MANUFACTURING LAND PRODUCTIVITY AND LAND-USE FORECASTING:
AS EXPERIENCED BY THE PETROLEUM REFINING INDUSTRY
OF B.C.'S LOWER MAINLAND

by

ROY HOWARD FLETCHER
B.A.Sc., University of British Columbia, 1951

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

in the Department
of
Community and Regional Planning

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA
April, 1962
In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Community and Regional Planning, Faculty of Graduate Studies

The University of British Columbia,
Vancouver 8, Canada.

Date April 9, 1962
ABSTRACT

Improved techniques for forecasting land needs for urban development are required with continuing population and economic growth for the provision of adequate services at reasonable cost. Current local forecasting techniques exclude the direct measurement of land used in industrial activities and its correlation with industrial production. With continuing technological improvements in industrial processes it is likely that the relation between land and output will vary and particularly in the manufacturing industries.

A review of the Petroleum Refining Industry's experience by a direct mailed questionnaire to all Lower Mainland of B. C. refiners indicated a declining importance of land in relation to output over the last two decades. Trends in refinery output, employment, and land in active use, show an increasing productivity of both land and labor. The increase in productivity of manufacturing land exceeded that of labor over the past twenty years in this industry group.

A conceptual comparison was made between two types of forecast where, in one, the factor of increasing output per unit of land was excluded. The comparison was inexact since somewhat different industries were compared. However, it appeared that over a twenty-year period the exclusion of the productivity of land factor in the example could lead to significantly different results. The difference between the
techniques was an indicated requirement of 1200 acres versus 600 acres in total land needed up to 1980 by the industry group.

Before the factor of land productivity in manufacturing and other industries can be adequately considered changes are required in the methods of collecting statistics. These changes would enable a correlation between output, employment, population, and land within the urban area.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ABSTRACT</th>
<th>ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>vii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>I. THE CHANGING NEED FOR LAND AND LABOUR</td>
<td>3</td>
</tr>
<tr>
<td>The Changes: Population Growth; Industrialization; Urbanization</td>
<td></td>
</tr>
<tr>
<td>Future Population</td>
<td></td>
</tr>
<tr>
<td>The Need for Land and Labour</td>
<td></td>
</tr>
<tr>
<td>II. FORECASTING URBAN LAND</td>
<td>21</td>
</tr>
<tr>
<td>Urban Growth Determinants</td>
<td></td>
</tr>
<tr>
<td>The Economic Study</td>
<td></td>
</tr>
<tr>
<td>III. INCREASING LAND PRODUCTIVITY IN MANUFACTURING INDUSTRY</td>
<td>31</td>
</tr>
<tr>
<td>The Approach</td>
<td></td>
</tr>
<tr>
<td>Field Survey</td>
<td></td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
</tr>
<tr>
<td>IV. DIRECT AND INDIRECT METHODS OF FORECASTING URBAN LAND USE</td>
<td>47</td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>Forecast by Apportionment</td>
<td></td>
</tr>
<tr>
<td>V. DIRECT URBAN LAND FORECAST</td>
<td>58</td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
</tr>
</tbody>
</table>

iv
BIBLIOGRAPHY ................................. 65

APPENDIX I. QUESNAY'S ZIG-ZAG CHART AS INTERPRETED
       BY H. WOOG ............................. 68

APPENDIX II. LEONTEIF INPUT-OUTPUT ANALYSIS ............. 74

APPENDIX III. COPY OF SURVEY QUESTIONNAIRE ............... 84

APPENDIX IV. AN ESTIMATE OF 1980 THROUGHPUT FROM THE
       LOWER MAINLAND REFINERIES (B. C.) ......... 85

Introduction
The Nature of Petroleum Refining
B. C. Estimated Consumption and Refinery Throughput of Diesel Fuel and Motor Gasoline
Competitive Position of Lower Mainland Refineries
1980 Throughput in Lower Mainland Refineries
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1. Rate of Population Increase in Europe during the Interwar Period</td>
<td>7</td>
</tr>
<tr>
<td>1-2. Rate of Population Increase in Canada and the U. S. by Decades, 1870-1950</td>
<td>7</td>
</tr>
<tr>
<td>1-3. Level of National Productivity Showing the Period When a Specified Level is Reached</td>
<td>9</td>
</tr>
<tr>
<td>1-4. Rates of Increase in Productivity, Canada and the United States</td>
<td>10</td>
</tr>
<tr>
<td>1-5. Life Expectancies at Birth, England and Wales</td>
<td>17</td>
</tr>
<tr>
<td>2-1. Selected Statistics on Manufactures</td>
<td>29</td>
</tr>
<tr>
<td>2-2. Gross Domestic Product per Man Hour in 1949 Dollars</td>
<td>29</td>
</tr>
<tr>
<td>2-3. Labour Force in Canada</td>
<td>30</td>
</tr>
<tr>
<td>3-1. Petroleum Refineries in British Columbia, 1960</td>
<td>36</td>
</tr>
<tr>
<td>3-2. Questionnaire Summary Data</td>
<td>39</td>
</tr>
<tr>
<td>3-3. Throughput Ratios of Summary Data for Lower Mainland Oil Refinery Group</td>
<td>40</td>
</tr>
<tr>
<td>6-2. The Inter-Industry Flow of Goods and Services, Canada, 1949</td>
<td>76</td>
</tr>
<tr>
<td>6-3. Input into Each Industry per Dollar of Output, Canada, 1949</td>
<td>78</td>
</tr>
<tr>
<td>6-4. Total Output of Each Industry and Total Primary Input Resulting from the Production of a Dollar's Worth of Final Output of an Industry, Canada, 1949</td>
<td>82</td>
</tr>
</tbody>
</table>
## LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Population of Major World Areas, 1750-1940</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Food and Population</td>
<td>14</td>
</tr>
<tr>
<td>3.</td>
<td>Change in the Consumption of Major Forms of Energy</td>
<td>87</td>
</tr>
<tr>
<td>4.</td>
<td>Production of Saleable Products, B. C. and Yukon Refineries</td>
<td>90</td>
</tr>
<tr>
<td>5.</td>
<td>Modern Petroleum Refinery, photograph</td>
<td>42</td>
</tr>
<tr>
<td>6.</td>
<td>Interpretation of Quesnay's Tableau Economique</td>
<td>71</td>
</tr>
</tbody>
</table>
INTRODUCTION

"We must make plans, who looks not before, finds himself behind."

-Publius Syrus, 44 B. C.

During the last 100 years, Canada has experienced a population increase of 15 million persons. Prior to 1871, less than 20 per cent of the population lived in urban areas while today more than 65 per cent live in cities or towns. The existing areas have had to provide additional homes, shops, schools, streets, water supplies, lighting, and recently such innovations as freeways, for 11 million persons.

Provision of these services has required large expenditures by both government and private bodies. The extent of their spending programs and the provision of services have been based on anticipated development and social need to suit the physical life of the investments. Thus if 20 years are required to amortize the physical plant or equipment that equipment must be usable and of adequate capacity for 20 years. An inaccurate estimate of future development will tend to result in costlier services by either shortening their life, through early replacement, or increasing annual costs through excess capacity.
Increasing importance has been attached to urban land forecast methods as greater public and private investments are required. Also greater attention is given to the intensity of development by industrial activity within each zoning district. This dissertation examines briefly the present forecasting methods and introduces a factor to be considered further in forecasting manufacturing land requirements.

The first Part of the thesis, chapters I and II, describes certain world phenomena affecting land use forecasting and ways of estimating their extent at local urban places. Also, this section introduces the hypothesis that an increasing 'productivity' in manufacturing land can be anticipated.

The second Part, chapters III and IV, examines the hypothesis and discusses some of its significance to land use forecasting methods. The last chapter summarises the preceding discussion.

Examination of the hypothesis has been limited to one industry, petroleum refining, and this is restricted to the lower mainland of British Columbia since specific information for the industry as a whole is not readily available. Several reference readings, while not entirely appropriate, have been included in the bibliography as general references respecting petroleum refinery activity and location.
CHAPTER I

THE CHANGING NEED FOR LAND AND LABOUR

The Changes: Population Growth; Industrialization; Urbanization

Population growth

Increasing world population has been a phenomenon for at least two hundred years. In 1750 the estimated number of persons in all countries was between 0.5 and 0.7 billion and this was to exceed two billion before 1950. The rate of world increase has been relatively uniform over this period but large variations have occurred in some continents as well as different rates between countries. The graph of Fig. 1 shows the range of population increases between selected continents.

World population is dependent upon births and deaths which, within biological limits, can be controlled to some degree. Birth control is predominantly a cultural phenomenon which can be applied at various rates and in various manners. Historically this has been achieved by child abandonment while today means are instituted to prevent conception.¹ Deaths, to

¹Roland Rene, Land Economics (New York: Harper and Bros., 1958), p. 91: "The sex appetite is a biological fact, but the reproductive tendency, as shown by the birth rate, is a cultural
Fig. 1 POPULATION OF MAJOR WORLD AREAS 1750-1940
SEMI-LOG PLOT
(From T.W. Schultz, Economic Organization of Agriculture, 1953, p.37)
a substantial degree, can be reduced by advances in medical
science, adoption of hygiene practices, and increasing food
supplies above malnutrition levels. Thus the reduction of
deaths is also related to social and economic as well as
cultural traits. These factors of world population apply also
to individual nations and continents but, in addition, they are
also affected by migrations.

Migration has a direct affect on continental populations
by adding to or deleting from the base population. They also
affect the world population indirectly by a different
distribution of human resources of people, capital, and labor.
Such was the case in North America during the migration to the
'New World' in the last century. The greatly increased popula-
tion enabled more agricultural production which not only
sustained the increased population in North America but also
provided considerable exports of food to Europe and elsewhere.
Hence with migration a rising world population was possible
after food supplies increased.\(^2\)

\(^2\)T. W. Schultz, *The Economic Organization of Agriculture*
to ascertain the rate of growth of the population to determine
the rate at which the demand for food is increasing. The
causality, however, runs the other way, which means the increase
in the supply of food comes first and the growth of population
occurs as a result."
The combined effect of migrations, birth control, and 'death control' is noted for different continents in previous Fig. 1 while changes in Europe, over a shorter period, are shown in Table 1-1. These illustrations show that the disparity of population increase does not stop at the continent but continues to individual portions within continents. In Table 1-2 this disparity over time within one country is shown where, in Canada, the rate of increase has varied between 11 and 33 per cent per decade since 1871.

In forecasting future population, increasing difficulty arises in obtaining a representative projection as the geographic area decreases in size. A forecast of future total world population could be made with more certainty than one for a local urban area. Principally the changing local increase results from the greater ease of movements between smaller areas of people, goods, labor, and capital.

**Industrialization**

The second phenomenon during this period of world population increase has been a continuing increase in the industrialization of labor processes. By using machines for production assistance, a greater output per worker has been possible. Also completely new fields of consumer products, machines, machine parts, and mechanical labor-saving devices, have been introduced. Thus new products such as the automobile, the television set, the automatic toaster, have become available
### TABLE 1-1

**RATE OF POPULATION INCREASE IN EUROPE DURING THE INTERWAR PERIOD**

<table>
<thead>
<tr>
<th>Country</th>
<th>Per cent Increase 1920-1939</th>
<th>Approximate Increase per Decade (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U. K. and Ireland</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>West Central Europe</td>
<td>12.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Northern Europe</td>
<td>12.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Southern Europe</td>
<td>18.2</td>
<td>9.1</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>30.5</td>
<td>16.1</td>
</tr>
<tr>
<td>Europe without U. S. S. R.</td>
<td>16.3</td>
<td>8.6</td>
</tr>
<tr>
<td>U. S. S. R.</td>
<td>27.0</td>
<td>14.2</td>
</tr>
</tbody>
</table>

*Source: Schultz, op. cit., p. 40.*

### TABLE 1-2

**RATE OF POPULATION INCREASE IN CANADA AND THE U. S. BY DECADES, 1870 TO 1950**

<table>
<thead>
<tr>
<th>Decade</th>
<th>Per cent Increase per Decade in Population</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1870 - 1880</td>
<td>16.2</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td>1880 - 1890</td>
<td>11.5</td>
<td>25.5</td>
<td></td>
</tr>
<tr>
<td>1890 - 1900</td>
<td>12.5</td>
<td>20.7</td>
<td></td>
</tr>
<tr>
<td>1900 - 1910</td>
<td>33.3</td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td>1910 - 1920</td>
<td>22.2</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>1920 - 1930</td>
<td>18.2</td>
<td>16.1</td>
<td></td>
</tr>
<tr>
<td>1930 - 1940</td>
<td>10.5</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>1940 - 1950</td>
<td>21.7</td>
<td>14.4</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Schultz, op. cit., p. 39, and Canada Year Book 1960 (Ottawa: Queen's Printer, 1961).*

**Note:**
The decade for Canada actually is one year later than that in the U. S. where the Census occurs one year later.
as well as increased availability of staple products such as textiles and food stuffs.

Industrialization of processes started in Europe and from there it has been spreading to other parts of the world. The extent of this industrialization has been measured as the amount of production per man hour. Table 1-3 lists a relative rate of productivity for different countries and shows an approximate date when they reached definite levels of productivity.

The rate at which countries increase their productivity is variable and differs between countries. In 1800 both France and Germany had productivity rates less than .03 units. However Germany reached a tenfold increase by 1913 while France did not reach that point until 1924. The same productivity achievement had been achieved in Britain by 1890 or two decades before that of France and Germany.

Productivity increases also vary over time within a country and Table 1-4 shows this variation in Canada and the U. S. A., for the period 1910 to 1955. In Canada, a two percent increase in productivity has occurred annually on the average between 1926 and 1955, for both business and agricultural sectors. However in that time the rate has varied from a high of eleven per cent to a low of one-half per cent per year in the agricultural sector and between 1.7 and 3.2 per cent in the business sector.
## TABLE 1-3

**LEVEL OF NATIONAL PRODUCTIVITY SHOWING THE PERIOD WHEN A SPECIFIED LEVEL IS REACHED**

(Measured in international units of real national product per man-hour)

<table>
<thead>
<tr>
<th>Range</th>
<th>At 0.03</th>
<th>0.10-0.15</th>
<th>About 0.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Period</td>
<td>Level</td>
<td>Country</td>
</tr>
<tr>
<td>France</td>
<td>1800</td>
<td>0.03</td>
<td>Britain</td>
</tr>
<tr>
<td>Germany</td>
<td>1800</td>
<td>-</td>
<td>France</td>
</tr>
<tr>
<td>India</td>
<td>1860</td>
<td>-</td>
<td>Sweden</td>
</tr>
<tr>
<td>Japan</td>
<td>1890</td>
<td>-</td>
<td>Greece</td>
</tr>
<tr>
<td>China</td>
<td>1930</td>
<td>-</td>
<td>Eire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Belgium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Italy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Norway</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Switzerland</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>U. S. S. R.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Estonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hungary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Portugal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Turkey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ecuador</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brazil</td>
</tr>
</tbody>
</table>

TABLE 1-4

RATES OF INCREASE IN PRODUCTIVITY\(^a\)
CANADA AND THE UNITED STATES
(Per cent per annum)

<table>
<thead>
<tr>
<th>Period</th>
<th>Agricultural Sector</th>
<th></th>
<th>Business Sector</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>U. S.</td>
<td>Canada</td>
<td>U. S.</td>
</tr>
<tr>
<td>1910-55</td>
<td>-</td>
<td>1.95</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1926-47</td>
<td>0.60</td>
<td>2.14</td>
<td>1.71</td>
<td>1.55</td>
</tr>
<tr>
<td>1926-55</td>
<td>2.24</td>
<td>2.92</td>
<td>1.91</td>
<td>3.00</td>
</tr>
<tr>
<td>1947-49</td>
<td>2.75</td>
<td>7.40</td>
<td>1.78</td>
<td>3.65</td>
</tr>
<tr>
<td>1947-53</td>
<td>8.82</td>
<td>4.57</td>
<td>2.35</td>
<td>3.32</td>
</tr>
<tr>
<td>1949-53</td>
<td>11.23</td>
<td>3.23</td>
<td>2.64</td>
<td>3.17</td>
</tr>
<tr>
<td>1949-55</td>
<td>7.54</td>
<td>4.05</td>
<td>2.68</td>
<td>2.96</td>
</tr>
<tr>
<td>1951-53</td>
<td>3.78</td>
<td>3.92</td>
<td>3.24</td>
<td>2.62</td>
</tr>
<tr>
<td>1951-55</td>
<td>2.85</td>
<td>4.84</td>
<td>3.01</td>
<td>2.56</td>
</tr>
<tr>
<td>1953-55</td>
<td>0.51</td>
<td>5.78</td>
<td>2.76</td>
<td>2.50</td>
</tr>
</tbody>
</table>


Future economic forecasts must consider the factor of industrialization and changing productivity of labor in agriculture and business. As indicated, this productivity increase is not constant but has wide variations over short periods.

Industrialization of agriculture and related product distribution methods have reduced the number of farm workers required in proportion to total population. This reduction has also been increased by improved farm techniques.
Urbanization

The change to an industrialization of industry has been accompanied or preceded by cultural changes and a withdrawal from agrarian living. With increased productivity in agriculture more people were released from farm work. They tended to relocate in cities with the greater opportunities for employment. Coincidently, the industrialized processes located their factories in these urban areas. As a result the urban places grew rapidly with the influx of surplus farm workers and with the increased population resulting from increased food supplies.

By 1851 fifty per cent of the population in England and Wales lived in urban areas and this increased to 80 per cent by 1931.\(^3\) In the Canada of 1871, less than 20 per cent of the inhabitants lived in towns while today this proportion exceeds 65 per cent. Thus the Canadian urban areas have provided facilities for 11 million persons since 1871 with today's population of more than 18 million. A greater change has occurred in the U. S. A. where by 1950 more than 64 per cent of its population lived in urban places.

A preceding section described the large immigrations to North America and thus the increased urban population in this continent resulted from a combination of factors. These factors include the net natural increase in population; the net

\(^3\)Canada, Census Monographs 1931, No. 6, Rural and Urban Composition of the Canadian Population (Ottawa: King's Printer, 1938).
migrations from the rural areas; and the net immigrations to urban places from other countries. Future estimates of urban populations will be dependent in part on the distribution of people between rural and urban areas.

Future Population

Food supplies

One of the major determinants of world population is food supplies. Arable land on the surface of the earth is limited at 9.7 per cent and perhaps another 17.3 per cent of the total land surface is suitable for pasture.\(^4\) Increased food production is likely to come from either utilization of potentially arable land or from increasing yields per acre or from a combination of the two.

United States' recent experience has shown that increased food production has resulted from both increased yields and increased acreages in production. In 1935-39 about 29\(\text{ha}\) million acres were used for domestic production of food and by 1950-54 this area increased to 319 million acres. In the same period the U. S. population changed from 129 million to 157 million. By assuming a constant food intake per capita, the amount of land in domestic production per capita decreased from 2.35 to

2.03 acres per person over the period.\(^5\)

The United States' experience in increasing food supplies is typical of many countries and the recent experience for several continents is shown in Fig. 2. World production of food increased 55 per cent since the pre-war period while population increased less than 45 per cent. This relative surplus production has not been a uniform feature for each country. Western Europe has had the greatest per capita gain while Africa produced the least of those continents shown. Oceania appears to have incurred a uniform deficit between increased population and food while other continents such as North America have maintained a uniform per capita gain. It is likely that the uniform apparent food surplus in North America is exported to other countries in world trade.

Studies of future agricultural output indicate a continuation of past trends and in Canada the Royal Commission reported as follows:

We would anticipate that over the next twenty-five years agricultural output may grow by perhaps 65 per cent to 70 per cent and that the growth will be accompanied by only a slight increase in the acreage of land in farms and a further substantial decline in the farm labour force.\(^6\)

\(^5\)Loc. cit.

Fig. 2  FOOD AND POPULATION 1961

(From Food and Agricultural Organization, United Nations, 1961)
It would appear, then, that greater production of foods is likely to continue and to be achieved by both increased yields per acre and by increased acres in farm use. In Canada, the increased demand for farm lands appears slight for the next twenty years while the expected increased agricultural production could sustain a population some 60 per cent greater. The entire increased population is likely to reside in urban areas as the forecast of the Royal Commission expected a decline in the required farm labor force.

As suggested in previous sections, population growth is essentially a cultural phenomenon and one in which all benefits of agriculture need not go to support a greater number of persons. Instead these rewards can be utilized for increasing personal possessions or increased physical wealth. Essentially an increase in per capita output of agriculture means that less time is required for food production. Consequently more time can be used for the creation of other physical goods or alternately the additional time can be used for non-productive leisure pursuits.

**Economic growth**

Experience in many Western countries has shown that the agricultural benefits have been used not only for increased population but also for increasing personal wealth. This relationship was realized and described in the mid-eighteenth century by the Physiocratic Economists.
This group postulated that all wealth came from nature and, for prosperity, state controls should enhance the 'natural order' rather than interfere with it. In his book, of 1758, *Tableau Economique*, Francois Quesnay described the dependency of all national economy on the 'Surplus' of agriculture. With a zig-zag diagram he portrayed the economy and showed the relationship between agriculture and manufacturing and how all classes of people were affected by the rewards of agriculture. A description of his diagram is attached as Appendix I.

The effect of economic growth was also realized and studied by Adam Smith. In 1776 he presented his work, *An Enquiry into the Nature and Causes of the Wealth of Nations*, and postulated that value arises from the labor expended in the process of production. Smith and other "Classical Economists" attributed the increasing wealth to the product of industry based on technological improvements. However Smith's study was made in Great Britain where considerably less agriculture and considerably more manufacture was conducted than in France, the area studied by Quesnay.

During this period of increasing wealth there was also an alarming increase in population. So much so, that concern was expressed over the ability of agriculture to keep pace with the rate of increase without the standard of living falling to a subsistence level. The advances in medical science greatly altered and increased the life expectancy as shown in Table 1-5. Thus with reduced death rate and constant
birth rate the population increased its rate of net gain.

TABLE 1-5
LIFE EXPECTANCIES AT BIRTH, ENGLAND AND WALES

<table>
<thead>
<tr>
<th>Sex</th>
<th>Time period, years of expected life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1871-1880</td>
</tr>
<tr>
<td>Males</td>
<td>41.4</td>
</tr>
<tr>
<td>Females</td>
<td>44.6</td>
</tr>
</tbody>
</table>

Concern over the inability of agriculture to keep pace with population growth was heightened in 1820 by Malthus's economic "Principals." In his book, Malthus envisaged:

\[\ldots\text{the economy as consisting of two major sectors: one industrial, one agriculture. Technological progress he regarded as a phenomenon confined to the industrial sector}.\ldots\text{and unmitigated diminishing returns was the primary characteristic of the agricultural sector.}\]

The consequence then, of increasing population was a declining standard of living as progressively less productive lands were used. However not all economists were of the same view and Karl Marx refused to believe that the human race would continue its high reproduction rate until subsistence was reached. His clearer view of the economy saw that the produce and wealth

---


extracted from the colonies was sufficient to compensate for the seemingly decreasing returns of agriculture. His confidence was justified and the birth rate in Britain dropped faster than the increase through lengthened life span. During the interwar period, 1920-1939, the rate of population increase per decade in the United Kingdom was less than four and one-half per cent.

Economic growth and population growth are inter-related so that one may be increased at the sacrifice of the other. Also experience has shown that both phenomenon may increase together. However they are both cultural affected phenomena and while the rate of cultural change may be slow it is difficult to forecast precisely the extent of either one or of both. Nevertheless, it is likely that both will continue to increase in North America. In viewing the likely changes W. W. Rostow relates the following six determinants of economic growth:

1. the propensity to develop fundamental sciences;
2. the propensity to apply science to economic ends;
3. the propensity to accept innovations;
4. the propensity to seek material advance;
5. the propensity to consume;
6. the propensity to have children.

---

9 Russell, op. cit., p. 19: "In the 1870's however, the birth rate began to fall, and continued to do so till finally it fell faster than the death rate, and so we attained our present low rate of increase. The main cause ... was the spread of deliberate family limitation."

10 Schultz, op. cit., p. 40.

A change in any one of the determinants will affect the per capita national wealth. If technological advancement ceases to be conceived, accepted or applied the increases in productivity will stop. If the products of industry are not consumed or if people take the entire rewards in leisure, economic growth will cease. If the population increases as fast or faster than the gains in productivity the per capita distribution of wealth must remain static or decline.

The Need for Land and Labor

The previous sections have endeavoured to illustrate two major phenomena of the last two centuries. These are increasing world population, and economic growth particularly in some countries. They have also attempted to relate the two and to indicate what changes might be expected in them in the future. The conclusion is to expect a continuation of the trend where world population increases and economic growth continues. The extent of these changes will vary considerably between countries and will reflect their respective cultures.

As agricultural productivity increases there will be proportionately fewer persons needed on the farms. Thus, under present employment conditions the increased population will tend to locate in urban centers and continue the trend to greater urbanization. In this way greater demands will be placed on urban land and on urban facilities and greater expenditures will be required by both public and private sources to meet these demands.
As extensions to permanent services are required and as replacements of them are being made, greater attention is being placed on precise estimates of future urban population and economic activity. These estimates are enabling adequate services to be provided at minimum cost.
CHAPTER II

FORECASTING URBAN LAND

Urban Growth Determinants

The trend towards increasing urbanization has been demonstrated in the preceding chapter. It is likely that the population of Canada will increase in size significantly in the next twenty years as well as locate predominantly in urban areas. The relationship between economic growth and population growth was described where both can progress simultaneously or one at the expense of the other. For the next twenty years, it is likely that increases will occur in both population and economic activity.

Growth in specific urban areas is more difficult to anticipate than total growth in national urbanization. Experience has shown that the big cities tend to get bigger and that existing urban centers expand rather than new centers originate. However, the growth rate for any particular urban area will depend on several unique factors. Two principal attractions of a specific area are its amenities and its employment opportunities.
With equal employment opportunities people will tend to live in areas where social and physical environment are most suitable to their individual preference. However, if job opportunities are scarce or non-existent the individual would locate or relocate in more opportune places. Local features and amenities such as climate, heritage, or view are considerably more static than variations in employment opportunities. Therefore by comparing population trends for all urban places, it is possible to detect settlement advantages in individual areas. The quantitative measure of this advantage would be difficult to ascertain since it also includes other factors such as employment opportunities.

In arriving at a population forecast for the urban area, the amenity factor would tend to be a constant parameter while the employment opportunities would be a variable parameter. Hence the employment forecast has a great importance for determining future urban development. Employment is one part of economic activity and labor is used in combination with other resources of capital, material, and land. It is difficult to separate any one of the four to study in isolation and thus a comprehensive economic study of all factors will offer the most information depicting future conditions.
The Economic Study

The use of economic studies for physical planning

A study of the national economy will include a forecast of the six propensities for economic growth of W. W. Rostow as described in Chapter I. Thus a national economic forecast is also a forecast of population and cultural behavior. In most countries the urban area also is an integral part of the cultural and economic life of the nation. Therefore it is necessary to relate the urban economic forecast to the national forecast. Once this is done the urban economic study can be used to assist physical planning of the urban area.

By indicating employment opportunities, the economic study enables an estimate of future local population. Also, in detailed economic studies, the distribution of employment to different business sectors will enable an estimate of land requirements in zoning districts. Generally, in most cities, manufacturing businesses are restricted to locating in industrial zones while service type businesses are located in commercial zones.

National economic studies

Most national economic studies are made in terms of output, as measured by dollars and employees. With the exception of agriculture, land areas are not considered as a variable within current national economic studies. Thus in relating the
urban area to the nation a new correlation must be made between output, or employment, and requirements of land.

A national economic study, such as the Royal Commission study of Canada's economic prospects, is a very lengthy and detailed study of many components of the total national economy. These components are summarily interrelated where possible and intuitive judgement used to forecast the total economy. Recently new technical methods are being developed to assist in determining the extent of inter-relation of the component parts.

Description of the interrelationships of the economic structure was given by Quesnay in his Tableau Economique of the eighteenth century. This was reaffirmed by Leon Walras in his book Elements d'Economie Politique Pure\(^1\) of 1876, and revived by Wassily Leontief in 1936. Leontief introduced a method of measuring the interdependency which has now been called the "input-output analysis."

In this method the inputs and outputs of all firms, by sections of the economy, are tabulated in a double entry form. This form, or matrix, is a listing of related business transactions. Applying advanced algebra to the form, the degree of interrelatedness can be calculated. This calculation is quite lengthy especially for a large table, and is nearly prohibitive

\(^{1}\text{Canada, Dominion Bureau of Statistics, Paper no. 72, Inter-Industry Flow of Goods and Services, 1949 (Ottawa: Queen's Printer, 1960).}\)
without the use of high speed computers. A description of the Leontief approach is attached in Appendix II as it was applied to Canada's National Accounts.

This analysis method is generally limited to larger economic areas such as the nation where statistical data is readily available but it has been used with some success in smaller units. An analysis of the B. C. Economy was presented by R. E. Boston in 1961 showing the current inter-relation of B. C. business sectors. He showed that the effect of a new steel smelter would probably be a three per cent production increase in petroleum products, transportation and leather products.

Forecasts using this method will tend to be more accurate but only because more knowledge is available about the interrelatedness of different businesses. Even with this method, intuitive judgement must be used to predict the future demand and future interrelatedness of firms.2

Urban economic studies

Many urban economic studies are made indirectly from earlier national economic forecasts. The inaccessibility of

---

2Canada, D. B. S. Supplement to Paper 72, op. cit., p. 17: "The use of constant input-output ratios . . . leaves some questions unanswered . . . . (1) To what extent would change in the quantity of input be met through inventory change rather than by current production? (ii) To what extent would an increase in output in an industry require an increase in plant and equipment in that or other industries . . . . (iii) To what extent will change in relative price cause substitution of one input for another?"
production data at the local level plus a greater variation in production make direct studies of long term economic prospects difficult. Therefore a preferred approach is to apportion the national forecast to the local level. This is done by careful consideration of trends in the relationship between local production and national production. A local forecast is then produced by combining national forecast with the expected future share to be contributed by the local area. Since the national forecast is generally made in terms of output and labor input, but not land, it is necessary to adjust the urban labor forecast to a land requirement forecast.

Economic forecasts can be extensive and time-consuming and therefore attempts have been made to find reliable short-cut methods. The Economic base concept has been used for just such purpose. Essentially this approach tries to identify only the key or 'base' industries and thus reduce the number of businesses to be studied. Hans Blumenfeld describes the concept as follows:

Take, for instance, a copper mining village with 1,000 miners. There will be, say, 600 people employed locally in retail trade and consumer services; if the family coefficient is 2.5 the population will be 400. If the company hires another 1,000 miners, it is safe to predict that they will shortly be followed by about 600 more 'secondary' employed persons and that the population will increase to 8,000. Inversely if the company lays off 500 miners, the population will in due course shrink to 2,000.3

In practice it would be necessary to study only the future mining employment since the other secondary workers are directly affected by changes in the base industry.

The concept was first utilized in 1936 by Homer Hoyt in a housing demand study for the U. S. Federal Housing Administration. Since then he and others have refined the technique to improve its accuracy. Essentially, this method still requires a forecast of national output and its interrelation with the local area. It does, however, reduce the total effort in the study by requiring only a portion of the total economy to be intently studied.

Like the apportionment method this approach must still introduce the relation between output and land to enable a forecast of urban land requirements.

Limitation of urban economic studies

For physical planning purposes the economic studies outlined do not directly determine future requirements of urban land but future employment levels. When the relationship between employment and land is constant these methods are adequate. However, if the relation changes, additional study must be undertaken.

In some economic activities, such as agriculture, there is opportunity to use different combinations of labor, capital, and land for a fixed amount of production. This appears to be true also in the manufacturing industries where greater amounts
of capital and less amounts of labor are being used. The result is an apparent productivity of labor and experience in Canada has shown a three-fold increase in manufacturing worker output between 1917 and 1957 as shown in Table 2-1. In a shorter period, see Table 2-2; it appears that this productivity of manufacturing labor exceeds that of other urban located industry.

This trend towards increasing manufacturing productivity can be expected to continue and the Royal Commission on Canada's Economic Prospects expects an increasing proportion of the labor force in service industries by 1980 as shown in Table 2-3. Thus the proportion of workers in all other urban located industries, including manufacturing, will probably decline.

The increase in the apparent productivity of labor has been primarily as a result of additional use of capital in the form of faster machines and improved techniques. These machines have not necessarily required additional land in proportion to their increased output. Therefore it might be expected that a certain apparent productivity of land exists in the manufacturing industries. This productivity of land might be analogous to that of agriculture where increasing yields are produced per acre as a result of different combinations of capital and labor.
### TABLE 2-1

**SELECTED STATISTICS OF MANUFACTURES**

<table>
<thead>
<tr>
<th>Year</th>
<th>Value added by Manufacturing (millions of dollars)</th>
<th>Value added by Manufac­ture Employees (thousands)</th>
<th>Average Value added per Employee (thousands of dollars)</th>
<th>Average Value added per Establishment (thousands of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1917</td>
<td>1281</td>
<td>607</td>
<td>2112</td>
<td>22</td>
</tr>
<tr>
<td>1920</td>
<td>1621</td>
<td>599</td>
<td>2707</td>
<td>23</td>
</tr>
<tr>
<td>1929</td>
<td>1755</td>
<td>667</td>
<td>2634</td>
<td>22</td>
</tr>
<tr>
<td>1933</td>
<td>919</td>
<td>469</td>
<td>1962</td>
<td>24</td>
</tr>
<tr>
<td>1939</td>
<td>1531</td>
<td>658</td>
<td>2326</td>
<td>25</td>
</tr>
<tr>
<td>1944</td>
<td>4015</td>
<td>1223</td>
<td>3284</td>
<td>28</td>
</tr>
<tr>
<td>1956</td>
<td>9605</td>
<td>1353</td>
<td>7099</td>
<td>37</td>
</tr>
<tr>
<td>1957</td>
<td>9822</td>
<td>1359</td>
<td>7227</td>
<td>38</td>
</tr>
</tbody>
</table>


### TABLE 2-2

**GROSS DOMESTIC PRODUCT PER MAN HOUR IN 1949 DOLLARS**

<table>
<thead>
<tr>
<th>Sector</th>
<th>1946</th>
<th>1955</th>
<th>Per cent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>.58</td>
<td>.99</td>
<td>70</td>
</tr>
<tr>
<td>Resource industries</td>
<td>1.67</td>
<td>2.45</td>
<td>47</td>
</tr>
<tr>
<td>Primary manufacturing</td>
<td>1.46</td>
<td>1.97</td>
<td>35</td>
</tr>
<tr>
<td>Secondary manufacturing</td>
<td>1.35</td>
<td>1.77</td>
<td>31</td>
</tr>
<tr>
<td>Transportation, storage and communications</td>
<td>1.43</td>
<td>1.73</td>
<td>21</td>
</tr>
<tr>
<td>Trade, finance, service and construction</td>
<td>1.31</td>
<td>1.46</td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry</th>
<th>Per cent of Labor Force for Year Shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1931</td>
</tr>
<tr>
<td>Retail and wholesale</td>
<td>11.2</td>
</tr>
<tr>
<td>Finance, insurance, and real estate</td>
<td>2.4</td>
</tr>
<tr>
<td>Community and Business</td>
<td>6.3</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.5</td>
</tr>
<tr>
<td>Personal (except restaurants)</td>
<td>7.0</td>
</tr>
<tr>
<td>Government (except armed forces)</td>
<td>2.8</td>
</tr>
<tr>
<td>Armed forces</td>
<td>0.1</td>
</tr>
<tr>
<td>Total service</td>
<td>30.2</td>
</tr>
<tr>
<td>Other industries</td>
<td>69.8</td>
</tr>
<tr>
<td>Total labor force (thousands of workers)</td>
<td>3,922</td>
</tr>
<tr>
<td>Total population (thousands)</td>
<td>10,363</td>
</tr>
</tbody>
</table>


<sup>1</sup>Median forecast.
CHAPTER III

INCREASING LAND PRODUCTIVITY IN MANUFACTURING INDUSTRY

The Approach

Measurement of productivity of manufacturing land

Chapter I discussed the changes occurring in world population, industrialization, and urbanisation and suggested that most countries are progressing towards greater per capita output of food and manufactured goods. It also covered the phenomenon of increasing yields from agricultural lands as a result of different use of capital and labor together with improved technology. By analogy with agriculture's increasing productivity, Chapter II expressed an expectation of a similar occurrence in manufacturing industry where, by re-application of labor and capital together with technical innovation, a greater output from manufacturing land appears possible.

This 'productivity' of manufacturing land has had little measurement in the past primarily as a result of insufficient statistical data. Individually, adequate information exists for the firm and each business firm expands or contracts its land acquisitions to suit needs and expectations. However, the sum
or total land requirements for an entire manufacturing group is not readily available. Hence, municipal governments have difficulty in allocating or zoning adequate amounts of land for industrial purposes and they also find difficulty in allocating related investments in transportation systems, waste and water systems, or power distribution networks all of which require long term investments.

Municipal statistics are gathered which show the amounts of land zoned for manufacturing purposes as well as showing ownership of individual parcels. But, these statistics are collected for determining an assessed value of the land and improvements for taxation purposes. Therefore the prime concern is with the value of the parcel rather than the extent of the land actually in use. By selecting a limited number of sites to look at in detail, it is possible to detect changes in the percentage of the site used for any given industry or group of industry. However, to be meaningful this will require correlation with output from the site on a basis of unit area. Output statistics are not collected by municipal governments and thus it is difficult to correlate land requirements with output. The Dominion government does collect data of output from industries but they do not gather information respecting areas of land for industrial use.

The first step in testing the hypothesis of 'manufacturing land productivity' lies in obtaining appropriate data for both
land and output in a manner that will permit correlation over a period of time. By obtaining this information for selected time periods it will be possible to support or reject the hypothesis. Since difficulties are encountered in trying to use and correlate a combination of municipal and Federal data, the preferred approach is to obtain the appropriate data directly from the industry concerned. In this way a complete correlation of data can be obtained.

The hypothesis will be tested in only one industry group and thus care should be taken in selecting a representative group.

Criteria for selection

The attempt here will be to look at the possible productivity of manufacturing land in its smallest unit, a single industry group. Thus care should be taken in selecting the group so it is representative of a complete manufacturing process. The following criteria were decided to be important in selecting the industry group:

1. There needs to be a distinct pattern of locational concentration so the entire group can be contacted without missing any of them.

2. Permanence of location is also desired to enable comparative evaluations over different time periods.

3. The manufacturing process should be indivisible to facilitate comparisons over time.
4. For simplicity of survey, an industrial group with a small number of firms is preferred.

**Selection of industry**

Two possible alternates were considered for examination. They were the Petroleum Refining industry group and the Terminal Grain industry. In each instance there are only a few firms in the industry group. Also there is a very distinct locational concentration for both of them where the Refineries are predominantly market oriented and the Terminal Grain industry predominantly port oriented.

Description of the Terminal Grain industry as a manufacturing industry might be considered as a distortion of the concept of manufacturing and statistically this group is divided between the transportation group and the milling industries. However when viewed in the context of local industry a reasonable similarity to other manufacturing industries can be found. In Vancouver and New Westminster, the Terminal Grain industry is located in industrial zones and it occupies a major portion of those lands reserved for port oriented industry. As a manufacturing process, the industry receives raw material, the grain, and processes it by cleaning, drying or milling before shipping the finished grain or flour.

The Terminal Grain industry requires land for the process stages of: railway marshalling yards, elevator sidings,
elevators, mills, marine docks, loading equipment, and office space. The railway right of way is excluded as a part of the industry since it is required by national transportation policy.

Indivisibility of this industry appears very strong and it is unlikely that changes in the basic process would alter over time. Under the Canada Grain Act all shipments of wheat must be made under the supervision of the Board of Grain Commissioners for Canada. The actual receiving of grain and the processing of it is done under license from the Board.

The Petroleum Refining industry also represents a limited number of firms processing petroleum in the Lower Mainland. There are four refineries which represent the following companies: British American Oil Company Ltd., Imperial Oil Ltd., Shell Oil Co. of Canada Ltd., and Standard Oil Co. of B. C. Ltd.—see Table 3-1. In each case the refinery receives raw materials, crude oil, and processes it into finished petroleum products. Indivisibility exists also in the petroleum refining group and it is not practical to divide or interrupt the manufacturing process. However, a complicating factor does arise since the nature of the finished product has not remained constant.

Over the last two decades major changes have occurred in the number and in the character of finished petroleum products. A great many specialty fuels and specialty products have been introduced in addition to the production of more complex motor fuels of improved characteristics. Additional
### Table 3-1

**PETROLEUM REFINERIES IN BRITISH COLUMBIA 1960**

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Source of Crude</th>
<th>Crude Capacity Barrels per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. A. Oil Company Ltd.</td>
<td>Port Moody</td>
<td>Alberta</td>
<td>18,000</td>
</tr>
<tr>
<td>Imperial Oil Ltd.</td>
<td>Ioco</td>
<td>Alberta</td>
<td>32,000</td>
</tr>
<tr>
<td>Pacific Petroleums Ltd.</td>
<td>Taylor</td>
<td>B. C.</td>
<td>1,900</td>
</tr>
<tr>
<td>Royalite Oil Co. Ltd.</td>
<td>Kamloops</td>
<td>Alberta</td>
<td>21,000</td>
</tr>
<tr>
<td>Standard Oil Co. of B. C. Ltd.</td>
<td>Burnaby</td>
<td>Alberta</td>
<td>18,000</td>
</tr>
<tr>
<td>X-L Refineries Ltd.</td>
<td>Dawson Creek</td>
<td>B. C.</td>
<td>2,800</td>
</tr>
<tr>
<td>Shell Oil Co. of Canada Ltd.</td>
<td>Burnaby</td>
<td>Alberta</td>
<td>21,000</td>
</tr>
</tbody>
</table>


Land has been required for these additional treating plants and therefore a comparison with earlier years is not as simple as in the Terminal Grain Industry. It can be expected in the future that similar process complexities will occur in the refining of crude petroleum and perhaps the extent of this will be comparable with past experiences. Thus it might be more desirable to include these changes rather than to exclude them.

The Petroleum Refining industry was selected primarily for ease of collecting field data. A total of over twenty interviews was anticipated for the Terminal Grain industry.
while only four were required in the Petroleum Refining group. It was felt that the reduced number of interviews in the Refining group was commensurate with the time available for field collection of data. Thus, the Petroleum Refining industry group in the Lower Mainland was selected for case study.

Field Survey

Description

Prior to undertaking the field survey a questionnaire form was prepared for subsequent presentation to each refinery respondent. A copy of this form is attached as Appendix III.

Three different years were selected for obtaining data to enable detection of trends. These years were the Census years of 1941, 1951, and 1961. In each year data was requested for the following three items.

1. Refinery throughput\(^1\) for year-
2. Employment during year-
3. Land Requirements in Industrial Zone-

Each refinery management was visited and during interview the nature and purpose of the survey was discussed together with explanatory information concerning the particular data required. One copy of the questionnaire form was left with each manager to be completed and returned to the University.

\(^1\) Throughput refers to the physical output from the refinery or the amount of material "put through" the plant.
A complete response was received and each refiner generously assisted in providing the requested data which required a review of operation records going back twenty years.

**Survey result**

Individual replies to the questionnaire were treated as a group and combined as shown in Table 3-2. Between 1941 and 1961 the group throughput of the refineries increased four times; the number of employees doubled; and the amount of land in active use doubled. Thus a greater utilization of both land and labor has occurred between the two periods. Ratios of these three factors, 'throughput,' labor, and land are shown in Table 3-3 where throughput is the numerator of the ratio.

As described earlier the measure of throughput does not allow for changes in process which since 1941 are more complex and costly. It does include crude oil received and processed and also receipts of finished and semi-finished products. The receipts of finished and semi-finished products have been included as they are an integral part of the total refinery economics even though the amount of these receipts is small. While the source of the crude oil changed from California to Alberta following completion of the Trans Mountain Pipeline, the total energy per barrel of the crude oils are similar. Therefore the comparison of land in active use is being made on the basis of similar material inputs to the industry.
### TABLE 3-2

**QUESTIONNAIRE SUMMARY DATA**

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Group(^a) Summary by Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1961</td>
</tr>
<tr>
<td>1) Total refineries' throughput for year: based on intake of crude and semi-finished products barrels (in thousands)</td>
<td>22,582</td>
</tr>
<tr>
<td>2) Employment during year:</td>
<td></td>
</tr>
<tr>
<td>i. mandays (in thousands)</td>
<td>224</td>
</tr>
<tr>
<td>ii. employees (mean number employed)</td>
<td>907</td>
</tr>
<tr>
<td>3) Land requirements in Industrial Area</td>
<td></td>
</tr>
<tr>
<td>i. total area at refineries, acres (onsite and offsite)</td>
<td>1,339</td>
</tr>
<tr>
<td>ii. area in active-use(^c), acres (onsite and offsite)</td>
<td>453</td>
</tr>
</tbody>
</table>

Source: Original data collected by questionnaire to four refineries in Lower Mainland, which was personally presented to respondent and left for return by mail to the University.

\(^a\)Changes have occurred within the industry since 1941 including the opening of the fourth refinery in 1958 as well as dispersal of some activities to other sites. The survey attempted to collect data for the years 1941, 1951, and 1961.

\(^b\)This column contains data for the year 1945 for one respondent, which has been used without alteration.

\(^c\)Active-use includes: process areas, tank farms, offices, fill stands, blending and packaging plants, rail spurs, roadways, maintenance areas.
<table>
<thead>
<tr>
<th>Description and Units</th>
<th>Ratio by Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Group throughput per mandays worked in year, (barrels per manday)</td>
<td>1,000 523 556</td>
</tr>
<tr>
<td>2) Group throughput per employee in year, barrels per man, thousands</td>
<td>24.9 13.4 14.5</td>
</tr>
<tr>
<td>3) Group mandays worked per employee in year, (mandays per man)</td>
<td>247 256 261</td>
</tr>
<tr>
<td>4) Group throughput per unit land in active use in year, (barrels per acre, thousands)</td>
<td>49.7c 36.4 26.2</td>
</tr>
</tbody>
</table>

Source: All data taken from Table 3-2.

a Group consists of oil refiners in Lower Mainland of B. C., and while the composition of the group has changed along with different distribution of activities, the survey endeavored to collect comparable data for the selected years.

b This column contains data for 1945 and one respondent only; the rest are 1941, and it was included without alteration.

c This value would be 54.2 M barrels per acre if only the earlier three refiners were considered; i.e., deducting both throughput and land in active use at fourth refinery from the group total.
The refineries utilized their resources in 1941 in a manner so that they required a total of 215 acres of active-use land and processed a total of 5 1/2 million barrels during the year. By proportion, more than 26 thousand barrels of throughput were refined for each acre of land in active use. This ratio increased 38 per cent in 1951 to 36 thousand barrels a year per acre. A similar increase of 38 per cent occurred during the following decade when, in 1961, the throughput per acre reached nearly 50 thousand barrels per year. Between the twenty years 1941-1961 there was an 89 per cent increase in annual throughput per acre.

For study purposes the term active-land-use includes all land that is necessary for conducting petroleum refinery operations and includes: process areas, tank farms, offices, fill stands, blending and packaging plants, rail spurs, roadways, and maintenance areas. Excluded from this definition is land held for future use and unusable land. The amount of unusable area in the case of this industry is large as a result of the steep slopes where the refineries are located. Several of the refinery sites have rises in elevation of 100 feet or more and up to 300 feet. A photograph illustration is shown in Figure 5.

In native soils an artificially protected slope would be stable on a 1 1/2 to 1 incline and untreated slopes require considerably flatter inclines. As consequence not all the land can be utilized and a large portion must remain in an unusable
Fig. 5  AERIAL PHOTOGRAPH OF PETROLEUM REFINERY  
LOWER MAINLAND OF B.C.

Legend

1. Tank farm  
2. Process area  
3. Office  
4. Fill Stand  
5. Blending & Packaging Plant  
6. Railway  
7. Maintenance Area
slope until extensive terracing is carried out with vertical retaining walls. However such a proposed terracing is costly and in most cases prohibitive. It is unlikely that within the next twenty years the price of land will increase sufficiently to justify the cost of terracing. The unusable land could be approximated by an equivalent strip 150 feet wide for every 100 foot rise in elevation. Where the difference in elevation is 300 feet, this strip would be 450 feet wide.

A rough appraisal of the land in the refining group indicates that about one half of the recorded area is unusable as a result of the steep slopes. In 1941 the refinery group held 562 acres while only 215, or about one half, were in active use. Similarly in 1951 and 1961, the apparent excess land was predominantly unusable.

Using refinery throughput as the numerator, the proportionate changes in labor over the period are presented in Table 3-3. In 1941 there were 556 barrels refined per manday worked. This declined in 1951 to 523 barrels per manday and possibly as a result of the greater effort in 1941 during the war and labor shortages. By 1961 the output per manday per 1000 barrels almost doubled that of 1951. The decreasing manday year per employee has resulted from a shorter work week and increased holidays from work. As a consequence, the changes in throughput per employee are not as great as the changes in throughput per manday. In 1941 the ratio of mandays per employee
was 261 days per year and this dropped to 256 in 1951 and further to 247 in 1961. Over the twenty years there has been a five per cent decrease in the number of mandays per employee per year. The first decade of this period saw a 2\% decrease while the second decade received nearly twice that or 3 1/2 per cent decrease.

Summary

This case study of the Petroleum Refining Industry in the Lower Mainland of B. C. was completed with results that verified the hypothesis. Over the last two decades the apparent increase in refinery throughput per worker rose from 15 to 25 thousand barrels per year or an increase of 67 per cent. During the same time the apparent increase in throughput per unit of land increased from 26 to 50 thousand barrels per acre per year for an 89 per cent increase. Thus there has been a 'productivity' of manufacturing land in the Petroleum Refining group and the increase has exceeded the apparent productivity of labor during the same period.

Conclusion

Continuing land productivity increases in the Petroleum Refinery group or in other manufacturing industries will significantly affect the forecast amount of land required. A similar experience in all manufacturing industries of the same proportion as this example would result in an overestimation of
future industrial land requirements. Using the past changes in
the Refinery group as an example, if the 'productivity' of
manufacturing land were excluded, this overestimation would
approach 100 per cent over a twenty year period.

Municipal land assessment records are inadequate for
use in forecasting industrial land requirements. In the Refinery
group, 1339 acres were held by the refiners in 1961 while only
453 acres were in active use. The greater portion of the
difference was unusable land resulting from steep slopes at
the site. Generally, the assessment land measure is not
concerned with actual land use but rather with the 'best use'
that the land has and this is measured ultimately in dollars
rather than in acres used.

Government statistics of production in the industrial
groups are not generally coincident with planning areas or
regions. Employment data are available locally for every firm
with more than ten employees and consequently it offers
opportunity for use as a substitute for production data. How­
ever if it were used to predict the land requirements in this
example for 1961, based on 1941 data of employees per acre, it
would be ten per cent in error even though the precise number
of future employees was known in advance. The effect of this
error would be to exaggerate the difference between actual and
forecast requirements in excess of 10 per cent. If the initial
labor estimate were 33 per cent high, the 10 per cent error in
employees per acre would produce a 50 per cent error in land
estimates.
It is unlikely that a satisfactory system of data collection for land use forecasts could be obtained from utilizing existing data collection sources. Possibly, a new and separate data collection system would be required which might utilize effectively the present Federal, Provincial, and Municipal departments concerned with collecting statistical information. Such a new system would consider the location of the firm with respect to zoning districts; the quantitative measure of production; the divisibility of the firm into other industrial groups; and the amount of land in active use as well as total land held in reserve.
CHAPTER IV

DIRECT AND INDIRECT METHODS OF FORECASTING
URBAN LAND USE

Introduction

Chapter II discussed methods of forecasting employment and output which were of interest for physical planning of urban areas. With these methods an approximation could be made of future land area requirements for specific purposes. These methods included the Economic Base concept, the Input-Output analysis, and the Apportionment technique of relating a study for a large area to a smaller area or region.

The Economic Base method provided a short-cut way of estimating future employment from a study of only one portion of the total employment. By isolating this portion, or base, and by predicting employment changes in it, a ratio could be applied to produce the total forecast employment. As a forecasting means for projecting average needs in different zones, the method is incomplete. However, by supplementing the study with information on densities, such as employees per acre, a land forecast can be made. Also, by selecting the base group to coincide with the firms operating in a distinct zoning district, such as the manufacturing group, a correlation can be
obtained between employment forecast and land forecast in the same zoning district. If the manufacturing group were selected as the base, a forecast of the balance or secondary employment could be made by applying the base ratio.

The Apportionment technique is a means of utilizing state or national forecasts for local or urban purposes. The principle relies on an interdependence between the several parts and the whole where the economic activity of each part is affected by and affects all other parts. Thus if the local area has consistently each year enjoyed \( x \) per cent of the national employment it is probable that this will continue in the future. Hence a forecast of employment for the nation can be apportioned to suit the local level. However, like the economic base approach, it does not indicate land forecasts and these must be derived by relating land to the forecast. Since a national production forecast may be in dollars or in numbers of employed, the derivation must relate land to either dollars or employees.

The Input-Output approach as a means of economic forecast offers a more precise method for determining output. In principle it acknowledges the interrelationship of all business enterprises and thus assists in determining the effect of the one upon the other. Its use precludes having complete accounting data for all business groups and thus its utility is limited to the national level. As such it has little direct application for urban land forecasting. It does offer, though, a more promising
means for precise national economic forecasting which could be used indirectly, by apportionment, for local forecasts.

Each of these forecast methods is an indirect approach to forecasting land use. The prime study of forecast does not consider land but rather output in dollars or by employees. As such it excludes from view some of the inherent phenomena between output and land.

Chapters II and III introduced a concept which is excluded from the indirect approach to land forecasting. This concept appears analogous to the familiar 'productivity of labor' in manufacturing industries and also to the productivity of agricultural land. The concept was applied or tested in one industry group which gave a positive indication of increasing manufacturing output per acre of land. This chapter will discuss what effect the increased productivity of land could have if it were included in a forecast of the industry group examined. It will do this by presenting two methods of land forecast: the indirect apportionment method, and the direct survey method.

Forecast by Apportionment

National forecast

The forecast to be apportioned in this example is the study undertaken by the Royal Commission on Canada's Economic Prospects.\(^1\) Their forecast of selected industrial groups was

---

made on the basis of observed trends and economies of the group as adjusted by intuitive reasoning. In each major industry group considerable coherent statistical data was available respecting employment, value of production, and cost of manufacture. Petroleum and Coal Products industry was one of the selected major groups for their forecast.

Two major industries comprise this group: 'petroleum refineries,' and 'other petroleum and coal products industries.' This latter industry is further subdivided to include: roofing compounds, paving, coal gas manufacture, coking plants, and fuel briquettes. A growth factor of 400 was assigned to the Petroleum and Coal Products group to represent the increase in output between 1955 and 1980. By 1980 the gross value of their production would reach 4.65 billion dollars with 1.2 billion of the total added by the production process.² Allowing for apparent productivity increases in labor, they predicted a 40 per cent increase in employees to reach a total employment in 1980 of 24 thousand.

This national forecast of output for the Petroleum and Coal Products group can now be apportioned to reveal the share contributed by the Lower Mainland Region of B. C. Fortunately this has already been done for this industry group by the Lower Mainland Regional Planning Board³ as part of a bigger study and

²Ibid., Table J and Table K.

³Lower Mainland Regional Planning Board, Manufacturing Industry in the Lower Mainland Region of British Columbia 1931 to 1976 (New Westminster, 1960); Lower Mainland Regional Planning Board, The Dynamics of Industrial Land Settlement (New Westminster, 1961).
therefore needs not to be duplicated. Rather, an attempt will be made to describe the Board's study and the method they used to reach the apportioned forecast.

Apportionment by Lower Mainland Regional Planning Board

The first step in making the land forecast for the local area was to determine what share of future national production would be contributed by this area and to convert this output into an employment forecast. This step is explained in the Report, "Manufacturing Industry in the Lower Mainland Region of British Columbia."

This study used statistical data generally from the Dominion Bureau of Statistics to represent value of production and employment in the local area. This data was readily available for census district which closely approximates the region under review. In addition an interview was held with each operating firm which augmented the necessary data and enabled a basis for intuitive reasoning in the forecast.

A review of past experience showed that the Lower Mainland region contributed 1.2 per cent of the total 1931 national output in petroleum and coal products, and non-metallic minerals groups. This share steadily increased to 4.4 per cent by 1956 and the 'Board's' judgement was that this share would increase to 5.5 per cent by 1976. In their study they combined the petroleum and coal products group with the non-metallic minerals group. This latter group comprises building product industries such as cement manufactures, lime manufacturers, ready-mix
concrete, clay products, mineral wool manufacture and other similar activities.

Gross value of production for the combined major groups was forecast by the Royal Commission at 5.4 billion dollars in 1980 and of this amount 1.6 billion was added by manufacturing process. Their estimate of combined employment in the two groups was 69 thousand persons.

The 'Board' advanced the Royal Commission forecast from 1980 to 1976 and arrived at a gross value of production in the combined major groups of 4.1 billion dollars. The Lower Mainland share of this production, at 5.5 per cent, is 226 million dollars or an increase of 604 per cent between 1953 and 1976.

Employment in 1976 was determined by projecting present employment with the growth factor reduced by the expected productivity increases. The Royal Commission anticipated annual increases in the apparent productivity of labor of 2 1/2 per cent for the non-metallic mineral group and five per cent for the products of petroleum and coal group. The 'Board' combined these increases into an annual rate of three per cent for the two groups. On this basis they prepared a forecast employment of 5.5 thousand by 1976 in the two groups. Further study enabled the total employment to be divided into each industry group and

---

*The Royal Commission excluded cement manufacturing and abrasives manufacturing from their definition of secondary manufacturing. These industries are included in the D. B. S. major group, non-metallic minerals. However these processes were not represented in the local region until late 1950's.*
2,000 of the total were expected in the Petroleum and Coal Products industry group. This completed the first step in the land forecast.

This first step required three individual judgements which are cumulative in their probable error of the final employment forecast. The first was a selection of the future percentage share of national output; the second was a judgement of the relationship between output and employment; and the third, applicable in this case only, was in determining what portion of the total combined group employment forecast would be expected in the Petroleum and Coal products group. These, of course, will be probable errors in addition to the probable error of the national forecast of production.

The second and final step in making the land forecast is described in the report, *The Dynamics of Industrial Land Settlement*. This study converts the employment forecast into a land forecast.

Municipal assessment records were used to obtain the amount of land in each industry group for their survey undertaken in 1958. During the survey each respondent firm indicated the portion of their site in active use. Thus, they could prepare an estimate of the present industry land probably in active use by 1976. For the Petroleum refining and coal products group this portion was estimated at 70 per cent by 1976.
The relation between employment and areas of land in the industry group was made by a simple ratio of the two. The forecast ratio of density was made by a judgement of trends in gross densities of newly established firms and firms established in the early 1900's. From these the 'Board' selected a future site density of 0.8 workers per acre for existing unused portions of site area, and 0.4 workers per acre for densities appropriate to new land acquisitions. The result was a forecast for an additional 1200 acres in the industry with an additional 567 workers.5

The second step introduced two more judgements one of which would produce a cumulative probable error in the total land forecast. These judgements were in determining the future employee densities, which is accumulative and the estimation of land presently held in reserve to be used by 1976.

Some idea of the precision of the apportionment forecast method can be determined as follows. Assuming a skill of judgement of plus or minus ten per cent the probable error of the total forecast can be determined by the sum of the accumulative number of judgements. If each judgement were made with the same ten per cent skill the five individual judgements would result in a probable error of plus or minus fifty per cent. That is, the final land forecast of an additional 1200 acres could go as high as 1800 acres or as low as 600 acres.

5 The "Lower Mainland Regional Planning Board of B. C., The Dynamics of Industrial Land Settlement", Table V.
Direct forecast of future land area

Industrial output is determined by market demand, and a forecast of output is made by forecasting probable demand. In this example of a direct approach to land forecasting, a forecast has been made for the output from the petroleum refineries in the Lower Mainland region. This forecast is attached as Appendix IV.

In meeting this output, the industry can utilize its resources of land, labor, and capital in various ways. The actual relationship between them will vary over time and will be dependent upon the industries' economics. By using greater amounts of capital, to install new technical methods and better equipment, the output can be increased without necessarily increasing either land or labor. In this way there will be an apparent increasing productivity of labor and also an apparent productivity of manufacturing land.

The field survey of the Petroleum Refining group, as described in Chapter III, showed that the 1961 output was 50 thousand barrels per acre. Over the last two decades this output had increased 89 per cent in fairly uniform increases per decade. A further 89 per cent increase could be expected by 1980 by continuation of this trend. But, without examination of the internal economies of the industry as well as viewing external economies, it is difficult to predict this continuation. However on the basis of petroleum providing a smaller part of the total energy market in the future it is likely that more
specialty products will be produced. As a result, a greater amount of land would be required for these additional processes. On this basis, an increase of only 50 per cent could be expected which would result in an output of 75 thousand barrels per acre by 1980.

The production forecast of Appendix IV has a mean value of 42 million barrels output annually by 1980. This throughput is likely to be achieved by the use of 560 acres of land. At present 453 acres are in active use out of a total of 1339 acres. However a rough estimate of the existing land indicates about one half of it is unusable for development. Thus only about 670 acres are available but, this is still in excess of the forecasted requirement.

By using this direct approach, three independent judgments were required: a selection of the output by 1980, an estimation of the acres required per barrel of output, and an estimate of the land presently held in reserve to be used by 1980. Assuming the same skill in estimating of 10 per cent accuracy that was used in the previous example, a probable error of plus or minus 30 per cent could be expected for the final land forecast. This would be expressed as between 400 and 700 acres. If the higher value were realized an additional 30 acres might be required.
Comparison of direct forecast and apportioned forecast

A direct comparison of the end result of the two forecasts is not possible since they do not represent identical industries. The direct forecast was made solely for the Petroleum Refining industry while the apportioned forecast included more than this with the coal products or manufactured gas industry. However with introduction of natural gas the existing gas plant (B. C. Electric Co.) has become idled. Assuming that a comparison can be made the following differences are noted:

1. The apportionment forecast indicates a need for 1200 additional acres by 1976 while the direct method forecasts a surplus of land by 1980.

2. The apportionment technique has a probable error of plus or minus 50 per cent while the direct method has only 30 per cent probable error if the same skills are applied to each estimate.

3. The forecast employment by apportionment is 2000 workers. Using the data of the direct survey an increase of 100 per cent in worker output can be expected which will produce an estimate of 840 workers by 1980.
CHAPTER V

DIRECT URBAN LAND FORECAST

Summary

Need for physical planning in Canada

Since 1871 the population of Canada has increased by 15 million. During this period the population shifted from predominantly rural to urban centers so today more than 65 per cent of all Canadians live in cities. As a result the urban places have had to provide homes, shops, schools, streets, water, and all other related services for 11 million additional persons. Most of the additional population moved to existing big urban centers with their greater employment opportunities which resulted in the big cities getting bigger.

To keep pace with this growth federal, provincial, and municipal government spending increased from 0.8 billion dollars in 1926 to 11 billion in 1960. Private disposable income increased also with a fourfold per capita increase since 1926. A portion of the increased per capita wealth has been spent on providing personal transportation offered by the automobile. With auto-dominant transportation, the social and cultural desires for suburban living have materialized and the
cities have expanded sideways and tended to spread out in low density development. This lower density together with a greater population has increased the cost of servicing land with roads, water, and sewers as well as more recent improvements and has caused concern about how these additional costs are to be financed.

Population forecast and economic forecast

The rapid growth of the cities and metropolitan areas requires a program of planned spending to keep pace of the demand for new services. The basis for making this spending program is the forecast of population and employment. For the nation, the population forecast is made by a perusal of the likely additions and deletions to the population.

A separation of population from economic forecasts is difficult since, in part, population is a reflection of the socio-economic well-being of the country. Both the cultural values and economic proficiency of society affect the rate of births, deaths and migrations. With given resources and income, a society can choose, within limits of regulation, between spending the entire income for subsistence in a growing population or they can control population and spend some portion of income on physical and aesthetic forms of leisure.

As income increases there is greater choice between spending the increment on leisure or on increased population. In practice the Western countries have tended to do both
resulting in increased population and increased per capita wealth. Thus a forecast of population is inextricably tied to a forecast of economic growth. The generalized conditions affecting such a forecast are expressed by W. W. Rostow in the six propensities of a society to develop as described in Chapter I.

The smallest coherent unit in making such a forecast of population and economic growth is the nation since today there are large economic and cultural ties between the various areas or regions of the country as well as jurisdictional limits restricting free movement of people, goods and capital. At the city level another problem arises in making a forecast of population. There are no controls over movement in or out of Canadian urban areas and thus changes can occur quickly in migration rates or in the shipments of goods and capital. However these changes might be anticipated readily providing there is data representing movements of these factors. Unfortunately such statistics presently are not collected for the local areas in all instances.

Urban land forecast

In the urban area land is needed for many different purposes and the amount in any one purpose is dependent in part on the size of the population and the intensity of economic activity. Thus the urban area also requires a forecast of population and of local economics and it requires this in
relation to actual site locations which will permit the land
use plan to be implemented by zoning regulations. A forecast
of increased manufacturing activity, for example, when correlated
with acres of zoned land will permit an extension or reduction
of area or services in that zone.

In the past studies have been made independently for
future population and future economic activity in urban areas
but not without consideration of each other. Generally an
economic study has been favoured as a means of forecasting the
land requirements for industrial, commercial and manufacturing
uses, while the population forecast has been favored for
anticipating required areas of residential land. In making the
economic study frequent recourse is made to national forecasts
and to relate this to the local requirements. However, in
Canada, the national forecast rarely considers the economic
factor of land as a part of the variables of production in
industry. It confines itself to considering only capital
and labor in relation to output. Thus the relationship of
land to production becomes obscured in relating national
economic forecasts to the urban area.

Apparent productivity of manufacturing land

In this current study an attempt was made to demon­
strate the variable use of inputs of land in manufacturing
industries. By analogy to the apparent productivity of labor
and productivity of agricultural land an hypothesis of product­
ivity in manufacturing land has been postulated. Experience in
the Petroleum Refining industry in the Lower Mainland of B. C. substantiates this thesis where the apparent "land productivity" doubled between 1941 and 1961.

The testing of such a thesis can readily be done by a direct survey method which relates land to output from that land.

**Direct and indirect urban land forecasts**

With changing land productivity in manufacturing industries an attempt should be made to relate future output to land by direct survey methods.

For illustrative purposes, a comparison was made between an indirect approach to land forecasting and a direct one. The direct approach is discussed in Chapter IV and the same section describes an earlier study by the Lower Mainland Planning Board of B. C. This comparison could not indicate the degree to which each method was sensitive to detecting changes in land productivity since they cover somewhat different industry groups. However some measure of the precision of the two methods can be indicated.

If estimating accuracy were 100 per cent in each method, which is most unlikely, the probable error of the final answer would reflect the precision of each judgement multiplied by the number of accumulative judgements. Where one judgement is dependent on another prior judgement, the probable error is compounded.
Five accumulative judgements were made in the indirect forecast reviewed while only three were made in the direct forecast. If the precision of each judgement was plus or minus ten per cent, the probable error of the indirect forecast is plus or minus 50 per cent while the direct forecast error is probably plus or minus 30 per cent. Thus the direct approach offers a more precise forecast of future land requirements.

Considering these two methods as local labor forecasting techniques, the probable error would be the same in each case based on three judgements.

Conclusion

Urban land forecasts will assist effective and efficient governmental and private investment to accommodate a growing population and changing economic structure of local areas. Imprecise survey methods will either encourage sprawled development if they are too high or will impose individual restrictions if they are too low. In this respect care should be taken in selecting the method of making the forecast to ensure the greatest degree of precision.

The direct forecast method for estimating industrial land requirements appears to offer a greater precision than the indirect or apportionment method and it also offers a means for detecting changes in the apparent productivity of urban land by relating output to land. In addition, it also introduces a qualitative measurement of the land in use and available for use.
Present statistical data do not identify industrial activity by location in urban zones and therefore do not permit a correlation between output and land area.

Since the federal government collects statistical data respecting employment and output and the municipal governments collect land use data it is unlikely that adequate or comparable information will be available for urban land forecasting until alterations are made in each data collection system.

These changes would recognize current sources of collecting statistics and would change the purpose of collection by including urban land forecast purposes with particular attention to correlation of population, employment output and land.
BIBLIOGRAPHY

Books


Articles and Periodicals


Reports and Technical Papers


The Dynamics of Industrial Land Settlement. New Westminster: Lower Mainland Regional Planning Board of B. C., October 1961.

Public Documents


**Special References (Petroleum Refining)**


APPENDIX I

QUESNAY'S ZIG-ZAG CHART AS INTERPRETED BY H. WOOG

The 'tableau' presented by Quesnay in 1758 was his attempt to portray the dependence of the national economy upon that of agriculture and to show the inter-dependency of transactions between the three social classes of Land Owners, Productive Class, and the Sterile Class. He also used it as an illustration to show the results of disequilibrium caused by improper interference of the government especially in taxation and hoarding.

The diagram of Fig. 6 is an interpretation of Quesnay's Tableau in equilibrium which has been presented by Dr. Henri Woog, The Tableau Economique of Francoise Quesnay (Bern: A. Francke, 1950), p. 99: "The juxtaposition of the zig-zag diagrams in equilibrium and in the state of disequilibrium corresponds to Quesnay's discrimination of the 'ordre naturel' and the 'ordre positif.' Solely the exposition of both versions of the Tableau demonstrates the central importance of the conception of circulation within the Physiocratic Theory;" p. 36: "The Tableau economique in equilibrium constitutes an attempt to present the successful process of production and circulation in a 'nation agricole' resulting from the strict observations of the natural order. In other words, the Tableau relates to a state of economy attained by the consequent application of the principles of the 'ordre naturel' to the 'ordre positif.' It represents an economic system that has virtually realized the postulates expounded by the Physiocratic Theory . . . ."
Woog. This diagram has extended the basic features of the original "Tableau" to include the "Analyse" or written description by Quesnay that accompanied his presentation. In his text he described the social classes as:

The Land-owning class constitutes the socially predominant category of the nation. It embraces the State, or Sovereign, the worldly land-proprietors, and the clergy . . . .

while the Sterile class comprised the manufacturers and the merchants of the nation. His description of the productive class represented the independent farmers. A fourth class of workers or "menu people" is neglected in his "Tableau economique" since it comprises only the population deriving its wage-income solely from the source of manual work.

Dr. Woog uses a diagram to illustrate Quesney's theory of economic regulation and growth. The diagram shows that the agricultural harvest yields are sufficient: to refund the working capital consumed or used in the growing process; to provide an interest on the invested or fixed capital; and to leave a surplus or net product (produit net). The net product is distributed as profit to the farmer, as tithe to the clergy, and as taxes and rents to the land owners. Clearly, the prosperity of the land owners, the clergy as well as the farmer are dependent upon the production and sale of the agricultural produce. Consequently, the nation's prosperity and, as a result its economic growth, are connected to the

\[ \text{Ibid.}, \ p. \ 18. \]
proper regulation of the production and distribution of the agricultural produce. Common welfare depends upon the farmers' wealth.

Preferablement a tout, le royaume doit etre bien peuple de riches cultivateurs.3

The produce of the fields must be sold at adequate prices to enable everyone to share in the 'surplus' and this necessitates proper regulation of the production.

The agriculture process of production depends on an adequate organization of the circulation sphere in the sense that its possibilities of development and amelioration rise and fall together with the quantity of commodities that farmers are in a position to purchase in exchange for their products. According to the assumption that solely the 'grande culture' produces wealth in form of surplus, there ensues an interdependence of the individuals in a community: the farmers' welfare depending on the other classes' willingness and capacity to spend their incomes on the purchase of agricultural goods, whereas the entire nation's prosperity is closely connected with the effectiveness of the farming methods.4

The intricacies of the normal circulation of money which result in the distribution of wealth, are shown in the "Tableau" an interpretation of which has been made by Dr. Henri Woog and is shown in Fig. 6, "Interpretation of Quesnay's Tableau Economique."

In the chart the consumption of agricultural products is made by both the Sterile and the Land Owning classes. Similarly, consumption of the manufactured product is made by

---

4Woog, op. cit., p. 22.
Fig. 6. Interpretation of Quesnay's Tableau Economique

\[ \text{Productive Class} \quad \text{Land Owners} \quad \text{Sterile Class} \]

\[ \begin{array}{cccccc}
(a) & (b) & (c) & (d) & (e) & (f) \\
2000 & 2000 & 1000 & 1000 & 1000 & 1000 \\
1000 & 1000 & 1000 & 1000 & 1000 & 1000 \\
500 & 500 & 500 & 500 & 500 & 500 \\
250 & 250 & 250 & 250 & 250 & 250 \\
125 & 125 & 125 & 125 & 125 & 125 \\
125 & 125 & 125 & 125 & 125 & 125 \\
1000 & 1000 & 2000 & 2000 & 2000 & 1000 \\
\end{array} \]

\[ \text{Henri Woog, p. 75: "Quesnay's Tableau economique completed according to the data supplied by the Formula."} \]

both the productive and the land-owning classes. The 2000 units at the top of column (b) represent the part of 'rent' paid to the land owners, as shown by its movement to the top of the column (d) (by direction of the arrow). The 1000 units at the top of the column (e) is the part of the working capital of the Sterile class.
Starting at the beginning of a cycle, the sterile class use this working capital to make an initial purchase of 1000 units of agricultural produce. The land owners also make a purchase of 1000 units of agricultural produce which is immediately returned to the land owning class as repayment of working capital. A second expenditure of the land owners is made for manufactures worth 1000 units which is immediately used by the sterile class for two purposes: one to buy additional food and agricultural goods; and the second, 500 units, to start replenishing their working capital. It is noted that the portion used for food is quickly returned to the land owners. As shown in column (e), each receipt of the sterile class is dispersed in like manner between agricultural goods and replacing working capital. This continues in diminishing amounts as the cycle proceeds, until the entire working capital of 1000 units is replaced. See total at bottom of column (f).

It is realized of course that in fact the total circulation of agricultural or manufactured goods does not continually decrease but there is continual addition of new sums to the process which also have the secondary stimulating effect of the first sum as shown in this table. That is, the consumption of both agricultural produce and manufacturing produce tends to be uniform throughout the year, rather than diminishing, and initial expenditures are made continually by all three classes.
Over the complete cycle the sterile class has had receipts of 2000 units: 1000 each from the land owners and productive classes; and has made expenditures of 2000 units; 1000 of which went to the productive class directly and the other 1000 indirectly to the land owners class after receipt by the productive class, i.e., the amounts shown in columns (b) and (c) coming from the sterile class.

The Land Owners have accepted the initial 2000 unit of rent plus another 2000 units accumulated over the cycle by returns from the productive class. In this period they have expended only 2000 units; 1000 each to the other two classes; and hence have retained the 2000 units of rent intact (presumably available for expansion of the manufacturing processes or for more agricultural activities).

The productive class, after initial rent payment amounting to 2000 units, received a total of 3000 units where 1000 came from the land owners and 2000 from the sterile class. Excluding the rent payment, this class made expenditures of 3000 units; 1000 units for manufactures, and 2000 units for replacing working capital.

It can be seen from this table that in a well-regulated economy the needs of all classes can be met and still result in a residue, the rent, for expanding the economy.

Quesnay in cooperation with Mirabeau wrote further on the results of a disequilibrium of the economy and used the same method of presentation with the "Tableau." However, this is not included here.
APPENDIX II

LEONTEIF INPUT-OUTPUT ANALYSIS
(Using matrix algebra)

Input-output analysis, as described in Chapter II, is a technique used to determine the inter-relationship of industries within a given area. The area is generally a large economic unit such as the nation but with further refinement it might be used for a smaller area such as a region. The method utilizes dollar values of all transactions of firms (or groups of firms) considering purchases and sales from other firms both within the area and outside the area. These values are tabulated in a large 'two account' tabulation sheet where each transaction is accounted for twice, once as a sale and once as a purchase for the two parties to the transaction.

In this way it can be seen that a dependency exists between firms where the sales of one may be the purchases of another in the normal operation of the firm. Determination of the extent of such dependency is a laborious task when approached by the trial and error method and the technique lends itself to the application of that part of mathematics called 'Matrix Algebra.' With this mathematical assistance, the task of resolving the inter-dependencies is reduced where it is feasible.
in practice to solve the problem but generally only with the use of rapid electronic computers.¹

A typical tabulation of the type used in the input-output analysis is shown in Table 6-2, with a simple reduction in form shown in Table 6-3. It is possible to duplicate these tables in algebraic terms by using equations to represent the horizontal rows. Then the output of the industry, shown in column 51, is the sum of individual columns entries for that industry and which can be expressed in the form:

\[ a_1x_1 + a_2x_2 + a_3x_3 + \ldots + a_nx_n = b \]  

where \( b \) is the output of a given industry and the \( ax \)'s represent the transactions with all other individual industries. The symbol \( x \) would represent a production factor of the industry, with its identifying separate subscript, and symbol \( a \) is the ratio of that factor used in transaction with industry \( b \).

In the example of Table 6-2, the value of the first term of equation (1), the \( a x \), would be 75.2 million dollars. Similarly the value of the second term, \( a x \), would be 5.5 million dollars and so on until every column was entered in the equation for the row industry and equated to the last column value of 1260 million which is the value of symbol \( b \). When this algebraic approach is used for all the rows the result is a group of equations which

---

¹R. E. Boston, "A Simulation of the Economy of British Columbia," *Engineering Journal*, vol. 44, no. 11, November 1961, p. 74: "A simple aggregate model (20x20) can be prepared and tested in about one or two man years . . . . The machine elapsed running time (the computer) would be about one hour at a charge of some \$40. (per programme)."
TABLE 6-2
THE INTER-INDUSTRY FLOW OF GOODS AND SERVICES, CANADA, 1949
(Producer's prices in millions of dollars)
-Table as shown is not complete-

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>45</th>
<th>48</th>
<th>49</th>
<th>51</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture</td>
<td>Forestry</td>
<td>Fishing, hunting, trapping</td>
<td>Metal mining and smelting and refining</td>
<td>Personal expenditure on consumer goods and services</td>
<td>Value physical change in inventory</td>
<td>Exports of goods and services</td>
<td>Financial output total</td>
</tr>
<tr>
<td>1.</td>
<td>Agriculture</td>
<td>75.2</td>
<td>5.5</td>
<td>-</td>
<td>0.2</td>
<td>745</td>
<td>582</td>
<td>73</td>
</tr>
<tr>
<td>2.</td>
<td>Forestry</td>
<td>0.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>51</td>
<td>-32</td>
</tr>
<tr>
<td>3.</td>
<td>Fishing, hunting, trapping</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>-</td>
<td>11</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>4.</td>
<td>Metal mining and smelting and refining</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>543</td>
<td>14</td>
</tr>
<tr>
<td>44.</td>
<td>Imports of goods and services</td>
<td>26.1</td>
<td>0.5</td>
<td>1.8</td>
<td>45.5</td>
<td>674</td>
<td>33</td>
<td>-13</td>
</tr>
<tr>
<td>48.</td>
<td>Wages, salaries ...</td>
<td>134</td>
<td>199</td>
<td>17</td>
<td>206</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>51.</td>
<td>Capital consumption allowance</td>
<td>183</td>
<td>18</td>
<td>18</td>
<td>52</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>53.</td>
<td>Total input</td>
<td>2,402</td>
<td>432</td>
<td>118</td>
<td>644</td>
<td>10,923</td>
<td>3,938</td>
<td>49</td>
</tr>
<tr>
<td>54.</td>
<td>Total input excluding intra-industry consumption</td>
<td>2,327</td>
<td>432</td>
<td>117</td>
<td>644</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

-continued-
TABLE 6-2--Continued

Source: This table is an excerpt from Table 1, "The Inter-Industry Flow of Goods and Services, Canada, 1949" as shown in D. B. S. publication no. 13-513, occasional, Supplement to The Inter-Industry Flow of Goods and Services Canada, 1949 (Ottawa: Queen's Printer, 1960).

Note:

The table shows the dollar accounts for all industries in Canada by output (given along the rows) and input (given down the column) for each major industry group with every other group and including balance sheet items such as exports; imports; inventory change; and wages and salaries. For example: agricultural produce of some form was needed in the agricultural industry itself, the forest industry, the metal mining industry, and so forth including personal expenditures of 745 million (in row 45). To produce these amounts, the agricultural industry had the inputs of column 1, which shows an inward consumption of its own produce of 75.2 million. Also, it required inputs of 0.4 million from the forest industry but nothing was required from fishing or metal mining, etc. Wages and salaries for this amount of production were 134 million and it required a capital input of 183 million (plus others not shown) for a total input of 2,402 millions of dollars.
### Table 6-3

**Input Into Each Industry Per Dollar of Output, a Canada, 1949**
(Producer's prices in dollars)

*Table as shown is not complete*

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>38</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the origin of input into an industry read the column for that industry.</td>
<td>Agriculture</td>
<td>Forestry</td>
<td>Fishing, hunting, and trapping</td>
<td>Metal mining, smelting</td>
<td>Transportation, Storage, Trade</td>
</tr>
<tr>
<td>1. Agriculture</td>
<td>-</td>
<td>.012726</td>
<td>-</td>
<td>.000311</td>
<td>.000677</td>
</tr>
<tr>
<td>2. Forestry</td>
<td>.000172</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3. Fishing, hunting, trapping</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4. Metal mining, smelting</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18. Rubber products</td>
<td>.007305</td>
<td>.000231</td>
<td>-</td>
<td>.001865</td>
<td>.002989</td>
</tr>
<tr>
<td>19. Textile products</td>
<td>.004941</td>
<td>.003933</td>
<td>.030822</td>
<td>.000932</td>
<td>.001261</td>
</tr>
<tr>
<td>28. Iron and steel products</td>
<td>.013965</td>
<td>.031004</td>
<td>.004281</td>
<td>.017091</td>
<td>.004483</td>
</tr>
<tr>
<td>44. Imports of goods and services</td>
<td>.011215</td>
<td>.001157</td>
<td>.015411</td>
<td>.070696</td>
<td>.025823</td>
</tr>
<tr>
<td>48. Wages and salaries</td>
<td>.057792</td>
<td>.460898</td>
<td>.142123</td>
<td>.320696</td>
<td>.430469</td>
</tr>
<tr>
<td>51. Capital consumption allowances</td>
<td>.078761</td>
<td>.041185</td>
<td>.154966</td>
<td>.080019</td>
<td>.062129</td>
</tr>
<tr>
<td>54. Total input excluding intra-industry consumption</td>
<td>1.000000</td>
<td>1.000000</td>
<td>1.000000</td>
<td>1.000000</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

*continued*
TABLE 6-3--Continued

Source: This table is an excerpt from Table 2, "The Inter-Industry Flow of Goods and Services, Canada, 1949," D. B. S. publication no. 13-513, occasional, Supplement to The Inter-Industry Flow of Goods and Services, Canada, 1949 (Ottawa: Queen's Printer, 1960).

In this table, total output of an industry is defined so as to exclude output consumed within the same industry.

Note:

This table has been derived from the preceding table of "Inter-Industry Flow of Goods and Services, Canada, 1949" where these tabulated figures are that portion of the total inputs for 'the column industries' required from the 'row industries;' i.e., of the total input (1.000000) into Forestry, Agriculture provides the portion of .012726 or a little more than one per cent of the inputs into that industry.
are inter-related and which must be solved simultaneously. The labor involved in the solution of the equations can be reduced by using the notion of matrix which is expressed by Schwerdtfeger\textsuperscript{2} as follows:

\[ \begin{align*}
\text{all}x_1 + \cdots + \text{aln}x_n &= b_1 \\
\text{a21}x_1 + \cdots + \text{a2n}x_n &= b_2 \\
& \vdots \\
\text{aml}x_1 + \cdots + \text{amn}x_n &= b_n
\end{align*} \]

(3)

looks rather clumsy and even the abbreviated form

\[ \begin{align*}
\sum_{\text{v}=1}^{\text{m}} a_{\text{mv}}x_\text{v} &= b_{\text{m}} \\
(3')
\end{align*} \]

offers only a reduction in writing. Evidently the system consists of separate parts which are comprehended by the following three "matrices,"

\[ \begin{align*}
A &= \begin{bmatrix}
\text{all} & \cdots & \text{aln} \\
\vdots  & \ddots & \vdots \\
\text{aml} & \cdots & \text{amn}
\end{bmatrix} \\
b &= \begin{bmatrix}
b_1 \\
\vdots \\
b_m
\end{bmatrix} \\
x &= \begin{bmatrix}
x_1 \\
\vdots \\
x_n
\end{bmatrix}
\end{align*} \]

(3'')

which in fact reproduces the essential elements of (3) or (3') when the above notations are assumed. This representation is certainly the shortest which can be imagined; moreover we shall introduce later on the definition of matrix multiplication so that the left-hand member of (3'') not only appears as a symbolic form, but actually describes the algebraic operation represented by the left-hand members of the equations (3).

As can be seen from the above quotation, the concept of matrix, with subsequent developments, enables the simplification of the computation required in resolving a multitude of

simultaneous equations. The tabular form of the input-output table arrays the data in matrix form to which the theory of matrices may be applied.

The outcome of the mathematical solution is shown, in our example, as Table 6-4. This table shows that a stimulation in agricultural output of $100 will produce a 'feed-back' so a total output of $103.33 is reached. The benefit to other industries is seen by scanning column one where forestry output rose by 30¢, iron and steel products by 20¢, metal mining by 8¢ and so on. Assuming that the stimulated output of agricultural was in export markets, this would require a direct import of $6.04 as shown in column one, row 44.
### TABLE 6-4

TOTAL OUTPUT\(^1\) OF EACH INDUSTRY AND TOTAL PRIMARY INPUT RESULTING FROM THE PRODUCTION OF A DOLLAR’S WORTH OF FINAL OUTPUT OF AN INDUSTRY, CANADA, 1949\(^2\)

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>38</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For the total output of each industry and the primary input resulting from the production of a dollar's worth of final output of an industry read the column of that industry.</td>
<td>Agriculture</td>
<td>Forestry</td>
<td>Fishing</td>
<td>Metal mining</td>
</tr>
<tr>
<td>A. TOTAL OUTPUT PER INDUSTRY FROM THE PRODUCTION OF A DOLLAR’S WORTH OF FINAL OUTPUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Agriculture</td>
<td>1.033265</td>
<td>.013404</td>
<td>.000744</td>
<td>.002251</td>
<td>.002090</td>
</tr>
<tr>
<td>2. Forestry</td>
<td>.003059</td>
<td>1.001305</td>
<td>.003199</td>
<td>.005292</td>
<td>.005961</td>
</tr>
<tr>
<td>3. Fishing</td>
<td>.000301</td>
<td>.000002</td>
<td>1.000000</td>
<td>.000008</td>
<td>.000016</td>
</tr>
<tr>
<td>4. Metal mining</td>
<td>.000816</td>
<td>.001421</td>
<td>.000504</td>
<td>1.001166</td>
<td>.001312</td>
</tr>
<tr>
<td>18. Rubber products</td>
<td>.008446</td>
<td>.000913</td>
<td>.000931</td>
<td>.002649</td>
<td>.003933</td>
</tr>
<tr>
<td>20. Textile products</td>
<td>.007538</td>
<td>.004322</td>
<td>.031435</td>
<td>.001744</td>
<td>.002850</td>
</tr>
<tr>
<td>28. Iron and steel</td>
<td>0.020233</td>
<td>0.034266</td>
<td>0.007709</td>
<td>0.021848</td>
<td>0.012319</td>
</tr>
<tr>
<td>B. TOTAL PRIMARY AND UNALLOCATED INPUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44. Imports, goods and services</td>
<td>.060430</td>
<td>.031587</td>
<td>.061397</td>
<td>.098241</td>
<td>.051399</td>
</tr>
<tr>
<td>48. Wages, salaries</td>
<td>.166288</td>
<td>.515387</td>
<td>.210961</td>
<td>.410718</td>
<td>.525780</td>
</tr>
<tr>
<td>51. Capital consumption allowance</td>
<td>.103931</td>
<td>.051056</td>
<td>.168810</td>
<td>.101655</td>
<td>.082623</td>
</tr>
<tr>
<td>Total primary and unallocated input</td>
<td>.998463</td>
<td>.998946</td>
<td>.998950</td>
<td>.998718</td>
<td>.999979</td>
</tr>
</tbody>
</table>

-continued-
Source: This data has been taken from Table 3 in the Dominion Bureau of Statistics supplement to Paper 72, "The Inter-Industry Flow of Goods and Services, Canada, 1949 (Ottawa: Queen's Printer, 1960).

1 The total output of an industry is defined by the D. B. S. so as to exclude the output consumed within the same industry.

2 This table reproduces only a portion of Table 3 and hence is not complete.
Manufacturing Industry Land Study

Petroleum Refining Questionnaire; Confidential Data to be used only as an Industry group study

Date; March 7th, 1962 Firm Name

Data requested by Roy H. Fletcher

Data Requested for following Years

<table>
<thead>
<tr>
<th>Year</th>
<th>1961</th>
<th>1951</th>
<th>1941</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Refinery Throughput for year- (based on intake of crude and semi-finished or finished product) bbls.</td>
<td>4,750,000</td>
<td>1,880,000</td>
<td>1,351,000</td>
</tr>
<tr>
<td>2) Employment during year- #</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. in man days onsite-</td>
<td>47,000</td>
<td>25,000</td>
<td>21,000</td>
</tr>
<tr>
<td>b. in man days offsite-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. mean number employed during year on &amp; off site-</td>
<td>188</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>3) Land Requirements in Industrial Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Acres of Company land in Industrial Zones ;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. onsite-</td>
<td>139</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>ii. offsite -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Acres of land in active use*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. onsite-</td>
<td>77</td>
<td>46</td>
<td>40</td>
</tr>
<tr>
<td>ii. offsite -</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Active use includes; process areas, tank farms, offices, fill stands, blending & packaging plants, rail spurs, road-ways, maintenance areas

# Employees working in the industrial zone only and includes workers at refinery, workers at offsite storage area and workers at offsite fill stands which are in Industrial Zones. (Lake City Tank Farm for example)
APPENDIX IV

AN ESTIMATE OF 1980 THROUGHPUT FROM THE
LOWER MAINLAND REFINERIES (B. C.)

Introduction

This estimate of 1980 throughput from the Lower Mainland Refineries has been prepared to assist in the forecast of land required by this industry group up to 1980. It considers petroleum as one of several competing sources of energy in the Province and endeavors to select the determining characteristics of petroleum that give it market advantage. The probable demand for energy with these particular attributes is then estimated and from this forecast total throughput of the refineries is made.

B. C. Consumption of Major Forms of Energy
1941-1961-1980

Since 1941 the annual consumption of energy in the province has more than doubled. During 1961 an estimated 8,402 tons (coal equivalent) of energy were consumed while in

1Intuitive judgements in this estimate are based on the author's six years' experience as a refinery engineer.
1941 3,717 tons were used. The major forms of energy used in this period comprised petroleum, electricity, gas, coal and wood. While the same forms of energy are used today a drastic change exists in the respective contributions each makes to the total energy consumption.

Fig. 3 illustrates those changes in consumption for the major fuels since 1941. There has been a substantial increase in the use of petroleum, electricity, and natural gas which have substituted for coal and wood. Two significant reasons for this substitution have been the far greater utility of petroleum, electricity, and gas over that of coal and wood, and the improved availability of these substitute energy sources.

Electricity has found exceptional utility in the home and today it has great use for lighting and appliances such as ironers, toasters, refrigerators, furnace motors and so on where other forms of energy are less suitable. It also offers utility in the industrial field where the electric drive motor has tended to replace the steam engine and stationary oil engine as prime movers. When there has been an abundance of inexpensive electric power, such as at Kitimat, it has been used in ore refining processes for reducing aluminum, copper, and iron.

The supply of electric power at less than five mills, or today's competitive rate for electric energy, is in excess of

\(^2\)See Fig. 3.
Fig. 3 CHANGE IN THE CONSUMPTION OF MAJOR FORMS OF ENERGY, B.C. SELECTED YEARS 1941, 1951, 1961

Canada, Central Electric Stations,
" Electric Power Statistics, monthly
" Coal and Coke Statistics, 1961
" Refined Petroleum Products, monthly

Note: Some statistics include both B.C. & Yukon;
1951 plotted values use 1953 data for gas, wood, & petroleum.
the expected demand up to 1980. Thus this source of energy appears sufficient to encourage more consumers to take advantage of its greater utility. It might be expected by 1980 that electricity provides a greater portion of the total energy consumed.

Natural gas has offered its greatest utility in the heating of buildings and in firing industrial type furnaces. In the home the gas offers the least cost heating installation with a minimum cost of operation and maintenance and hence the majority of new heating installations in those areas served by natural gas are gas fired units. Since the introduction of natural gas is recent, 1956 when the B. C. E. converted, the full impact of this fuel has yet to be felt. Natural gas supply is far in excess of current demand and Westcoast transmission Co. has license to export 51 million cubic feet annually until 1981. During the first full year of operations, 1958, they transported 90 billion cubic feet of gas. With a favourable gas supply it is likely that natural gas will be the major source of heating energy by 1980.

---

3 The estimated supply of prime hydroelectric power in B. C. is 22.5 million kw of which 2.7 has been developed. According to J. Davis in Power Benefits and Costs in British Columbia, the additional generating demand by 1980 will be 5.2 million kw for a total of 7.9 million kw. Thus places the expected demand equal to about one-third the supply.

Petroleum products such as gasoline, diesel, and other motor fuels have offered the greatest utility as energy sources for mobile equipment and vehicles. Today the greatest single use for petroleum is in motor gasoline which amounted to 29 per cent of B. C.'s total refinery production. In 1941 less then one and one-half million barrels of motor gasoline were refined and this increased to over three million by 1952 which more than trebled by 1961 to 10 million barrels. Diesel fuel consumption while negligible prior to the dieselization of the railways in the early 1956's rose rapidly to nearly four million barrels in 1961, as shown in Fig. 4.

Increases in consumption of other products also took place in the two decades since 1941 and especially in the last decade. The major increases were in light fuel oils and in the stove oil-kerosene group. Principal uses for these products have been for heating of buildings and for domestic cooking. Since 1951 the consumption of heating oils increased fivefold and generally as a result of the greater utility offered by automatic oil heat.

The relative decline in refinery production of heavy fuel oil reflects the changing rate of conversion of crude oil into its component parts so a greater proportion of gasoline can be produced. It also reflects the increased demand for different products such as light fuel oils and diesel. These curves show refinery output and not total B. C. consumption. In 1961 the refinery output of heavy fuels was less than
Fig. 4 PRODUCTION OF SALEABLE PRODUCTS
B.C. & YUKON REFINERIES

Source - D.B.S. Refined Petroleum Products monthly, 1961
" Refined Petroleum Products annual, 1951, 1952
" Monthly Report on Refined Petroleum Products in Canada 1946
" Petroleum Products Industry in Canada 1941
provincial consumption by over two and one-half million barrels and the difference was imported.5

The supply of petroleum crude oil appears sufficient to expect a continuation of the favourable position in the energy market held by this fuel. The 1960 world production of crude oil approached twenty-two billion barrels and Canada produced 2.5 per cent of this total for over one-half million barrels per day. World reserves in 1960 were more than three hundred billion barrels and they increased from two hundred billion barrels in 1956.6 Thus at present rate of use there is nearly fifteen years proven supply.

The greatest utility and competitive advantage of petroleum lies in the mobile equipment and vehicle fuel market. It can be expected that this market will continue to consume a greater proportion of refined petroleum products. Generally, the use of oil as heating energy will be substituted by natural gas particularly in urban areas or locations of large heating load which justify provision of a pipeline network to supply natural gas. The two important 'mobile' fuels, by quantity, are motor gasoline and diesel fuel. Others that are equally important but not used in large quantity are the aircraft motor and turbine fuels.


In the future, as in the past, there probably will be different types of petroleum fuels such as those required to supply the expected turbine engines for trucks, automobiles and perhaps ultimately the railways. The inaugural use for these turbine drives would possibly occur not in automobiles but in the larger power units of trucks or locomotives. Thus it is unlikely before 1980 that the consumption trends of motor gasoline would alter radically even though there might be change in the use of diesel fuels. In any event, the total consumption of future 'mobile' fuels can be estimated on the basis of today's trends in current combined mobile fuels of diesel and motor gasoline.

The Nature of Petroleum Refining

Petroleum crude oil is a mixture of simple and complex hydrocarbon molecules ranging from the gaseous state through the liquid phase and into the solid state. The composition and mixture of these different molecules will vary between oil fields but will generally consist of four main groups called paraffins, napthenes, olefins and aromatics. Commercial products are made from these groups by selective separation such as distillation, and by subsequent conversion processes. These later operations actually convert or change the structure of the molecule into a different form say by making gasoline from guel oil molecules. Upon completion of the separation and

conversion processes, the finished products are treated to remove undesirable impurities after which they are ready for market storage.

The hazardous nature of petroleum products makes them unsuitable for prolonged storage and all components of the crude oil must be marketed. The ability to convert one type molecule into another greatly facilitates the marketing of the entire contents of the crude barrel but there are definite limits to the degree of conversion. The facility for conversion has been greatly improved over the last two decades as suggested by Fig. 4. In 1941 about 27 per cent of the 'crude barrel' was recovered as motor gasolines. This portion increased to 35 per cent in 1946 and by 1952 it was 39 per cent.

With greater emphasis in the future on the 'mobile fuels' there will be additional need for higher conversion rates in both the gasolines and the diesel-type fuels. As shown in Table 6-1 the conversion rate of diesel between 1955 and 1960 stayed fairly uniform at about 14 per cent, while the production of motor gasoline altered between 30 and 36 per cent. With future advances in petroleum processes it can be expected that the process conversion rates for both diesel and motor gasoline can be improved by 1980. For estimate purposes it will be assumed that the apparent conversion rate of motor gasoline will increase to 42 per cent by 1980 and that in the same time there is likely to be an increase in the apparent diesel fuel conversion rate so it reaches 18 per cent.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation gasoline</td>
<td>1.5</td>
<td>1.4</td>
<td>1.3</td>
<td>1.7</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Aviation turbine</td>
<td>.3</td>
<td>.5</td>
<td>.5</td>
<td>.9</td>
<td>.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Motor gasoline</td>
<td>29.8</td>
<td>30.2</td>
<td>27.6</td>
<td>37.1</td>
<td>35.3</td>
<td>36.4</td>
</tr>
<tr>
<td>Diesel</td>
<td>13.8</td>
<td>14.1</td>
<td>27.6</td>
<td>14.4</td>
<td>14.6</td>
<td>14.5</td>
</tr>
<tr>
<td>Kerosene, stove oil, tractor</td>
<td>10.8</td>
<td>10.2</td>
<td>7.2</td>
<td>8.1</td>
<td>8.4</td>
<td>8</td>
</tr>
<tr>
<td>Furnace oil, no. 2 and light no. 3</td>
<td>12.8</td>
<td>11.1</td>
<td>11.4</td>
<td>13.6</td>
<td>15.1</td>
<td>15.3</td>
</tr>
<tr>
<td>Heavy fuel no. 4, no. 5, no. 6</td>
<td>31</td>
<td>32.5</td>
<td>24.4</td>
<td>24.2</td>
<td>24.2</td>
<td>23.2</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Total consumption (millions of barrels)</td>
<td>22.0</td>
<td>25.4</td>
<td>29.9</td>
<td>23.7</td>
<td>25.3</td>
<td>26.0</td>
</tr>
</tbody>
</table>

Source: Canada, Department of Mines, op. cit. Data derived from Table 38.
The estimated 1980 refinery throughput will be based on these two conversion rates as being co-determining factors in the amount of crude oil to be processed. The greater of the two individual product estimates, motor gasoline and diesel fuel, will determine the total throughput. This assumes that the balance of the crude will be able to satisfy the market economically for all other products. The others would include aircraft fuels, heating and illuminating oils, asphalt production, naphtha specialties including dry cleaning fluids, liquid petroleum gases, lubricating oils, and petrochemical feed stocks.

B. C. Estimated Consumption and Refinery Throughput of Diesel Fuel and Motor Gasoline

Motor gasoline

Motor gasolines are consumed by a great number of individual purchasers for personal automobile transportation. These buyers consume by far the greatest amount of all motor gasolines and therefore future consumption can be estimated by viewing likely changes in the number of these consumers and in the probable changes in the amount they buy. Transportation studies in metropolitan areas of the U. S. forecast a 20 per cent increase in the number of trips per capita between 1959 and 1980. They also forecast, in smaller metropolitan areas,  

that the increased number of trips will be made mostly by automobile with only a slight increase in per capita use of public transit vehicles.

By 1980 it is likely that B. C. and its metropolitan areas will be still auto-dominant so that a 20 per cent increase in person trips can be expected to occur in the private automobile. If we assume that the mean length of the future trip is the same as at present, the estimated consumption of motor gasoline will increase by the expected increase in population as well as by the additional 20 per cent increase in per capita trips.

The B. C. Research Council population forecast for B. C. in 1975 is 2.7 million persons. By projecting their expected trend to 1980 a population of 3.5 million persons might be expected in B. C. At present the B. C. estimated population is nearly 1.6 million. Applying these values to the present annual consumption of motor gasoline, 9.7 million barrels, an estimated consumption in 1980 of 20.2 million barrels can be expected.

With an assumed apparent conversion rate of 42 per cent for motor gasolines, the estimated B. C. refinery throughput could reach 48.3 million barrels by 1980.

**Diesel fuel**

Diesel fuel markets differ from the motor gasolines since there are fewer purchasers. The major buyers of diesel
are the railroad companies and, in lesser degree, the freight trucking companies. In this case there is more opportunity for a contract purchase with greater certainty of price, quality, and quantity.

In B. C. the principal commodity moved by the railways is the prairie grain moving to the Pacific ports for export. Using this shipment as a measure, the estimated future consumption of all diesel fuels will be based on the likely changes in grain export from the Pacific ports.

Grain movements in Canada are made under the direct control of the Board of Grain Commissioners. By adjusting laid down prices at the port and effectively controlling railway shipping costs, the Board can use the port handling facilities at each port to best advantage. At present about 37 per cent of total Canadian grain exports are handled at Pacific ports. With increasing trade between Canada and the Orient this percentage could increase up to 41 per cent of the total exported. With the current world population increasing together with a continuing industrialization of the less-developed countries there can be expected an increased export of Canadian grain. Assuming a mean annual increase of 2 per cent in exports, the estimated grain shipments in 1980 could be some 40 per cent greater than present.

---

9Canada, Board of Grain Commissioners for Canada, Canadian Grain Exports Crop Year 1958-59 (Ottawa: Queen's Printer, 1959).
Applying this increase to the present consumption of diesel fuels, an expected consumption in 1980 of six million barrels could be reached. This would be equivalent to 33 million barrels of refinery crude throughput using the apparent conversion rate of 18 per cent or 44 million barrels if the current 14 per cent conversion rate were used.

The above estimate of diesel fuel assumes that the determining part of the total consumption is that used in transporting grains on the railway. It also assumes that the total diesel uses will be proportional to the change in grain shipments.

**B. C. 1980 probable refinery throughput**

The previous sections have considered the likely amounts of motor fuel, gasoline and diesel, which will be consumed in B. C. by 1980. The estimates have been based on data for provincial consumption in 1961. This also can be construed to be provincial refinery production since at the same time there were no imports of these products.

Of the two estimates, that for the processing of motor gasolines is the greater. Thus the expected refinery processing of crude oil would reach 48 million barrels or over 1.8 times the B. C. throughput in 1961.
Competitive Position of Lower Mainland Refineries

World markets

The refineries in the Lower Mainland are located with access to deep sea tanker shipping and thus are in a favourable physical position to supply all foreign markets with finished products. However whenever export markets consume a variety of products it is more economic to ship crude oil for processing at the market center. In the case where large quantities of only one type product is required, there is an opportunity for trade. An example of this would be in the supplying of aviation fuels to an outpost airfield. However the size of the Pacific petroleum product market is considerably greater in the U. S. than in Canada and it would be less difficult for U. S. refiners to find an economic market for the unconverted portion of the 'crude barrel' left from producing this specialty product. It can be expected in the future that there will be export quantities of specialty products and perhaps more so in the aircraft fuels but the total amount of these exports is unlikely to be determinant in the total amount of crude oil processed.

Domestic markets

The estimated total B. C. refinery throughput has been made for the domestic market available to the B. C. refiners. Location has an important part in the amount processed by any refinery and the more favourable site is one located near the
market which reduces transport costs. Also, nearness to individual product markets is another advantage so that transport costs for all products will be minimized.

In B. C. the market for motor gasoline is predominantly in the Lower Mainland Region and it is unlikely that a radical change will occur in the settlement pattern over the next twenty years. However, with completion of the Peace River Project, there can be expected a great increase in northern settlement comparable with the rate of growth of Edmonton in Alberta. The construction of the power project and the subsequent building of urban and industrial settlements will consume a large amount of motor gasolines.

The market for diesel fuels will follow the route of the railways and, to lesser degree, the highways. At present the bulk of the rail shipments are near the southern border of the province but following increased mineral activity in the Peace River area and the working of the Pine Point deposits, additional rail shipments will occur in the central and northern parts of the province.

With increased markets for both diesel and motor gasoline in the northern part of the province there will be a reduction in the share of total B. C. throughput refined in the Lower Mainland. The refinery at Kamloops might be expected to have a considerably increased share of the total as a result of its nearness to the railways, its proximity to the new trans-Canada highway, and its intermediate position between the southern
and northern markets. It also is favourably located for supply of crude oils via the Trans Mountain Pipeline System and the proposed extension of the B. C. Peace River pipeline.

The two northern refineries, at Taylor and Dawson Creek, are in a favourable position for supplying the increase in northern markets. Also they are close to the supply of crude oil in northeastern B. C. and are connected to it by the Trans Prairie Pipeline Co. system. The Taylor plant is an absorption gas plant which removes liquid petroleum products from the natural gas before it enters the Westcoast Transmission Co. system for shipment to southern markets. Thus, this area is served by refineries with an exceptionally high motor gasoline conversion rate from the enriched crude oil. The capacity of these two refineries is about 5000 barrels per day and in 1961 the Trans-Prairie Pipeline carried 3000 barrels per day. The Westcoast Transmission line carried a gas flow in the order of 90 billion cubic feet during 1958. The export license for the line is in the order of 50 billion cubic feet and possibly this constituted the major portion of the total 1958 flow of gas in the line. Gas consumption in the B. C. E. distribution system reached close to 14 billion feet in 1959 where less than 14 per cent of the residential buildings used this fuel for heating. As the percentage of residences with

---

gas heat increases and as population increases, the domestic flow of gas by 1980 could increase tenfold. Including exports the gas handled in the line could double by 1980. The effect of this on the northern refineries would be to double their production of both motor gasolines and diesel fuels with a very high yield of gasolines. It is possible that the northern refineries will provide ample motor gasolines for the local market but with a conversion favouring gasolines there will be a tendency for under-production for the northern diesel market. Thus it can be expected that a deficit in diesel supply in the northern area would be met by either Alberta Refineries or by the Southern B. C. refineries. It is unlikely that the Kamloops refinery would be able to make up the deficit since, presumably its greatest demand would be for diesel fuels to supply the three railways and also minor amount to provide for an expected increased diesel market on the new Trans-Canada Highway.

As the central and northern parts of the B. C. and Alberta areas become settled they will create a greater market for motor gasolines which will permit more diesel fuel production from the central and northern refineries. This will result in the Lower Mainland refineries producing a smaller portion of the total B. C. refinery throughput. In 1961 about 87 per cent of the total throughput was refined in the Lower Mainland. It is probable that by 1980 this percentage will decline to 85 per cent of the total B. C. throughput.
1980 Throughput in Lower Mainland Refineries

Total energy consumption in B. C. has more than doubled in the last two decades and the lion's share of the increase has gone to products of petroleum. Generally speaking, petroleum has substituted for coal and wood as energy sources which has resulted in a five-fold increase in its consumption since 1941. During the next two decades it is likely that natural gas and electricity will substitute for many of the present petroleum uses where they are more economic and offer a greater utility.

Petroleum products have changed radically over the past twenty years going from a dominant heavy fuel market to a predominantly motor fuel market. This change has followed the advantages and greater utility of petroleum as a fuel for mobile vehicles and equipment. This utility as a 'mobile' fuel is expected to be the greatest advantage of petroleum during the next two decades. While the character of the 'mobile' fuels may change to suit the impending gas turbine drives, it is likely that they will still be served best by petroleum fuels. This advantage will tend to increase the conversion rate of the mobile fuels from the present apparent 60 per cent rate to about 75 per cent.

This estimate assumes that the forecast of 'mobile' fuel demand can be made on the basis of present mobile fuel products and that the determinant product in 1980 will be the equivalent fuel of today's motor gasoline. On this basis a
provincial consumption of motor gasoline equivalent to 50 million barrels of refined crude oil is expected by 1980. During 1961 a little more than 26 million barrels were run to stills in B. C.

Competitive advantages of the Lower Mainland Refineries will decline by 2 per cent up to 1960 with increased settlement and industrial development in the central and northern parts of the province. Thus the Lower Mainland share of the provincial throughput will be in the order of 85 per cent.

This estimate is based solely on provincial domestic markets and it is felt unlikely that foreign exports of refined petroleum from B. C. will occur on a sustained basis. Therefore by 1980 the Lower Mainland Refineries can be expected to refine annually between 35 and 50 million barrels of crude petroleum.