocarbon types for a better understanding of some of the future material.

**Paraffins**

The paraffinic or aliphatic hydrocarbons are called open-type hydrocarbons since the carbon atoms are arranged in straight chains or straight chains with shorter side chain branches. The straight chain groups are called normal paraffins. Straight chain and branched-chain groups occur in the natural production of crude oil and natural gas. These branched-chain types are called isomers, which have the same composition as the normal hydrocarbons but have a different molecular structure and different physical properties. An example will perhaps make this relationship more clear.

<table>
<thead>
<tr>
<th>Normal Butane ((C_4,H_{10}))</th>
<th>Iso Butane ((C_4,H_{10}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point - 0.5°F.</td>
<td>Boiling Point - 10.2°F.</td>
</tr>
<tr>
<td>H - C - C - C - C - H</td>
<td>H - C - C - C - H</td>
</tr>
<tr>
<td>H H H H H H</td>
<td>H H H H H H</td>
</tr>
<tr>
<td>H - C - H - C - H</td>
<td>H - C - H - C - H</td>
</tr>
<tr>
<td>H H H H H H</td>
<td>H H H H H H</td>
</tr>
</tbody>
</table>

It is obvious that isomers may not occur in the series from propane downward to methane, however, as the number of carbon atoms grows larger. The possible isomers are very many. In work done by the bureau of standards, 

4Hatch, *op. cit.*, p. 4.

5Fieser and Fieser, *op. cit.*, p. 95.

28 paraffin hydrocarbons have been isolated. These include all ten straight-chain hydrocarbons from methane to normal decane plus 18 branched-chain hydrocarbons.⁷

The paraffin, or open-type, hydrocarbons may be further subdivided into three groups. These groups are called the alkanes, the alkenes, and the alkynes. The normally occurring group of paraffins are the alkanes, or saturated group. However, for a consideration of the petrochemical industry we should look into the unsaturated groups which may be obtained by cracking processes from the alkane series.

The alkane, or saturated, series derives its name from the fact that all the carbon valences are saturated with hydrogen. The general equation for this group of hydrocarbons is \( C_n H_{2n + 2} \). To illustrate this structurally we may consider ethane.

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\mid & \quad \mid \\
\text{H} - \text{C} - \text{C} - \text{H} \\
\mid & \quad \mid \\
\text{H} & \quad \text{H}
\end{align*}
\]

The alkane series, because of being saturated, is the most stable group. Chemical reactions with this group are generally much more difficult than with the unsaturated hydrocarbons.

The first of the unsaturated groups is the alkene, or ethylenic, hydrocarbon series. Hydrocarbons in this series, which are also called olefins, have one less hydrogen atom per carbon atom in the ethane constituent of the molecule as compared to the saturates. The general equation

\[7\text{Fieser and Fieser, op. cit., p. 95.}\]

\[8\text{Ibid., pp. 24, 31.}\]
for this group is $C_nH_{2n}$, and we may show this relationship structurally as:

<table>
<thead>
<tr>
<th>Ethylene</th>
<th>Butylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>H H</td>
<td>H H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C=C</td>
<td>H - C - C=C - C - H</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>H H</td>
<td>H H H</td>
</tr>
</tbody>
</table>

It is seen that two valence arms of the carbon atoms form a double bond in the ethylene groups. There is no single carbon substance in the alkene series. The alkene substances are highly reactive as compared to the alkanes or saturated hydrocarbons.  

The second group of unsaturated hydrocarbons in the open-type series is called the alkyne or acetylenic group. In this series, the simplest member is acetylene itself, which is ethylene with one molecule of hydrogen removed. To make this arrangement possible the carbon atoms share three valence bonds. The general equation for the alkyne, or acetylene, series is $C_nH_{2n-2}$. Structurally acetylene is shown as:

```
H H
|   |
C=C
```

Naming of this series is often taken from the acetylene base. Thus, $CH_3CH_2C≡CH$ may be called ethylacetylene, or it may be called butyne in keeping with the overall family name.

**Naphthenes**

The second classification of hydrocarbons mentioned earlier is the naphthenic group. The constituents of this group are also called

---


cycloparaffins because of their molecular structure. The carbon atoms in the naphthenes are saturated, but because of the ring structure of the molecule this condition is accomplished with only two atoms of hydrogen per atom of carbon. The general equation for this group is \( C_n H_{2n} \), which is the same as for the alkenes; but the molecular structure is quite different. Cyclopropane contains the smallest number of carbon atoms possible for the cycloparaffin series. Cyclohexane is shown as an example of the cyclic molecular structure.

\[
\begin{array}{c}
\text{H} & \text{C} & \text{H} \\
\text{H} & \text{C} & \text{C} \\
\text{H} & \text{C} & \text{C} \\
\text{H} & \text{C} & \text{C} \\
\text{H} & \text{H} & \text{H}
\end{array}
\]

The chemical activity of the naphthenes is generally not great because of the saturated carbon atoms.\(^\text{11}\)

**Aromatics**

The aromatics, or benzene series, are the final type of hydrocarbons found in petroleum. Domestic crude oils do not ordinarily contain a very large percentage of aromatic compounds. The aromatics are unsaturated hydrocarbons in a ring structure. Benzene is the basic hydrocarbon in this group, as well as the most important in usage. Other hydrocarbons in this group are toluene, xylene, cumene, and styrene. The general

\(^\text{11}\)\textit{Ibid.}, pp. 46-47.
formula for the aromatic series is \( C_n H_{2n - 6} \). Benzene may be shown structurally as:

\[
\begin{align*}
\text{H} & \\
\text{H} \quad \text{C} & \quad \text{C} \quad \text{H} \\
\text{H} \quad \text{C} & \quad \text{C} \quad \text{H} \\
\text{H} & 
\end{align*}
\]

After becoming familiar with the principal constituents of petroleum and natural gas, the next item for consideration shall be the occurrence of these minerals in Louisiana and a comparison of them with those found in Texas and in the nation. The importance of certain of these raw materials in making petrochemicals shall also be considered.

**Crude Oil**

The first commercial production of crude oil in Louisiana was found near Jennings in 1902. Since that time the petroleum industry has grown to the dominant position in the State in investment and value of output.

In 1960 crude oil production in Louisiana was the second largest in the nation, holding that position for the third consecutive year and moving away from California, the state in third position. By observing Figure 5, a semilogarithmic chart, it may be seen that Louisiana's rate
FIGURE 5
PRODUCTION OF CRUDE OIL IN
LOUISIANA, TEXAS, AND THE UNITED STATES, 1946-1960
(Thousands of Barrels)

Source: Minerals Yearbook
Oil and Gas Journal

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of increase in the production of crude petroleum is greater than that of Texas or the entire United States. However, in terms of absolute values, shown in Table II, Texas is far in front having more than double the production of Louisiana. The two states together produce more than 50 percent of the domestic crude oil. Louisiana contributed more than 15 percent of the total domestic output of crude oil in 1960 compared to less than 11 percent in 1950. Louisiana's growing share of domestic crude production may be seen in Figure 6.

A trend line fitted to the Louisiana production figures for the period 1946-1959 by the least squares method yields the following equation:

\[ Y_c = 237,497 + 15,460 X \]

origin at 1952
\( x \) units - 1 year
\( y \) units - thousands of barrels

We may see then that the trend increase in the production of crude oil since the end of World War II has exceeded 15 million barrels per year.

Crude oil as it comes from the ground has practically no value for use in that state. The American Indians did use some in its raw form for medicinal purposes but, even though any respectable witch doctor of the time had a supply on hand, demand did not become significant until the early 1850's. At that time a Pittsburg druggist distilled some of the crude material to make a satisfactory illuminant to compete with "coal oil" which was obtained by coal distillation. The demand for the refined product caused increased activity in seeking the raw material and led to the formation of a company to discover new supplies of the precious liquid which was selling for $18 per barrel. The formation of this company led to the completion in 1859 of the first oil well.\(^{14}\) This

---

<table>
<thead>
<tr>
<th>Year</th>
<th>United States</th>
<th>Louisiana</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946</td>
<td>1,733,939</td>
<td>143,669</td>
<td>760,215</td>
</tr>
<tr>
<td>1947</td>
<td>1,856,987</td>
<td>160,128</td>
<td>820,210</td>
</tr>
<tr>
<td>1948</td>
<td>2,020,185</td>
<td>181,458</td>
<td>903,498</td>
</tr>
<tr>
<td>1949</td>
<td>1,841,940</td>
<td>190,826</td>
<td>744,834</td>
</tr>
<tr>
<td>1950</td>
<td>1,973,574</td>
<td>208,965</td>
<td>829,874</td>
</tr>
<tr>
<td>1951</td>
<td>2,247,711</td>
<td>232,281</td>
<td>1,010,270</td>
</tr>
<tr>
<td>1952</td>
<td>2,289,836</td>
<td>243,929</td>
<td>1,022,139</td>
</tr>
<tr>
<td>1953</td>
<td>2,357,082</td>
<td>256,632</td>
<td>1,019,164</td>
</tr>
<tr>
<td>1954</td>
<td>2,314,988</td>
<td>246,558</td>
<td>974,275</td>
</tr>
<tr>
<td>1955</td>
<td>2,484,428</td>
<td>271,010</td>
<td>1,053,297</td>
</tr>
<tr>
<td>1956</td>
<td>2,617,432</td>
<td>299,421</td>
<td>1,107,808</td>
</tr>
<tr>
<td>1957</td>
<td>2,616,901</td>
<td>329,896</td>
<td>1,073,867</td>
</tr>
<tr>
<td>1958</td>
<td>2,448,987</td>
<td>313,891</td>
<td>940,706</td>
</tr>
<tr>
<td>1959</td>
<td>2,571,578</td>
<td>354,520</td>
<td>981,234</td>
</tr>
<tr>
<td>1960</td>
<td>2,573,691</td>
<td>392,202</td>
<td>931,996</td>
</tr>
</tbody>
</table>

**SOURCE:** Minerals Yearbook, Oil and Gas Journal
FIGURE 6
CRUDE OIL PRODUCTION FOR LOUISIANA, TEXAS, AND ALL OTHER STATES, 1946-1960
(Thousands of Barrels)

Source: Minerals Yearbook
Oil and Gas Journal

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event allowed the great expansion of refinery facilities which have provided us over the years with a wide range of products demanded by our advancing technology.

Refineries have been the key to petrochemical growth. The petrochemical plants have to a large extent located where they may obtain the refinery off gases which formerly were burned as fuel or flare gas. It has been estimated that approximately 50 percent of the petrochemical raw materials are by-products of refining operations.\textsuperscript{15} It would be expected then that petrochemical plants would be most common where the greatest concentration of refineries are found.

The top three states in refinery capacity are, in order, Texas, California, and Louisiana. The capacities of operating refineries in Texas and Louisiana, plus the total United States capacity are shown in Table III. The location of refining capacity is much less concentrated in Louisiana and Texas than is the production of crude oil. Louisiana and Texas together only have slightly more than 34 percent of the total United States refining capacity. Louisiana contributes only about eight percent of the United States refining capacity.

The picture looks somewhat brighter for Louisiana when considering rates of growth in the post World War II period (1946-1959). Louisiana refining capacity has more than doubled in this period while California's capacity has increased less than 50 percent. Total refining capacity in the United States has increased almost 90 percent, shading Texas but not

\textsuperscript{15}C. M. Blair, "Plastics and Fibers on the Gulf Coast." A paper presented at the New Orleans meeting of the American Institute of Chemical Engineers, February, 1961.
### TABLE III

**OPERATING REFINERY CAPACITY FOR LOUISIANA, TEXAS, AND THE UNITED STATES AS OF DECEMBER 31, 1946-1960**

*(Barrels per Day)*

<table>
<thead>
<tr>
<th>Year</th>
<th>United States</th>
<th>Louisiana</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946</td>
<td>5,336,399</td>
<td>366,350</td>
<td>1,484,175</td>
</tr>
<tr>
<td>1947</td>
<td>5,825,566</td>
<td>400,900</td>
<td>1,692,250</td>
</tr>
<tr>
<td>1948</td>
<td>6,230,505</td>
<td>458,700</td>
<td>1,798,200</td>
</tr>
<tr>
<td>1949</td>
<td>6,222,998</td>
<td>466,500</td>
<td>1,687,188</td>
</tr>
<tr>
<td>1950</td>
<td>6,701,815</td>
<td>492,900</td>
<td>1,803,419</td>
</tr>
<tr>
<td>1951</td>
<td>7,161,366</td>
<td>504,520</td>
<td>2,006,073</td>
</tr>
<tr>
<td>1952</td>
<td>7,481,701</td>
<td>529,529</td>
<td>2,107,100</td>
</tr>
<tr>
<td>1953</td>
<td>7,782,103</td>
<td>587,075</td>
<td>2,132,000</td>
</tr>
<tr>
<td>1954</td>
<td>8,069,154</td>
<td>643,500</td>
<td>2,201,350</td>
</tr>
<tr>
<td>1955</td>
<td>8,380,801</td>
<td>704,650</td>
<td>2,283,800</td>
</tr>
<tr>
<td>1956</td>
<td>8,808,841</td>
<td>730,650</td>
<td>2,398,300</td>
</tr>
<tr>
<td>1957</td>
<td>8,939,907</td>
<td>707,500</td>
<td>2,414,200</td>
</tr>
<tr>
<td>1958</td>
<td>9,540,741</td>
<td>735,650</td>
<td>2,536,142</td>
</tr>
<tr>
<td>1959</td>
<td>9,789,355</td>
<td>777,610</td>
<td>2,561,920</td>
</tr>
<tr>
<td>1960</td>
<td>9,933,725</td>
<td>794,457</td>
<td>2,584,840</td>
</tr>
</tbody>
</table>

**SOURCE:** *Petroleum Facts and Figures*  
*Oil and Gas Journal*
equalling Louisiana's rate. These relative relationships may be seen in Figure 7, which is plotted with a logarithmic Y-axis.

Even though Louisiana's refinery capacity increased more than 100 percent during the period studied compared to less than 75 percent for Texas, the absolute amounts were strongly in Texas' favor. While Louisiana's capacity increased by more than 400,000 barrels per day, the increase in Texas refining capacity was about two and one-half times that amount. At the end of 1960, Louisiana had refining capacity of less than 75 percent of its 1960 crude oil production while refining capacity in Texas was 101 percent of crude oil production.

By examination of Table IV it may be seen that in two areas in Texas, each including a circular space having a radius of not more than 20 miles, have total refining capacity greater than the entire state of Louisiana. This situation would seem to be a major factor in the greater petrochemical expansion on the Texas Gulf Coast than along the coastal region in Louisiana since petrochemical plants feed largely from refinery residue gases.

The Houston and Beaumont-Port Arthur areas of Texas outstrip any other areas in the nation in concentrated refinery capacity. Baton Rouge, Louisiana, holds third place in the Gulf Coast with only one refinery which is the largest in the United States.

Plans for immediate refinery expansion are not too great with current units running at a nation-wide average of less than 90 percent of capacity.\(^{16}\)

FIGURE 7
OPERATING REFINERY CAPACITY FOR TEXAS, CALIFORNIA, LOUISIANA, AND THE UNITED STATES, 1946-1960
(Millions of barrels per day as of December 31 each year)

United States
Texas
California
Louisiana

Source: Petroleum Facts and Figures
Oil and Gas Journal
TABLE IV

TOTAL REFINING CAPACITY AND NUMBER OF REFINERIES
FOR CERTAIN AREAS IN LOUISIANA AND TEXAS AS OF JANUARY 1, 1961*

(Barrels per Calendar Day)

<table>
<thead>
<tr>
<th>Area</th>
<th>Number of refineries</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houston (includes Texas City and Baytown)</td>
<td>8</td>
<td>907,050</td>
</tr>
<tr>
<td>Beaumont Port Arthur (includes Orange and Port Neches)</td>
<td>5</td>
<td>871,040</td>
</tr>
<tr>
<td>Baton Rouge</td>
<td>1</td>
<td>365,000</td>
</tr>
<tr>
<td>Lake Charles</td>
<td>2</td>
<td>238,000</td>
</tr>
<tr>
<td>Corpus Christi</td>
<td>5</td>
<td>207,750</td>
</tr>
<tr>
<td>New Orleans</td>
<td>3</td>
<td>163,000</td>
</tr>
</tbody>
</table>

*Does not include refineries having capacities of less than 20,000 barrels per day.

SOURCE: Oil and Gas Journal
However, it is expected that the largest growth in refinery capacity by 1975 will be in the Gulf Coast area. The expansion, which will be marketed principally in the East Coast area, is anticipated principally in Texas. The New York-Philadelphia-Baltimore area is expected to follow the Gulf Coast in refinery expansion with about one-half of the added capacity projected for the Gulf Coast.\footnote{John Robert Lindsey, The Location of Oil Refining in the United States (Unpublished Ph.D. dissertation, Cambridge: Harvard University, 1954), p. 396.}

The refineries are operated to convert crude petroleum into fuels and lubricants for our highly mechanized society. As a by-product of cracking and reforming operations a mixture of saturated and unsaturated hydrocarbon gases is produced. These gases contain molecules with from one to four carbon atoms. The more reactive and chemically desirable of these gases are the olefins or alkenes in the paraffin series.

The various components of this gaseous mixture must be separated and purified before they may be used in chemical processes. Since this treatment requires additional equipment beyond the needs of ordinary refining, the smaller refineries usually burn these gases as fuel or flare them. For ethylene, it is not generally considered economical to install separation and purification facilities at refineries having a daily capacity of much less than 50,000 barrels.\footnote{Confidential discussion with an oil company executive.}

The naphthenic and aromatic hydrocarbons used as chemical raw materials may also be separated and purified in the refining process through the use of specially designed equipment. The uses of these
raw materials in petrochemical production will be discussed after considering the other principal source of paraffinic hydrocarbons, natural gas.

**Natural Gas**

Natural gas, which contributes about 25 percent of the petrochemical raw materials,\(^{19}\) occurs in commercial quantities in about half of the states in the United States. However, the major portion of natural gas production occurs in two states, Louisiana and Texas. In 1960, Louisiana produced approximately 23 percent of the domestic production while Texas contributed about 47 percent. All other states combined produced only 30 percent of the total United States production. Gas production figures in absolute amounts are shown in Table V.

By inspection of Figure 8 it may be observed that Louisiana's rate of increase in gas production has been growing at a faster pace than either that of Texas or the total United States. However, Louisiana's gas production is still only about one-half that of Texas.

Liquefied petroleum gases provide the remaining 25 percent of the hydrocarbon raw materials for petrochemical manufacture.\(^{20}\) Liquefied petroleum gas, commonly called L. P. G., is a mixture of liquefied hydrocarbons obtained from natural gas. This mixture consists primarily of propane and butanes with small amounts of lighter and heavier components. The liquefied petroleum gases are in vapor form at atmospheric pressure and temperature; thus to be maintained in liquid form they must

\(^{19}\)Blair, *loc. cit.*  
### Table V

**Production of Natural Gas in Louisiana, Texas, and the United States, 1946-1960**

(Thousands of Cubic Feet)

<table>
<thead>
<tr>
<th>Year</th>
<th>United States</th>
<th>Louisiana</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946</td>
<td>6,190,200</td>
<td>769,000</td>
<td>3,054,900</td>
</tr>
<tr>
<td>1947</td>
<td>6,733,203</td>
<td>852,600</td>
<td>3,242,000</td>
</tr>
<tr>
<td>1948</td>
<td>7,178,777</td>
<td>973,000</td>
<td>3,450,000</td>
</tr>
<tr>
<td>1949</td>
<td>7,546,825</td>
<td>1,025,500</td>
<td>3,822,000</td>
</tr>
<tr>
<td>1950</td>
<td>8,479,650</td>
<td>1,136,820</td>
<td>4,407,800</td>
</tr>
<tr>
<td>1951</td>
<td>9,689,372</td>
<td>1,391,600</td>
<td>4,930,100</td>
</tr>
<tr>
<td>1952</td>
<td>10,272,566</td>
<td>1,524,900</td>
<td>5,286,800</td>
</tr>
<tr>
<td>1953</td>
<td>10,645,798</td>
<td>1,596,000</td>
<td>5,459,000</td>
</tr>
<tr>
<td>1954</td>
<td>10,984,850</td>
<td>1,700,600</td>
<td>5,620,000</td>
</tr>
<tr>
<td>1955</td>
<td>11,719,794</td>
<td>1,948,000</td>
<td>5,836,000</td>
</tr>
<tr>
<td>1956</td>
<td>12,202,159</td>
<td>2,146,000</td>
<td>5,989,000</td>
</tr>
<tr>
<td>1957</td>
<td>12,906,669</td>
<td>2,347,000</td>
<td>6,101,000</td>
</tr>
<tr>
<td>1958</td>
<td>13,146,635</td>
<td>2,728,000</td>
<td>6,083,000</td>
</tr>
<tr>
<td>1959</td>
<td>11,740,600</td>
<td>2,811,900</td>
<td>5,515,000</td>
</tr>
<tr>
<td>1960</td>
<td>12,987,700</td>
<td>2,990,000</td>
<td>6,110,000</td>
</tr>
</tbody>
</table>

**Source:** Minerals Yearbook

Oil and Gas Journal
FIGURE 8
PRODUCTION OF NATURAL GAS IN LOUISIANA, TEXAS, AND THE UNITED STATES, 1946-1960
(Trillions of Cubic Feet)

Source: Minerals Yearbook
Oil and Gas Journal

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be kept under pressure. Most natural gas processing plants have facilities to separate the liquefied petroleum gases from the gas stream so that they may be sold separately. This separation is done because the LPG is of higher monetary value than the total gas stream.

A seemingly paradoxical situation exists in Louisiana with regard to the production of liquefied petroleum gases. Louisiana produces approximately 23 percent of the nation's natural gas but only seven percent of the liquefied petroleum gases. This situation may be largely explained by two factors. The first is that much of Louisiana's natural gas is obtained from miocene sand deposits which are low in content of propane and heavier components. The average yield of all natural gas liquids (including natural gasoline, LPG, finished gasoline, and naphtha) in 1958 was 0.65 gallons per 1000 cubic feet of gas processed in Louisiana while in Texas the average yield was 1.57 gallons per thousand cubic feet. The second factor limiting liquefied petroleum gas production is the fact that much of the natural gas production comes from marsh areas of the state where location of processing plants has been difficult. Thus, the gas produced in these areas has gone to the pipelines without separation of the LPG components.

Data on production of liquefied petroleum gases is shown in Table VI. It may be seen that Texas leads the nation in the production of liquefied petroleum gases with 53 percent of the total. Oklahoma is the second most important producer while Louisiana is in fourth position with only


22 Obtained in conversation with an executive of a gas producing company.
## TABLE VI

**PRODUCTION OF LIQUEFIED PETROLEUM GASES**

(Thousand of Gallons)

<table>
<thead>
<tr>
<th>Year</th>
<th>United States</th>
<th>Louisiana</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946</td>
<td>1,409,345</td>
<td>118,421</td>
<td>684,459</td>
</tr>
<tr>
<td>1947</td>
<td>1,891,818</td>
<td>147,097</td>
<td>984,860</td>
</tr>
<tr>
<td>1948</td>
<td>2,209,071</td>
<td>182,218</td>
<td>1,154,228</td>
</tr>
<tr>
<td>1949</td>
<td>2,430,506</td>
<td>223,356</td>
<td>1,247,561</td>
</tr>
<tr>
<td>1950</td>
<td>3,035,844</td>
<td>258,930</td>
<td>1,665,006</td>
</tr>
<tr>
<td>1951</td>
<td>3,627,834</td>
<td>287,238</td>
<td>2,042,208</td>
</tr>
<tr>
<td>1952</td>
<td>4,285,386</td>
<td>297,444</td>
<td>2,456,874</td>
</tr>
<tr>
<td>1953</td>
<td>4,692,870</td>
<td>287,280</td>
<td>2,777,880</td>
</tr>
<tr>
<td>1954</td>
<td>5,204,304</td>
<td>292,226</td>
<td>2,983,962</td>
</tr>
<tr>
<td>1955</td>
<td>5,972,698</td>
<td>291,138</td>
<td>3,450,430</td>
</tr>
<tr>
<td>1956</td>
<td>6,487,413</td>
<td>305,222</td>
<td>3,731,047</td>
</tr>
<tr>
<td>1957</td>
<td>6,655,282</td>
<td>335,142</td>
<td>3,831,664</td>
</tr>
<tr>
<td>1958</td>
<td>6,783,000</td>
<td>410,869</td>
<td>3,786,575</td>
</tr>
<tr>
<td>1959</td>
<td>7,874,510*</td>
<td>505,388*</td>
<td>4,356,262*</td>
</tr>
<tr>
<td>1960</td>
<td>8,288,785**</td>
<td>595,315**</td>
<td>4,392,410**</td>
</tr>
</tbody>
</table>

*Adjusted  
**Estimated

**SOURCE:** *Petroleum Facts and Figures*  
*Oil and Gas Journal*
seven percent of the nation's production. The poor relative position of Louisiana as compared with Texas and the United States is shown in Figure 9.

Now that we have surveyed the extent of Louisiana's hydrocarbon resources we should consider how these materials are used in petrochemical manufacture.

Hydrocarbon Raw Materials for Petrochemicals

Many of the petroleum hydrocarbons have several possible intermediate and end products through various reactions. Whereas there are approximately 3,000 different petrochemical products, only some 300 are commercially important. Coal may be used interchangeably with petroleum as a source of many of the petrochemical building blocks. Figures 10 and 11 show the routes from the petroleum, natural gas, or coal raw material through the intermediate stages to the finished product for more than 300 chemicals. These figures may be used to trace the various intermediate and end product possibilities for a given hydrocarbon.

In considering the individual hydrocarbons as petrochemical raw materials, we shall start with the lowest in the series, methane. Methane is obtained from and is the principal constituent of natural gas. A typical natural gas analysis may be represented by the following: Methane, 87.77 percent; ethane, 7.29 percent; propane, 2.72 percent; butanes, 1.24 percent; pentanes and heavier, 0.98 percent. This

---

FIGURE 9

PRODUCTION OF LIQUEFIED PETROLEUM GASES
IN LOUISIANA, TEXAS, AND THE UNITED STATES, 1946-1960
(Billions of Gallons)

Source: Petroleum Facts and Figures
Oil and Gas Journal

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particular analysis was obtained by a natural gas producing company from field production. Naturally, the analysis of gases from different fields or areas will not be exactly the same, but the proportions of the various components will remain fairly constant.

Methane is used to a great extent in Louisiana in the manufacture of ammonia. Natural gas and air are the basic ingredients. Hydrogen is taken from the gas and nitrogen from the air to form the product, \( \text{NH}_3 \). Since methane is the chief component of natural gas, it becomes the main source of hydrogen for ammonia manufacture by this process. A typical analysis of natural gas after processing through a relatively efficient gas processing unit to remove the heavier hydrocarbons would yield approximately the following: methane, 94.18 percent; ethane, 5.03 percent; propane, 0.79 percent. This analysis was obtained of the effluent gas from a gas processing plant.

Methane is becoming more important recently as a raw material in making acetylene, which has many chemical uses. The importance of acetylene as a petrochemical intermediate may be seen in Figure 11. Monochem, Inc., jointly owned by United States Rubber Company and Borden Company, broke ground in April, 1961, for a $25 million plant at Geismar, Louisiana, for the production of acetylene and vinyl chloride. Initial capacity is set at 80 million pounds annually for acetylene using methane as the principal raw material. Adjacent plants planned by Borden and U. S. Rubber to use the acetylene and vinyl chloride will expand investment in the complex to $50 million.\(^2\)


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Ethane and propane from natural gas provide a major source of ethylene, the largest volume of petrochemical building block. The other major source of ethylene is the refinery off-gases resulting from cracking and reforming operations. The use of ethylene for chemical conversion has been forecast at 5.5 to 6.0 billion pounds per year by 1965. The President's Materials Policy Commission has projected the requirement for ethylene for chemical uses in 1975 to be 8.1 billion pounds per year. The President's Materials Policy Commission predicted ethylene needs for chemical conversion to be 4.45 billion pounds in 1960, which is about ten percent below the 5.1 billion pounds produced for chemical conversion in 1959.

Many oil companies have installed facilities in recent years to recover ethylene from their processing units. Until 1953, most of the ethylene production was captive or produced by the company using it as a building block. However, since that time merchant ethylene of 98 to 99 percent purity has become widely available in the Gulf Coast area. A company desiring to use ethylene does not need to build its own ethylene producing facilities in most Gulf Coast locations, especially in the region between Lake Charles, Louisiana, and Houston, Texas. The reason for the decision of oil companies to start converting ethane to ethylene


may be seen in the price structure. Ethane, with a value as a fuel of $.008 per pound, may be dehydrogenated to form ethylene which sells at $.050 per pound.\textsuperscript{28} This is an increase of more than 500 percent in value of a unit of product. This economic condition has led producers to a general overcapacity situation at present.

Because of the fact that ethylene cannot be readily shipped and stored,\textsuperscript{29} the companies using ethylene as a petrochemical building block have located near the ethylene producing facilities. An example of this raw material pull which overrides market considerations may be seen in the polyethylene producing industry. The Gulf Coast has only about two percent of the United States market for polyethylene, yet approximately 72 percent of the total United States productive capacity for this plastic is concentrated in the Gulf Coast area.\textsuperscript{30}

A new commercial use for ethylene is being fostered by Continental Oil Company at its multi-million dollar "ALFOL" alcohol plant now under construction adjacent to its refinery near Lake Charles.\textsuperscript{31} The process involves connecting ethylene molecules to produce straight-chain alcohols with an even number of carbon atoms ranging from C\textsubscript{6} through C\textsubscript{18} primarily. This plant is a result of work done by Conoco's staff of scientists and engineers in adapting the process discovered by a

\textsuperscript{28}Unit Sales Values taken from: United States Tariff Commission, \textit{Ibid.}

\textsuperscript{29}Blair, \textit{loc. cit.}

\textsuperscript{30}Nelson, \textit{loc. cit.}

\textsuperscript{31}James W. Bateman, "Conoco Chooses the Gulf Coast for its "ALFOL" Plant." A paper presented at the 44th National Meeting of the American Institute of Chemical Engineers in New Orleans, February, 1961.
German scientist to commercial potential. It will be the first plant of its type to synthesize these alcohols which have previously been derived from the fatty acids present in a variety of natural animal and vegetable fats and oils. This is an example of the research and development work which has maintained the tremendous growth rate for petrochemicals since the end of World War II.

The production of propane and propane derivatives for chemical conversion increased to a total of 5.5 billion pounds in 1959. The greatest potential for future expansion in the C₃ family seems to rest in polypropylene. This plastic is derived by dehydrogenating propane to form propylene then converting the monomer to polypropylene. Polypropylene is a heat resistant, nonabsorbent, nonconductive plastic with many potential uses in construction, packaging and housewares. Facilities for the production of polypropylene have been constructed recently by Hercules Powder Company adjacent to the Cities Service refinery in Lake Charles, Louisiana, and by Humble Oil and Refining Company at its Baytown, Texas, refinery. As demand grows, capacity in this product will be added by other companies with polyolefin facilities on the Gulf Coast.

A very large part of the propane produced for chemical conversion is cracked to form ethylene, which is the most widely used hydrocarbon raw material for petrochemicals. Propylene, the olefinic propane derivative, is principally obtained as a by-product of refinery cracking operations.

---

32United States Tariff Commission, _loc. cit._

This situation provides an abundant source for current needs of propylene and is very economical, selling at about one-third the price of ethylene in 1959. The estimated requirement of propylene for chemicals in 1975 is 2.8 billion pounds.\textsuperscript{34} Estimated production for 1960 was 2.0 billion pounds, which is about ten percent below the 1959 production of 2.2 billion pounds.\textsuperscript{35}

The C\textsubscript{4} hydrocarbons are next in line in the aliphatic or paraffinic series. The synthetic rubber industry absorbs the biggest part of the C\textsubscript{4} intermediates in the manufacture of different types of synthetic rubber. Butadiene is the largest volume petrochemical intermediate in the butane series. Butadiene is obtained by dehydrogenating normal butylene obtained from a refinery cracking process. Butadiene is the principal ingredient of SBR (styrene-butadiene rubber) representing about 70 percent of its composition.\textsuperscript{36}

Typically, the refinery, butadiene facilities, and rubber plant are located close to each other to reduce problems in interchange of materials. Two such complexes have been developed in Louisiana. These two synthetic rubber producing facilities resulted from the formation of the Rubber Reserve Company immediately prior to World War II. This government rubber company was created in the interest of national defense and administered the production of thousands of tons of GRS (government rubber-styrene) during the war. In 1955 the government sold the SBR, butadiene and styrene

\textsuperscript{34}President's Materials Policy Commission, loc. cit.

\textsuperscript{35}U. S. Tariff Commission, loc. cit.

\textsuperscript{36}J. D. Sutherland, "Basics of SBR Production." A paper presented at the 13th meeting of the Southern Rubber Group at New Orleans, October, 1960.

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plants to private industry. In most cases the operating companies which ran the plants for the government bought them. Technological improvements have added greatly to the quality of synthetic rubber since the end of World War II. Plants for making polyisoprene-polybutadiene and butyl rubbers are adding significant capacity to the existing SBR synthetic facilities, which are also undergoing expansion.37

The C5 and heavier members of the aliphatic or paraffinic series of hydrocarbons are relatively insignificant for petrochemical manufacture. In 1959, the C2, C3, and C4 hydrocarbons and their derivatives accounted for more than 90 percent of the production of aliphatic hydrocarbons for chemical conversion.38 The estimated total requirements of C5 and heavier aliphatic hydrocarbons for chemical use in 1975 are only slightly in excess of one billion pounds annually.39

The aromatic and naphthenic hydrocarbons remain now to be considered. The total production of these hydrocarbons for chemical conversion in 1959 amounted to about 6.7 billion pounds, or slightly more than one-third of the production of aliphatic hydrocarbons for chemical conversion.40 Benzene is the principal building block for petrochemicals in this group. Benzene is produced as a result of refinery cracking and reforming operations. Cyclohexane may be dehydrogenated to form benzene, or normal hexane may be converted to benzene through a cyclization process.41

38U. S. Tariff Commission, loc. cit.
39The President's Materials Policy Commission, loc. cit.
Small amounts of the aromatics are found in crude oil production, but separation of these aromatics must ordinarily be combined with isomerization and dehydrogenation facilities to prove economically feasible. Benzene and cyclohexane provide the basis for styrene, toluene, cumene, and xylenes production. The importance of these chemical intermediates may be seen by examination of Figures 10 and 11. It is expected that by 1975 the aromatics requirements from petroleum and natural gas will be approximately doubled to more than 12.5 billion pounds annually.\footnote{Ibid., p. 208.} Table VII shows a list of 40 primary petrochemical products and intermediates with the principal source of each.

**Non-hydrocarbon Raw Materials**

Of the many non-hydrocarbon raw materials used in petrochemical production, the most important is salt. Salt is found in the Gulf Coast area in salt domes which have extended upward from the mother bed some 30,000 to 40,000 feet below the earth's surface. The tops of these domes have risen to many places to within a half mile or less from the surface of the earth.\footnote{John M. Dale, "How Gulf Coast Salt Domes Serve the Petrochemical Industry." A paper presented at the National Meeting of the American Institute of Chemical Engineers at New Orleans, February, 1961.}

The salt may be produced by mine and shaft methods or by pumping fresh water into the domal area to remove brine. The use of brine in the manufacture of chlorinated hydrocarbons is widespread in the Gulf Coast area. In the last few years two major petrochemical plants have been built in Louisiana near salt domes from which brine is obtained for
<table>
<thead>
<tr>
<th>Primary products and hydrocarbon intermediates</th>
<th>Principal Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural Gas</td>
</tr>
<tr>
<td></td>
<td>Cracked Naphtha</td>
</tr>
<tr>
<td></td>
<td>Virgin Naphtha</td>
</tr>
<tr>
<td></td>
<td>Refinery Operations</td>
</tr>
<tr>
<td></td>
<td>Normal Butylenes</td>
</tr>
<tr>
<td></td>
<td>Ethylene</td>
</tr>
<tr>
<td></td>
<td>Propylene</td>
</tr>
<tr>
<td></td>
<td>Ethylene-benzene</td>
</tr>
<tr>
<td></td>
<td>Propylene-benzene</td>
</tr>
<tr>
<td></td>
<td>Heavy Naphtha</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>x</td>
</tr>
<tr>
<td>Acetylene</td>
<td>x</td>
</tr>
<tr>
<td>Ammonia</td>
<td>x</td>
</tr>
<tr>
<td>Amyl Alcohol</td>
<td>x</td>
</tr>
<tr>
<td>Benzene</td>
<td>x</td>
</tr>
<tr>
<td>Normal Butylene</td>
<td>x</td>
</tr>
<tr>
<td>Butadiene</td>
<td>x</td>
</tr>
<tr>
<td>Secondary-butyl alcohol</td>
<td>x</td>
</tr>
<tr>
<td>Cresols and Cresylic Acid</td>
<td>x x</td>
</tr>
<tr>
<td>Cumene</td>
<td>x</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>x</td>
</tr>
<tr>
<td>Cyclopentadiene</td>
<td>x</td>
</tr>
<tr>
<td>Chloroethane</td>
<td>x</td>
</tr>
<tr>
<td>Ethanol</td>
<td>x</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>x</td>
</tr>
<tr>
<td>Ethyl chloride</td>
<td>x</td>
</tr>
<tr>
<td>Ethylene dichloride</td>
<td>x</td>
</tr>
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<td>Other aromatics</td>
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<td>Vinyl chloride</td>
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**SOURCE:** Resources for Freedom

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their process needs. These are the Dow Chemical Company plant at Plaquemine and the plant of Wyandotte Chemical Company at Geismar.

The salt domes may be of two types. The "piercement" type domes are those which have broken through the earth formations in their rise toward the surface. Over half of the piercement type domes have already been found to yield oil or gas on their flanks or tops. The "deep-seated" domes are those which have not moved upward with enough force to break through the formations above it but have caused some tilting of the higher formations. More than two-thirds of the salt domes found along the Gulf Coast are of the piercement type in which the average depth to the salt is 2,000 feet or less.44

The method used in obtaining brine from a salt dome is to pump fresh water into the dome and force out the salt-saturated brine solution. The brine is transported by pipeline from the producing well to the chemical processing plant. The production of chlorinated hydrocarbons has risen from less than 400 million pounds per year in 1940 to more than three billion pounds per year in 1960.45 Total plant capacity for chlorinated hydrocarbons in 1960 was in excess of 4 billion pounds per year with more than 55 percent of this capacity being on the Gulf Coast.

Louisiana currently has three plants in operation and one under construction for the production of chlorinated hydrocarbons. The three plants already in operation are Ethyl Corporation in Baton Rouge, Dow

44Ibid.

Chemical in Plaquemine, and Columbia Southern in Lake Charles. The plant under construction is that of Monochem at Geismar. In Texas there are five plants in the strip along the Gulf from Freeport eastward to Port Neches making chlorinated hydrocarbons.

There are five different chlorinated hydrocarbons having annual production of more than 100 million pounds each. These are, in order of quantity of production: vinyl chloride, ethyl chloride, trichloroethylene, carbon tetrachloride, and perchloroethylene.46

In addition to salt and petroleum hydrocarbons, the salt domes are also a source of sulfur, which is formed in some instances on top of the salt upheaval. Although sulfur has been found associated with only eight percent of the Gulf Coast salt domes, these have supplied more than 80 percent of the world's supply of elemental sulfur over the last 45 years.47 Sulfur, however, is not too significant as a raw material for petrochemical manufacture even though its importance to the nation's economy for the manufacture of sulfuric acid is tremendous.

The salt dome has a permanent use after its store of salt has been removed. The cavity remaining may be used as storage space for off season products or for raw materials which may be purchased advantageously. The advantages of salt domes for storage are as follows:48

1. Economy - especially for high pressure storage.
2. Lower insurance costs because of less risk of accident.

46Ibid.
47Dale, "How Gulf Coast Salt Domes Serve the Petrochemical Industry," loc. cit.
48Ibid.
3. Atmospheric temperature changes do not affect stored products.
4. Safety from enemy attack in the event of war.
5. Leaves land surface free for other uses.

In a given salt dome, which may be up to ten miles in diameter, there may be several cavities created by the extraction of salt. In each cavity a different product may be stored for use as desired. There are presently five dissolved salt cavities being used for underground storage in Louisiana as compared with 43 in Texas and 70 in the entire United States. 49

We have considered the types of petrochemical raw materials, their occurrence and something of their uses in the production of intermediates and finished products. We must now consider the future sources of these raw materials, and more specifically, how Louisiana stands in the reserves picture.

**Raw Material Reserves**

In dealing with reserves of crude oil and natural gas, the amounts given refer to the proven resources which are recoverable by presently known methods. Some authorities in oil field management assert that with current technology not more than one-third of the oil underground may be considered as a recoverable reserve. 50 The reason for the continued high degree of research interest in finding new recovery methods is quite obvious from this information.

50 Duncan, loc. cit.
Reserves of crude oil in Louisiana amounted to 4,785 million barrels as of December 31, 1960.\textsuperscript{51} At the rate of withdrawal in 1960, which is the highest on record, these reserves would last about 12 years. It may be seen in Figure 12 that crude oil reserves are increasing at a slightly greater rate than production. A significant fact in Louisiana reserves picture is its steady increase while the total United States reserves of crude oil declined between 1959 and 1960 as they did between 1956 and 1957. Louisiana's reserves are about 15 percent of the total domestic crude reserves. It would seem that Louisiana is in no danger of running out of oil soon.

The reserves of natural gas in Louisiana provide even more protection than do the crude oil reserves. The reserves of natural gas amount to about 63.4 trillion cubic feet, which is equal to slightly more than 21 years supply at the 1960 rate of withdrawal.\textsuperscript{52} It may be seen in Figure 13 that the rates of growth in natural gas production and reserves have been almost constant from 1952 until the present. However, between 1946 and 1952 the rate of increase in production was greater than that of reserves. With the present relationship between production and reserves, the natural gas outlook for Louisiana seems very bright. Louisiana's present natural gas reserves constitute 24 percent of the total reserves of natural gas in the United States.

The crude oil reserves in Louisiana have been growing at a consistently faster rate than Texas or total United States reserves in recent years.

\textsuperscript{51}The Oil and Gas Journal, LIX (March 27, 1961), p. 64.

\textsuperscript{52}Ibid., p. 66.
FIGURE 12
CRUDE OIL PRODUCTION AND RESERVES
IN LOUISIANA, 1946-1960

Production
(Millions of Barrels)

Reserves
(Billions of Barrels)

Source: Minerals Yearbook
Oil and Gas Journal

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FIGURE 13
NATURAL GAS PRODUCTION AND RESERVES
IN LOUISIANA, 1946-1960

Source: Minerals Yearbook
Oil and Gas Journal

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Crude oil reserves in Texas have declined in absolute amount for almost every year since 1951. However, at the end of 1960 Texas held almost 47 percent of the nation's crude oil reserves, down from approximately 54 percent in 1950. The relative positions of Louisiana and Texas to the total United States reserves may be seen in Figure 14.

Louisiana's natural gas reserves have also been increasing at a faster pace than total domestic reserves while the relative position of Texas has been declining. This relationship may be seen in Figure 15. Although Texas has not been maintaining its proportion of total reserves, it still contained more than 45 percent of the total domestic reserves at the end of 1960 as compared to 55 percent a decade earlier. Kansas was in third position at the end of 1960 in natural gas reserves with less than one-third the reserves of Louisiana.

Reserves of liquefied petroleum gases, the other major hydrocarbon raw material, are not measured separately. These reserves are contained in the reserve figures of natural gas liquids, which includes natural gasoline and condensate along with the L. P. G. components. Louisiana's reserves of natural gas liquids are less in proportion to the national total than the natural gas reserves. On the other hand, the reserves of natural gas liquids in Texas are higher proportionally than their natural gas reserves. The respective figures for Louisiana and Texas are 21 percent and 53 percent as of December 31, 1960.

The long-range outlook for the entire petroleum industry is somewhat clouded. The production of crude oil in the United States is expected to continue to rise until about 1980 when the annual production is anticipated
FIGURE 14
CRUDE OIL RESERVES IN LOUISIANA, TEXAS, AND THE UNITED STATES, 1946-1960
(Billions of Barrels)

Source: Minerals Yearbook
Oil and Gas Journal

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FIGURE 15
NATURAL GAS RESERVES IN LOUISIANA, TEXAS, AND THE UNITED STATES, 1946-1960
(Trillions of Cubic Feet)

Source: Minerals Yearbook
Oil and Gas Journal

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at four billion barrels.\textsuperscript{53} From that time, crude production is expected to decline rather slowly with an ultimate recovery of about 250 billion barrels.

It is anticipated by some persons that by 1970 the petroleum industry will be on the threshold of the "beginning of the end" with other energy sources gradually capturing a larger part of the market until by the year 2000 the energy derived from oil and gas will be practically insignificant.\textsuperscript{54} The fuels expected to grow in importance are Uranium and fluids from coal. However, it is estimated that less than two percent of the physical output of oil and gas is used as petrochemical raw materials.\textsuperscript{55} Thus the somewhat gloomy long-range outlook for petroleum will apparently not have any significant effect on petrochemicals for two or three decades.

Within the next fifteen to twenty years costs may restrict the use of petroleum and natural gas hydrocarbons as petrochemical raw materials even if supply is no problem.\textsuperscript{56} Since most petrochemicals may be made from coal by alternative processes a shift may be in order if the price of oil and gas continues to climb at a rapid pace. Oil shales also hold promise as a source of raw materials for petrochemical manufacture in case of exceedingly high prices or dwindling supply of crude oil and natural gas.


\textsuperscript{54}\textquotedblleft Drilling for Oil in 1975," \textit{The Petroleum Engineer}, XXXI (April, 1959), B-19.


Some price data may give a firmer basis for the consideration of coal as a petrochemical raw material. During the period 1950 to 1958 the average price of Louisiana natural gas at the wellhead increased 143 percent while crude oil prices climbed 23 percent. In this same period the average price of coal at the mine in the United States rose less than one percent. It would seem then that Louisiana is in a strong position in quantity of reserves but that the price of its petrochemical raw materials may cause a weakening of its position in the future.

Summary

The principal petrochemical raw materials are hydrocarbons obtained from petroleum and natural gas. Petroleum hydrocarbons occur in nature in three types: paraffinic, naphthenic, and aromatic. The paraffins, or aliphatic, hydrocarbons are the most commonly occurring type. The paraffins may be broken down further into three groups. These are the alkanes, or saturates, and the more chemically active unsaturated groups the alkenes, or olefins, and the alkynes, or acetylenes.

Louisiana holds second place in the nation in production and reserves of crude oil and natural gas. Louisiana and Texas together contribute more than one-half the national output and reserves of crude oil and almost three-fourths the national output and reserves of natural gas. Louisiana provides about one-fourth of the national total in natural gas, and Texas makes up approximately one-half of the total. For crude oil, the proportions are about 15 percent and 36 percent for Louisiana and Texas.

57 Blair, loc. cit.
58 Blair, Ibid.
Crude oil as it comes from the ground is of little use in petrochemical manufacture. About 50 percent of all petrochemicals are made from gaseous by-products of petroleum refining operations. These refinery off gases are separated and used as building blocks for petrochemical manufacture.

Louisiana maintains third position in refining capacity behind Texas and California. Louisiana and Texas together have more than one-third of the nation's refining capacity, but Texas has more than three times the Louisiana capacity. In two different areas along the Gulf Coast, Texas has refinery concentrations totaling more than the entire refinery capacity in Louisiana.

Natural gas and liquefied petroleum gases are about equally divided as hydrocarbon sources for the remaining petrochemicals. Most of the natural gas is processed to remove the liquefied petroleum gases and heavier hydrocarbon fractions from it. Ethane is also removed in some gas processing facilities for dehydrogenation to form ethylene, the largest volume petrochemical building block. Louisiana is in a very strong position in natural gas, but because of the nature of the gas and certain geographical factors the production of liquefied petroleum gases is low in relation to gas production.

Supplies of salt and sulphur are found in the Gulf Coast salt domes. These non-hydrocarbon elements are used in the manufacture of some petrochemicals. Salt is much more important because of its use as the chlorine source in the manufacture of chlorinated hydrocarbons.

The major raw material advantage Louisiana seems to hold is its improving relative position in the production and reserves of crude oil and natural gas. The raw material factors which would tend to restrict
the growth of the petrochemical industry in Louisiana are the lack of refining capacity in relation to crude oil production and the relatively small amount of liquefied petroleum gases produced in the state, which is partially attributable to the lack of processing facilities for natural gas. Another possible limitation to petrochemical growth is the fact that almost half the state's refining capacity is centered in one plant. An area analysis in a later chapter will provide further elaboration on this point. Within the next two decades rising petroleum prices may also force a shift in petrochemical plants from an oil field location to a coal mine location.
CHAPTER IV

LAND, LABOR, WATER, AND POWER

The four factors of land, labor, water, and power have varying degrees of significance for different industries. In this chapter an effort will be made to relate the importance of these factors to the petrochemical industry and to consider how the needs of these factors are met along the Gulf Coast and in Louisiana particularly.

Land Requirements and Resources

The companies surveyed in Louisiana were generally blessed with an abundance of land for present and potential needs. Only one petrochemical producer among those contacted in the State is lacking sufficient land for further expansion. This company has virtually reached a standstill as far as major additions to its present facilities are concerned. This condition, however, is certainly the exception rather than the rule.

Along the banks of the Mississippi River between Baton Rouge and Belle Chasse, below New Orleans toward the Gulf, lie thousands of acres of land suitable for industrial plants. The most desirable sites seem to be along the winding 130 mile stretch of river between Baton Rouge and New Orleans.

Industrial land along the river is generally available at about $1,500 per acre although choice waterfront sites may be priced at $3,000
per acre. In July, 1960, Dow Chemical Company purchased 980 acres adjacent to its 1900 acre original holding for $1,000 per acre.

While the cost of land is not of major significance to a large-scale industrial purchaser (an extra one-half to one million dollars for land would probably not affect the construction of a large plant), the availability for present and future needs must be given considerable attention.

In the petrochemical industry, one company tends to feed off of another leading to the growth of complexes. The chemical intermediate manufactures like to provide land near their plants for potential customers. Since the major portion of petrochemical manufacturing in Louisiana and the Gulf Coast is engaged in the production of intermediates, each plant--especially the newer ones--ordinarily will be surrounded by land which it hopes to sell or lease at some later date to its customers. Of course, sufficient land should be purchased to allow for expansion of the company's own facilities.

Another land factor in the petrochemical industry is safety. The danger of explosion and fire is a constant hazard in the operation of a petrochemical plant. When oil refineries and petrochemical plants are jammed together fence-to-fence as in the Baton Rouge and Houston Ship Channel areas, the misfortune of one company can possibly spread to others in rapid sequence.

It was pointed out in the first chapter that Baton Rouge, Lake Charles, and New Orleans are the centers of the petrochemical activity in the state.

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1John A. Conway, "Old Man River Becomes Young Man on the Run," Newsweek, XLIX (June 24, 1957), 84.

2Industrial Activity Resume, 1960, Baton Rouge Chamber of Commerce.
The land availability situation in the Baton Rouge-New Orleans area is pretty well covered by considering conditions along the Mississippi River. The Lake Charles area should next be given attention.

At Lake Charles, the land along the Calcasieu River provides the most desirable industrial sites. All the major plants in the area are located along the river between Lake Charles and the point where the Intracoastal Waterway intersects the Calcasieu Ship Channel. The distance between these two points is approximately ten miles, all of which is not suitable for industrial plants because of low, marshy areas. Thus, it seems that the potential for expansion of the petrochemical industry, or any type industry, in the Lake Charles area is somewhat limited for the long run by the lack of available land. It also appears that most of the desirable land in this area is presently controlled by companies already located there. However, this land is available to users of their products who would desire to establish a plant in this location.

An industrial canal is planned by the Port of Lake Charles which would provide additional land of a very desirable nature for industrial expansion. This proposed canal is to be built from the proceeds of a bond issue which had not been submitted to the taxpayers for approval in the early part of 1961 but which is scheduled to be voted upon in 1961. Plans call for the canal to extend eastward perpendicular to the Calcasieu Ship Channel near the juncture of the Ship Channel and the Intracoastal Waterway.

In the Texas Gulf Coast region the principal petrochemical locations are in the Houston area along the Houston Ship Channel and in the Beaumont-Orange-Port Arthur area along the Neches and Sabine Rivers and along Sabine Lake. The only location which seems to be crowded to near capacity is the
Houston Ship Channel between the San Jacinto Monument and the Turning Basin. However, there is still room in this huge industrial complex for limited additional expansion. The relatively uncrowded Beaumont-Orange-Port Arthur area seems to have the brightest prospects for the Texas Gulf Coast.

Even though a company may have abundant raw material supplies, wide expanses of land on which to build, and the most modern equipment available, it must have an adequate labor force to be able to operate successfully. With this fact in mind it will be proper to consider next the labor factors in the petrochemical industry with special attention to conditions in Louisiana.

**Labor Requirements and Characteristics**

An outstanding characteristic of the petrochemical industry is the high investment per employee. This characteristic may be stated in another manner as having a low labor requirement per dollar of plant investment.

The average plant investment per employee for the plants covered in the survey conducted in connection with this report was slightly less than $90,000. The minimum investment per employee reported was $30,000 while the maximum was $167,000. The older plants, those started prior to 1950, had the lower investment per employee. The newer plants, those placed in operation since 1950, had a much higher investment per employee. The average for the newer plants was $128,000 with none less than $100,000.

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while the investment per worker in the older plants was less than $40,000 in every case.

It may be seen from the above figures that expansion in the petrochemical industry does not greatly affect employment figures. Using the average investment per employee for the newer plants we can determine that $50 million in petrochemical expansion, a sizable investment, would produce permanent employment in operations and maintenance for only about 390 persons. Of course, temporary employment would be swelled by construction needs, but this would dissipate upon completion of the construction project.

In the entire state of Louisiana in 1959 investment in industrial expansion totaled almost $133 million, creating 3,308 new jobs.\(^5\) This was an average of $40,000 investment per employee. The chemical and petroleum products group contributed 53 percent of the investment but only 19 percent of the new jobs with an average investment per employee of $113,000. This figure may be compared with investment per employee of $45,000 in the paper and paper products classification, $8,100 in food and kindred products, and $4,600 in lumber and wood products.

It is obvious that expansion of the petrochemical industry will not provide direct employment for large numbers of persons. However, through increasing demands for service facilities which must be supplied for the companies as well as their personnel the total effect on employment is greater than is initially apparent.

\(^5\) Approvals under the 10-year Tax Exemption Law and the Industry Inducement Law from records of the Louisiana Department of Commerce and Industry.
The average income of workers in the petrochemical industry is higher than the average for all manufacturing enterprises. In the Gulf Coast region the wages in the petrochemical industry tend to lag slightly behind those set in petroleum refining. The types of jobs are very similar in the two groups requiring a large proportion of skilled or semi-skilled employees. Average earnings in Baton Rouge are probably comparable with those of most other Gulf Coast locations. Data for this area show the average hourly earnings in the petrochemical industry to be $3.21 while average in all manufacturing was $2.85 per hour.\(^6\)

Average hourly earnings over the entire nation for 1960 show $3.01 for petroleum refining and $2.78 for industrial organic chemicals.\(^7\) The average for all manufacturing was $2.29. This indicates that Baton Rouge wages are higher than the national average for these types of industry. This situation is apparently true generally for the entire Gulf Coast.

Leaving petrochemicals briefly we should note that the high-wage condition in refining and chemicals has a repelling effect on other industries. Thus a company in some light manufacturing industry would not want to locate in an area where the dominant industries are petroleum and chemicals because of the disturbing influence on employee morale of the lower paid workers.

The quality of Louisiana labor was generally praised by the companies interviewed. One industrial relations director in particular was highly


\(^7\)Monthly Labor Review, LXXXIV (March, 1961), 315, 323.
enthusiastic over the energy, attitude, and productivity of local labor as compared with that in the northern part of the United States where the company had other operations. He was also very favorably impressed with the integrity and businesslike manner of local labor leaders. Some of the others interviewed were far less favorably impressed with labor union leadership, but all were generally well satisfied with the quality of workers.

The majority of the companies interviewed had a labor union representing their employees. However, some had maintained the more desirable direct relationship between employee and employer.

The president of the Polymer Chemicals Division of W. R. Grace and Company, T. T. Miller, in an address before the Rotary Club of Baton Rouge in November, 1956 pointed out a shortage of skilled construction craftsmen in the Baton Rouge area. Evidently this shortage still exists since it was mentioned by others in the interviews. The increasing demands for skilled personnel were also brought out in the interviews. As plants increase automation to control costs and maintain higher product quality standards the requirements for highly skilled personnel become greater.

**Employment Practices**

The employment of a high proportion of local people was unanimous among the companies interviewed. The percentages ranged between a low of 75 and a high of 95 for the proportion of employees who were hired in the vicinity of the plant.

The job types for which personnel were imported were primarily technical and administrative, although one company found it necessary
to import a skeleton force of operative and maintenance personnel as well. This situation arose because of a very specialized process.

In the normal situation, the operations and maintenance personnel are hired during construction and are trained on the job as construction proceeds. In some instances the training of key operative and maintenance personnel is handled at a similar facility of the company in a nearby state if such a facility exists. The men are then sent back to the new plant before startup.

The educational facilities of the state including secondary and trade schools, colleges, and universities were generally praised by the companies located there. It was pointed out that the ordinarily high quality of education and training performed by these institutions had made the recruiting job of the companies far simpler than would have been the case in some locations.

Neither the land availability nor labor supply were indicated as a primary factor in plant location on any of the questionnaires. These factors were indicated to be important secondary factors in most cases, however. A factor shall now be considered which was listed as a primary factor in most of the replies—second only to raw materials as the leading location factor for some companies. That factor is water.

The Importance of Water

Water serves four principal industrial purposes for the petrochemical industry. These four uses are cooling, process needs, waste disposal, and transportation. Water demands for cooling, processing and waste disposal will be considered at this time while its use as a transportation medium will be reserved for discussion in the section dealing with transportation.
The most significant industrial water requirement is for cooling purposes. In the petroleum refining and petrochemical industries demands are especially heavy where thermal transformation processes are used. Cooling water is ordinarily run through the cooling unit and returned to its source with only a small loss resulting from evaporation. More than 90 percent of the industrial water withdrawn is used for cooling, and, on the average, 95 percent of this water is returned to its sources.

Process water is used for washing purposes, to make process steam, to carry suspended materials, and for other purposes in refining and petrochemical plants. Process water may be a once-through material or it may be in other cases reused several times. Where the process water becomes contaminated with some waste material it must be disposed of, otherwise it may be filtered or treated and used again.

The typical industrial water use per barrel of refined petroleum is 770 gallons while 660,000 gallons are required to produce a ton of synthetic rubber.

Industrial waste disposal has become an increasing problem in recent years. However, water for waste disposal was indicated as a secondary location factor on the questionnaires while water requirements for cooling and process needs were considered as primary factors. Where a high volume water stream in relation to the amount of waste disposal is available

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9Henri Wolbrette, II, testimony before the Senate Select Committee on National Water Resources in Alexandria, Louisiana, December 1, 1959.

10Woodward, op. cit., p. 29.
the problem of waste riddance is slight. Plants may also use the desolate swamplands of Southern Louisiana as a depository for harmless plant waste material. The control of waste disposal problems is handled by a state stream pollution commission which works with the manufacturers, sportsmen, trappers, and fishermen to avoid harmful practices. One company reported a fairly severe disposal problem which resulted from the flat, swampy terrain's not providing sufficient runoff for the effluent material.

Despite elaborate equipment to remove harmful materials from streams, many companies have had unpleasant and costly experiences with waste disposal problems. Oil operators in the Gulf Coast area had such an experience when oystermen sued various companies for a total of more than $40 million to settle claims for destroying oyster beds. The culprit was found almost six years later to be a microscopic ocean parasite. However, the cost of industry-sponsored research carried on by company biologists, colleges, and universities to find the trouble-maker was approximately $2,000,000.

Total withdrawal of water for all purposes by the petroleum refining and chemical industries in Louisiana is currently in excess of 1500 million gallons per day. Since it is estimated that these industries use less than 25 percent of all industrial water withdrawals, the total withdrawals for all state industry would probably exceed six billion gallons per day.

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12 Wolbrette, loc. cit.
The importance of water to the petrochemical industry is evident from the preceding discussion. The next point to consider will be that of water availability in Louisiana and the Gulf Coast area.

**Water Availability**

The greatest water asset in Louisiana is the Mississippi River. With an average flow of more than 300 billion gallons of water per day it is the nation's largest fresh water supply. This source alone is equal to about 50 times the total industrial water requirement in the State of Louisiana.

The total flow of all streams originating in the United States, also called the average runoff, is approximately 1,160 billion gallons of water per day. Of this total the Mississippi River contributes more than 25 percent. With enough water to supply more than the entire nation's current water needs, the Mississippi has been a powerful attraction drawing industry to its banks along the stretch from Baton Rouge to New Orleans.

The river has not always served to encourage industrial development in the area South of Baton Rouge, however. At one time it was a deterrent causing industry to seek high ground because of the danger of rampaging floods. With the present system of levees to control flood waters industrial companies are no longer forced to locate plants on the higher land starting at Baton Rouge as was the Standard Oil Company when it built its

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14 Woodward, *op. cit.*, p. 3.

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refinery in 1909.\textsuperscript{15} The Bonnet Carre and Morganza Spillways along with other improvements have been built to handle any presently envisioned flood conditions.

In the Baton Rouge and New Orleans areas there are also ground water resources to supplement the flow of surface water in the Mississippi. In Baton Rouge, excellent water is obtainable at both 400-foot and 700-foot levels.\textsuperscript{16} Very little treatment is required for the ground water; so several companies use ground water for at least part of their industrial needs.

In the New Orleans area ground water is available from 200-foot, 400-foot and 700-foot sands.\textsuperscript{17} The 700-foot sand is the most prolific, yielding approximately 15 billion gallons annually. Deeper water is available, but it is not so desirable because of high chloride content. The quality of the ground water in New Orleans is not equal to that in Baton Rouge. Water for domestic purposes is obtained from the Mississippi River in New Orleans because of ground water supply problems. Baton Rouge, however, uses ground water from its abundant supply for domestic purposes.

The Calcasieu River on which most of Lake Charles industry is located is not generally suitable for either domestic or industrial water because of high salt water invasion in certain times of the year. Thus ground

\textsuperscript{15}Leon C. Megginson, \textit{The Industrial Development of the Baton Rouge Area}, Unpublished manuscript, Louisiana State University, 1956, pp. 1, 2.

\textsuperscript{16}Baton Rouge \textit{Water}, Chamber of Commerce, 1958, p. 3 and talks with industry officials.

\textsuperscript{17}Surface and Ground Water Resources of the New Orleans Area, Chamber of Commerce of New Orleans, p. 9.
water resources, which have been more than adequate in volume, must be used for practically all purposes. However, the ground water level in the Lake Charles industrial area is falling at the rate of five feet per year.\(^{18}\) Obviously, some steps must be taken in the near future to prevent the development of a critical water supply problem in this region.

It has been estimated that industrial water use will increase to 4,380 million gallons per day in Louisiana by 1980.\(^{19}\) This represents an increase of almost 200 percent over the 1959 requirements. Almost 95 percent of the 1980 demand is expected to come from surface sources. This estimate may be an understatement of the actual requirements at that time since the figure given above was an estimate for only those companies presently operating in the state.

It has been estimated that the industrial water needs of the entire Lower Mississippi River Basin will be 17.7 billion gallons per day by 1980.\(^{20}\) This quantity would place the region in eighth place in the nation among the 17 major river basin areas. The Lower Mississippi was in tenth place in the nation in 1955 measured by industrial water use with less than four billion gallons per day. The major part of industrial water use in the Lower Mississippi region apparently takes place in the Baton Rouge-New Orleans area.

Of the two areas which the Lower Mississippi area is expected to pass in industrial water use in the period 1955-1980, one is the Western

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\(^{18}\) Wolbrette, loc. cit.

\(^{19}\) Ibid.

\(^{20}\) Woodward, op. cit., p. 39. The Lower Mississippi refers to the eastern sections of Arkansas and Louisiana, the western sections of Tennessee and Mississippi plus very small portions of Missouri and Kentucky.
Gulf-Rio Grande area, which includes the western section of Louisiana, the southern section of Texas and parts of New Mexico and Colorado. Industrial water use in this area is expected to reach 14.6 billion gallons per day in 1980, up 300 percent from 1955 as compared with a 400 percent increase for the Lower Mississippi basin. The other river basin area expected to be passed in this period is the Missouri-Hudson Bay region. Industrial water use for the entire nation in 1980 is expected to be 66 percent of total gross use as compared with 45 percent in 1955.

The water outlook for Texas varies greatly with the geographic location. In the western part of the Texas Gulf Coast between Corpus Christi and Victoria the average annual runoff varies between one and two and one-half inches. In the area from Houston eastward to Lake Charles, the runoff varies between 10 and 15 inches per year, increasing in the easterly direction. From Corpus Christi southwestward along the remainder of the Gulf Coast there is a critical moisture problem. The region from Freeport eastward along the coast toward Louisiana is one of surplus water.

The city of Houston with its thirsty industry and growing population is taking steps to maintain its adequate water resources. Plans to construct two dams on the Trinity River will create reservoirs which are expected to supply Houston's industrial water needs for the next 50

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21Ibid., p. 65.

22Texas Natural Resources, Texas Natural Resource Committee, June, 1959, p. 28.
Permits for this construction have been granted. Another dam and reservoir on the San Jacinto River is planned for immediate construction. This project combined with the other dam and reservoir, Lake Houston, already existing, will provide a good surface water supply. These surface resources will combine with ground water resources to provide for immediate needs while the Trinity River projects are more for long-run demands.

The Beaumont-Orange-Port Arthur area seems to have adequate water supplies for both present and future needs without need for conservation or redistribution projects. The combined average annual runoff of the Neches and Sabine Rivers is about 13,206,000 acre feet. This is equivalent to approximately 12,100 million gallons per day. The surface resources of these two streams plus ground water resources in the area provide the Beaumont-Orange-Port Arthur region with a good fresh water supply for the foreseeable future.

Now that the primary problem of water requirements and availability has been covered, there remains yet another important factor to consider in this chapter. This next factor for consideration will be power.

**Power Use and Availability**

Some of the companies interviewed considered power as a primary factor and some considered it as a secondary location factor. Adequate power is very important to petrochemical manufactures; however, there

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seems to be no particular advantage of the Gulf Coast for power supply as compared to other possible locations.

There are five power companies operating in the Gulf Coast area between New Orleans and Brownsville, Texas.25 The New Orleans area is served by Louisiana Power and Light Company. Gulf States Utilities Company serves the area along southern Louisiana from Baton Rouge to the Texas border with the exception of a section in the center portion served by Central Louisiana Electric Company. Gulf States Utilities Company also serves the upper coast of Texas. The central section of the Texas coast is served by Houston Power and Light Company while the lower part of the coastal area is served by Central Power and Light Company of Corpus Christi, Texas.

There were mixed reactions of the companies interviewed concerning the use of purchased electric power. Some of the companies felt that their funds could be more profitably invested in their particular type of manufacturing specialty rather than tying up capital in power generation facilities. Approximately half of the companies, however, because of lower cost, a desire to be self-sufficient, some particular manufacturing process, or tradition, operate their own power plants. One company felt that it could not tolerate any power failure due to any external causes over which it has no control. In two cases where the companies generated their own power the cost was considered lower than purchased power. When large amounts of steam are required in the production process, electric power may be generated relatively inexpensively in most cases. Where an industrial plant uses exhaust steam in its process, it is possible to generate electricity at about one-third the heat required

25Taken from a letter written by a utility company executive.
in a straight condensing plant. Where no process steam is required, electric power may be purchased and a boiler may be installed for low pressure heating requirements. Merchant steam which may be sold to any buyer is not available except close to a power plant. For this reason most companies must produce their own steam requirements, and some companies, complementary to steam generation, will produce their own electric power. Thus, cost and dependability are the major factors inducing companies to produce rather than purchase their own electric power, while steam is usually generated as a matter of necessity.

The cost of fuel is a significant factor in power generation where hydro-electric power is not available. Although the abundant supply of natural gas in the Gulf Coast area has tended to keep generating costs low, one high-ranking utility company executive pointed out that he did not consider cheap power to be a major factor in industrial development of the area because of the availability of equally cheap power in other sections of the country.

**Summary**

This chapter has dealt with the location factors of land, labor, water, and power. Of these four factors only water and power may be considered as major location factors for petrochemical manufacturers in deciding upon a plant site. The other two factors are certainly important secondary factors. The factor of water was a more commonly acknowledged primary factor than power.

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Land availability has become a problem only in the Houston Ship Channel area of the Gulf Coast. In the Lake Charles area the availability of desirable land is more restricted than in the Baton Rouge-New Orleans area of Louisiana or the Beaumont-Orange-Port Arthur area of Texas. In other Texas Gulf Coast locations there seems to be no land problem.

Desirable land for petrochemical plant location is invariably near some adequate source of fresh water. The major fresh water source in the United States is the Mississippi River. This factor gives the Baton Rouge-New Orleans strip the top rating among Gulf Coast sites. However, surface water is not essential to plant needs for process and cooling purposes. Ground water may be used to support industry's needs as is done in the Lake Charles area.

There seems to be no major industrial water supply problems in the Gulf Coast area except for that portion from Corpus Christi southward. The second most desirable Gulf Coast location from the standpoint of water availability is the Beaumont-Orange-Port Arthur area.

The labor supply for the petrochemical industry seems adequate throughout the Gulf Coast area; however, a premium price may be demanded as compared to some alternative locations throughout the nation. The petrochemical industry is one which has low labor requirements per unit of investment.

Electric power is supplied by five utility companies in the Gulf Coast area which provide an adequate amount of power for industrial growth. However, many companies generate their own power rather than purchasing from the public supply available. Since process steam is
required by most petrochemical manufactures, and this is not widely available as a merchant product, the companies are frequently forced to produce their own steam power. Where adequate steam is available and electricity demands are great, the petrochemical manufacturer may be able to generate its own electric power more cheaply than it can be purchased from a utility. The other major motive for electric power production rather than purchase is greater dependability. However, if a company wishes to purchase electric power there seems to be an abundant supply in all parts of the Gulf Coast.
CHAPTER V

TRANSPORTATION, MARKETS, AND INDUSTRIAL COMPLEX LOCATION

Transportation, including facilities, uses, and cost, is considered first in this chapter. The form of goods produced and principal markets are also considered. Finally, industrial complex location is discussed which relates how transportation, market, and raw material factors affect the growth of complexes. All of the material presented in this chapter will refer primarily to the Louisiana Gulf Coast location.

The transportation factor which is considered in this chapter is rather a broad one covering several types of transportation. Transportation of raw materials and finished products is the primary consideration, although the companies surveyed did give some thought to personnel transportation—chiefly airline service. The types of transportation considered will be ocean-vessels, barges, railways, motor trucks, and pipelines. The extent of use of these various methods and their costs are also covered in this section. Transportation facilities available will be considered first.

**Transportation Facilities**

Deep water port facilities, inland waterways, and railways were listed as primary location factors by various companies surveyed for this report. The transportation method most frequently given the primary rating was the railway system. In second place among the primary
listings was the deep water port factor with one company listing this as a secondary factor. In third position among the primary transportation factors came inland waterways with two companies giving this factor a secondary rating. None of the companies listed railways as a secondary location factor. The public highway system was not listed as a primary factor by any of the companies; however, one company indicated highways as a secondary factor. The most common primary location factor, railways, will be considered first.

The Louisiana Gulf Coast is generally well-served by railways in the large cities. The centers of petrochemical location in South Louisiana—Baton Rouge, Lake Charles, and New Orleans—are also the major points of population concentration in the area.

Freight service in Baton Rouge is provided by four major railways. However, one of these lines is located on the opposite side of the river from Baton Rouge, which makes service of this line much less valuable than the other three.

Lake Charles, on the Western side of the state, is served by three major railways. These railroads are the Kansas City Southern Lines, the Missouri Pacific Railroad, and the Southern Pacific Railroad (T. and N. O.).

The metropolitan area of New Orleans is served by eight major trunk line railroads. These railroads, which operate a total of more than

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1Baton Rouge Chamber of Commerce.

2Lake Charles Association of Commerce.

3Chamber of Commerce of the New Orleans Area.
50,000 miles of track throughout the United States, give New Orleans the
top rating for rail transportation. New Orleans owns the Public Belt
Railroad, which provides a connecting link among the railroads, wharves,
and industries along its 166 miles of track. Railway connections with
port facilities are provided in all locations.

The three major petrochemical centers in Louisiana all have deep-
water ports which permit ocean-going vessels to serve these locations.
Baton Rouge boasts the farthest inland deep-water port on the Mississippi
River.\(^4\) The distance from the Port of Baton Rouge to the Gulf of Mexico
is 235 miles. The port facility provides a direct transportation link
with all the world. Thus, both rail and barge cargo may be transferred
to deep-water vessels at this point for export shipment.

The Port of Lake Charles lies only 32 miles inland from the Gulf of
Mexico.\(^5\) The Port of Lake Charles is the smallest of the three ports
serving major petrochemical centers in Louisiana. Approximately 1,000
ships per year call at this port which provides a major service of link-
ing Lake Charles industry directly with the rest of the world.

New Orleans has the major port in Louisiana. The Port of New
Orleans is the second largest in the United States in cargo value.\(^6\)
Approximately 5,000 ships visit New Orleans annually loading and unloading
cargo from all over the world. International trade is encouraged
and facilitated by a 25-acre "neutral" Foreign Trade Zone.

\(^4\)Baton Rouge Chamber of Commerce.

\(^5\)Lake Charles Association of Commerce.

\(^6\)Put Your Plant in New Orleans, New Orleans Public Service Company,
1960.
The Port of New Orleans will be more readily accessible when the Mississippi River-Gulf Outlet, which is under construction, is completed in 1967. The first half of this $105 million project, a channel 36 feet deep by 250 feet wide, is scheduled for completion in 1963. This outlet will cut approximately 40 miles from the route now traveled by ships between the Gulf of Mexico and the inland ports of Baton Rouge and New Orleans. The distance up the river from the Gulf to New Orleans is presently 110 miles.

Inland waterways, the third ranking transportation factor, serve all three Louisiana Gulf Coast petrochemical centers. Baton Rouge is linked commercially to the Great Lakes region by barge traffic along the Mississippi River and its tributaries. In 1958, more than 172 million tons of cargo were shipped in inland traffic on the Mississippi River System. The Mississippi River also provides access to the Intracoastal Canal, which runs 1066 miles from the Mexican Border across Texas, Louisiana, Mississippi, Alabama, and into northeast Florida.

The Intracoastal Canal, which intersects the Calcasieu Ship Channel a few miles below Lake Charles, provides the principal avenue for barge traffic to and from Lake Charles. The Intracoastal Canal, which was completed in 1949, carries as much tonnage as the Panama Canal and more than twice as much as the St. Lawrence Seaway. Barge movement on the Calcasieu

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8 Ibid.


10 Ibid.
River above Lake Charles is relatively insignificant. There are eight barge lines which serve the city.

New Orleans is the most favorable location for inland waterway connections. It is at the junction of the Mississippi River and the Intracoastal Canal. Twelve common carriers and more than 50 contract carriers serve the New Orleans barge shipper.\(^{11}\)

A combined system of federal and state highways plus numerous motor truck lines provide the Louisiana Gulf Coast area with an adequate highway transportation system.

Now that a general view of the transportation facilities available in the South Louisiana petrochemical centers has been given, the use of these facilities by the petrochemical companies should be considered.

**Transportation Methods Used**

Petrochemical industries in the Louisiana Gulf Coast area use a variety of transportation methods for bringing in raw materials and shipping out products. The incoming and outgoing materials are transported by rail, ship, barge, motor truck, pipeline, and aircraft. For the companies surveyed in connection with this report, the most commonly used method of bringing in raw materials was by pipeline, and the most commonly used method of shipping out finished product was by railway. Pipelines, which are rather specialized transportation methods for the petroleum and petrochemical industries, were not discussed in the preceding section dealing with more common methods of transportation. More attention will be given to pipelines later in this chapter.

\(^{11}\)"Put Your Plant in New Orleans," *op. cit.*
The companies surveyed were requested to indicate the principal method of transportation for their major raw materials and products. The form of the product or raw material was also requested. Aircraft movement of materials was of such minor importance that it has been eliminated from further consideration in this study. The primary importance of aircraft as a means of transportation in the petrochemical industry is for the movement of personnel.

There were 20 responses in the raw materials section of the questionnaire. Of these, 65 percent indicated that raw materials were brought in by pipeline, 25 percent by rail, and five percent each by barge and highway. Ships were not indicated as a method of raw material transportation by any of the companies interviewed.

The principal forms in which the raw materials were purchased were as a gas or as a liquid at atmospheric pressure. Closely following these two forms were raw materials purchased as a liquid under pressure. The most uncommon form for raw materials was the solid state.

The most commonly used method of transporting finished product among the companies surveyed was by rail. There were 36 responses in the products section of the questionnaire. Forty-four percent of the responses indicated that the products were shipped by rail. Twenty-two percent of the products were shipped by barge and by highway, and six percent were transported by ocean vessels and by pipeline.

The most common form of the finished product was a liquid under pressure, amounting to 47 percent of the products. Twenty-eight percent of the products were shipped as a solid and 25 percent as a liquid at atmospheric pressure. None of the products were sold in the gaseous state. Most of the pressurized liquids were shipped by rail, the liquids
at atmospheric conditions were shipped principally by barge, and equal numbers of solid products were shipped by rail and highway.

Since transportation facilities available, and methods used, have been presented, the next point to consider is that of costs of transportation.

**Transportation Costs**

At the beginning of this study it was recognized that companies would be reluctant to give specific cost information. The companies were asked if they expected to minimize costs in the location they chose as compared to other plant location sites. Only one company indicated that transportation costs were expected to be minimized at the Louisiana location, and they felt that this objective had been accomplished.

While specific transportation cost data were not obtained, typical long-haul costs are available for various transportation methods. The typical long-haul cost for tanker transportation is 1.4 mills per ton mile.\(^{12}\) This cost per ton mile increases to 2.0 mills for barge transportation, 17.0 mills for rail transportation and 50.0 mills by way of truck. Although the tanker is obviously the cheapest method of transportation, its use is limited by the fact that over 5 million gallons per voyage must be shipped to justify the investment required.\(^{13}\) Likewise,

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\(^{13}\) *ibid.*
the barge shipment, to realize the lowest cost of transportation, must consist of more than 3 million gallons. Single barge shipments may be made of smaller quantities but at a higher price per unit. Quantity minimums are very small for rail and highway shipments.

It seems somewhat paradoxical that the companies would be so desirous of a deep-water or inland waterway location when most of their products are moved by rail. However, it must be remembered that the data given in the previous section on product movements was for the number of products, not volume of shipment. Only the large-volume products may be moved economically by barge or ship transportation whereas numerous small-volume products are moved most economically by rail.

Another reason for the desirability of a waterway location, aside from the fact that large-volume products must be moved by water transportation to maintain competitive delivered prices, was disclosed in the interviews. The railroad companies will provide more attractive rates to a company which has the alternative of shipping by barge or rail, whereas if a company has only the alternatives of rail or highway shipment the rail rates will not be nearly competitive with barge rates. Thus, competition among the transportation agencies accrues to the advantage of the company which has access to both rail and water transportation.

Now that transportation methods, uses, and costs have been presented, the next logical location factor for consideration is markets.

**Petrochemical Markets**

The basic types of goods marketed should be defined before going into a discussion of markets. The two basic types of goods, classified
according to destination, are industrial goods and consumer goods. Industrial goods are those "purchased by business units, not for personal consumption, but to assist in, or to enter into, the production of other goods or services." Consumer goods may be defined as those "purchased by individuals or families because of the type of satisfactions they are expected to yield in consumption." Most of the petrochemicals manufactured on the Gulf Coast may be classified as industrial goods.

The industrial goods may go through several stages before being converted into a consumer good for personal consumption. Stages in the transformation from a basic petrochemical building block to a finished consumer good may be seen by referring back to Figures 10 and 11. For example, it may be seen that ethylene may be converted into ethylene oxide then to ethylene glycol, which makes a permanent-type anti-freeze. Ethylene may also be converted into polyethylene, which may be used in making toys, housewares, squeeze bottles, or wrapping film. For another example, the versatile benzene may be converted into ethyl benzene, then to styrene and SBR (styrene-butadiene rubber) before being used to manufacture automobile tires.

The petrochemical manufacturers provide a small but specialized market for the petroleum refiner, natural gas producer, or processor. It has been mentioned earlier that the petrochemical industry uses much

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15 Ibid.
less than five percent of the petroleum and natural gas produced. The chief competition of the petrochemical industry for the use of their petroleum raw materials comes from fuel and blending stock demands.

There are three major market regions for the finished petrochemicals manufactured in the Gulf Coast area. The first of these market regions is the Eastern Seaboard industrial region running from Baltimore northward to New Haven, including New York City, Philadelphia, and the State of New Jersey. The second major market region is the Eastern Interior industrial region which includes the states of Ohio, West Virginia, and the western half of Pennsylvania. The third major market region is the Western Interior industrial region centered at Chicago and including the adjacent portions of the states of Wisconsin, Illinois, Indiana, and Michigan.

Within these petrochemical market areas lie the greatest part of the plants which convert the finished petrochemical products into consumer goods. The consumer goods manufacturers are located near the centers of population and purchasing power because of the usually small unit purchases of consumer goods accompanied by high costs of transportation. The consumer good manufacturers, however, are large volume purchasers of finished petrochemical products which may be shipped in bulk without the packages and frills ordinarily required in consumer goods.

Personal income figures help to reveal the best market places for consumer goods. The residents of the nation's major market area—a group

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of seven states running northeastward from Illinois to New York and New Jersey—earned more than 42 percent of the total personal income in the United States (Excluding Alaska and Hawaii) in 1960. The residents of Louisiana and Texas and those of all the states adjoining them—New Mexico, Oklahoma, Arkansas, and Mississippi—earned less than nine percent of the total personal income of the United States in 1960. Texas and Louisiana contributed more than two-thirds of the personal income of these six states, but all six together had less total personal income than the state of New York. However, the total for Louisiana and Texas was about equal to that of Illinois, Ohio, or Pennsylvania. This factor provides the basis for expectations by some persons in the Louisiana-Texas region that an increasing number of consumer goods manufacturers will move into the area.

The paucity of markets for finished petrochemical products in the Gulf Coast area may be further realized by considering some specific products. Seventy-two percent of the nation's capacity for making polyethylene is located on the Gulf Coast, yet only two percent of the national total is consumed on the Gulf Coast. For SBR compound, 58 percent of the United States capacity is located on the Gulf Coast, but only two percent is consumed there.

For the intermediate products, however, the market picture is different. For ethylene, 67 percent of the nation's capacity is located

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on the Gulf Coast, and an equal amount is consumed there.\textsuperscript{19} For butadiene, the principal component of SBR compound 79 percent of United States capacity is located on the Gulf Coast, and 58 percent of national consumption takes place there. Some butadiene is shipped to a market location for further processing.

Ammonia, an inorganic petrochemical, is a product which is largely sold to the ultimate consumer near the point of manufacture either in its liquid anhydrous form or as a solid in ammonium nitrate fertilizers. The location of plants that manufacture ammonia seems to follow the maximum profit theory of location very closely. The location currently seems to depend primarily upon the transportation costs to the market, with the location of greatest market having control in determining the location of the plant. Most of the existing Gulf Coast plants were located because of raw material availability. This location allowed them to serve most economically the large southern agricultural market and to ship finished product to the other market locations. The most costly raw material in most ammonia manufacturing processes is natural gas. Since natural gas pipelines now crisscross the nation, the raw material location has lost its advantage. The other raw materials for ammonia manufacture are ubiquitous materials, air and steam. Thus, it is cheaper to ship the raw material, gas, to the market-located plant than it is to ship the finished product from a raw material-located plant to the market. This condition has led to a considerable over-capacity situation in the ammonia industry. Present ammonia capacity is more

\textsuperscript{19}Tbid.
than 50 percent greater than demand. Further expansion of this industry in the near future is unlikely unless there is some major technological development involving new uses of the product.

The principal aspects of the domestic market for petrochemicals have been considered. However, before going on to industrial complex location, the world market position of Louisiana and the Gulf Coast should be considered.

Louisiana boasts the nation's second largest port in the value of goods handled, the third largest in volume of goods. The Port of New Orleans was also the second largest in volume at one time but has lost its position to the Port of Houston, the center of the Gulf Coast petrochemical industry. The Gulf Coast ports are in a most favored location for trade with Latin America and are in a very suitable position for trade throughout the world. Louisiana's share of the overseas sales of chemicals and products amounted to $40 million in 1956. This amount was more than 20 percent of the state's foreign sales of manufactured goods. Continental Oil Company in deciding upon its new "ALFOL" alcohol plant discovered that industrial alcohol markets in widely separated parts of the world could be served as well, if not better, from Lake Charles as from locations on either the East or West Coasts.

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Some American companies, however, are building foreign plants which may someday provide competition in American markets. These plants have a direct and immediate effect of reducing world markets for some of the petrochemical firms operating within the United States. These actions, however, must be taken for competitive reasons.

The transportation and marketing aspects of plant location in South Louisiana have now been considered. The next item for consideration is location in industrial complexes.

**Industrial Complex Location**

Industrial complexes may popularly have three different meanings. The growth of one company providing several different processes and products in one location may be called an industrial complex. The growth of several different companies in one industry in a given location is also called a complex. Finally, the growth of several different industries in one locational area is referred to as an industrial complex.

The tendency of companies, industries, and groups of industries to grow in a given location has been recognized by Weber and others and identified as factors of agglomeration. These agglomerating forces were discussed in Chapter II along with the general advantages of industrial complex location.

Complexes in the petrochemical industry are located in the Louisiana Gulf Coast area at Baton Rouge, Lake Charles, and New Orleans. The major petrochemical complex in the State is at Baton Rouge with Lake Charles in

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second place. These raw material oriented complexes use feedstocks which are principally refinery products. Thus, it is not surprising that the major petroleum centers are, in order, Baton Rouge, Lake Charles, and New Orleans.

The obvious hub for the Baton Rouge petrochemical complex is the refinery of the Esso Standard Division of Humble Oil and Refining Company. This refinery, the largest in the United States, is a prolific producer of the paraffins, olefins, and aromatics, which are basic petroleum raw materials for the petrochemical industry. The Esso Refinery, which comprises almost half of the refining capacity of the entire State of Louisiana, is the only one operating in the Baton Rouge area.

There are eight major petrochemical manufacturing plants in the Baton Rouge area which use refined petroleum fractions as a raw material. These are Allied Chemical Corporation, Copolymer Rubber and Chemical Corporation, Dow Chemical Company, Ethyl Corporation, Foster Grant Company, Incorporated, W. R. Grace and Company, Naugatuck Chemical Company, and Wyandotte Chemicals Corporation.24 One other plant, Stauffer Chemical Company, processes refinery sludge acid and hydrogen sulfide gas to make Sulfuric acid and Sulfur.

A maze of pipelines connects each plant to its primary source or sources of raw materials. These pipelines carry such materials as ethylene, propylene, butylene, butadiene, LPG mixtures, benzene, brine, styrene, clorine, and others among the plants in the complex. The Esso

Refinery, in addition to being a major supplier of petrochemical building blocks, is a large-scale producer of butyl rubber.

Monochem, Incorporated, which is building a petrochemical plant within the confines of the Baton Rouge complex, next to the Wyandotte plant at Geismar, will use natural gas as the basic raw material. The plant is scheduled for completion of initial construction work late in 1962.25

The Lake Charles complex has two refineries which serve as the basic source of supply for the petroleum derived building blocks. These two refineries, Cities Service Refining Corporation and Continental Oil Company, have refining capacity equal to almost one-quarter of a million barrels per day or about two-thirds that of the Esso Refinery in Baton Rouge.

Two companies, Petroleum Chemicals, Incorporated (PCI) and Calcasieu Chemical Corporation (CCC) are key points in the Lake Charles complex.26 Petroleum Chemicals, Incorporated is jointly owned by Cities Service and Continental. Cities Service and Continental also own the majority interest in Calcasieu Chemical Corporation, which is operated by PCI. The PCI complex, which is fed directly with by-product streams from the two refineries, consists of an ammonia plant, a butadiene plant, and an ethylene plant. Reformer off gases from the two refineries is fed to the ammonia plant where a pure stream of hydrogen is separated for ammonia manufacture.


The ethane-ethylene-and-heavier stream from the ammonia plant plus ethane and ethylene rich by product gases from the refineries are fed to the ethylene plant. Ethylene is separated and purified in the ethylene plant, which also provides a propylene product of better than 95 percent purity. A large part of the ethylene goes to Calcasieu Chemical's ethylene oxide-ethylene glycol plant. Additional ethylene is sent by pipeline to Orange, Texas to supply Du Pont and Spencer Chemical Company plants. Thus, the Lake Charles complex is connected to the southeast Texas complex around Orange, Beaumont, and Port Arthur. Continental Oil Company's "ALFOL" alcohol plant, when completed, will also use ethylene from PCI.

The butadiene plant converts butanes and butylenes into butadiene, producing hydrogen in the process which is routed to the ammonia plant. The principal butadiene user is Firestone Tire and Rubber Company which uses butadiene as a major constituent in SBR compound.

Also tied into the Lake Charles complex are Hercules Powder Company's polypropylene plant and Columbia-Southern's ethylene dichloride facility.

Olin Mathieson Chemical Corporation, the other major petrochemical producer in the Lake Charles area, uses natural gas in the manufacture of ammonia. Thus, Olin, like Monochem in the Baton Rouge area, is not tied to the system for a major part of its raw material.

In the New Orleans area the lack of refining capacity to produce merchant petrochemical building blocks has limited growth of the petrochemical industry. The only major petrochemical plant in the New Orleans area processing refinery produced petroleum fractions is that of Shell Chemical Company in Norco, which obtains feed stock from the adjacent Shell Oil Company refinery. The Shell refinery, whose production of petrochemical building blocks is captive for the adjoining Shell Chemical
Company, is the largest in the New Orleans area, contributing more than 61 percent of the area's refining capacity. Total refining capacity in the New Orleans area from three refineries is less than 45 percent of Baton Rouge's one refinery. Two small petrochemical plants in the New Orleans area process lube-oil stocks to make specialty products.

The second largest refinery in the New Orleans area, Tennessee Oil Refining Company, has recently expanded capacity and has scheduled production of basic aromatic petrochemicals. Construction is expected to be completed for the new petrochemical facilities in 1961.

The other two major petrochemical producers in the New Orleans area are American Cyanamid Company and Monsanto Chemical Company. American Cyanamid produces a variety of products from natural gas at its Avondale plant. Among those products produced are acrylonitrile, acetylene, and ammonia. Monsanto produces ammonia, ammonium nitrate and adipic acid at its Luling plant using natural gas as the hydrocarbon feed. Thus, it may be seen that New Orleans petrochemical growth has been primarily based upon natural gas while the major growth in the State, at Baton Rouge and Lake Charles, has been based upon refinery by-product hydrocarbons.

Two recent reports indicate bright prospects for the continued growth of Louisiana's petrochemical industry. Indications have been given that Chemoil Corporation will build a 40,000 barrel per day refinery somewhere between Baton Rouge and New Orleans. This refinery is expected to cost about $60 million and will produce the olefins, ethylene and propylene.

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It has also been reported that Union Texas Natural Gas Corporation will build a 200-million-pound-per-year ethylene plant somewhere along the Louisiana Gulf Coast. Although Chemoil had not purchased land in the indicated area by June 1, 1961, the proposed refinery is scheduled for completion by 1963. The products of these proposed plants could serve to attract petrochemical manufacturers to build polyolefin facilities or other products using the versatile ethylene as a building block. The new ethylene and propylene facilities might also allow for expansion or further diversification of the petrochemical plants already located in the Louisiana Gulf Coast area.

The proposed Union Texas Natural Gas plant is of sufficient size to produce relatively low cost ethylene which will attract users to the area. Some idea of the economies of scale in ethylene manufacture may be seen in Table VIII. The cost figures given were obtained from the manager of the chemical process division of a large international construction firm. Whereas these costs may vary with the nature and cost of individual feedstocks and the type and purity of by-products produced, the incremental manufacturing cost with plant size is valid.

TABLE VIII

MANUFACTURING COST OF ETHYLENE FOR VARYING PLANT SIZES

<table>
<thead>
<tr>
<th>Plant Size-MM#/YR</th>
<th>Manufacturing Cost-¢/#</th>
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<tbody>
<tr>
<td>50</td>
<td>3.1</td>
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<tr>
<td>100</td>
<td>2.4</td>
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<tr>
<td>200</td>
<td>1.9</td>
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<tr>
<td>300</td>
<td>1.75</td>
</tr>
<tr>
<td>500</td>
<td>1.5</td>
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</table>

28 Ibid., p. 69.
At an output of 200 million pounds per year it may seem that the company would gain large economies of scale as compared to a 50 to 100 million pound plant. The cost per pound is almost 40 percent less than the cost for a plant of 50-million-pound capacity.

Union Texas Natural Gas is the largest gas processor in the State of Louisiana having a daily throughput in its three processing plants of 1,643 million cubic feet of gas. Two of the plants, processing 1,500 million cubic feet per day, are located in Acadia Parish. This location is about midway between the petrochemical complexes at Baton Rouge and Lake Charles. The smallest plant is East of New Orleans in St. Bernard Parish. A plant located to take advantage of the output of these two plants, which process 25 percent of the gas processed in Louisiana, would seem ideal. Natural gas liquids totaling three-quarters of a billion gallons daily are recovered at these two plants.

It would seem that the most likely location of an ethylene plant to take advantage of the ethane and propane produced would be at one of the two existing gas processing plants at Eunice or Rayne. This plan would allow the use of existing auxiliary facilities. These by products could be used as fuel or possibly sold with the effluent gas stream from the gas processing plant. However, there might be other reasons, such as water availability, transportation facilities, etc.—factors not readily apparent at this time—which would cause the plant to be located in some other place and the raw material pipelined to it.


30Ibid.
The advantages to be found in industrial complex location have been exploited by petrochemical companies in three locations in Louisiana. The two major ones at Baton Rouge and Lake Charles have been based primarily on the concentration of significant refinery capacity. The third complex, in the New Orleans area, uses principally natural gas as its basic raw material.

While the petrochemical complexes of Baton Rouge and Lake Charles are certainly impressive, they cannot match the massive refinery-oriented concentration of petrochemical firms in the Houston-Freeport-Beaumont-Orange-Port Arthur complex. Firms in this area are linked by more than 800 miles of pipelines costing about $16 million (excluding gas, oil, and water lines) which have caused the region to be named the "Spaghetti Bowl."31

A large petrochemical complex is growing in the Delaware Valley, which is second only to the Southeast Texas area in refinery capacity.32 The rapidly developing area which stretches along the Delaware River from Philadelphia to Wilmington, Delaware, is at the juncture of the States of New Jersey, Delaware, and Pennsylvania. In addition to having plentiful refinery-produced raw materials, the area lies in a more favorable market location than the Gulf Coast. Approximately one-third of the population of the United States lives within a 300 mile radius of Philadelphia.33 However, these advantages have not been able to overcome

31"Money in the Spaghetti Bowl," Houston, XXIX (April, 1958), 16.
32P. H. Stormont, "Big Petrochemical Center Takes Shape," Oil and Gas Journal, LVIII (December 19, 1960), 54-55.
33Ibid.
the combination of plentiful low-cost raw materials and other inducements of the Gulf Coast.

Summary

In this chapter the factors of transportation, markets, and industrial complex location have been considered. Transportation availability by rail, ocean vessel, and barge were all considered as primary factors by various companies contacted. Pipelines were the most widely used transportation facilities for raw materials while railways were used most commonly for product transportation. Barge and highway facilities were also used frequently for outbound shipments. Transportation facilities seem quite adequate in the major Louisiana petrochemical centers of Baton Rouge, Lake Charles, and New Orleans. However, New Orleans has the advantage over the others in transportation facilities.

The petrochemical firms provide most of their own markets among themselves for basic and intermediate materials. When the chemicals are ready for conversion into consumer goods they are mostly sent North or Northeast to population and purchasing power centers where the consumer good factories are concentrated. The outlook for any significant movement of consumer goods manufacturers into the state seems rather dim because of the low purchasing power in Louisiana, and surrounding states. Texas may hold some hope for a trend of this nature because of Houston and Dallas primarily. World markets are accessible from all three Louisiana petrochemical centers and are not without value. However, European and Latin American petrochemical markets are being satisfied to an increasing extent by moves of manufacturers to establish plants in these areas.
Industrial complex development in the petrochemical industry is influenced by several factors. Chief among these are market availability through the interchange of basic and intermediate products, simplified pipeline transportation for hard-to-handle materials in the form of gases or liquids under pressure, and sizeable economies of scale. Petrochemical complexes have developed on the Louisiana Gulf Coast at Baton Rouge, Lake Charles, and to a lesser extent, New Orleans. Plants located in these areas are shown in Table IX.

In addition to those companies listed, Chemoil Corporation has announced that it will build a 40,000 barrel per day petroleum refinery in the Baton Rouge-New Orleans area and will produce olefins. Union Texas Natural Gas Corporation is reportedly planning to construct a 200 million pound per year ethylene plant somewhere along the Louisiana Gulf Coast.

The future pattern of growth of petrochemical complexes in Louisiana seems somewhat uncertain. In considering this problem it should be kept in mind that the major share of present industry has been located as a result of petroleum refinery by product availability. Any significant expansion of existing refinery facilities seems somewhat remote for the near future because of considerable overcapacity in existing refineries. It has also been predicted that future expansion of Gulf Coast refinery capacity would occur primarily in Texas.

The Baton Rouge Complex is largely tied to one primary source of supply, the Humble refinery. Having only one source of supply creates several problems among which is monopoly pricing. It was discovered in the interviews that petrochemical building block prices are currently higher in the Baton Rouge area than in the Southeast Texas area. In
<table>
<thead>
<tr>
<th>Baton Rouge Area</th>
<th>Lake Charles Area</th>
<th>New Orleans Area</th>
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<tr>
<td>Allied Chemical Corporation</td>
<td>Calcasieu Chemical Corporation</td>
<td>American Cyanamid Company</td>
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<tr>
<td>Copolymer Rubber and Chemical Corp.</td>
<td>Cities Service Refining Corporation</td>
<td>Monsanto Chemical Company</td>
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<td>Dow Chemical Company</td>
<td>Columbia-Southern Chemical Corp.</td>
<td>Shell Chemical Company</td>
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<td>Ethyl Corporation</td>
<td>Continental Oil Company</td>
<td>Tennessee Oil Refining Company</td>
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<td>Foster Grant Co., Inc.</td>
<td>Firestone Tire and Rubber Corp.</td>
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<td>W. R. Grace and Co.</td>
<td>Hercules Powder Corp.</td>
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<td>Humble Oil &amp; Refining Corp.</td>
<td>Olin Mathieson Chemical Corp.</td>
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<td>Monochem, Inc.</td>
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<td>Naugatuck Chemical Co.</td>
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<td>Wyandotte Chemicals Corp.</td>
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* Includes plants under construction

SOURCE: Oil and Gas Journal
this area between Houston and Orange are located 13 refineries with total capacity of approximately 1.8 billion barrels of crude oil per day—almost two and one-half times the capacity of all refineries in the State of Louisiana. Associated with these refineries are large facilities for producing merchant olefins and aromatic petrochemicals in the basic and intermediate groups. Thus, it would seem that further petrochemical growth in the Baton Rouge area would depend largely upon increased sources of supply. However, the basis for future growth might be shifted from being refinery-oriented to a natural gas base.

The best prospect for growth in natural gas based petrochemicals would seem to depend on chemicals from acetylene. The Monochem-Borden-U. S. Rubber complex, now partially under construction, is a large step in that direction for the Baton Rouge area.

The New Orleans area has little basis for expansion of refinery by product petrochemicals. The largest refinery in the area, belonging to Shell Oil Company, is provided a captive market by the adjacent Shell Chemical Company. Natural gas has provided the raw material basis for the American Cyanamid and Monsanto plants. American Cyanamid makes acetylene for internal use in its operations. Future expansion in the area of producing ammonia from natural gas, which Monsanto does at its Luling plant, seems rather remote. New Orleans may be able to attract some consumer goods plants because of the population concentration in the area and easy access to Latin American markets.

The Lake Charles area, although the second largest refining center in the state, has relatively small refining capacity. However, additional expansion is likely with existing raw material facilities. Any expansion
beyond this will probably be limited by land availability and a falling ground water level.
CHAPTER VI
POLITICAL, SOCIAL, AND OTHER FACTORS INFLUENCING
PLANT LOCATION

In this chapter the remaining location factors to be presented in
this report are identified and evaluated. These factors are generally
regarded as secondary and are primarily political and social factors.
The chapter is divided into three segments. The first, dealing with
political factors, considers taxes, political stability, and the industry
inducement plan. The second section deals with social factors including
community facilities and community relations. The last part of the
chapter considers other factors not included in political or social
factors and not covered in previous discussion. These factors include
the availability of surplus war plants, climate, construction costs,
and special agreements.

Political Factors

Taxation. Petrochemical companies operating in the State of
Louisiana may be required to pay a half a dozen or more types of state
taxes.\(^1\) The most important of these as a revenue source for the State
is the Severance Tax, which yielded more than $112 million in 1959.\(^2\)

\(^1\)These include ad valorem tax, corporation franchise tax, foreign
corporations capital stock tax, income tax, incorporation tax on domestic
corporations, power use tax, severance tax, and unemployment compensation
tax.

\(^2\)Bureau of the Census, State Tax Collections in 1959, (Washington:
This tax levied on natural resources severed from soil or water gets most of its substance from the State's reserves of crude petroleum and natural gas. Owners of these natural resources paid approximately 96 percent of all severance taxes paid in Louisiana during the Fiscal Year 1958-1959.³ Severance taxes on Sulphur and Salt brine used in manufacturing also affects the petrochemical industry, but not to any great degree.

With only one exception the companies interviewed for this study felt that the severance tax on natural resources was higher in Louisiana than in any other possible plant location. The strongest feeling about severance taxes came from those companies who use natural gas as a principal raw material. The severance tax on natural gas in Louisiana is $.023 per thousand cubic feet of gas while the tax on Texas gas is eight and one-half percent of the value of the gas.⁴ The average well head price for gas in Texas is about $.105 per thousand cubic feet which would make the tax per thousand feet about $.009. The Louisiana severance tax on natural gas is more than 150 percent greater than that in Texas, which is Louisiana's chief competitor in attracting plants to use the gas as raw material in chemical processes.

The disparity between natural gas taxes in the two states was not so great as it is now until 1958. The Louisiana Legislature increased the gas gathering tax by 100 percent to $.02 per thousand cubic feet in 1958. Then, in a special session called later in the year, the entire two cents was shifted from the gas gathering tax to the gas severance tax.


⁴Ibid., p. 102.
tax for fear of unconstitutionality of the former tax measure. The additional $.02 severance tax was scheduled to expire in August, 1960. At that time, however, the tax was extended for four additional years, which will run through the term of the present administration.

In the case of corporate income tax, Louisiana is also in an unfavorable position as compared to Texas. The rate of corporate income tax in Louisiana is four percent whereas Texas collects no corporate income tax. However, Louisiana, like many other states, allows the deduction of federal income tax before figuring taxable income. Thus, the income tax is not too significant in comparison to the severance tax.

Only in the case of the ad valorem tax does Louisiana seem to have a claim to tax advantage as compared to Texas. The State of Louisiana has had in effect since 1946 a ten-year exemption program from payment of state and local property taxes. Texas had no such tax exemption program.

Only two of the companies interviewed felt that the tax exemption program was of any significance in making the location decision. One company rated the program as a primary factor and the other as a secondary factor. Most of the companies felt that the plan was more in the nature of tax postponement rather than tax exemption. The feeling was that higher than average taxation after the exemption program would counteract the initial ten-year advantage.

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6Louisiana Department of Commerce and Industry, Louisiana Invests in Industry, p. 6.
Some of the companies felt that it would be preferable to lower the assessed valuation of property to a more moderate level and do away with the exemption program. They felt that this would provide better community relations for the company and help dispel the popular conception of Louisiana as a high tax state. Regardless of feelings about the tax exemption plan, all had taken advantage of it and were well pleased in their relations with the tax exemption board.

A much more thorough examination of the tax exemption program is given in a fairly recent article by William D. Ross. This study was the result of a survey of 259 companies of all types and sizes concerning the tax exemption program in Louisiana.

The other taxes levied on petrochemical producers are relatively insignificant in proportion to total tax collections. Louisiana's taxes applying to the petrochemical industry have caused some to propose this as a major reason for the failure of the State to keep in pace with Texas in petrochemical development. Although this study does not support this feeling, it must be kept in mind that only those companies which were willing to accept the tax conditions of location in Louisiana were interviewed.

Political Stability. Closely allied with taxes is the factor of political stability. Not one of the respondents in the survey indicated political stability as either a primary or secondary factor in plant

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location. However, several mentioned that political instability was a factor which had probably caused several companies in their industry to locate elsewhere.

Examples of erratic behavior in both the legislative and executive branches of the state government, along with conversation with executives of other companies, were given as the reasons to support the observations. The current requirement of a two-thirds majority in both houses to increase existing taxes or levy new ones has probably had some settling influence on tax legislation. Most of the companies interviewed concluded that, from their experience, the political instability factor was more imaginary than real and little, if any, worse than in most other states.

Louisiana has attempted to ameliorate the condition of high taxes through the ten-year tax exemption program on ad valorem taxes. It also has a growing list of successful, expanding companies to help dispel the fear of problems of instability. Louisiana also has a plan to provide direct assistance in providing facilities for new or expanding plants.

Industry Inducement Plan. The industry inducement plan provided for in the State Constitution allows parishes, wards, and municipalities to enter into an agreement with a manufacturer to provide plant sites and buildings for the industrial tenant. Financing to provide these facilities may be obtained by the parish, ward, or municipality, which may issue bonds that meet certain specifications. The cost of

the facilities will supposedly be paid off over a period of time through the agreement to a long-term lease by the industrial tenant.

This plan has been used throughout the state to attract numerous small manufacturing enterprises. The industry inducement plan has not been used as an inducement to bring any of the companies covered by the scope of this report to the State of Louisiana. However, this plan may be of some use in the petrochemical industry in attracting some smaller consumer goods manufacturer to a location in Louisiana.

This concludes the discussion of the political factors including taxes, stability, and industry inducement. Next, consideration shall be given to social factors of plant location. The first factor shall be community facilities.

**Social Factors**

*Community Facilities.* Community facilities include principally schools, churches, hospitals and recreational facilities. Also included in the definition of community facilities will come streets and public conveyances.

These facilities seem generally satisfactory in the major areas of petrochemical development in South Louisiana. Only one company indicated any of these facilities as having any significance in the location decision. This company indicated that schools and churches were a secondary factor. However, the willingness of the taxpayers in a community to support the financing of schools, hospitals, and recreation facilities is a good sign and certainly a plus factor for the community as an industrial site.
One company was having a problem because of the lack of Protestant churches. The company's plant site was located several miles from the major metropolitan area near a small town with a predominantly Catholic population. The company's technical personnel, brought in from other areas, were predominantly Protestant. The technicians were forced to live in the somewhat distant major city and commute to work. This situation has caused inconvenience to the company as well as less than desirable community relations in the immediate plant area.

**Community Relations.** Problems of community relations have generally been relatively minor or non-existent for the companies surveyed. Since the plants mostly located in or near large cities where social backgrounds are heterogeneous, the problems of adjustment for the incoming employees and the area residents have been few. One factor which has aided greatly in minimizing the problems of social adjustment has been the practice of hiring local residents for the majority of the jobs.

Several companies found that they had Southerners in their organizations who were happy to have the opportunity to transfer back to the South to fill the staffs of technical and administrative personnel required. There were also cases mentioned where transfer offers were rejected because the desired personnel did not wish to move to Louisiana.

Some companies indicated that community relations are not a problem in making the economic plant location decision but that the problem arises as soon as the location decision is made. When the decision to build is made, the company immediately launches a program designed to
build good community relations. A recent article by a Field Project Manager for the Du Pont Company supports this principle.¹⁰

Now that political and social factors have been dealt with in this chapter, the factors not covered in any of the preceding material will be considered. These factors will include the existence of government-built plants, climate, construction costs and special or secret arrangements which may determine location.

**Surplus Government-Built Plants**

The existence of several petrochemical plants in Louisiana may be attributed directly to government decisions to build war plants in the Louisiana Gulf Coast area. When the supplies of natural rubber were cut off from the United States early in World War II, the government was forced to take quick action to provide a synthetic substitute for this essential material. Research by oil and rubber companies had already been performed to establish a process for the manufacture of synthetic rubber made from petroleum-derived raw materials. The Rubber Reserve Company, set up by the government, accelerated the program to establish synthetic rubber plants about the country.

Two refineries in Louisiana, at Baton Rouge and Lake Charles, were chosen as raw material suppliers. The principal raw material was butadiene, a diolefin produced through a cracking process. Rubber plants were constructed near the refineries. In 1955 the government plants were sold to private industry. Copolymer Rubber and Chemical Corporation took over the butadiene and synthetic rubber plants in

Baton Rouge. Petroleum Chemicals, Incorporated, is the owner of the butadiene plant in Lake Charles, and Firestone continues to operate the rubber plant which it purchased from the government.

Olin-Mathieson, in Lake Charles, also bought the synthetic ammonia plant which it built and operated for the government during World War II. This plant uses natural gas as the principal raw material. All the plants have been expanded and modernized under private ownership.

Similar government-owned plants were built and operated by private industry on the Texas Gulf Coast during the war. These plants are now contributing to Texas' petrochemical output under private ownership.

Climate

The mild climate found in the Louisiana and Texas Gulf Coast area was listed as a primary factor by one company and as a secondary factor by another company. Among the other companies surveyed, none considered the climate as significant in the plant location decision.

One company reported that a particular aspect of the South Louisiana climate was undesirable for their operations. The high humidity in the region was causing considerable trouble with their electronic control equipment.

Construction Costs

The costs of construction are often thought to be related closely to climatic conditions. However, not one of the companies surveyed indicated that they had expected to reduce construction costs by choosing a Gulf Coast location as compared to any other. The companies interviewed use basically the same type construction in the Northern locations that they do in the Gulf Coast. Several years ago, the trend
in plant construction in cold climates was to use indoor construction, which added to the costs of building a plant in the North as compared to the South. However, with properly planned maintenance work, companies have found that, with minor exceptions, the same type construction may be used in cold or warm climates for the chemical industries.11

The factors of government-built plants, climate, and construction costs have been discussed in this section. The lone remaining factor to be considered is the possible existence of special or secret agreements which may influence plant location.

**Special Agreements**

The factor of special agreements is one which is not commonly mentioned among lists of factors. There does not seem to be any substantial proof that such a factor even exists. However, in talking with people outside of the petrochemical industry the factor was mentioned.

The alleged factor enters through reciprocal buying and selling agreements among companies or through special tax rates or tax exemptions given by tax authorities to certain companies. It seems likely that such agreements could readily exist between companies since interchange of materials is one of the basic factors contributing to complex growth within the industry. Also, it would seem possible that special tax concessions could be made on a ward, parish, or municipality level without attracting too much attention. However, it would seem much

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more difficult for concessions to be made at the state tax level without knowledge of its being spread about.

At the state level, whole industries may be made exempt from certain taxes. This discriminatory action should certainly attract companies in the favored group. An example of this may be seen in the power use tax which provides that power used in manufacturing operations using the electrolytic process is exempt. This tax applies especially to the primary metals industry. Another example may be seen in the petrochemical industry where gas used in the manufacture of carbon black is exempt from the severance tax. There are several carbon black plants located throughout the State which use natural gas; however, the current trend seems to be to use certain refined oil stocks for carbon black manufacture. Thus, the legislature of the State seems agreeable to relieving some groups from paying certain taxes.

However, there is no proof that these tax incentives were given as a result of bargaining or special agreements. The degree of competition among states for industrial expansion may in some cases lead to special agreements unknown to the general public.

**Summary**

Louisiana's severance taxes on oil and natural gas are the highest of any major producing state in the nation. This directly affects the petrochemical industry. The severance tax on natural gas is especially severe.

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13Ibid., p. 76.
The corporate income tax is not too great and compares favorably with other states in the nation generally. However, the State of Texas, Louisiana's competitor for Gulf Coast petrochemical plants, has no corporate income tax.

The ten-year exemption from ad valorem taxes is good for the early years of operation. However, the program is looked on more as a tax postponement plan than a tax exemption plan because of high assessments after the exemption expires.

The general feeling of political instability in Louisiana has been given more credit for impeding Louisiana's industrial expansion than the factor of high taxes. Companies operating in Louisiana tend to discount the instability factor in comparison with other states.

Community facilities and relations are generally good in the Louisiana Gulf Coast area. Companies work hard to cultivate good community relations after the location is decided upon.

The advent of World War II forced this nation to have to manufacture certain synthetic materials. Four companies are now operating petrochemical plants built under government sponsorship but purchased by private companies since the end of the war.

The moderate climate is generally favorable to petrochemical plant operations but not a significant factor in location choice. The mild southern climate has no appreciable effect on methods or costs of construction as compared to a northern location.

The influence of special agreements among companies or between companies and state or local governments was left unanswered. No proof of any unwarranted agreements was discovered. It seems likely that companies would enter into reciprocal buying and selling agreements.
where facilities are close together in various locations. This would have some effect on price and thus, probably on location. The most likely place for special tax concessions in the form of low assessment, etc., would seem to be at the local rather than the state level.
CHAPTER VII

SUMMARY AND CONCLUSIONS

In the concluding chapter of this report, the findings of the study are presented in light of objectives set forth in the introductory chapter.

Plant Location Factors in the Gulf Coast Petrochemical Industry

The primary factors which have influenced petrochemical growth on the Louisiana-Texas Gulf Coast are raw materials, water, and transportation. The most important of the three principal factors is that of raw materials. Power was rated next in importance by the companies surveyed for this report.

The states of Texas and Louisiana are in first and second places respectively in the production of crude oil and natural gas. These minerals are the basic source of raw materials for the petrochemical industry. The petrochemical industry, however, uses only a minor portion of the production of these resources. Major uses of crude oil and natural gas are to serve as fuels and lubricants. The natural resources must be processed to make them suitable for certain specific uses in the form of gasoline, kerosene, motor oil, etc.

Petroleum refinery by-products provide about 50 percent of the hydrocarbon raw materials for petrochemical manufacture. The remainder of the hydrocarbon raw materials come from natural gas and natural gas liquids.
Louisiana is in third place in the nation in refining capacity while holding a firm grip on second place in crude oil production. The fact that Louisiana's refinery capacity has not maintained the same relative position as that of crude oil production has limited the availability of petrochemical feed stocks in the state.

Ample supplies of natural gas are available in Louisiana since the state produces almost one-fourth of the output of the entire nation. Although the output and reserves of natural gas are second largest nationally, the production of natural gas liquids--chiefly liquefied petroleum gases--has been low.

Liquefied petroleum gas (LPG) is a rich source of ethylene, propylene, and butylenes and provides the hydrocarbon source of about 25 percent of all petrochemicals. Louisiana produces about seven percent of the nation's LPG. One major factor contributing to the LPG shortage in Louisiana has been the lack of natural gas processing facilities. Recent expansion plus announced plans for further gas processing facilities will greatly improve the production situation for LPG. Thus, the petrochemical raw material picture for LPG stocks seems to be much brighter than that for raw materials from crude oil refining operations. However, before the LPG can be used in petrochemical manufacture, additional processing must be performed to convert the normally occurring saturated hydrocarbons into more reactive olefins. This operation may be performed by the gas processor, petrochemical manufacturer, or refiner.

Water, the second major location factor, is plentifully available to Louisiana industry locating along the banks of the Mississippi River. The Mississippi is the largest fresh water source in the United States,
supplying more than the current industrial needs of the entire nation. Water is generally available in adequate quantities all along the Louisiana-Texas Gulf Coast except for the western part of Texas. Water is vital to the petrochemical industry for cooling, process use, and waste disposal.

A diversity of transportation facilities on the Gulf Coast have aided in the growth of the petrochemical industry. The three most important transportation methods used are rail, barge, and ocean vessel. In the Gulf Coast area, the petrochemical centers have grown near deep-water ports. In Louisiana the ports, and centers of petrochemical location, are Baton Rouge, Lake Charles, and New Orleans. The port locations provide access to markets on the East Coast and throughout the world.

The Gulf Intracoastal Waterway connects the Gulf Coast with the inland markets in the Great Lakes area and some eastern regions through the Mississippi River and its tributaries. The Louisiana locations, especially those between Baton Rouge and New Orleans, are most favorably located for barge shipments to inland markets.

Numerous railways in the Gulf Coast area connect the petrochemical centers with most of the United States. Transportation service is provided by this means for finished products and raw materials although most of the raw materials are purchased at a nearby location and brought in by pipeline. Competition among transportation mediums has provided a favorable transport cost condition.

Petrochemical manufacturers usually require a dependable and plentiful supply of power--both electric and steam power. Public utilities in the Gulf Coast area provide an ample supply of low-cost electric power.
Special conditions of dependability or high steam requirements make it necessary for some companies to generate their own power. Low-cost fuel and generally abundant water supplies make power generation economical on the Gulf Coast, but no more so than in some other parts of the nation.

Other factors which were rated as primary factors by only one of the companies included in the survey were access to markets, availability of surplus war plants, tax exemption program, moderate climate, and location in an industrial complex. Factors which have not been previously mentioned and which received only one indication as a secondary factor were land availability, labor supply, community attitudes, land cost, and schools and churches.

All of the factors which were considered to be of either primary or secondary importance have been indicated above. Other factors on the questionnaire were indicated as insignificant in making the plant location decision.

The results of the survey shall now be considered in their relation to plant location theory.

**Location Theory and the Petrochemical Industry**

Three general types of location theory were presented in the second chapter of this study. These three general areas of location theory were least cost theory, locational interdependence theory, and maximum profit theory. The work of Isard shall be classified with the least cost theories.

It should be kept in mind throughout this section that nearly all respondents were unaware of the existence of economic theories of plant location. The comparisons made are based upon observation and general discussion rather than on direct response.
The least cost theory seems to be most generally applicable to the Gulf Coast petrochemical industry. In referring to the growth of petrochemicals in the Gulf Coast area, an official of a large petrochemical construction firm has explained it in the following manner. "The petrochemical industry came to this area for the uncomplicated reason that it can here produce at the lowest cost."\(^1\)

Data obtained in the questionnaire on cost reduction expectations for certain factors was scanty. Three companies indicated that raw material cost reduction expectations had been met, two out of three indicated that fuel costs met expectations, and the same response was obtained on power costs. Two companies indicated that taxes were expected to be lower at the Louisiana location. One of the two companies was satisfied by the results. Another company indicated that outgoing transportation costs had met cost reduction expectations in Louisiana.

The cost decisions in petrochemical manufacture are not as involved as they may become in other industries. Costs are usually associated with two factors, raw materials and transportation. Many of the basic raw materials are not readily transportable over long distances in closed vessels except by using high-pressure containers, cooling equipment, or both. Volume requirements are not large enough to justify the expense of running pipelines, thus necessitating a raw material site for most petrochemical plants. The costs of raw materials may vary significantly with different locations.

The cost of transporting the product to market is the other major cost item determining location. A location where barge and deep-water port facilities are available provides less expensive transport costs than locations with no waterway facilities. Since the finished products are usually in a form which allows their shipment by any of several methods, the calculation of lowest cost is relatively simple, but time consuming.

The raw material and market location factors will usually determine least cost location since it is unlikely that a sufficiently low labor cost area could be found to have any great significance on cost. This situation exists because of the relatively low labor requirements in petrochemical manufacture.

Before any calculations on costs of raw materials or transportation charges may be made, the water supply problem must be considered. The factor of high water requirements in petrochemical manufacturing may have the effect of limiting the location choice in some instances.

The forces of agglomeration, first noted by Weber and expanded on by other least cost theorists, have influenced the growth of the Gulf Coast petrochemical industry. These forces include economies of scale and growth in proximity to auxiliary enterprises or industries.

Although most of the petrochemical plants seem to have located in general conformity to the least cost theory, the locational interdependence theory should be mentioned. The locational interdependence theory would seem to be more applicable to the consumer goods manufacturers. The locational interdependence theorists' assumption of equal costs of production at all locations serves to eliminate this theory from association with the petrochemical industry.
The theory of maximum profit location, in addition to the least cost theory, seems applicable in the petrochemical industry. Although the least cost location is usually that of maximum profit also, the maximum profit theory covers situations where a location will be chosen which is not that of least production cost. Such a situation exists where the plant is located with the objective of controlling a certain segment of the market.

The ammonia industry seemingly has followed the maximum profit theory in recent location of plants. The current trend is to build smaller plants designed to serve a specific market and located in the market area. This trend was pointed out by manufacturers in Louisiana with large, raw material oriented plants. Wide availability of hydrogen from pipelined natural gas has enabled this change in the ammonia industry.

Whereas the theories of least cost and maximum profit seem to explain most petrochemical plant locations, there are some locations with which existing economic theory apparently does not deal. A situation of this type was encountered in studies conducted for this report.

The Louisiana site selected by a particular company was not the most desirable from the cost or profit point of view. The location was chosen because of the desire to decentralize the company's manufacturing operations. The company used economic analysis to find the location which would give the lowest cost, except for the southeast Texas Gulf Coast area where a similar plant was located. The new plant provided

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the company with new sources of raw materials, new water supplies, and different transportation routes to market. A new labor force was also acquired which had no union affiliation. This decentralization movement may be classed as a deglomerating force according to the system of the least cost theorists.

Now that petrochemical plant location has been compared to location theory, the specific conditions affecting Louisiana are reviewed. Consideration is given to the petrochemical industry in Louisiana relative to that in Texas.

Conditions Affecting Louisiana's Petrochemical Industry

Louisiana's petrochemical industry has grown abundantly since the end of World War II. This growth has been confined almost entirely to the Gulf Coast area. Three principal centers of petrochemical concentration are found at Baton Rouge, Lake Charles, and New Orleans. Greatest growth has taken place around Baton Rouge and Lake Charles. These two areas are especially suitable because of adequate petroleum refining capacity to furnish petrochemical building blocks, ample water supplies for cooling and process needs, and a complete transportation system. Growth around New Orleans has primarily been in gas-derived petrochemicals.

Expansion of the petrochemical industry in Louisiana, even though great, has been overshadowed by that on the Texas Gulf Coast. There are more than twice as many major petrochemical plants between Houston and the Louisiana border than between Lake Charles and New Orleans.3

One seemingly obvious explanation for the difference is that in the Houston-Beaumont-Orange-Port Arthur area of Texas the refining capacity is more than double that of the entire state of Louisiana. The southeast section of Texas also has ample fresh water supplies and complete transportation facilities.

The basic raw materials for petrochemicals are crude oil and natural gas. Texas has more than double the crude oil production and reserves of Louisiana. Louisiana has about one-half as much production of natural gas as Texas but exceeds one-half the reserves. The rate of growth of production and reserves for crude oil and natural gas is greater in Louisiana than in Texas. The production of liquefied petroleum gases in Texas was more than five times that in Louisiana in 1960.

Closely allied with the raw material supply situation is that of raw material costs. Two companies stated that costs of raw materials are greater in Louisiana than in Texas. One company located its plant in Louisiana only because the raw material it needed was not available in Texas. Recent expansion of facilities by the large refineries in Texas has changed this condition to one of over capacity in Texas. Over capacity and competition in Texas by several large refineries has brought prices downward for basic building blocks. Competition does not exist to any significant degree in Louisiana.

With the natural resources picture so overwhelmingly in favor of Texas, it should be further expected that Texas would have broader petrochemical growth. Nevertheless, there are other things, aside from raw materials and processing facilities, to be considered.

Transportation to the Great Lakes region by barge is easier from Louisiana than from the Texas Gulf Coast region. A very significant
factor in Louisiana's favor is the Mississippi River, which provides the Baton Rouge-New Orleans area with the largest fresh water source in the nation, in addition to the transportation route.

The political factors in plant location have not been in Louisiana's favor. Political factors are probably far down the list for most companies. However, when other more significant factors are about evenly balanced, the political considerations take on additional significance.

The factors of high taxes and an unfavorable political climate have probably had some adverse effect on development of the industry within Louisiana. The taxes are especially high on severance of natural resources, particularly natural gas. The ten-year tax exemption has been of relatively minor significance in attracting petrochemical manufacturing companies to Louisiana. The factor of political instability has almost certainly caused some companies to dismiss a Louisiana location without giving it due consideration. However, petrochemical companies operating in Louisiana have found a generally satisfactory political climate.

Expansion of the petrochemical industry in Louisiana has been gratifying; nevertheless, it is felt that this industry has failed to meet its full potential. There seem to be two primary reasons for this failure. The first is that crude oil refining capacity and natural gas processing facilities have not kept pace with production of these natural resources. The second is that an unfavorable political impression has been created which has caused the rejection of Louisiana as a potential plant location site by some companies without giving the State full consideration.
This entire report has dealt thus far with Louisiana's past growth in the petrochemical industry and that of the entire Gulf Coast area. Now, briefly, what can be said of the future of the industry, particularly in Louisiana?

The Future of the Petrochemical Industry in Louisiana

It is generally agreed that the future of the petrochemical industry is good but that its rate of growth will slow down. It is commonly acknowledged also that the Gulf Coast will continue to be the dominant location for the petrochemical industry for quite some time in spite of a market area movement by some segments of the industry.

The discernible trend away from the Gulf Coast may be seen in a recent survey of new construction and expansion projects. This survey indicates that 42 percent of the projects are scheduled or under way on the Louisiana-Texas Gulf Coast. Slightly less than one-third of the Gulf Coast projects are in Louisiana.

The outlook for chemicals made from natural gas and natural gas liquids seems brightest for Louisiana. Processes to make acetylene from natural gas are economical for large-size plants. Acetylene is a very active intermediate serving to make many petrochemicals. One large plant in Louisiana is now making acetylene from natural gas to use as a chemical intermediate, and another large plant is under construction.

The recent increase in natural gas processing plants in South Louisiana plus announced plans for others makes the outlook for chemicals

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from ethylene, propylene, and butylene seem brighter on the Louisiana Coast. Increased plant capacity in the United States for production of these basic petrochemical building blocks is expected to increase by about 70 percent or more by 1970.5

With increased production of ethane, propane, and butanes, plants should be built to convert them into olefins. One such project is the reported 200-million-pound-per-year ethylene plant of Union Texas Natural Gas Company. If Louisiana's industry is to grow, these plants must be of large enough volume to obtain economies of scale enabling them to compete with prices in Texas.

Further expansion of refinery capacity by any significant amount is not immediately likely in Louisiana. Future growth of refinery-oriented petrochemicals will most likely consist of aromatics, benzene, toluene, and xylenes. Refinery-oriented production of materials for synthetic rubber seems also to be a good growth prospect. Texas holds a wide advantage in the potential growth of refinery-oriented petrochemicals.

Market orientation of some facilities will contribute to a general decrease in importance of the Gulf Coast. Major construction of ammonia plants will occur in new market areas except where excess hydrogen is available as a by-product. Since increased dehydrogenation facilities are expected, ammonia capacity will probably grow in Louisiana by this indirect method. New facilities for producing natural gas-based ammonia are highly unlikely in Louisiana. The high Severance Tax on natural gas in Louisiana further supports this prediction.

5"Newsletter," Oil and Gas Journal, LIX (May 15, 1961), i.
Plants for making polyethylene are almost certain to locate in Louisiana if ethylene prices become competitive with prices in Texas. Polypropylene expansion beyond presently announced construction is not likely for several years unless product research develops new uses. Recent enthusiasm for this product has evidently led to an overcapacity condition for the next several years. The trend in location of other polymer plants, e.g., polybutadiene, polystyrene, polyvinylchloride, seems to be toward a market location with monomers being transported from the raw material area where they are produced.

The Baton Rouge-New Orleans area is the most likely place for future large-scale expansion in Louisiana because of a large water supply, easier access by barge to interior markets, and the complex of industries already there. An additional inducement will be the Mississippi River-Gulf outlet which will provide a shorter trip for ocean vessels.

In summary, Louisiana has not done badly in attracting petrochemical plants relative to Texas when considering its limitations. These limitations have principally been the shortage of petrochemical building block producers and an undesirable political reputation. The future will be brighter if these unfavorable factors are overcome.

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6Cubbage, *op. cit.*, pp. 116-117.
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APPENDIX A

PLANT LOCATION QUESTIONNAIRE

This information will be held in strict confidence.

1. Name of company _________________________________________________

2. Location of plant(s) in Louisiana ________________________________
   city parish

3. Year plant was placed in operation in Louisiana __________________

4. Approximate total investment in plant and equipment (to nearest
   $500,000) ______________________________________________________

5. What was the initial investment when the plant went on stream?
   $ __________________________________________________________________

6. Approximate total employment _____________________________________

7. Employment when plant began operations ___________________________

8. Approximate annual payroll $ _____________________________________

9. (a) Is this plant a branch of or a subsidiary of some other company?
    _ yes __ no

   (b) If yes, what is the nature of the other company? (check desired
       response)

       __ gas transmission ___ petroleum ___ chemical ___ other (Please specify)

10. Products--please see separate sheet

11. Raw materials--please see separate sheet

12. Approximately what proportion of your product is sold within a 25-
    mile radius of your plant to serve as a feedstock for another
    manufacturer? ________________________________________________

13. (a) Approximately what proportion of your feedstock is purchased
    within a 25-mile radius of your plant?_________________________

    (b) About what proportion of this feedstock has been previously
        processed? ________________________________________________
14. Approximately what proportion of your personnel was employed locally? _______________________________________________________

15. For what reasons were employees brought in from outside the state? (please rank 1, 2, 3, etc. Do not rank insignificant alternatives)
   ___ outstanding ability  ___ personnel not locally available
   ___ long company service  ___ others (please specify)
   ___ lower cost

16. For what type jobs do your import personnel? (please rank as a proportion of total employees in that type work)
   ___ administrative  ___ operative
   ___ technical  ___ general labor

17. Do you have enough land available adjacent to your present plant site to satisfy your prospective future needs?  yes  no

18. (a) Was any of the plant site cost defrayed by any local group for the purpose of industry inducement?  yes  no
   (b) If yes, what proportion? ___________________________________

19. (a) What is the primary source of your power?  ___ public utility
   ___ company power plant
   (b) If you maintain your own power supply, what is the reason for this?
      ___ lower cost
      ___ other source not available
      ___ other (please explain) ____________________________

20. (a) Have you applied for exemption from state and local ad valorem taxes under the state's ten-year exemption plan?  yes  no
   (b) Do you feel that you have been treated fairly by the tax exemption board in your dealings with them?  yes  no
      If no, explain______________________________________________
                                          ____________________________
21. How is Louisiana's state income tax on corporations compared with other possible plant location sites? ___higher ___lower ___about the same

22. Do you feel that Louisiana's severance taxes on natural resources are: ___higher ___lower ___about the same as those of other states with possible plant location sites?

23. Below are listed a group of factors which commonly influence the choice of plant location. Please write the letter (G) for any of these factors which were significant in influencing your decision to locate in the Gulf Coast area. Write the letter (L) beside those factors which caused you to locate specifically in Louisiana. If the same factor caused both your Gulf Coast and Louisiana location, please write in the letters (GL). Also, please indicate by circling the P or S whether these factors were of primary (P) or secondary (S) significance. Disregard those factors which were insignificant in your location choice.

( ) Access to markets P S
( ) Availability of raw materials P S
( ) Process and cooling plus war plants P S
( ) Water availability P S
( ) Water for waste disposal P S
( ) Power availability P S
( ) Deep water port P S
( ) Inland waterways P S
( ) Railways P S
( ) Public highway system agencies P S
( ) Land availability P S
( ) Raw material reserves P S
( ) Schools and churches P S
( ) Medical and recreational facilities P S
( ) Safety from enemy attack P S
( ) Lower wages P S
( ) Labor supply P S
( ) Availability of surplus non-union labor P S
( ) Community attitudes P S
( ) Location in an industrial complex P S
( ) Aid from state agencies P S
( ) Low cost power P S
( ) Political stability P S
( ) Land cost P S
( ) Moderate climate P S
( ) Others (please specify)

24. If your location decision were to be made again now, would there be any change in location? ____yes ____no

If yes, why? ________________________________________________

__________________________________________________________

25. What factors or conditions have proven least satisfactory in your present location? ________________________________________

__________________________________________________________

__________________________________________________________

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26. Was any study made of the economic theories of industrial location such as those advanced by Weber, Losch, or Hoover to use as a guide in your plant location decision?  ____yes  ____no

27. How were you initially led to consider Louisiana as a plant location site?  (please check)

  ____Factory location service  ____State Commerce and Industry Department
  ____Company staff group  ____Utility company
  ____Chamber of Commerce group  ____Others (please specify)
  ____Transportation company

28. (a) What costs did you expect to reduce by choosing this location rather than some other?  (please check)

  ____Raw materials (excluding transportation)  ____yes  ____no
  ____Labor  ____yes  ____no
  ____Maintenance, repairs and supplies  ____yes  ____no
  ____Fuel  ____yes  ____no
  ____Power  ____yes  ____no
  ____Incoming transportation  ____yes  ____no
  ____Outgoing transportation  ____yes  ____no
  ____Construction  ____yes  ____no
  ____Taxes  ____yes  ____no
  ____Land  ____yes  ____no

(b) Have these economic objectives been realized?  Answer only for those checked in (a).  (please check)

  ____yes  ____no
  ____yes  ____no
  ____yes  ____no
  ____yes  ____no
  ____yes  ____no
  ____yes  ____no
  ____yes  ____no
  ____yes  ____no
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VITA

Robert N. McMichael was born in Shreveport, Louisiana, on October 9, 1926. He is the only child of Mr. and Mrs. E. R. McMichael who reside in Grand Cane, Louisiana. He graduated from Grand Cane High School in 1945. In August, 1948, he graduated from Louisiana Polytechnic Institute with a Bachelor of Science degree in Chemical Engineering. Shortly afterward, he married Miriam Hope Platt, and to this union have been born two sons, aged ten and five years.

After graduation from college, he was employed in the petroleum industry in various engineering assignments in both domestic and foreign operations. In 1956, he enrolled in the Graduate School of Louisiana State University where he received the degree of Master of Business Administration in August, 1958. After completing all the requirements for the doctorate except the dissertation, he accepted a position as Assistant Professor in the Division of Business Administration at Northeast Louisiana State College in September, 1960. He is now a candidate for the degree of Doctor of Philosophy.
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Candidate: Robert Nance McMichael

Major Field: Business Administration

Title of Thesis: Plant Location Factors in the Petrochemical Industry in Louisiana

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

July 25, 1961