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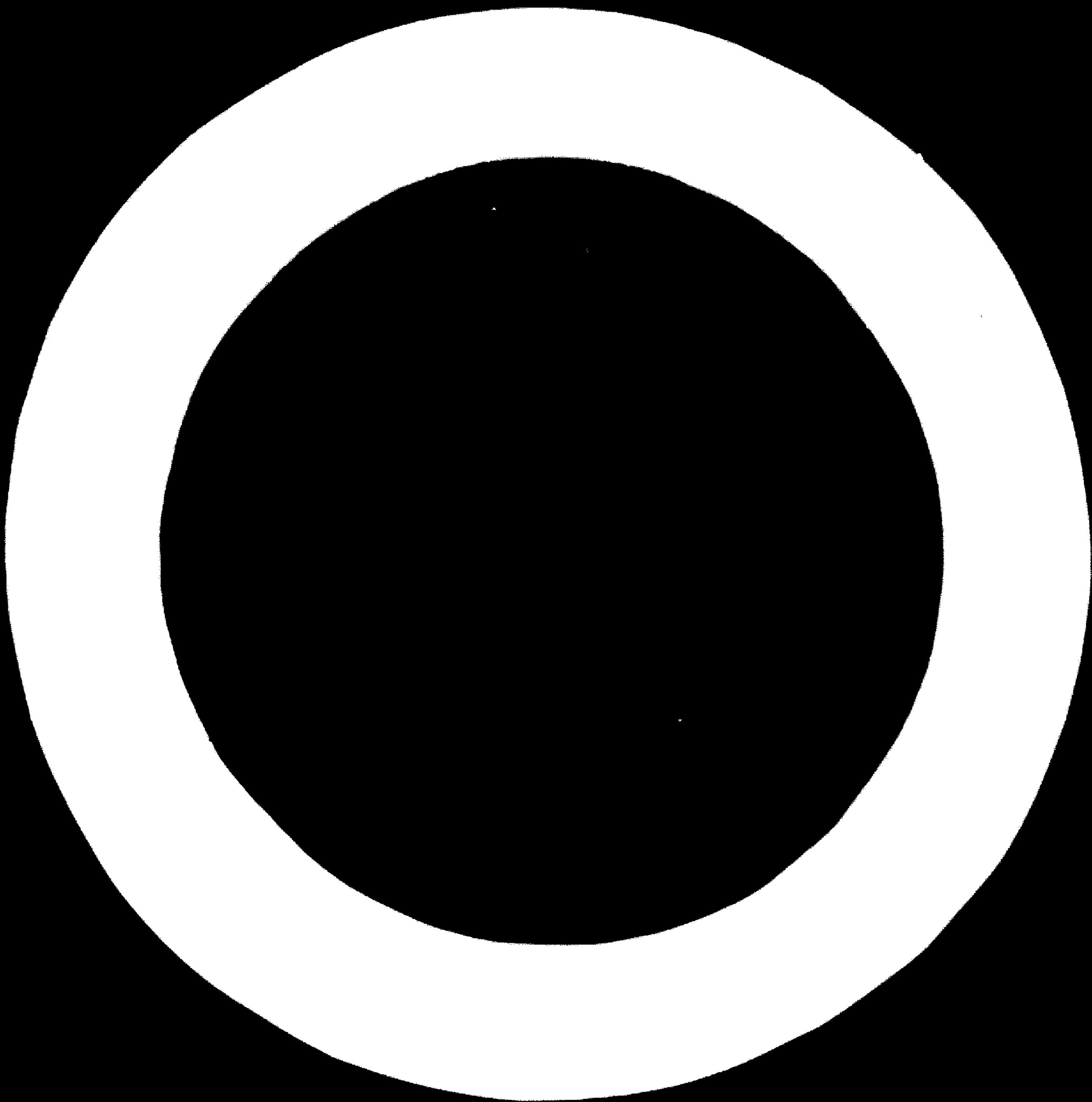
Studies in Economics of Industry

1 Cement / Nitrogenous Fertilizers based on Natural Gas

UNITED NATIONS



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1

Cement / Nitrogenous Fertilizers based on Natural Gas

UNITED NATIONS

New York, 1963

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ST/ECA/75

UNITED NATIONS PUBLICATION

Sales No.: 63. II.B. 3

Price: $U.S. 0.75 (or equivalent in other currencies)

FOREWORD

The need for detailed data on inputs and investment costs for individual industries has been felt by many developing countries engaged in planning their industrial development in connexion with the programming of projects for specific industries. The elaboration of development plans is in general started with highly aggregated projections, but it cannot be confined to this macro-economic level; it is also necessary for operational purposes to link aggregative planning to that of individual industry sectors. Furthermore, availability of pre-investment data is essential in cases where it is necessary to make a preliminary evaluation of the feasibility of establishment of specific industries. In all cases, it is not enough to collect data based on the industrial practice in industrial countries; these have to be analysed and adjusted to the economic and technological conditions of the under-developed countries.

The two studies presented here have been prepared by the Research and Evaluation Division of the Centre for Industrial Development, Department of Economic and Social Affairs, under the work programme formulated by the Committee for Industrial Development (E/3600), and endorsed by the Economic and Social Council in resolution 872 (XXXIII); they form part of a series of studies designed to develop a body of data for a certain number of selected industries of interest to under-developed countries along the lines described above.

The first study, "Pre-investment data for the cement industry", contains investment and other input coefficients for the cement industry based on analysis of data originating in a certain number of countries, both in developed and under-developed areas. The second study relates to the industry of "Nitrogenous fertilizers based on natural gas"; in the latter study major emphasis is placed on the analysis of the differentials in fixed investment and other major input requirements in this industry between a developed country (in this case the United States of America), and a typical developing country.

Explanatory notes

The following symbols have been used in the tables throughout the report:

Three dots (...) indicate that data are not available or are not separately reported

A dash (—) indicates that the amount is nil or negligible

A blank in a table indicates that the item is not applicable

A minus sign (−) indicates a deficit or decrease, except as indicated

A plus sign (+) indicates a surplus or increase

A full stop (.) is used to indicate decimals

A comma (,) is used to distinguish thousands and millions

A slash (/) indicates a crop year or financial year, e.g., 1955/56

Use of a hyphen (-) between dates representing years, e.g. 1953-1955, signifies the full period involved, including the beginning and end years.

References to "tons" indicate metric tons, to "gallons" American gallons, to "dollars" or "$", United States dollars, and to "DM", German (Federal Republic) mark, unless otherwise stated.

The term "billion" signifies a thousand million.

Annual rates of growth or change, unless otherwise stated, refer to annual compound rates.

Details and percentages in tables do not necessarily add to totals, because of rounding.

ILO refers to the International Labour Organisation.

OEEC refers to the Organisation for European Economic Co-operation.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

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I. PRE-INVESTMENT DATA FOR THE CEMENT INDUSTRY

Introduction

Two major considerations have led to the selection of the cement industry as a pilot study in the industrial development data project. First, certain technical characteristics make this industry particularly suitable for international comparisons. Secondly, the establishment of cement plants in newly developing countries is of sufficient importance to merit direct attention.

The technology of the production of cement is a relatively simple one, there being basically few variants—wet and dry processes—the requirements of which differ by an amount well within the order of magnitude of estimating errors.[1] The dry process may be produced either in rotary kiln plants or in automatic shaft kiln plants. This study, however, is confined mainly to rotary kiln plants (wet and dry), but automatic shaft kiln plants are discussed briefly, because of limited data, in appendix I. In general, the technological characteristics of local raw materials, particularly their water content, determine the choice between the wet and dry processes. Cement is moreover a relatively homogeneous product; standard portland cement accounts for over 90 per cent of total output of this item in the United States and Japan and practically all the output in most under-developed countries.

The procedure which has been followed in this study is based upon an examination of the principal components of cost of production and of investment, drawing upon experiences in both developed and under-developed countries. International comparisons are undertaken in order to discover the variations in these elements. An examination of the causes of these variations is then presented to assist those interested in programming the establishment of this industry in the less developed countries, with special attention to factors which are particularly relevant in the latter countries. The data have been drawn from engineering sources; in some instances, however, particularly with respect to fuel and energy inputs, these have been derived from aggregate data for the entire industry. It should be kept in mind that engineering data often reflect conditions which relate to the particular projects from which the data are drawn and to that extent should be cross-checked with data derived from a more aggregated source material. A certain number of data used have been reproduced in appendix I as an aid in using this study in programming the establishment of cement plants in developing countries.

Cement is essentially a resource-tied commodity. Barring exceptional circumstances, cement plants are located close to the quarries of the two basic raw materials, clay or shale and limestone.[2] For this and other reasons, which are noted below, the analysis will not distinguish between quarrying and manufacturing, but will treat the production as an integrated process. It may happen that limestone, which is also an important raw material for other industries, would be purchased from local mining concerns. Appendix I contains some data on inputs for quarrying which permits the identification of the input coefficients concerned.

The composition of unit cost for producing cement is indicated in table 1; the figures are in the nature of orders of magnitude. In the course of this study the major components of cost will be analysed individually.

Table 1. Composition of unit cost for cement production in selected countries

(Percentage of total)

Item	*Germany (Fed. Rep.)*[a]	*USSR*	*USA*
Depreciation	21.6	9.6	22.5
Wages	8.2	22.3	13.9
Fuel	21.0	} 37.1	14.3
Power	12.5		12.6
Others	36.7[b]	31.0[c]	36.7[b]
TOTAL	100.0	100.0	100.0

SOURCES:

Germany (Fed. Rep.). Otto Labahn, *Cement Engineers' Handbook* (Berlin, 1960);

USSR. Loginov, *Cement Industry, Prospects and Development* (Moscow, 1960);

United States. See appendix I to this study.

[a] Dry process plant with 100,000 ton per year capacity; item "Others" includes cost of raw materials, packing, maintenance, overhead, taxes, interest on fixed capital, social security contributions and miscellaneous.

[b] Includes direct material, maintenance, overhead, interest on fixed capital, and miscellaneous.

[c] Includes value of raw and purchased materials (24.6 per cent) and miscellaneous items (6.4 per cent).

Section 1. Analysis of investment requirements

Fixed investment includes equipment for the cement plant and quarrying installations, cost of erection, cost of buildings and storage facilities, land clearing and improvements (drains, sewers, necessary roads, etc.) and miscellaneous administrative and engineering expenses. Because of location problems and the large amounts of power used in production, electric power generating equipment is also sometimes being installed

[1] Technological problems are discussed in appendix I to this study. Cement is also produced, although on a limited scale, as a by-product of several industries, one of which is iron and steel, the raw materials being the blast furnace slag.

[2] Location problems are also discussed below.

on the plant site. Investment requirements for each of these items and their individual components depend in the first place on technical requirements and in the second place on the requirements of the local situation. For more detailed data involved in feasibility analyses, each of these items will have to be examined individually; for the present purpose, which is to provide an indication of the order of magnitude of the investment requirements, these items are aggregated into broad categories on the assumption that such aggregates are less likely to be affected by the individual circumstances. In the analysis which follows, attention will be given to the main variations which are indicative of the problems of quantification involved in programming industry in the newly developing countries.

On the technical level, the prime determinants of plant capacity are the size and number of kilns. The capacities of the other equipment, including equipment in the quarry, crushers and mills, are chosen in conformity with these key items. There appears to be considerable standardization of sizes for those items which bulk large in investment costs; this is due apparently to the efforts of the manufacturers specializing in this type of equipment to reduce their own production costs. As far as the under-developed countries importing this equipment are concerned, the selection of a desired size capacity within the medium range of operation generally selected by these countries should not raise serious problems, in view of the fact that a practically continuous range of capacity in the medium range is available on the international market.

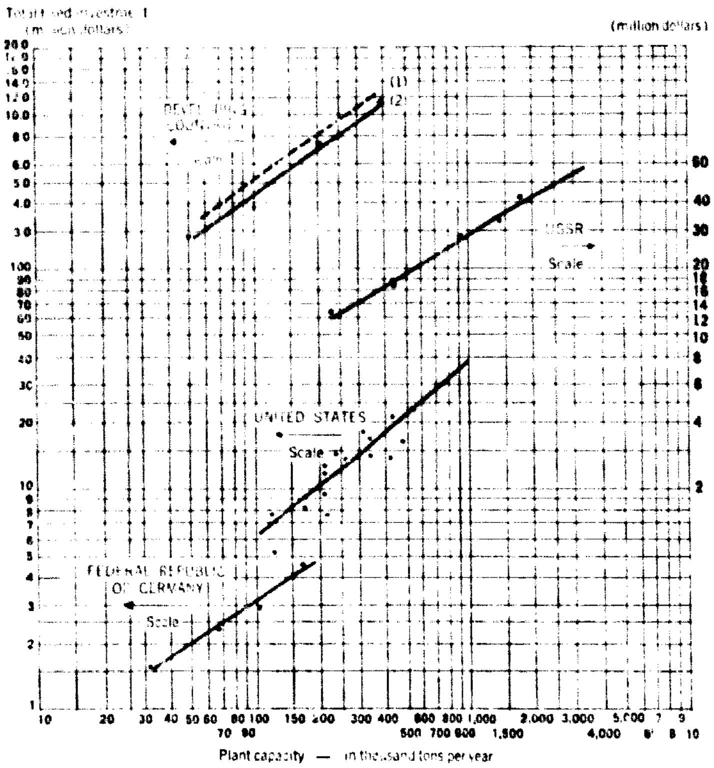
As indicated below, considerable flexibility exists with regard to material handling equipment at the plant and for the quarry. There is also a large degree of latitude with respect to automated quality control devices. Finally, equipment for dust collection varies widely in efficiency and investment costs, the newest and most efficient facilities accounting in some instances for an important portion of total investment.[3]

Requirements for building and storage facilities are also related to size of operations but local conditions play a very important role in determining costs for these items; climate and local standards of accommodation are among such factors. Similarly, land clearing and improvement are affected by location and general regional development. For example, remote sites would require roads and construction of railway sidings for transport.

The influence of scale of operations on total investment costs may be observed on the basis of data available for a number of countries, as shown in chart 1. Data for the United States relate to wet-process plants built in recent years; the data for the Federal Republic of Germany are based upon estimates for dry-process plants derived from a German engineering handbook for this industry, while the Soviet data relate to typical plant designs of recent years. The three sets of data indicate the existence of a constant

[3] In several newly constructed plants in the United States, cost of dust collecting equipments comprised about 5 to 8 per cent of total fixed investment.

Chart 1. Fixed investment related to capacity in Germany (Federal Republic), USSR, United States and developing countries



SOURCES:
Germany (Federal Republic), USSR, and United States: same as for table 1; developing countries; tables 3 and 4.

elasticity between size and total investment costs; that is, a constant ratio between the percentage increase in size and the percentage increase in total investment costs. The elasticity varies from 0.64 in the German data, 0.66 in the USSR data, to 0.77 in the United States data.[4]

[4] The relatively high value for the United States may be partly due to the fact that they are derived from (reported) investments in actual plants, whose design often involves provision for expansion in the near future. This is particularly true of the smaller plants, thus tending to bias the scale factor upward. The data for the other countries presumably applies to plants with balanced capacities at each level.

Direct comparisons of the absolute levels of these costs (see table 2) are extremely difficult for several reasons. The difficulties which beset international comparisons of data expressed in domestic currencies are well known.[5] The data from the USSR for the value of equipment have been converted from roubles into dollars, using a rouble/dollar ratio of 8 to 1; this ratio is based on the rouble price of one rotary kiln and the dollar price for a kiln with comparable

[5] See "Capital Intensity and Costs in Earth-moving Operations", *Bulletin on Industrialization and Productivity*, No. 3, (United Nations publication, Sales No.: 60.II.B.1).

Table 2. Fixed investment related to scale of plant in selected countries

(In dollars per ton of capacity)

Capacity in tons per year	Germany (Fed. Rep.)[a]		USSR[b]		US[b]	
	In dollars	As percentage of cost for 200,000 ton plant	In dollars	As percentage of cost for 200,000 ton plant	In dollars	As percentage of cost for 200,000 ton plant
33,000	48	200				
66,000	35	146				
100,000	29	121			65	120
200,000	24	100	63	100	54	100
400,000	19	79	40	64	45	83
500,000			36	58	43	80
1,000,000			29	46	30	56

SOURCES: Same as table 1.

[a] Dry process plant.

[b] Wet process plant, including power generating equipment. A rouble/dollar ratio of 8 to 1 used for conversion.

specifications. The current official rate, which is equivalent to about a 10 to 1 ratio for Soviet prices prior to the 1961 revaluation of rouble denominations and prices, appears to be too high for many Soviet capital goods.

In an earlier study undertaken by the United Nations Secretariat on construction equipment, it was found that a rate of 4 to 1 appeared to be appropriate for these types of goods.[6] Since the cement equipment industry is among the less advanced sectors, it is felt that the exchange rate for cement investment goods should be higher than that used previously in these studies; as will be seen below the rate which has been chosen nevertheless involves a number of difficulties.

Similar difficulties affect to some extent the comparison of the data for the Federal Republic of Germany with those for the United States. There is some evidence that in terms of purchasing power equivalent for industrial equipment the German mark rate vis-à-vis the United States dollar[7] was substantially higher than the former official rate.

[6] In this study, a "real" parity exchange rate was estimated. It was derived by comparing the prices of capital goods in the Soviet Union with similar capital goods on the international market. In the Soviet Union, price differential policies tend to favour capital goods in the producer goods sectors as compared to those in the consumer goods sectors. For more detailed discussion on the subject see *ibid.*, p. 21.

The lower costs for German equipment as compared to the United States, result in part from the exclusion in the German data of costs of land, land clearing and other development costs involved in opening up the quarry; in addition, the United States data include power generating equipment while the German data do not. The data for the United States plants apparently also include additional equipment for dust collection; highly automatized systems for measuring raw material inputs; more elaborate conveying equipment, and more elaborate building and storage facilities.

Investment data for plants in developing countries are now brought in for purposes of comparison. In table 3 are presented data on the investment costs for plants which result either from estimates or from actual construction records in these countries. Data for a hypothetical German plant described below are presented in the same table as plant A. Other observations designated B to H in this study are based on unpublished data made available to the United Nations.

An attempt was made to make the data comparable as far as possible. The cost of power plants, when included in the estimates, was excluded. Additional costs necessitated by the particular characteristics of

[7] See the studies prepared by the Organisation for European Economic Co-operation: *An International Comparison of National Products and the Purchasing Power of Currencies* (Paris, 1959), and *Comparative National Products and Price Levels* (Paris, 1958).

Table 3. Fixed investment in cement plants proposed for developing countries

(In thousand dollars and percentage)

Item	Plant A[a] (1960)		Plant B (1959)		Plant C (1958)		Plant D (1955)		Plant E (1955)		Plant F (1960)		Plant G (1960)		Plant H (1960)	
Capacity (tons per year)	100,000		66,000		100,000		100,000		200,000		335,000		400,000		400,000	
Process	Dry		Dry		Wet		Wet		Wet		Wet		Wet		Dry	
Investment item	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Machinery and equipment erected[b]	(1,381)	(50.4)	(2,205)	(62.4)	(2,805)	(61.9)	(1,700)	(50.3)	(3,070)	(44.4)	(5,050)	(45.1)	(6,023)	(43.2)	(6,144)	(43.8)
Quarry equipment	119	4.3	130	3.7	144	3.2	140	4.1	280	4.0	485	4.3	485	3.5	485	3.5
Cement making machinery	1,262	46.1	2,075	58.7	2,661	58.7	1,560	46.2	(2,790)	(40.4)	(4,565)	(40.8)	(5,538)	(39.7)	(5,659)	(40.3)
Burning and cooling	...	...	...	...	...	...	...	...	1,150	16.6	2,388	21.3	2,464	17.7	2,283	16.3
Milling facilities	...	...	...	...	...	...	...	...	490	7.1	1,307	11.7	1,416	10.1	1,589	11.3
Others	...	...	...	...	...	...	...	...	1,150	16.6	870	7.8	1,658	11.9	1,787	12.7
Building, foundation, silos	881	32.2	698	19.7	928	20.5	784	23.2	1,900	27.5	2,955	26.4	3,929	28.2	3,928	28.0
Utilities, contingencies and others[c]	476	17.4	633	17.9	796	17.6	893	26.5	1,940	28.1	3,196	28.5	3,987	28.6	3,956	28.2
Total, fixed investment	2,738	100.0	3,536	100.0	4,529	100.0	3,377	100.0	6,910	100.0	11,201	100.0	13,939	100.0	14,028	100.0
Fixed investment per ton adjusted to 1960 prices	$27.4		$55.7		$47.1		$40.5		$41.5		$33.4		$34.8		$35.1	

SOURCE: Appendix I.

[a] Plant A is a hypothetical German plant introduced for comparison purposes.

[b] Except for plant "A", ocean freight and insurance charges are included.

[c] "Utilities" include water supply and drainage facilities, vehicle pool as well as internal roads. It includes also electrical equipment such as starters, transformers, cables, high and low voltage installations, distribution boxes. "Others" include repair shop, spare parts, laboratory equipment, site development and engineering fees.

the project, such as remoteness of the site, which necessitated the provision of housing facilities for plant personnel, access roads, railroad extensions, etc., were also excluded. The costs of ocean freight, insurance, and local transportation of equipment were retained in the comparison. The estimates in these proposals are based mainly on European equipment prices, adjusted to prices of 1960 in order to take account of the difference in the dates to which the estimates relate.

In addition, a large international firm with experience in the cement industry has provided estimates of a range of unit fixed investment costs corresponding to selected scales of operations for plants which are generally suited to the conditions of the under-developed countries (see table 4). It is stated that such plants,

Table 4. Estimated minimal fixed investment costs per ton of capacity appropriate to developing countries

Plant capacity (tons per year)	*Fixed investment (dollars per ton)*
50,000	45–50
100,000	35–40
200,000	30–35
400,000	25–30

SOURCE: See text, p. 3.

including quarries, cover basic minimum equipment requirements and building and storage facilities; transport costs for imported equipment, installation of the equipment and land preparation have been taken into account.

Both sets of data show variation in unit costs with scale similar to that in the developed countries. The general level of costs for the seven proposed or actual plants is higher than that presented for the Federal Republic of Germany and somewhat higher than the minimum levels suggested by cement industry experts. In part, the differences between the data taken from the developing countries and those for the German plants reflect the additional costs of ocean freight, import profits, internal transportation and handling of the equipment. As to the cost of construction, while this tends to be lower in developing countries due to lower labour costs, the high costs of imported materials which are used in these installations tend to offset the former.

On the other hand, the figures in both sets are considerably lower than those corresponding to the United States practice. With respect to this difference, it has been pointed out earlier that the United States cost data cover the cost of a large number of quality control equipment which is not generally found in the under-developed countries and the use of elaborate dust collecting equipment.

Further discussion of the possibilities of reducing investment costs through substitution of labour for capital is dealt with below, in connexion with the discussion of the data on labour inputs.

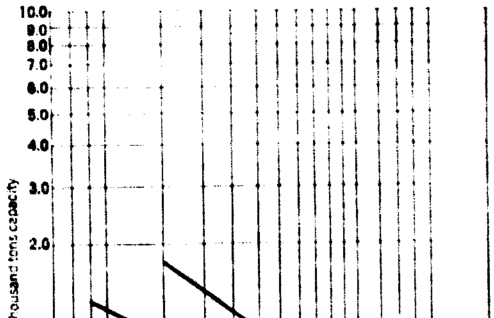
As a guide to the composition of fixed investment expenditure, the following ranges of costs, as suggested by cement experts, are given. Quarry and plant equipment account for 50 to 60 per cent of the fixed investment for plants without power generating equipment, quarrying equipment being some 5 to 10 per cent of total. Building and construction costs generally account for 30 to 35 per cent and miscellaneous administrative and engineering expenses account for the remainder. An additional 10 per cent (i.e., 20 per cent of equipment cost) may be added for expenses of transport in the case of imported equipment while the installation of power plants may add 10 to 15 per cent to the fixed investment costs. These data are of orders of magnitude similar to those suggested by the data for individual plants which are shown in appendix I to this study.

Section 2. Analysis of labour requirements

There are two principal problems relating to labour requirements which are explored in this section. The first relates to the influence of scale of operations on labour inputs; the second is concerned with labour capital substitution and will be examined in the light of the discussion above on capital requirements.

Data on labour requirements for cement production for different scales of operation of plant indicate that total requirements increase very slightly with increases in size of plant; consequently, labour inputs per unit of output fall sharply as scale increases. Data which are available for a wide range of size of plant in Japan, the USSR and the United States are shown in chart 2 and table 5. These figures refer to production workers only; allowances must be made for supervisory and administrative personnel.

Chart 2. Production workers per thousand ton capacity related to certain plant capacities



SOURCE: Same as for table 5.

Table 5. Production workers related to plant capacities in certain countries

(Production workers per 1,000 tons annual capacity)

Plant capacity (thousand tons per year)	*Japan*[a]	*USSR*[b]	*USA*
100	1.24		0.75
200	0.82	1.55	0.48
400	0.62	0.93	0.32
500	0.58	0.78	0.30
1,000		0.51	0.15

SOURCES:

Japan. Ministry of Labour, *Yearbook of Labour Statistics, 1960* (Tokyo, 1960).

USSR. Loginov, op. cit., p. 191.

USA. Estimates based on experts' opinions and data from a case history study of 18 new plants, published in *Rock Products* (May 1958 and May 1959).

[a] Excluding quarry labour. The Japanese data were derived from statistical averages relating average man-hour per ton to several actual output scales (see appendix I). Because capacity utilization in the industry as a whole was 74 per cent in 1959 and an increase in production does not require a proportionate increase in the labour force, labour force requirement, when related to capacity, will probably be lower than those given here.

[b] Based on data for typical plant designs in the USSR, 1958.

Estimates for selected countries of labour inputs, expressed in terms of man hours per ton of cement, are contained in table 6. These have been estimated on the basis of aggregate industry-wide statistics. It is interesting to observe that there are generally minor differences in the average level of labour inputs among the Western European countries and the United States, while the difference between India and the other countries is significant; the latter point shall be discussed below.

As indicated in the discussion of investment requirements, the capital input data for the Federal Republic of Germany and the United States lead to the expectation that labour inputs in the Federal Republic would be higher than in the United States. Comparable investment data are not available for other European countries to permit an evaluation of the variations in these instances.[8]

[8] A study of the cement industry in the United Kingdom, which appeared in the publication *The Structure of British Industry*, edited by Duncan Burns (Cambridge 1958), indicates that the equipment in this industry is relatively old.

Table 6. Average labour productivity in major cement producing countries

(Man-hours per ton of cement unless otherwise specified)

Country	*Year*	*Production and related workers*	*Administrative and clerical staff*	*Total*	*Share of production and related workers as percentage of total*
France	1960	1.83	0.50	2.33	77
Germany (Federal Republic)	1958	2.25	0.23	2.48	91
	1959[a]	1.84	0.34	2.18	84
	1960[a]	1.76	0.34	2.10	84
India[b]	1956	11.00	1.9	12.90	85
Italy	1960	2.02	0.36	2.38	85
Japan[c]	1958	1.79	0.74	2.53	71
	1959	1.54	0.72	2.26	68
Netherlands	1960	1.19	0.25	1.44	83
Switzerland	1960	1.34	0.25	1.59	84
USSR	1958	3.51	0.62	4.13	85
	1959	3.13	0.55	3.68	85
	1960	2.86	0.50	3.36	85
United Kingdom	1960	2.54	0.63	3.17	80
United States	1958	1.33	0.28	1.61	83
	1959	1.22	0.26	1.48	82
	1960	1.25	0.28	1.53	82

SOURCES:

India. *Financial Trends and Productivity in the Cement Industry*, Association of Indian Trade and Industry (Bombay, 1959), p. 78. Estimated on the assumption of 2,400 hours per year.

Japan. "Some Data on the Cement Industry" (Onoda Cement Company) No. 12, 1961 (mimeographed), pp. 45 to 46 (graph).

United States. Output: United States Bureau of Mines, *Minerals Yearbook, 1960*, p. 30. Employment and weekly hours paid: Bureau of Labour Statistics, *Employment and Earnings Statistics for the United States, 1909-1960* (Bulletin 1312), p. 80. Ratio of hours paid to hours actually worked: Bureau of Labour Statistics, *Monthly Labour Review*, January 1962, p. 36.

USSR. Annual output per worker: Loginov, op. cit., p. 111, *Tsement*, No. 5, 1961, p. 6. Annual hours worked: Krasnov, I. D., *Ekonomika stroitel'noi industrii USSR* (The Economics of the Construction Industry of the USSR), Moscow: 1960, p. 263. Allowance was made for progress towards a seven-hour day in 1959-60 (from 2,280 to 2,200 hours per year). Production workers assumed to be 85 per cent of total personnel (see appendix I).

Others. Output and employment: OEEC, *The Cement Industry in Europe*, July 1961. Hours per year adapted from ILO, *Yearbook of Labour Statistics*, 1961.

[a] Based on December employment.

[b] Excludes quarrying and includes contracted labour. The source calls the data "not comparable with other countries".

[c] Quarry labour is excluded from published "Production workers" data, but may be included in the "Total" and (residually estimated) "Administrative".

On the basis of detailed statistics available for the cement industry in Japan, the USSR and the United States, an attempt has been made to analyse inputs of the various components of the labour element: these data appear in table 7. The comparison is, of course, subject to many errors, including the possibility of

Table 7. Average labour requirements by type, selected countries

(Man-hours per ton of cement)

Type of labour and function	*Japan (1959)* Man-hours	Per cent	*USSR (1957)* Man-hours	Per cent	*United States (1959)* Man-hours	Per cent
Production and related workers						
Quarry	—	—	0.27	6.1	0.17	11.5
Cement plant proper						
Direct:						
Raw material preparation	0.24				0.20	
Fuel preparation	0.06		0.98		0.05	
Clinker grinding	0.11				0.12	
Burning (kiln)	0.20		0.52		0.20	
Sub-total	0.61	27.0	1.50	33.9	0.57	38.5
Indirect:						
Power plant and electrical equipment	0.27		—		0.06	
Equipment maintenance and repair	0.39		0.49		0.27	
Material handling, storage and transport	0.12		1.02		0.15	
Packing and shipping	0.15					
Other	—		0.44		—	
Sub-total	0.93	41.1	1.95	44.1	0.48	32.4
TOTAL, production and related workers	1.54	68.1	3.72	84.2	1.22	82.4
Non-production employees						
Engineering and technical	...		0.38		...	
Clerical and office	...		0.16		...	
Guards, janitorial and others	...		0.16		...	
Sub-total	0.72	31.9	0.70	15.8	0.26	17.6
GRAND TOTAL	2.26	100.0	4.42	100.0	1.48	100.0

SOURCES:

Japan. Production and related worker man-hours from Onoda Cement Company, "Some Data on the Cement Industry", No. 12, 1961, p. 45 (mimeographed, Japanese). Total estimated from graph, *ibid.*, p. 45. The residual, ascribed here to non-production employees, may include quarry workers.

USSR. See appendix I for production and related workers. Other personnel estimated from percentage of total labour force in 1957 (Loginov, op. cit., p. 118).

United States. Total and major breakdown from appendix I. The breakdown of production workers is estimated from data in *Tsement* (Moscow), No. 2, 1961, p. 30. The latter source reports an average total for the United States industry in 1959 of 1.29 man-hours, ranging from 0.475 to 2.30.

The comparability of some sub-categories between countries is not reliable. Materials handling personnel in the United States is apparently included in "Direct". In Japan, quarry labour is excluded from published production worker statistics; materials handling in the USSR includes transport of quarry materials to the plant. The major categories, however, appear to be roughly comparable.

differences in definition and scope of the various categories of labour. Judging by the description found in the sources, the content of the category "production and related workers" in Japan and the United States would seem to be conceptually close to "workers" in the USSR. The Japanese data exclude quarry labour, although it is possible that this item is included in the estimate of non-production employees. It is, nevertheless, felt that, for the purpose of the rough comparison which is being undertaken at this point, these data are sufficiently similar in definition.

It can be seen that the divergencies in labour inputs are not uniform for all groupings. This is more readily obvious if the data are rearranged in the form of relatives with figures for United States, assumed equal to 100. The relative man-hours per ton in the major categories are as follows:

Item	*USA*	*Japan*	*USSR*
Quarrying	100	—	150
Plant operation:			
Direct	100	100	250
Indirect	100	200	400
Administration	100	275	275
TOTAL LABOUR	100	150	300

The previous discussion of capital inputs indicated that for the USSR these inputs were high but noted the difficulties involved in the conversion problem. The data on labour inputs suggest that in fact there is considerably less investment requirement per unit of output in the USSR. Moreover, as will be seen below, power input per unit of output which is a crude indicator of mechanization is also lower in the USSR, than in the United States. This may be due to the relatively low level of mechanization of material handling in-plant transportation and various other auxiliary operations in the USSR cement industry; there are indications to that effect in the literature[9] and the data of table 7 appear to corroborate this situation.

In the case of Japan, the lack of data on capital requirements prevents further evaluation. It has also been observed that in Japanese industry material-handling and other operations are carried out with a relatively low level of mechanization.

The data in table 7 support this observation. On the other hand, as regards *direct* labour inputs the Japanese condition seems to correspond closely to that of the United States.

[9] See, for example, Loginov, op. cit., p. 117; M. F. Iurov, "Nekotorye voprosy komplekanoi mekhanizatsii i avtomatizatsii" (Some problems of comprehensive mechanization and automation), *Tsement*, No. 6, 1960.

Table 8. Estimated labour productivity in projected plants[a]

(Man-hours per ton of cement and percentage of total)

Type of labour	*Plant A (100,000 tons capacity)* Percentage	Man-hours	*Plant B (66,000 tons capacity)* Percentage	Man-hours	*Plant C (100,000 tons capacity)* Percentage	Man-hours	*Plant F (335,000 tons capacity)* Percentage	Man-hours	*Plants G and H (400,000 tons capacity)* Percentage	Man-hours
Production and related workers										
Quarrying	24.2	0.50[b]	35.3	1.35	36.5	1.18	5.3	0.15	5.5	0.13
Plant Operation	58.9	1.22	49.5	1.89	49.9	1.61	70.8	2.01	68.9	1.64
Of which:										
Maintenance and repair		[b]	9.4	0.36	11.1	0.36	3.22	0.66	23.9	0.57
SUB-TOTAL	83.1	1.72	84.8	3.24	86.4	2.79	76.1	2.16	74.4	1.77
Administrative and technical staff										
Laboratory	4.8	0.10	2.9	0.11	3.1	0.10	0.3	0.18	6.3	0.15
Technical supervision	4.8	0.10	5.8	0.22	4.6	0.15	3.9	0.11	3.4	0.08
Administration	3.4	0.07	6.5	0.25	5.9	0.19	7.4	0.21	7.5	0.18
Security	3.9	0.08	—	—	—	—	6.3	0.18	8.4	0.20
SUB-TOTAL	16.9	0.35	15.2	0.58	13.6	0.44	23.9	0.68	25.6	0.61
TOTAL	100	2.07[c]	100	3.82	100	3.23	100	2.84	100	2.38[c]

SOURCE:

Estimated from data on labour force for each plant shown in appendix I. Staff requirements for plant A are on a daily basis, i.e., no provision has been made for reserve labour to cover vacation and sick leave or absenteeism. Continual presence in each position was therefore assumed, depending on the number of work days per week in which each operation is conducted (see Labahn, op. cit., p. 75). For the remaining plants, it is assumed that the labour force incorporates reserve requirements, and an average actual work time of 2,400 man-hours per man-year was adopted.

[a] Plant symbols coincide with those in table 4.

[b] Excluding (contracted) quarry labour for removal of overburden and repair shop labour.

[c] Data apply to plant G. Plant H has identical requirements except for an additional 0.05 man-hours needed in the row grinding department.

Table 8 indicates that labour input per ton of cement in several of the above-mentioned plants relating to developing countries also shows, as might be expected, a declining trend with increasing size. This table indicates further the use of a large labour force for quarry operations in plants B and C. The substantially higher labour requirements in the latter operations would seem to reflect the substitution of labour for capital, as appears from the following estimates of investment in quarry as percentages of total equipment costs in five of these plants.

Plants	*Percentage of total*
B	5.9
C	5.1
F	9.6
G	8.1
H	7.9

Moreover, from the description of the equipment used in plants F, G and H, there appears to be a considerable amount of transport machinery not related to the quarrying operations as such but which is used to convey the crushed stone from the quarry or primary crusher. The substitution of labour for capital thus seems to be even greater than indicated by the above data. Nevertheless, it should be kept in mind that there are limitations to the extent to which quarry equipment can be replaced.[10]

It was pointed out in the discussion of investment requirements that, while it was possible to vary capital inputs in quarrying operations, the order of magnitude of savings through substitution of labour was small relative to total investment. Labour input data, on the other hand, indicate that, in spite of the small magnitude of capital saving, the increase in labour inputs in quarrying operations can be very large.[11] As can be seen from the data in table 8, labour inputs in quarrying operations can increase by as much as ten times, increasing the total labour inputs by as much as fifty per cent. This of course reflects in part the decrease in labour coefficient associated with scale; nevertheless it serves to illustrate the order of magnitude of possible capital labour substitution.

With respect to the administrative and technical personnel required both in developed and developing countries, it should be pointed out that many of the differences among countries reflect organizational and institutional arrangements characteristic of the countries concerned.

Attention was drawn at the beginning of this section to an estimate of labour inputs in India which are far in excess of that estimated for the more advanced countries. The source from which this estimate has been taken indicates that the data exclude quarrying operations, but gives no further indication of the factors leading to this situation. Recent studies of the cement industry in India indicate that a very large proportion of the plant in operation is extremely old and requires considerable labour inputs to maintain production. In these circumstances there is a tendency to fabricate spare parts on the site, an operation which is highly labour-intensive. This consideration would not apply in estimating labour requirements for a newly established industry.

On the basis of the discussion above, particularly with regard to the information available for new plants in under-developed countries, a rough indication of production labour requirements in these countries can be given by the following figures providing the range of magnitude (assuming 2,400 hours per man-year):

Annual capacity of plant (in thousand tons)	*Number of workers required per thousand tons*
50	1.4-1.7
100	1.1-1.4
200	0.9-1.2
300	0.8-1.0
400	0.7-0.9

To summarize, labour inputs per unit of output vary significantly with size of operation. Moreover, there are variations corresponding to alternative methods of materials handling in the plant proper while a considerable latitude exists with respect to quarrying operations.

Section 3. Other inputs

A. Fuel

Fuel inputs represent a substantial share of total operating costs in the manufacture of cement. The choice between the energy sources is dependent upon local conditions, the relative prices of coal, gas and fuel oil and the capital costs associated with the use of each source. The technical factors bearing upon this choice are beyond the scope of the present study.

In the view of a number of experts in this field, there appears to be no significant variation in unit fuel requirements with changes in scale of operations. There is some evidence of slight fuel savings in the larger kilns but these are not significant. The principal factor affecting fuel needs is the choice between use of either of the two basic processes since the wet process requires somewhat more fuel than the dry process. In table 9, data on average fuel inputs (expressed in terms of million kilo-calories per ton of cement), are given for a number of countries.

Table 9. Fuel inputs for cement production in selected countries

(In million kilo-calories per ton)

Country	*Yearly average*	*Wet process*	*Dry process*
Japan	1957	1.9	1.6
USSR[a]	1958	2.04	1.62
United States	1959	2.1	1.9

SOURCES:

Japan. Japan Productivity Centre, International Co-operation Administration, *The Cement Industry in Japan* (Tokyo, 1958);

USSR. Loginov, op. cit.;

United States. United States Bureau of Mines, *Minerals Yearbook* (Washington, 1960).

[a] Target norms for 1958 were 1.46 and 1.13-1.25 million kilo-calories per ton for wet and dry processes, respectively.

The differences among countries can be seen to be relatively minor. The estimate given as a production norm for the USSR reflects the estimated consumption for newer plants with recent technical innovations to save fuel. It is reported that the Japanese industry is

[10] Many of these factors have been explored in a study on earth-moving operations, published by the United Nations in *Bulletin on Industrialization and Productivity*, No. 3, op. cit. Among these factors may be cited the smallness of the site which limits the amount of labour that can be used, and the capacity of the cement plant itself, as well as the physical limitations inherent in manual handling of heavy rock.

[11] This statistical peculiarity has already been noted in the study by the United Nations Secretariat of earth-moving operations. It was found in one case that the capital stock per unit of excavation required by a mechanized technique was about twice that required by a labour-intensive one; at the same time the latter required an input of labour per unit of excavation fifteen times higher than the former. See "Capital Intensity and Costs in Earth-moving Operations", *Bulletin on Industrialization and Productivity*, No. 3, op. cit.

currently making considerable efforts to reduce fuel requirements through the improvement of kiln design and the use of heat reclaiming devices. With respect to the data for the USSR, it has been reported that the desire of the Government to mechanize output from the existing plants in the particular year for which the data had been collected has led to a utilization of kilns over their rate of capacity with consequent higher fuel expenditure.[12] Data for recently built plants in the United States indicate that such plants require fuel inputs of the same order of magnitude as the norms indicated for the USSR.

Low fuel inputs have been projected for the new plants in the developing countries for which data are analysed in this study. The dry process plants (plants B and C in the earlier tables) which employ gas as fuel are estimated to require 1.2 million kilo-calories per ton of cement. The wet process plants (plants F and G, using gas and furnace oil respectively) are estimated to require 1.39 million kilo-calories. It can be seen that the fuel requirements of these new plants using new equipment are comparable to those of new plants in developed countries, as mentioned in the previous paragraph.

The possibilities for reducing fuel input by redesigning basic equipment now in use have received some attention by technologists. It appears that the amount of fuel that can be saved through redesign or modification of machinery is of the order of 15 per cent; the possible net saving should of course take into account the cost of the equipment changes and the fact that these modifications would require some additional maintenance.

B. Electric power

There appears to be little change in electric power consumption with changes in the scale of operations. The power inputs are largely related to the nature of the raw material inputs and also to the quality of the final product.[13]

On the basis of aggregate data, average consumption of power in the United States in 1959 was 129 kilowatt-hours per ton, while in Japan in 1957 the comparable figure was 138 kilowatt-hours per ton.

In the USSR, consumption is estimated at 100 kilowatt-hours per ton. The considerably lower figure for power consumption in the USSR reflects a number of the above factors. First, there appears to be some evidence that, on the average, softer raw materials are used; secondly, the quality of the cement is on the average different from that used in other areas. Finally, the lower level of mechanization in the ancillary processes, such as materials handling, which was noted above in the discussion of capital requirements, reduces power input. It would appear in this connexion that Japanese power consumption should also be lower than in the United States in view of the similar situation with regard to materials handling, so that the higher input of energy in Japan should reflect primarily the nature of the raw materials used in cement manufacture.

In developing countries, power consumption for the above-mentioned plant F, which intends to use soft limestone, was assumed as 110 kilowatt-hours per ton, a figure close to the USSR average. On the other hand, plant F where harder raw materials will be used, power consumption was assumed at somewhat higher level, 120 kilowatt-hours per ton. The proposed power consumption figures for both plants are based on actual performance in the country of two plants, one using hard and the other soft limestone as raw materials.

C. Other material inputs

Under the assumption made earlier that quarrying is part of the cement production process, the only raw material input which is necessary for production is gypsum. Estimates of these inputs per 1,000 tons of ordinary Portland cement range from 30 to 50 tons, i.e., between 3 and 5 per cent by weight of final product. Variations are apparently due to the quality of the raw material and that of finished product. Standards for the proportion of additives vary considerably from country to country, as do quality specifications for final product. For example, the gypsum content of ordinary Portland cement in the United States is about 2.3 per cent; in Japan, 4 per cent; in the USSR, 9 per cent. Varieties of Portland cement can contain large proportions of additives; for example, slag-Portland cement in the USSR contains over 50 per cent of additives, and Puzzolan-Portland, about 30 per cent.

D. Transport and shipping costs

In view of the relatively low price per unit of output, transport and shipping costs play an important role in determining the feasibility of any cement plant, and in particular, its location and size. In order to illustrate this point the following data have been taken from a feasibility study relating to the establishment of a cement plant in a South-east Asian country. It was estimated that the cost of production in a proposed 300 thousand-ton plant at a specified location would be the equivalent of $13 per ton. Railway freight charges to two major markets located some 100 miles and 600 miles from the plant were estimated to be the equivalent of $2.60 per ton and $10 per ton, respectively, or some 10 to 70 per cent of production cost; this should be compared to the range of variation of about 100 per cent in the cost of production as a function of size for capacities ranging between 100 thousand to one million tons. Thus it is obvious that the size of the market and the resulting transport factor may be of a magnitude comparable to the size factor and should be carefully considered before reaching any conclusions on the establishment of individual plants. An example of the variations in unit costs of production of cement as a function of size are shown in table 10; the data on unit costs are given only to illustrate this point and may not reflect the actual supply conditions in the individual countries.

In this connexion, mention may be made of the bulk shipping techniques developed in industrial coun-

[12] See Loginov, op. cit., page 126.

[13] Particularly soft raw materials, such as marl and chalk, require less grinding. In the USSR, consumption per ton of cement varies from 35 to 40 kilowatt-hours per ton for chalk to 120 kilowatt-hours per ton for hard limestone.

Table 10. Illustrative unit costs for selected scales of operation in certain countries

Capacity in tons per year	Germany (Federal Republic of): In dollars	Germany (Federal Republic of): As percentage of cost for 200,000 ton plant	USSR: In dollars	USSR: As percentage of cost for 200,000 ton plant	United States: In dollars	United States: As percentage of cost for 200,000 ton plant
33,000	21	150				
66,000	17	121				
100,000	16	107			22	116
200,000	14	100	14	100	19	100
400,000	12	86	11	79	17	89
500,000			10	71	16	84
1,000,000			8	57	12	63

SOURCE: Same as for table 1.

tries in order to reduce transport and bagging costs,[14] particularly where markets can be reached by water routes. This type of transport is extremely cheap for plants with very large capacities but involves some additional investment in equipment that includes shipping, loading and unloading facilities which for most under-developed countries require additional foreign exchange outlay. These shipping techniques involve substantial economies of scale and they are only economical if there is relatively high concentration of demand in consuming centres.

It may also be noted that for countries with limited markets and poor supplies of raw material, there are certain advantages in the establishment of facilities for storing and bagging cement imported by the above bulk shipping techniques. The establishment of such facilities would provide some employment opportunities and would also permit the marketing of cement at favourable prices, based on the low cost bulk cement from large scale producers.

A novel system of distribution which has particular interest for developing countries involves the construction of grinding mills in large cement consumption centres located at large distances from cement plants. These mills would be supplied with clinker from large scale economic plants, and grind it with locally obtained additives. Since clinker is easier to handle and is relatively impervious to spoilage and spillage losses, additional savings would ensue in packing, materials handling, storage and freight. It would also permit greater concentration of clinker production with resulting gains from economies of scale. In the USSR, which has had some experience in this field, it is felt that the system is appropriate when consumption levels at the local points are of the order of magnitude of between 40 and 50 thousand tons per year, at distances of at least between 300 and 500 kilometres from the clinker plants.[15]

[14] Since local materials may be used for bagging, no estimate is provided at this time of the costs involved in this operation. See the data in Appendix I.

[15] Loginov, op. cit pp. 167-172.

Appendix I. Data and sources

INTRODUCTION

The data used draw heavily on current literature in technical magazines, interviews with cement consultant firms, as well as feasibility reports for plants to be established in several developing countries. Data relating to the experience of the USSR were derived mainly from: Loginov, *Cement Industry, Prospects and Development* (Moscow, 1960, in Russian); they relate to both industry averages, as well as model plants. Data for the Federal Republic of Germany are derived primarily from: Otto Labahn, *Cement Engineers' Handbook*. Data for Japan are taken mainly from: Onoda Cement Company, *Some Data on the Cement Industry*, October 1961 (in Japanese); Yasuhiko Ekeuchi and Masao Sato, "a Test Survey for the Analysis of Supply Conditions; a tentative estimation of production functions and capital coefficients for the cement industry", *Keizai-Bunseki*, Japanese Planning Agency, 1960 (in Japanese).

A. RAW MATERIALS

There are four basic chemical elements contained in cement: calcium, silicon, aluminum and iron. Raw material is available over most parts of the world. Following are the raw materials and their principal constituent chemical elements used in the production of cement: limestone (Ca); cement rock (Ca, Si, Al, Fe); marl (Ca); oyster shell (Ca); clay (Si, Al, Fe); shale (Si, Al, Fe); slag (by-product of pig iron smelting) (Si, Al, Fe), sand (Si); calcium carbonate (by-product) (Ca); sandstone (Si); bauxite (Al), diaspore (Al).

The use of the above-mentioned raw materials in cement production may be considerably limited when they contain a high percentage of an undesirable constituent, such as magnesium carbonate in limestone and other calcareous deposits, or excessive sulphur content in gypsum or pyrites.

B. CHOICE OF PROCESSES

i. *Dry vs. wet processes.* The most important factor determining the choice is the water content of the primary raw material. If the water content is high, the wet process will be chosen. This is the case with marl, granulated blast furnace slag, and some clays. If water content is very low, the dry process is preferred. Between these two cases, there is no rule-of-thumb to decide between one process or the other. The following major points enter in the final decision [a] (1) wet process consumes 20 to 25 per cent more fuel per ton than dry process and very cheap fuel may favour the adoption of wet process; (2) consumption of power is less in the wet

[a] In the past, the wet process was preferred because it produced more uniform cement than the dry process. This is no longer the case. Dry process equipment can be designed to produce cement which is homogeneous enough for commercial purposes.

process, 4 to 8 per cent; (3) initial fixed investment costs about 10 per cent more in the dry process than in the wet process; (4) dust; less dust is generally released in the wet process than in the dry process.[b] In the wet process, water is added to the raw materials to produce the slurry which usually contains 35–40 per cent water by weight.

ii. *Other processes.* The present study relates to standard Portland cement. Cement production from gypsum has been tried on a limited scale in some industrial countries. Cement is also obtained as a by-product of the sulphuric acid manufacturing process that utilizes gypsum as raw material. This process is rather highly capital intensive and in the opinion of an authority would not stand competition under normal market conditions for sulphur. This process should not however be dismissed altogether as unfeasible. It is conceivable that a country dependent on gypsum for the production of sulphur may have sufficient demand for both sulphuric acid and cement.

Other processes may be mentioned briefly: (1) processes utilizing blast furnace slags and industrial waste, such as calcium carbonate (a by-product in manufacturing caustic soda); (2) higher quality cements that require precision in proportioning raw mix, and in some cases, special processes and equipment, as well as additional storage facilities. They are: (*a*) high early strength cement; (*b*) low-heat hardening, including "hydraulic" cement used mainly in mass and underwater concrete construction, particularly large dams; (*c*) sulphate resisting cement.

C. Capacity and kiln technology

Until quite recently, relatively small plants were considered most economic. The major economies of scale, it was felt in the United States, were obtained at the level of about 250 thousand tons per year.[c] A change in attitude appears to have taken place throughout the world, and a trend toward larger plants is evident in most countries. From 1950 to about 1960, average capacity per plant in Japan has risen from 200 to 600 thousand tons; in the USSR, from 200 to over 450; in the United States, from 300 to 420. New plants of 2 and 3 million tons per year are no longer a novelty. These changes are due partly to increases in demand, but the advantages of larger kilns and other scale factors are also a major element.

[b] J. C. Witt, *Portland Cement Technology* (New York, Chemical Publishing Co., Inc., 1947).

[c] See S. M. Loescher, *Imperfect Collusion in the Cement Industry* (Cambridge: Harvard University Press, 1959), p. 40.

Table 1-1. Trends in average number of kilns and capacity per plant in selected countries, end of year

	Total			*Average per plant*	
Country and year	*Number of plants*	*Number of kilns*	*Capacity (in thousand tons)*	*Number of kilns*	*Capacity (in thousand tons)*
Japan:					
1950	33	80	7,031	2.4	213
1961 Oct.	49	173	31,175	3.5	636
USSR:					
1950	62	192	12,472	3.1	200
1958	83	286	37,350	3.4	450
1965 planned	102	384	75,000	3.8	735
United States:					
1950	152		45,855	..	300
1960	176		73,850		420

Sources:

Japan. *Some Data on the Cement Industry*; op. cit., p. 9; Yasuhiko Ekeuchi and Masao Sato, "A Test Survey for the Analysis of Supply Conditions; a tentative estimation of production functions and capital coefficients for the cement industry", *Keizai-Bunseki,* Japanese Planning Agency, 1960, p. 53.

USSR. Loginov, op. cit., pp. 61, 77, and 195; I. I. Kholin, "O tipe i moshchnosti namechaemykh k stroitel'stvu tsementnykh zavodav (On the type and capacity of cement plants slated for construction)", *Tsement,* No. 2, 1958, p. 12.

United States. United States Bureau of Mines, *Minerals Yearbook* for appropriate year.

The following table shows standard kilns and corresponding capacities for recently built plants in the United States and norms for model plants in the USSR.

Table 1-2. Standard kilns and plant capacities, Canada, United States and USSR

Capacity tons per year	*Number of kilns and dimension (diameter × length in metres)*	*Capacity tons per year*	*Number of kilns and dimension (diameter × length in metres)*
I. *Canada and the United States*		510,000	2 kilns—3.50 × 3.96 × 122[a]
		1,000,000	2 kilns—5.03 × 4.57 × 4.88 × 140.21[a]
120,000	1 kiln—3.05 × 122	II. *USSR*	
210,000	1 kiln—3.50 × 130	230,000	2 kilns—3.0 × 2.7 × 3.0 × 127[a]
260,000	1 kiln—3.66 × 137 or 3.73 × 140	450,000	2 kilns—3.6 × 3.3 × 3.6 × 150[a]
340,000	2 kilns—3.44 × 122	675,000	3 kilns—3.6 × 3.3 × 3.6 × 150[a]
430,000	2 kilns—3.66 × 137	900,000	2 kilns—4.5 × 170

Sources:

Canada and the United States: "Case History Study of Ten New Cement Plants" and "Case History Studies of Eight Cement Plants Installed in 1958", *Rock Products* (May 1958 and May 1959).

USSR. Loginov, op. cit.

[a] Dumb-bell type kilns. Instead of one uniform diameter they have two or more diameters extending over certain lengths of the kiln.

Table 1-2 indicates that capacities of up to 200,000 tons per year may be built with one technological line. In the United States practice, starting with 340,000 tons, two or more technological lines prevail. In the USSR experience, two technological lines start at 230,000 tons capacity. Returns to scale and the advisability of continuous cement production while overhauling equipment suggest the feasibility of planning at least two technological lines. Four technological lines are the maximum under USSR planning norms.

From the point of view of developing countries, the lower limit to the range of scales may be of particular interest. Rotary kiln plants with capacities ranging between 35,000 and 50,000 tons per year have been built. Recent improvements in the automatic shaft kiln plants (discussed below), that are particularly adapted to low capacities, make them worthy of close consideration in this regard.

D. Initial fixed investment

1. *Federal Republic of Germany*

Total initial fixed investment for a rotary dry process plant with a capacity of 300 tons per day is estimated at 12 million DM. The cost distribution is indicated in the following table.

Table 1-3. Fixed investment, Germany (Federal Republic of) plant A

Item	*Thousand DM*	*Percentage of total*
Cement-making machinery, erected	5,000	43.5
Refractory material, installed	300	2.6
Electrical equipment, installed	300	2.6
Buildings, foundation, silos	3,700	32.2
Workshop and laboratory	450	3.9
Quarry equipment	500	4.4
Rail trades, water supply, drainage	400	3.5
Vehicle pool and works roads	450	3.9
Store (spare parts)	400	3.5
TOTAL	11,500	100.0

SOURCE: Otto Labahn, *Cement Engineers' Handbook* (Berlin, 1960).

The electrical equipment item comprises: motors, starters, distribution boxes, cables in the factory, transformers, high and low voltage installations, lighting. These costs do not include cost of power plant, land, forming the company, investigation of material, and starting up the quarry. The above cost figure was multiplied by the following factors to arrive at the estimated initial investment for the various capacities:[d]

0.55 for 100 tons per day

0.84 for 200 tons per day

1.25 for 400 tons per day

1.50 for 500 tons per day

1.70 for 600 tons per day

2.60 for 1,200 tons per day[e]

2. *United States*

Estimates of initial fixed investment were based mainly on the cost of initial investment of eighteen new plants built in the United States in the period 1956 to 1960. Case histories for eighteen new cement plants constructed during this period were published in *Rock Products* (May 1958 and May 1959). Initial investment was adjusted to prices in 1960. The index used was based on "Marshall and Stevens Annual Index of Comparative Equipment Costs for Cement Manufacturing" and "Engineering News-Record Index of Heavy Construction Costs".[f] The price indices are given below (they are weighed: 70 per cent for equipment, 30 per cent for construction):

1956	85
1957	92
1958	95
1959	97
1960	100

[d] See: Otto Labahn, op. cit.

[e] The factor of 1,200 tons per day was extrapolated.

[f] *Chemical Engineering* (March 6, 1961) pp. 115-116.

3. *India*

Table 1-4. Fixed capital cost per ton of capacity for various cement plants in India

Year	*Actual or estimated investment in fixed capital (in million rupees)* (1)	*Plant capacity (in thousand tons)* (2)	*Fixed investment per ton (in current rupees)* (3)	*Inflating factor index[a] 1951 = 1.00* (4)	*Fixed capital cost per ton in 1951 prices (in rupees)* (5)
1940	5.6	100	56	2.06	115
1949	9.4	50	189	1.15	217
1949	11.0	115	96	1.15	110
1950	11.9	115	104	1.11	115
1950	13.5[b]	115	117	1.11	130
1951	16.8	150	112	1.00	112
1956	7.9[c]	100	79		
1956	12.0[d]	200	60		

SOURCE: G. Rosen, *Industrial Change in India* (The Free Press, 1958), pp. 103-105; index on p. 67.

[a] The index was computed by estimating a weighted average of the "Index for Capital Replacement Cost, 1938-1953: Chemical and Allied Plant" (for machinery) and an index of sales value per ton of output of cement (for building costs). The former was weighted at twice the importance of the latter, based on the balance sheet distribution on fixed assets between machinery and plant. The computed indices are as follows:

Year	*Index*
1939	100
1940	109
1949	194
1950	[illegible]
1951	224

[b] A hypothetical plant. [c] An actual expansion. [d] A planned expansion.

These data have not been discussed in the text as information on the nature of the plants involved was not available in sufficient detail to permit analysis.

4. *Other countries*

The following estimates of capital cost per ton of annual output by the wet process were prepared by a United Nations technical assistance expert for a South-East Asian country. The data relate to 1955.

Capacity		*Capital cost in pounds sterling per ton of annual output*	
Tons per day	*Tons per year*	*With power plant*	*plant Without power*
200	Approx. 65,000	17	16
300	Approx. 100,000	11	13
400	Approx. 125,000	12	11

It was estimated that dry-process plants with similar capacities would cost between 10 and 20 per cent more. The investment cost for a 300-ton per day wet process plant, at 1955 prices, was as follows:

Table 1-5. Fixed investment, plant D

Item	*Cost in thousand pounds sterling*
(1) All cement-making machinery, including reduction gears grinding media (first charge) and fire bricks	350
(2) Electric motors with switchgear and starters, etc.	85
(3) Generating plant steam turbo alternators or (3*a*) *alternative*-transformer station equipment (20KV) (20,000)	155
(4) Quarry equipment-drilling machines, one excavator and dumpers, approx.	50
(5) Laboratory equipment	5
(6) Repair workshop equipment and tools for erection	15
(7) Freight by sea (no insurance), approx.	50
(8) Landing charges and duty, approx.	70
(9) Transport to site	12
(10) Erection (including unloading)	75
(11) Civil engineering work-building, roads, drains, etc.	280
(12) Railway sidings	25
(13) Fuel oil tanks	9
(14) Water supply installation and lighting	20
(15) Supervision, insurances and office expenses	40
(16) Contingencies and consulting engineering fees	100
With steam power plant, TOTAL	1,341
Alternative with transformer station—TOTAL	1,206

The following tables give details of fixed investment for 6 plants. These data are based on feasibility reports prepared for several developing countries and are based on unpublished materials.

Table 1-6. Capital investment, plants B and C (dry process), 1959

(*In thousand dollars*)

Item	*Plant B (100,000 tons per year)*	*Plant C (60,000 tons per year)*
Materials (f.o.b.):		
Quarry equipment	130	144
Kiln	365	480
Cement mill	112	144
Other mechanical equipment including crushers, mills, etc.	324	416
Storage, measuring, and control equipment, laboratories, etc.	639	836
Ocean freight (10 per cent)	157	202
Transport to site (3 per cent)	48	60
Sub-total materials	(1,775)	(2,282)
Erection:		
Supervisory and professional labour	174	202
Local labour	198	264
Erection equipment	57	57
Sub-total erection	(429)	(523)
Buildings, etc.	620	840
Auxiliaries	78	88
Housing for 18 and 15 men	214	228
Design, 5.4 per cent and 5.6 per cent	174	214
Contingencies, 7.5 per cent	247	313
Interest, 6 per cent	212	269
TOTAL, fixed capital	3,749	4,757
Working capital	310	420
TOTAL, capital	4,059	5,177

Table 1-7. Capital investment, plant E with annual capacity of 200,000 tons (wet process)

Item	*Estimated cost, f.a.s. port*	
	In thousand dollars	*In percentage*
Construction cost estimates (1955):		
Quarry and clay pit	86	1.0
Rock crushing	137	1.6
Clay handling	26	0.3
Raw mill	179	2.1
Flotation equipment	144	1.7
Slurry department	75	0.9
Burning and coaling	908	10.5
Coal handling and burning	147	1.7
Clinker grinding and gypsum handling	212	2.5
Cement storage and shipping	130	1.5
General, etc.	385	4.5
Electrical equipment and transmission	379	4.4
Sub-total	(2,808)	(33)
Power plant and auxiliaries	1,115	12.9
Building material, including housing and railroad	1,522	17.7
Spare parts	232	2.7
Ocean freight and insurance	793	9.2
Sub-total	(3,662)	(42)
Design of complete plant	391	4.5
Construction and installation of equipment	718	8.3
Technical assistance during start-up and initial operation	42	0.5
Sub-total	(1,151)	(13)
Preliminary engineering first and second phase	140	1.6

Table I-7 (*continued*)

Item	*Estimated cost, f.a.s. port* — *In thousand dollars*	*In percentage*
Preliminary (limestone investigation and analysis)	75	0.9
Supervision and inspection	175	2.0
Construction:		
Housing for plant personnel	140	1.6
Utilities for housing area	25	0.3
Access road to plant	20	0.2
Communication facilities	50	0.6
Fence, paving and lighting for lower areas	20	0.2
Construction sub-total	(255)	
Logistical support for contractors and field pv.	55	0.6
Contingency for cost variation, etc.	300	3.5
Sub-total	(1,000)	(11.6)
GRAND TOTAL	8,621	100.0
Actual expenditures (9 April, 1959)		
Procurement costs:		
Cement machinery and equipment	3,439	
Power plant equipment	1,159	
Spare parts for machinery	363	
General construction material	539	
Cement	226	
Lumber	196	
Reinforcing steel	181	
Structural steel buildings	745	
Construction and erection equipment	173	
Pol supplies	51	
Administrative supplies	51	
Sub-total	7,123	
Service costs:		
Preliminary engineering	137	
Design fee	391	
Procurement fee	87	
Procurement services	13	
Construction fee	174	
Construction services	713	
Supervision and inspection	235	
Operational technical assistance	91	
	1,844	
GRAND TOTAL	8,967	

Table I-8. Capital investment, plants F, G and H[a]

(In thousand dollars)

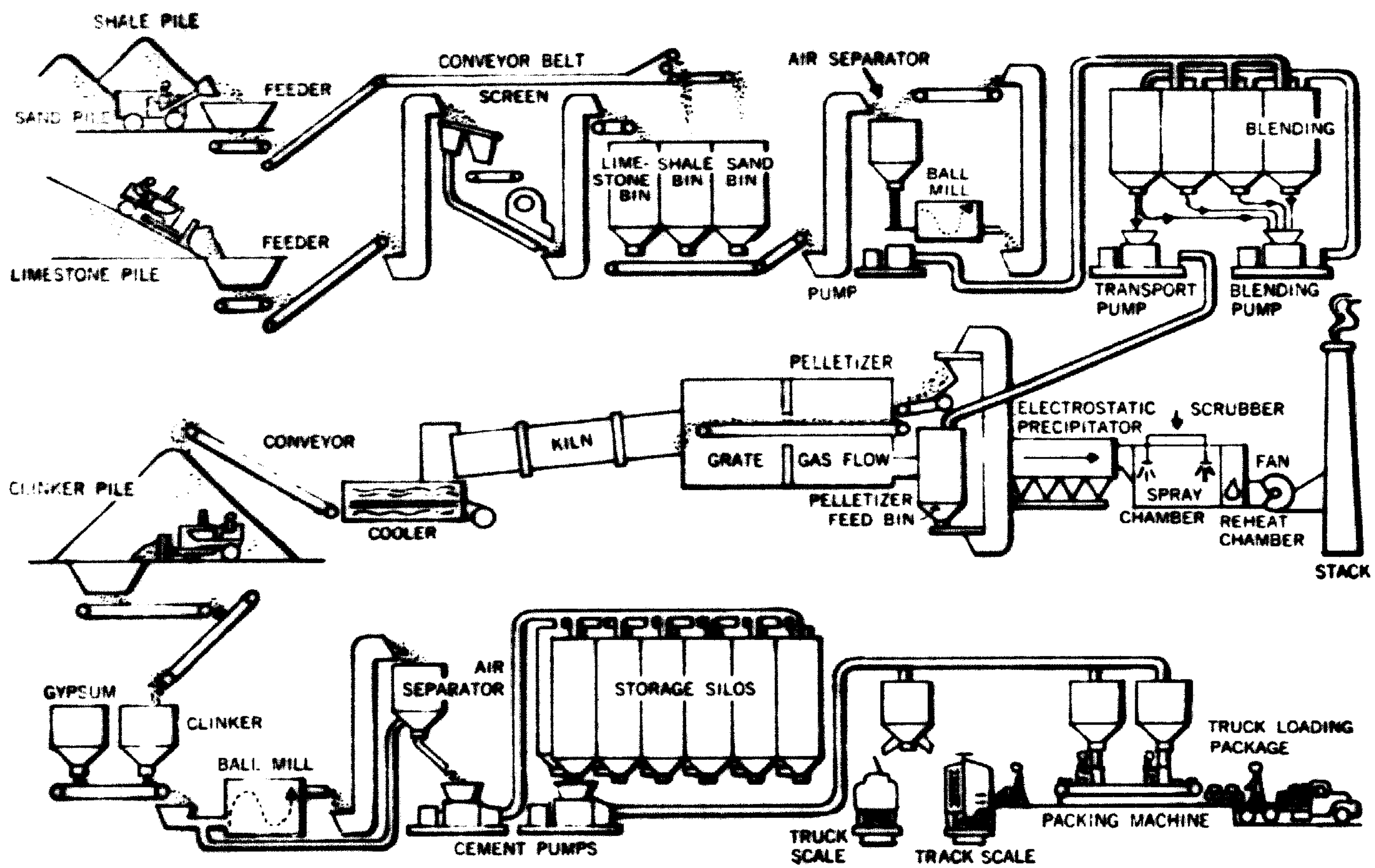
Item	*Plant F 335,000 tons annual capacity (wet process)* — *Foreign currency*	*Local currency*	*Plant G 400,000 tons annual capacity (wet process)* — *Foreign currency*	*Local currency*	*Plant H 400,000 tons annual capacity (dry process)* — *Foreign currency*	*Local currency*
Quarrying	485	30	485	248	485	248
Raw materials handling and storage	347	216	1,089	519	1,089	519
Milling facilities	1,307	402	1,416	466	1,589	521
Raw meal handling facilities	105	207	115	253	244	230
Burning and cooling	2,388	871	2,464	1,060	2,283	980
Clinker handling	115	111	113	117	113	117
Storage, packing and loadout	303	592	341	780	341	777
Plant service and buildings[b]	262	264	262	284	262	284
Utilities	1,113	699	284	445	264	427
Electric power and distribution[c]			1,015	566	1,015	566
Mobile equipment	83	1	151	3	151	3
Site development	34	296	35	282	35	282
Contingencies	601	369	707	499	717	496
TOTAL	7,143	4,058	8,477	5,462	8,588	5,440
TOTAL COST, local plus foreign currency	11,201		13,939		14,028	

[a] Cost is based on prices from the Federal Republic of Germany, Denmark and Italy. Quarry equipment and all electrical equipment based on United States prices.

[b] Building costs are based on structural steel frames and corrugated asbestos roofing and siding for factory building and concrete wall or masonry construction for service and office buildings. Structural steel fabricated and shipped from Europe.

[c] Since cost of power plant is excluded, this item probably includes electrical equipment, motors and other electrical items for distribution of electricity. In plant F, these items are probably included under utilities.

Chart I-1. Flowsheet of a cement plant, United States



E. Prospectus of cement plant equipment

A list of equipment normally used in a modern United States cement plant, summarized from case studies, is given below:

1. In quarrying

Shovel; drill; truck; primary crusher, secondary crusher, vibrating screen (in wet process if hard material used); apron feeder; conveyors, bucket feeders, travelling crane.

2. In cement plant

Raw material: weighing feeder; air separator; ball or ring roll mills; kiln feeder; dryers (for dry process); apron feeder; vibrating screen; conveyors, bucket elevators; slurry tank equipment (in wet process only).

Clinker: kiln; weighing feeder; air separator; cement cooler; clinker cooler; ball mills; conveyors, bucket elevator; vibrating screen; clinker crusher; dust collectors; auxiliary emergency drive for kiln; coal storage, handling, pulverizing and burning equipment, or fuel oil storage, heating, pumping and burning equipment; clinker storage bin; gypsum storage bin.

3. For storage, packing and shipping

Cement storage bin; packaging hopper, and machinery.

4. Power plant

Stand-by generating unit.

5. Laboratory equipment

6. Miscellaneous

Pumping equipment, water storage, maintenance equipment, fire protection equipment.

F. Data on labour input in various countries

1. *Federal Republic of Germany*

Table I-9. Labour requirements,[a] plant A

(100,000 ton per year plant)

Item	Number of workers
Quarrying (lime marl)	
Production (drilling and blasting)	3
Shovel operators	2
Dumper drivers	2
Fitters and maintenance men	3
Quarrying (clay)	
Production (drilling and blasting)	2
Dragline operators	2
Engine drivers	2
Fitters, maintenance men, compressor operators	4
	20
Plant	
Preliminary crushing (labourers)	2
Raw material grinding (mill attendants)	3
Cement grinding (mill attendants)	3
Coal grinding (mill attendants)	3
Kiln installation (burners)	3
Kiln installation (helpers)	3
Raw meal silo (labourers)	3
Cement silo (labourers)	3
Clinker store (crane drivers)	3
Packing plant (packers)	3
Packing plant (helpers)	3
Laboratory (helpers)	3
Store (labourers)	2
Artisans (fitters)	3
Artisans (electricians)	3
General labour (helpers)	9
Checkers (gate-keepers)	3
Total, direct labour	55
Salaried	
Works manager	1
Foreman burners	3
Foreman fitter	1
Laboratory technician	1
Bookkeeper	1
Correspondence clerk	1
Total, indirect labour	8

Source: Otto Labahn, *Cement Engineers' Handbook*, Berlin, 1960.

[a] These figures do not include labour requirement in repair shop.

To prepare the cost estimates appearing elsewhere in this paper, it has been assumed that the same labour force is needed for smaller plants. The following estimates have been made for labour force requirements for 200,000 tons per year and 400,000 tons per year capacity plants:

	200,000 tons per year	*400,000 tons per year*
Quarrying	28	36
Plant	62	74
Salaried	10	11
Total	100	121

2. *Japan*

Table I-10. Labour requirements in Japan by departments and scale of operation, 1959

(Man-hours[a] per ton of cement)

Operation or department[b]	*All plants covered*	*Under 200*	*200 to 300*	*300 to 400*	*400 to 600*	*600 and over*
	Scale of operation in thousand tons per year					
Direct labour						
Drying and mining	0.24	0.48	0.28	0.25	0.22	0.23
Fuel handling	0.06	0.10	0.06	0.08	0.05	0.05
Rotary kiln	0.20	0.36	0.23	0.20	0.18	0.18
Finish mill	0.11	0.23	0.13	0.16	0.09	0.08
Sub-total	0.61	1.17	0.70	0.69	0.54	0.54
Indirect labour						
Material and fuel porting	0.12	0.18	0.13	0.12	0.10	0.12
Boiler and turbine	0.13	0.24	0.13	0.17	0.10	0.12
Power	0.14	0.25	0.18	0.16	0.11	0.12
Repair (by repair shop proper)	0.23	0.49	0.25	0.24	0.24	0.18
Repair (by department crew)	0.16	0.43	0.21	0.13	0.15	0.12
Packing	0.15	0.25	0.13	0.18	0.15	0.13
Sub-total	0.93	1.84	1.03	1.00	0.85	0.79
TOTAL	1.54	3.01	1.73	1.69	1.39	1.33

SOURCE: (Japan, Ministry of Labour), *Yearbook of Labour Statistics, 1960*, p. 72.

[a] Production and related workers only. Excluded, non-production workers that include supervisory and inspection workers not directly engaged in production operations, clerks and technical workers.

[b] Quarrying operations apparently excluded.

Estimates of labour force for different size plants were made on the basis of the above data relating man-hour per ton of output to scale of operation. A man-year of 2,440 hours was assumed. Based on the above data, the following labour force requirements were derived:

Scale of output (tons)	*Number of workers required*
100,000	124
250,000	178
350,000	240
500,000	290

3. United States

Table I-11. Labour requirements by type in three United States plants, 1955
(*Man-hours per ton of cement*)

Item	*Plant 1* (wet process, 84 per cent capacity utilization)	*Plant 2* (dry process, 97 per cent capacity utilization)	*Plant 3* (dry process, 91 per cent capacity utilization)
OPERATION AND FUNCTION:			
Direct:			
Quarrying	0.23	0.05	0.23
Raw material preparation	0.12	0.16	0.16
Coal crushing	0.05	0.05	—
Burning (kiln)	0.17	0.10	0.32
Finish grinding	0.16	0.10	0.07
Indirect:			
Repair	0.16	0.30	0.40
Power	0.09	0.08	0.20
Warehouse	0.02	0.02	—
Packing and shipping	0.20	0.15	0.17
Administrative:			
Technical supervision	0.08	0.12	—
Clerical and office	0.06	0.22	0.31
Laboratory	0.06	0.05	—
Guards	0.08	0.13	0.25
TOTAL	1.48	1.53	2.11

SOURCE: Onoda Cement Co., *Some Data on the Cement Industry*, No. 12 (Oct. 1961), p. 45 (mimeographed, Japanese).

4. USSR

Table I-12. Labour requirements by departments and size of plant in USSR, 1957[a]
(*Man-hours per ton of cement*)

Item	Annual output per plant (in thousand tons): *Under 200*	*200 to 400*	*400 to 600*	*Over 600*	Average for 66 plants: *Man-hours*	*Percentage of total*
Quarrying[b]	0.09	0.43	0.25	0.18	0.27	7.3
Production shops (ex. quarry)	(3.21)	(1.88)	(1.52)	(1.06)	(1.50)	(40.3)
Of which:						
Crushing, milling and drying	1.83	1.20	1.04	0.71	0.98	26.3
Others[c]	1.38	0.68	0.48	0.35	0.52	14.0
Auxiliary shops[d]	3.98	2.61	1.89	1.39	1.95	52.4
Of which:						
Repair shops	—	—	—	—	0.49	13.3
Material handling, trucking and packing	—	—	—	—	1.02	27.3
Other	—	—	—	—	0.44	11.8
TOTAL	7.28	4.92	3.66	2.63	3.72	100.0

Table I-13. Labour requirements by operation in typical plants in USSR
(*Man-hours per ton of cement*)

Operations	*Plant 1*	*Plant 2*	*Plant 3*	*Plant 4*
Production of clinker (all operations, including quarrying and burning)	—	0.39	0.31	0.79
Additive drying	0.37	0.03	0.29	0.35
Cement grinding	0.25	0.18	0.22	0.32
Packing and filling	0.07	0.03	0.10	0.15
Repair and auxiliary shops	0.39	0.64	0.79	1.05
Transport-and-storage	0.62	0.45	0.59	0.58
Laboratory	0.06	0.07	—	—
TOTAL	1.76	1.79	2.30	3.24

SOURCE: A. J. Pen'kov, "O tekhniko-ekonomicheskikh pokazatel' iakh po trudu na tsementnykh zavodakh", ("Techno-economic labour indicators for cement plants"), *Tsement* (Cement), No. 3, 1960, p. 20.

Note: Plant 1 does not produce its own clinker. Plant 2 has easily quarried chalk deposits as lime source (Loginov, op. cit., p. 24). Plant 3 does not have its own limestone source—buys raw materials and uses metallurgical by-products.

SOURCE: Loginov, op. cit., pp. 113, 117 and 122.

[a] Original data in workers per 100,000 tons of output per year, or tons per worker per year were converted to man-hours by assuming an average of 2,280 hours per worker year. See Krasnov, I.D., *Ekonomika stroitel'noi industrii USSR* (Economics of the Construction Industry in the USSR) (Moscow, Gosstroiizdat, 1960), p. 263. Non-worker personnel (engineering and technical, clerical, guards, etc.) are excluded.

[b] Estimated as residual.

[c] Presumably the kiln department (burning).

[d] The breakdown of "auxiliary shops" labour is estimated from percentages given in Loginov, op. cit., p. 117.

Table I-14. Distribution of labour force in plants of a Soviet cement combine

(In percentage of total labour requirement)

Operations	Industrial labour force
Operation of technological equipment (including intra-shop transport in basic production)	23.2
Quarrying (raw material extraction)	6.1
Raw material transport (truck)	5.3
Repair work—all types	30.2
Cement packing and loading-and-unloading operations	12.8
Building repair and construction shops	4.1
	81.7[a]

SOURCE: M. F. Iurov, "Nekotorye voprosy Kompleksnoi mekhanizatsii i avtomatizatsii" (Some problems of comprehensive mechanization and automation). *Tsement* (Cement), No. 6, 1960, pp. 3-6.

[a] The remaining 18 per cent are presumably non-worker (technical, clerical, etc.) personnel.

Table I-15. Distribution of labour force in Soviet cement industry, 1957

Item	Labour force (in percentage of total)
Workers (production and auxiliary) and apprentices	84.2
Engineering and technical employees	8.7
Clerical and office employees	3.6
Other (janitors, watchmen, firemen, etc.)	3.5
TOTAL LABOUR FORCE	100.0

SOURCE: Loginov, op. cit., p. 118.

5. *Others*

Data in tables I-16 to I-18 are derived from unpublished sources. For additional information see section D in this appendix.

Table I-16. Labour force for plants B and C

(Number of persons engaged)

Type of labour	Plant B with 66,000 tons capacity per year: Supervisory and professional (foreign) employees	Plant B: Local employees	Plant C with 100,000 tons capacity per year: Supervisory and professional (foreign) employees	Plant C: Local employees
Quarrying				
Operator		3		3
Driver		4		6
Unskilled labour		30		40
Plant production				
Raw material, operator		3		3
Kiln, operator		3		3
Mills, operator		3		3
Packing and shipping, operator		3		3
Maintenance and repair:				
Skilled	1	6	2	8
Unskilled		3		5
General plant, unskilled		30		40
Administration and technical				
Laboratory:				
Chemist	1		1	
Assistant	1	1	1	2
Electrical technician:				
Engineer	1		1	
Supervisor	1		1	
Mechanical technician:				
Engineer	1		1	
Supervisor	3		3	
Administration:				
Administration manager		1		1
Technical manager	1		1	
Clerks	1	2	1	2
Typists, etc.		2		3
TOTAL	11	94	12	122

Table I-17. Labour force for plants F, G and H

(Number of persons engaged)

Type of labour	*Plant F*[a] *(335,000 tons capacity per year)*	*Plants G and H*[b] *(400,000 tons capacity per year)*
Quarrying	21	22
Plant (production)		
Secondary crushing, surge piles, storage	23	3
Raw grinding	18	18[a]
Burning and clinker cooling	27	27
Finish grinding	18	18
Silos and baghouse	89	87
Warehouse	6	6
Maintenance	92	95
Yard labour	8	19
Sub-total	281	273
Administrative and technical		
Laboratory	25	25
Technical	15	13
Administration	30	30
Security	25	34
Sub-total	94	102
Miscellaneous	14	36
TOTAL	411	433[b]

[a] Wet process.

[b] Plants G (wet process) and H (dry process) are very similar in design, and the projected staff is the same for both with the exception that plant H requires an additional nine men (not shown) in the raw grinding department.

Table I-18. Distribution of labour force by qualification, plants B and C

(In percentage of total)

Qualification	*Plant B*	*Plant C*
Local	89.5	91.0
Unskilled	60.0	63.4
Skilled	29.5	27.6
Supervisory and professional	10.5	9.0
	100.0	100.0

G. Average total cost

1. *Federal Republic of Germany*

Average total cost for the various capacities was computed on the basis of information available in Labahn, *Cement Engineers' Handbook*. In the *Handbook* calculations were given for 100,000 ton per year dry process plant. The plant uses lime marl and clay as raw material.

Table I-19. Average total cost per ton related to capacity (wet process)

(In DM)

Item	*Capacity in thousand tons per year* 33	66	100	200	400
Salaries	1.93	0.96	0.64	0.45	0.23
Wages[a]	11.70	5.85	3.97	2.34	1.43
Raw material	2.41	2.41	2.41	2.41	2.41
Fuel[b]	13.80	13.80	13.80	13.80	13.80
Power[c]	6.00	6.00	6.00	6.00	6.00
Packing[d]	5.00	5.00	5.00	5.00	5.00
Maintenance[e]	3.90	3.00	2.50	2.00	1.60
Overhead	2.00	2.00	2.00	2.00	2.00
Miscellaneous[f]	11.42	9.34	8.31	7.62	6.94
TOTAL, above items	58.16	48.36	44.63	41.62	39.41
Depreciation on fixed capital	18.00	13.64	10.80	9.18	6.98
Interest on fixed capital	12.00	9.10	7.20	6.12	4.65
TOTAL	88.16	71.10	62.63	56.92	51.04

[a] Includes wages in quarrying.

[b] Consumption of fuel for a wet process assumed at 25 per cent (1.38 million kilocalories per ton) more than dry process.

[c] Consumption of power in a wet process assumed at 85 kWh per ton, 6 per cent less than dry process.

[d] 100 per cent packed.

[e] Repair shop wages, spare parts, lubricants. Assumed at 2 per cent of initial fixed investment.

[f] Taxes, interest, social security contributions, directors' salaries, profits, bonuses, statutory reserve, etc. At 15 per cent of average total cost.

2. *United States*

The United States experience is based primarily on data from a case history study of eighteen new plants mentioned above and experts' opinion. The following table summarizes the experience of the United States:

Table 1-20. United States cement industry, capital requirement, operating date, input-output coefficients related to standard capacities (wet process)

	Capacity in thousand tons per year						
	120 (1 kiln 3 × 122 metres)	*210 (1 kiln 3.5 × 130 metres)*	*260 (1 kiln 3.66 × 137 metres)*	*340 (2 kilns 3.44 × 122 metres)*	*430 (2 kilns 3.66 × 137 metres)*	*510 (2 kilns 3.5 × 3.9 × 122 metres)*[a]	*1,000 (2 kilns 5 × 5.57 × 4.88 × 140.21 metres)*[a]
CAPITAL REQUIREMENT (*in thousand dollars*):							
1. Fixed capital[b]	7,000	11,250	13,200	16,000	19,000	21,000	30,000
2. Working capital (6 days)	210	320	380	480	580	650	1,040
TOTAL	7,210	11,570	13,580	16,480	19,580	21,650	31,040
OPERATING DATA, THROUGH SHIFTS AT 90 PER CENT TOTAL CAPACITY (*in thousand dollars*):							
1. *Material and supplies*							
Direct material							
Limestone[c]							
Clay[c]							
Gypsum	22	38	46	60	78	92	180
Bags[d]	37	66	79	104	135	159	311
Supplies[e]	90	140	160	200	240	260	380
TOTAL	149	244	285	364	453	511	871
2. *Power, fuel and water*:							
Power	227	401	485	610	822	968	1,894
Fuel	256	450	544	710	923	1,089	2,130
Water	14	24	29	38	49	58	113
TOTAL	497	875	1,058	1,378	1,794	2,115	4,137
3. *Manpower*							
(a) *Direct labour*	400	510	570	700	780	810	810
(b) *Indirect labour*:							
Managers and supervisors	30	48	48	77	77	77	77
Chemists	17	17	17	17	17	17	17
Office	17	27	32	38	38	38	38
Others	19	24	29	34	34	34	34
TOTAL	83	116	126	166	166	166	166
Miscellaneous and contingencies[f]	210	338	396	480	570	630	900
TOTAL, operating cost	1,339	2,083	2,435	3,088	3,763	4,232	6,884
PHYSICAL INPUTS AND COEFFICIENTS PER TON OF OUTPUT:							
Limestone (in tons)	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Clay (in tons)	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bags (number of bags)	23	23	23	23	23	23	23
Power (in kWh)	115	115	115	115	115	115	115
Fuel (in million BTU)	5.85	5.85	5.85	5.85	5.85	5.85	5.85
Water (in cubic metres)	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Gypsum (in per cent kilogrammes of weight)	40	40	40	40	40	40	40
Manpower (number):							
Direct labour:							
Skilled	15	19	21	26	29	30	30
Semi-skilled	15	19	21	26	29	30	30
Unskilled	45	57	63	78	87	90	90
TOTAL[g]	75	95	105	130	145	150	150

Table I-20 (*continued*)

	Capacity in thousand tons per year						
	120 (1 kiln) 3 × 122 metres)	*210 (1 kiln 3.5 × 130 metres)*	*260 (1 kiln 3.66 × 137 metres)*	*340 (2 kilns 3.44 × 122 metres)*	*430 (2 kilns 3.66 × 137 metres)*	*510 (2 kilns 3.5 × 3.9 × 122 metres)[a]*	*1,000 (2 kilns 4 × 5.52 × 4.8 × 140.21 metres)[a]*
Indirect labour:							
Managers and supervisors ..	3	5	5	5	5	5	5
Chemists	2	2	2	2	2	2	2
Office	3	5	6	7	7	7	7
Others	4	5	6	7	7	7	7
TOTAL	12	17	19	21	21	21	21
ECONOMIC COEFFICIENTS, THREE SHIFTS AT 90 PER CENT OF TOTAL CAPACITY (*in dollars per ton*):							
Direct labour	3.70	2.68	2.48	2.33	2.00	1.76	0.90
Direct material and water	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Power	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Fuel	2.37	2.37	2.37	2.37	2.37	2.37	2.37
Indirect labour and overhead cost[h]	3.37	3.13	2.97	2.82	2.50	2.30	1.61
Depreciation on fixed capital	4.93	4.50	4.36	4.05	3.70	3.47	2.53
Interest on fixed capital	3.89	3.55	3.44	3.20	2.92	2.74	2.00
AVERAGE TOTAL COST	21.03	19.00	18.39	17.54	16.26	15.41	12.18

SOURCE: Table calculated from data supplied by experts and data given in case history study of eighteen new plants issued in *Rock Products*, May 1958, May 1959.

[a] Dumb-bell type kilns. Instead of one uniform diameter they have two or more diameters extending over certain lengths of the kilns.

[b] Includes plant and quarry equipments, buildings and storage, land, excavation. Foundations and installations used.

[c] Included in land depreciation.

[d] Twenty per cent of production packaged.

[e] Refractories bricks, clay and cement, maintenance and repair parts, lubricants, hand tools, and maintenance insurance.

[f] Includes insurance, interest, sales cost, office supplies, auditing and legal services.

[g] Includes labour in quarry.

[h] Includes supplies and miscellaneous.

H. AUTOMATIC SHAFT KILN PLANTS

The standard capacity for this type of plant is 100,000 tons per year, with two kilns of 150 tons per day each. The upper limit is attained with four technological lines, giving 200,000 tons per year capacity. A cement plant with a capacity as small as 25,000 tons per year is possible with one 75-ton per day kiln. These plants may be designed for easy installation, making them adaptable for remote locations. Another advantage is the possibility of relocation of such plants, provided that they are designed with that purpose in mind. It is claimed that between 80 and 90 per cent of initial investment is recoverable.

Fixed investment is about 20 per cent lower than for an equivalent dry rotary kiln plant, according to Labahn. No data are available on over-all labour requirements. According to German and Swiss experience, fuel consumption is 0.85 to 1.20 million kilo-calories per ton of clinker.

There are several important limitations of the use of automatic shaft kilns. They are adapted only to the dry process. Raw material specifications as to plasticity and uniformity must be relatively high; a lower water content is presumably also desirable as in other dry processes. Only "lean" fuels with a small volatile material content, such as metallurgical coke or anthracite, can be used in the process. One manufacturer of the kilns has recently announced a successful experiment with either oil or gas firing. The limited maximum capacity of plants equipped with shaft kilns is another consideration, particularly where market conditions show promise of exceeding the 200,000 tons per year limit.

Furthermore, cement produced by shaft kilns has been of inferior quality (less uniform) compared to products of rotary kilns. Several manufacturers of shaft kilns, however, seem to have overcome this problem, largely through improvements in raw material and fuel preparation equipment and techniques. There is good reason to believe that a greater degree of technical know-how and operator skills is required than with rotary kilns. The more complex technology may be an important drawback to the use of shaft kilns in developing countries.[g]

[g] Sources on automatic shaft kilns:

(i) Otto Labahn, *Cement Engineers' Handbook*.

(ii) Herbert Hughes, "The De Roll Vertical Kiln", *Mining Engineering* (Dec. 1956).

(iii) Steven Gottlieb, "Shaft Kilns Solve Fuel Problems in Australia", *Rock Products* (October 1959).

(iv) Nathan C. Rockwood, "Uniform Cement from Vertical Kilns in Australia", *Rock Products* (March 1959).

Appendix II. Trends in production, consumption and trade

This appendix presents background statistical data on cement covering mainly the post-war period, although data for the pre-war years 1937-1938 are given for reference purposes. The following is a summary of the trends as derived from the available data.

Since 1947 world production of cement has been steadily increasing at the rate of 9.2 per cent per annum; a lower rate of growth, 7.9 per cent annually, has obtained, however, in the last decade. The fastest growing rates are shown by the Asian countries, the centrally planned economies, and the countries of the Middle East; North America registered the slowest growth. These differentials in rates of growth resulted in changes in the pattern of cement production and in the share of various regions in total world production. Although North America and Western Europe together still account for the greater part of world total output, their share has decreased from 72.1 per cent in 1947 to 51.0 per cent in 1960.

The substantial increase in world production of cement is reflected in the level of per capita consumption. Table II-4 shows the level of per capita consumption and the historical trend of this magnitude for a selected number of countries.

Western Europe has been the most active region in international trade. It has been predominant in the export market and maintained its relatively high share of total world imports. The trend, however, has been towards a decrease in this share.

Despite the increase in local production of cement in developing regions of the world, they remained most active in the import market, except for Latin America, which has consistently reduced its share of total world imports, from 37.7 per cent in 1947 to a low of 4.7 per cent in 1960. Africa remained a major importer of cement although its share in the total shows a slightly declining trend. On the other hand, Asia, the Middle East and the countries of centrally planned economies show an increasing trend for their share of total world imports. On the export side the share of the developing countries of the world has increased from about 4 per cent in 1947 to about 27 per cent in 1960. Countries of centrally planned economies recorded also a high increase in their share of the export market.

The share of North American countries in world trade, despite their high share in world production, has been relatively low.

Net trade as depicted by net exports and net imports by regions (see chart II-2) show that western Europe and countries of centrally planned economies have been net exporting regions. Since 1952, however, the volume of net exports of the former region has shown a declining trend.

Africa, the Middle East and Latin America have been net importing regions, with the latter region achieving gradually a position of self-sufficiency. Since 1951, Africa has recorded a slow downward trend in the volume of net imports.

Asia has been on the average a net importer since the war, although the region has been approaching self-sufficiency since 1955.

In the years immediately after the war the North American countries were net exporters, after which followed a period of self-sufficiency, a situation of net imports since 1953.

World trade comprises a small share of total world production, and has indicated a moderate downward trend (see charts II-3 and II-4). This downward trend is explained mainly by the increase in the production capacity of developing countries and consequently the share of local output in total demand has increased while that of imports has declined. This is indicated by the significant decrease in the ratio of imports to production in Latin America, Africa and Asia.

Table II-1. Rate of growth in cement production, by regions

(Percentage per annum)

Area	*1947-1960*	*1950-1960*
Africa	9.0	7.2
North America	4.3	3.6
Central and South America	8.6	7.6
Asia	16.4	12.9
Middle East	10.8	10.2
Oceania	7.2	6.7
Western Europe	9.0	6.4
Centrally planned economies[a]	13.9	11.6
World average	9.2	7.9

Source: Calculated from table II-2.

[a] Including China (mainland) and North Korea.

Table II-2. World cement production, 1937, 1938 and 1947 to 1960

(In thousand tons and percentages)

Area	*1937*	*1938*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*
WORLD TOTAL																
Actual	81,400	87,500	86,250	103,000	115,600	132,400	150,000	160,000	178,000	193,000	217,000	235,000	247,000	263,000	294,000	314,000
Percentage	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Africa																
Actual	1,211	1,295	1,968	2,115	2,238	3,116	3,493	3,754	4,192	4,731	5,347	5,669	6,037	6,474	6,622	6,891
Percentage	(1.5)	(1.5)	(2.2)	(2.1)	(1.9)	(2.4)	(2.3)	(2.3)	(2.4)	(2.5)	(2.5)	(2.4)	(2.4)	(2.5)	(2.3)	(2.2)
North America																
Actual	21,113	19,166	34,253	37,844	38,902	41,928	45,269	46,019	49,184	50,639	57,705	61,512	59,182	61,389	66,372	62,330
Percentage	(25.9)	(21.9)	(39.7)	(36.7)	(33.7)	(31.7)	(30.2)	(28.8)	(27.6)	(26.2)	(26.6)	(26.2)	(24.0)	(23.3)	(22.6)	(19.8)
Latin America																
Actual	2,333	3,199	5,028	5,344	6,364	7,225	7,913	8,892	9,766	10,727	11,967	13,407	14,851	15,293	15,772	16,784
Percentage	(2.9)	(3.7)	(5.8)	(5.2)	(5.5)	(5.5)	(5.3)	(5.6)	(5.5)	(5.6)	(5.5)	(5.7)	(6.0)	(5.8)	(5.4)	(5.3)
Asia																
Actual	8,731	8,959	3,598	4,416	6,748	8,627	11,684	12,830	15,027	17,857	18,075	20,989	24,305	25,669	29,140	35,750
Percentage	(10.7)	(10.2)	(4.2)	(4.3)	(5.8)	(6.5)	(7.8)	(8.0)	(8.4)	(9.3)	(8.3)	(8.9)	(9.8)	(9.8)	(9.9)	(11.4)
Middle East																
Actual	794	761	1,247	1,344	1,511	1,836	2,053	1,999	2,339	2,654	3,289	3,701	4,234	4,538	5,307	5,664
Percentage	(1.0)	(.9)	(1.4)	(1.3)	(1.3)	(1.4)	(1.4)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)	(1.7)	(1.7)	(1.8)	(1.8)
Oceania																
Actual	975	1,075	1,180	1,275	1,325	1,530	1,390	1,620	1,880	2,250	2,400	2,590	2,862	3,017	3,018	3,210
Percentage	(1.2)	(1.2)	(1.4)	(1.2)	(1.1)	(1.2)	(.9)	(1.0)	(1.1)	(1.2)	(1.1)	(1.1)	(1.2)	(1.1)	(1.0)	(1.0)
Western Europe																
Actual	36,472[a]	40,725[a]	27,932	36,038	41,726	48,252	53,249	56,992	62,726	67,081	75,333	78,793	80,893	82,582	92,247	97,929
Percentage	(44.8)	(46.5)	(32.4)	(35.0)	(36.1)	(36.4)	(35.5)	(35.6)	(35.2)	(34.8)	(34.7)	(33.5)	(32.8)	(31.4)	(31.4)	(31.2)
Centrally planned economies[b]																
Actual	9,660	10,385	10,149	13,390	16,750	19,765	20,718	25,369	28,971	32,230	37,705	40,882	46,801	52,890	61,057	70,886
Percentage	(11.9)	(11.9)	(11.8)	(13.0)	(14.5)	(14.9)	(13.8)	(15.9)	(16.3)	(16.7)	(17.4)	(17.4)	(18.9)	(20.1)	(20.8)	(22.6)
China (mainland),[c] *North Korea*																
Actual	...	2,290	749	...	660	...	2,490	2,362	3,904	4,831	4,863	6,990	7,755	10,543	14,196	14,795
Percentage	...	(2.6)	(.9)	...	(.6)		(1.7)	(1.8)	(2.2)	(2.5)	(2.2)	(3.0)	(3.1)	(4.0)	(4.8)	(4.7)

SOURCE: United Nations, *Statistical Yearbook.*

[a] Including Eastern Germany.

[b] Including China (Mainland) and North Korea.

[c] Beginning 1951, including North Korea.

Table II-3. World trade in cement, 1937, 1938 and 1947-1960[a]

(In thousand tons and percentages)

Area	1937	1938	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Africa																
Import—actual	1,068	995	865	1,617	2,036	2,038	2,884	2,803	2,556	2,528	2,488	2,275	2,298	2,266	2,400	2,848
Imports as percentages of total imports	(18.8)	(19.7)	(19.7)	(27.0)	(26.5)	(26.1)	(29.1)	(28.9)	(24.2)	(24.8)	(19.4)	(18.1)	(18.4)	(20.2)	(21.0)	(24.2)
Export—actual	30	24	20	20	28	144	135	87	222	174	246	272	340	260	317	253
Exports as percentages of total exports	(.5)	(.5)	(.4)	(.3)	(.4)	(1.7)	(1.2)	(.8)	(1.9)	(1.6)	(1.8)	(2.1)	(2.7)	(2.3)	(2.6)	(2.4)
North America																
Import—actual	328	310	199	225	383	461	527	544	450	441	1,361	1,304	839	616	925	719
Imports as percentages of total imports	(5.8)	(6.1)	(4.5)	(3.8)	(5.0)	(5.9)	(5.3)	(5.6)	(4.3)	(4.3)	(10.6)	(10.4)	(6.7)	(5.5)	(8.1)	(6.1)
Export—actual	78	111	1,168	1,022	781	417	500	542	437	337	459	451	534	237	322	196
Exports as percentages of total exports	(1.3)	(2.2)	(26.1)	(16.2)	(10.0)	(4.8)	(4.6)	(4.9)	(3.7)	(3.1)	(3.4)	(3.5)	(4.2)	(2.1)	(2.7)	(1.9)
Latin America																
Import—actual	925	828	1,658	1,750	1,755	1,780	2,050	2,120	1,795	1,415	1,350	905	994	687	677	555
Imports as percentages of total imports	(16.3)	(16.4)	(37.7)	(29.2)	(22.8)	(22.8)	(20.7)	(21.9)	(17.0)	(13.9)	(10.5)	(7.2)	(7.9)	(6.1)	(5.9)	(4.7)
Export—actual	1	2	60	135	115	275	290	265	170	160	280	333	219	258	337	338
Exports as percentages of total exports	(—)	(—)	(1.3)	(2.1)	(1.5)	(3.2)	(2.7)	(2.4)	(1.5)	(1.5)	(2.1)	(2.6)	(1.7)	(2.3)	(2.8)	(3.2)
Asia																
Import—actual	1,230	1,070	367	680	1,081	876	1,014	1,377	1,273	1,371	1,886	2,089	2,269	2,226	2,118	1,935
Imports as percentages of total imports	(21.6)	(21.2)	(8.3)	(11.3)	(14.1)	(11.2)	(10.2)	(14.2)	(12.1)	(13.4)	(14.7)	(16.7)	(18.1)	(19.9)	(18.5)	(16.5)
Export—actual	1,725	953	89	202	575	578	1,003	801	969	1,083	1,435	2,236	2,417	2,192	1,857	1,813
Exports as percentages of total exports	(28.7)	(18.8)	(2.0)	(3.2)	(7.2)	(6.7)	(9.2)	(7.2)	(8.3)	(9.8)	(10.7)	(17.1)	(18.9)	(19.7)	(15.4)	(17.1)
Middle East																
Import—actual	484	354	229	337	405	584	632	525	747	962	1,296	1,185	1,121	1,129	1,328	1,311
Imports as percentages of total imports	(8.5)	(7.0)	(5.2)	(5.6)	(5.3)	(7.5)	(6.4)	(5.4)	(7.1)	(9.4)	(10.1)	(9.4)	(9.0)	(10.1)	(11.6)	(11.2)
Export—actual	76	66	1	7	17	40	70	45	257	320	244	234	498	415	897	435
Exports as percentages of total exports	(1.3)	(1.3)	(—)	(.1)	(.2)	(.5)	(.6)	(.4)	(2.2)	(2.9)	(1.8)	(1.8)	(3.9)	(3.7)	(7.4)	(4.1)
Oceania																
Import—actual	13	12	25	34	103	190	502	296	304	314	262	113	97	91	94	72
Imports as percentages of total imports	(.2)	(.2)	(.6)	(.6)	(1.3)	(2.4)	(5.1)	(3.1)	(2.9)	(3.1)	(2.0)	(.9)	(.8)	(.8)	(.8)	(.6)
Export—actual	3	3	25	8	10	24	4	7	15	52	13	9	31	22	19	15
Exports as percentages of total exports	(.1)	(.1)	(.6)	(.1)	(.1)	(.3)	(—)	(.1)	(.1)	(.5)	(.1)	(.1)	(.2)	(.2)	(.2)	(.1)
Western Europe																
Import—actual	1,245[b]	1,315[b]	600	1,090	1,655	1,685	2,173	1,839	3,136	2,878	3,207	2,662	2,677	1,994	2,201	2,560
Imports as percentages of total imports	(21.9)	(26.0)	(13.6)	(18.2)	(21.5)	(21.6)	(21.9)	(19.0)	(29.7)	(28.2)	(25.0)	(21.2)	(21.4)	(17.8)	(19.2)	(21.8)
Export—actual	3,810	3,600	2,415	4,340	5,355	6,050	7,600	7,690	8,090	6,781	7,761	6,699	6,134	5,073	5,563	5,196
Exports as percentages of total exports	(63.3)	(71.0)	(54.0)	(68.9)	(68.4)	(70.1)	(70.0)	(69.3)	(69.2)	(61.6)	(57.9)	(51.3)	(47.9)	(45.5)	(46.2)	(49.0)

Centrally planned economies[c]																
Import—actual	**402**	**173**	**455**	**(268)**	**274**	**181**	**136**	**213**	**269**	**287**	**1,000**	**1,998**	**2,224**	**2,224**	**1,671**	**1,745**
Imports as percentages of total imports	(7.1)	(3.4)	(10.3)	(4.5)	(3.6)	(2.3)	(1.4)	(2.2)	(2.6)	(2.8)	(7.8)	(15.9)	(17.8)	(19.9)	(14.6)	(14.9)
Export—actual	292	319	694	(567)	962	1,106	1,239	1,637	1,540	2,111	3,061	2,800	2,594	2,792	2,735	2,321
Exports as percentages of total exports	(4.9)	(6.3)	(15.5)	(9.0)	(12.3)	(12.8)	(11.4)	(14.8)	(13.2)	(19.2)	(22.8)	(21.5)	(20.3)	(25.0)	(22.7)	(21.9)
World total																
Import—actual	5,700	5,050	4,400	6,000	7,700	7,800	9,900	9,700	10,550	10,200	12,850	12,550	12,550	11,200	11,450	11,750
Imports as percentages of total imports	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Export—actual	6,000	5,100	4,450	6,300	7,850	8,650	10,850	11,100	11,700	11,000	13,400	13,050	12,800	11,150	12,050	10,600
Exports as percentages of total exports	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)

SOURCE: The Cement Statistical and Technical Association, *World Cement Market in Figures, 1913-1956* (Malmö, Sweden) United Nations, *Trade Yearbook*. For individual countries appropriate national trade statistics publications were used.

[a] Export and import include intra-regional trade.
[b] Including Eastern Germany.
[c] Excluding China (mainland) and North Korea.

Table II-4. Apparent per capita cement consumption selected countries, 1937, 1938 and 1947-1960

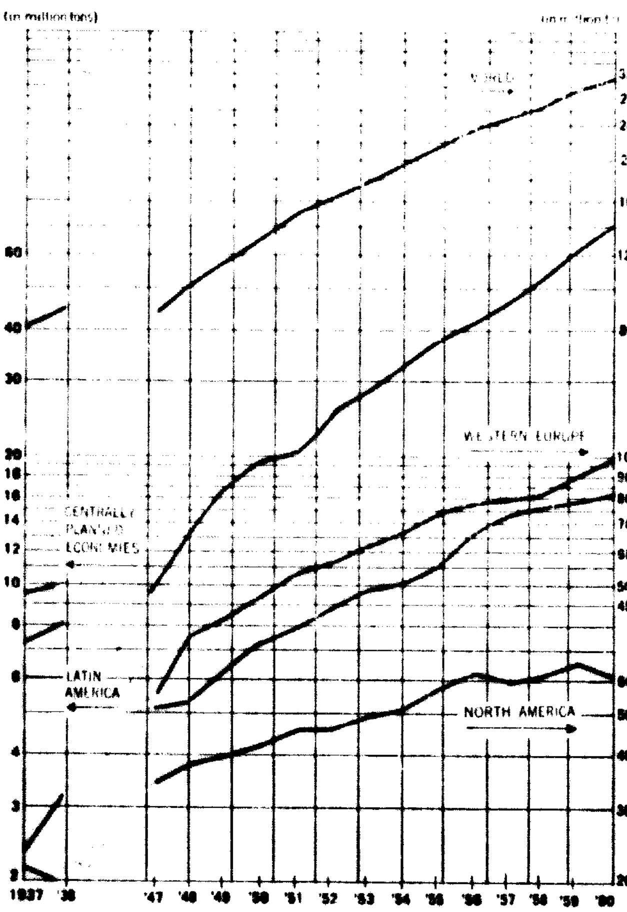
(In kilogrammes)

Area	*1937*	*1938*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*[a]
Africa																
Kenya	...	...	5.6	11.7	22.6	31.8	34.4	40.5	31.4	30.1	42.0	45.6	45.0	43.2	45.7	42.2
Morocco	...	...	38.8	60.4	64.4	72.6	103.3	117.2	106.0	96.8	88.3	77.9	57.2	45.5	35.4	60.2
United Arab Republic	22.2	25.2	34.2	39.5	44.7	50.3	54.7	44.1	44.8	48.4	58.1	59.7	52.4	52.6	53.2	60.6
America																
Argentina	86.4	95.8	92.3	97.9	98.8	118.0	113.0	112.4	90.0	104.2	107.9	108.4	121.4	124.5	117.3	134.5
Bolivia	9.3	8.2	14.0	13.4	14.0	12.7	13.7	13.4	11.9	10.7	12.4	11.0	9.4	9.6	9.5	8.1
Brazil	16.7	17.0	26.0	29.7	33.8	34.4	39.7	44.8	54.3	49.3	50.7	55.3	55.6	60.4	60.6	62.8
Canada	86.6	77.4	164.6	181.4	216.4	209.4	220.7	234.5	265.0	257.5	274.7	315.2	328.3	330.8	312.1	291.6
Chile	64.8	74.1	104.9	92.6	83.4	83.2	99.1	123.6	116.2	117.3	119.1	110.9	102.0	98.7	111.7	113.5
Dominican Republic	21.2	10.0	34.7	43.8	24.6	35.1	49.6	60.6	55.0	54.9	62.2	66.2	80.2	84.9	59.8	39.2
Ecuador	11.2	11.6	14.7	14.9	21.0	20.5	24.3	26.5	26.3	32.1	40.4	40.4	39.8	39.8	37.9	46.8
Mexico	19.1	20.3	34.1	34.4	49.7	57.6	62.5	66.4	64.5	63.1	69.1	76.9	83.1	79.6	81.3	88.2
United States	154.9	143.5	216.3	234.1	233.4	258.8	267.1	272.9	279.1	316.3	318.3	327.2	300.0	312.3	337.6	307.4
Venezuela	48.3	50.4	116.8	144.2	184.5	167.1	168.1	174.4	185.8	220.8	224.9	250.9	315.0	267.0	298.0	223.1
Asia and the Far East																
India	3.9	4.7	5.1	4.9	6.9	7.5	8.9	9.6	10.2	11.6	11.7	13.2	15.2	15.6	16.8	17.9
Iran	13.0		3.0	3.7	4.2	6.1	5.7	2.9	4.4	7.2	10.8	13.3	17.9	23.1	31.6	41.0
Japan	70.8	78.4	15.0	21.6	34.7	48.0	67.9	75.3	92.0	111.0	105.1	121.2	142.6	145.5	170.1	224.3
Pakistan				4.5	5.8	5.9	7.5	7.3	8.3	9.1	9.4	9.0	12.1	13.9	12.6	14.4
Europe																
Czechoslovakia	88.2	80.1	112.1	132.2	134.5	146.9	159.1	168.7	175.1	186.2	205.6	217.2	254.3	284.6	370.0	[illegible]
Poland	37.1	47.8	46.7	63.7	71.2	121.9	[illegible]	86.1	103.7	106.7	115.0	124.9	153.5	167.0	[illegible]	212.9
Yugoslavia	27.2	33.1	54.4	57.8	62.8	56.4	49.2	60.9	68.5	67.1	72.6	62.6	80.9	88.9	[illegible]	117.0

SOURCE: Computation based on data obtained from the same sources as tables II-1 and II-3.

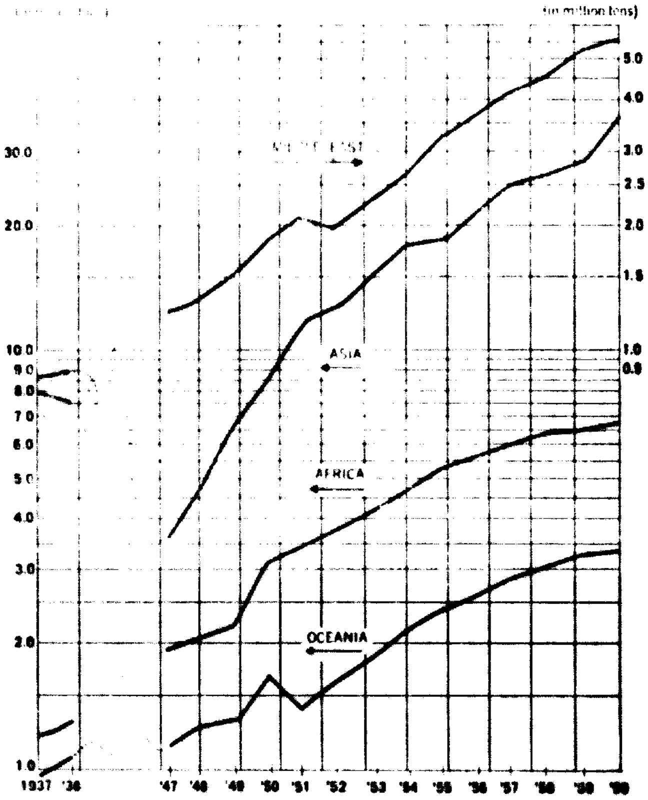
[a] Provisional data.

Chart II-1A. World cement production, 1937, 1938 and 1947-1960



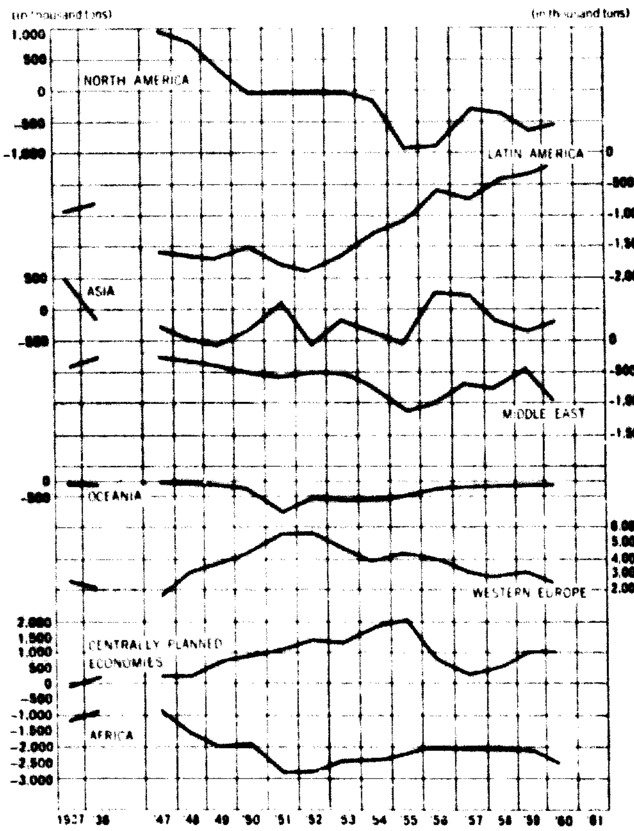
Source: Table II-1.

Chart II-1B



Source: Table II-1.

Chart II-2. Net export (+) and net import (—), by regions, 1937, 1938 and 1947-60



Source: Figures computed from table II-3.

Chart II-3A. Ratio of cement import to production, world total and by regions, 1937, 1938 and 1947-1960

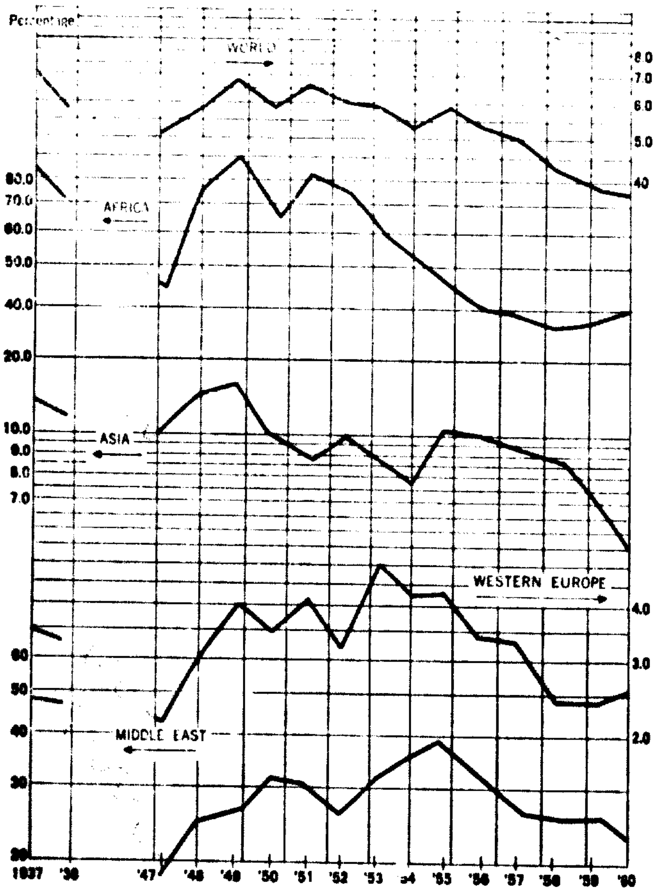
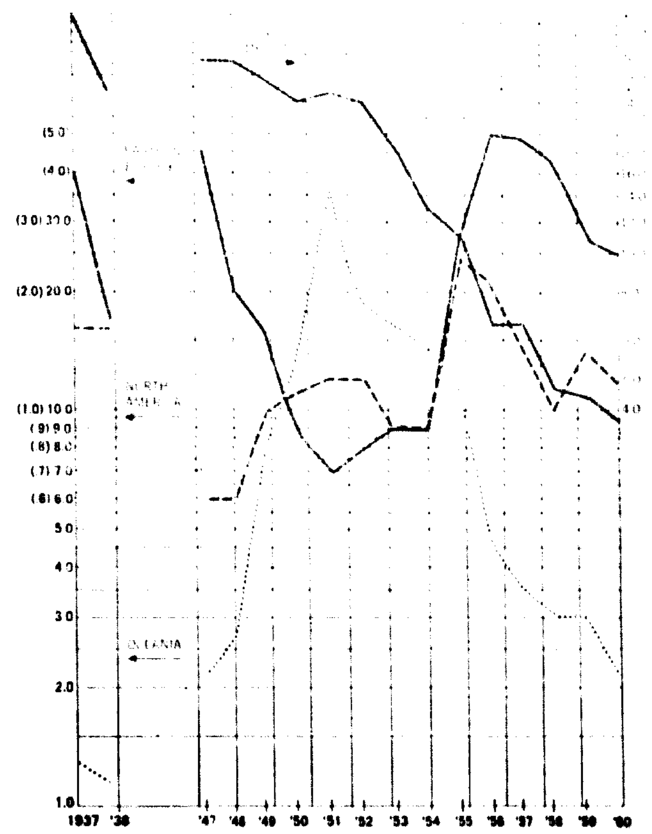


Chart II-3B



SOURCE: Tables II-1 and II-3.

Chart II-4A. Ratio of cement export to production, world total and by regions, 1937, 1938 and 1947-1960

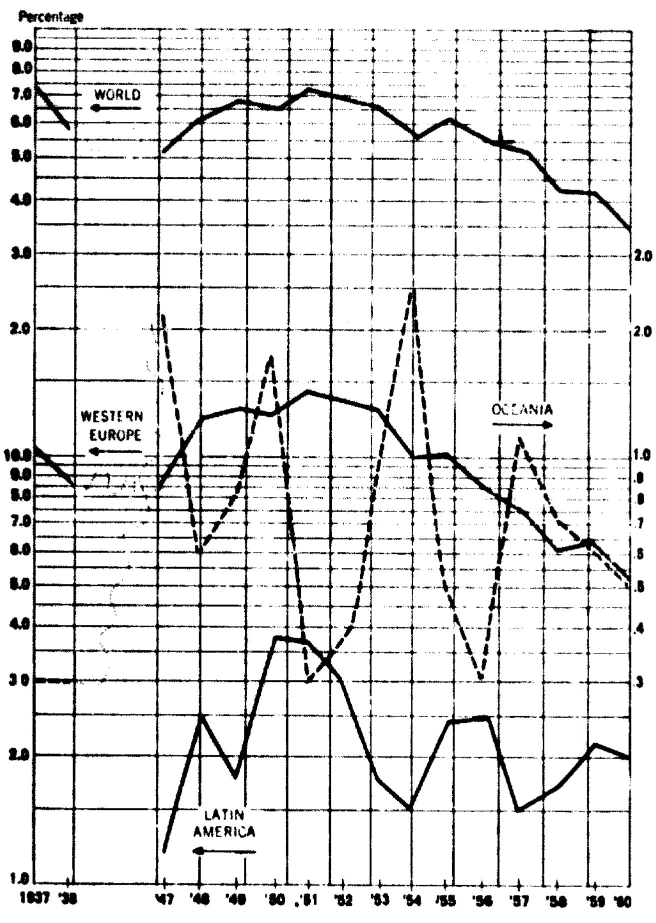
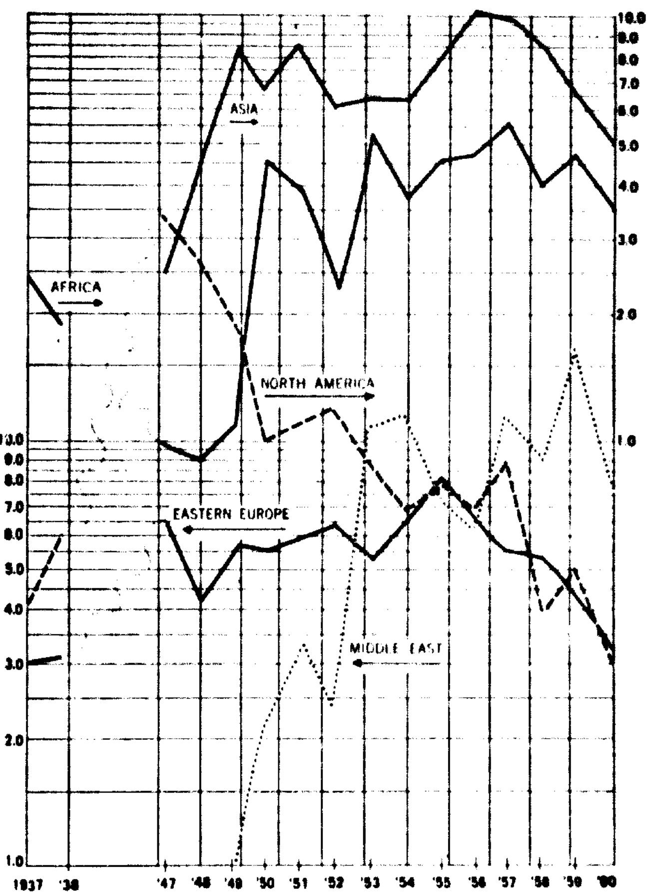
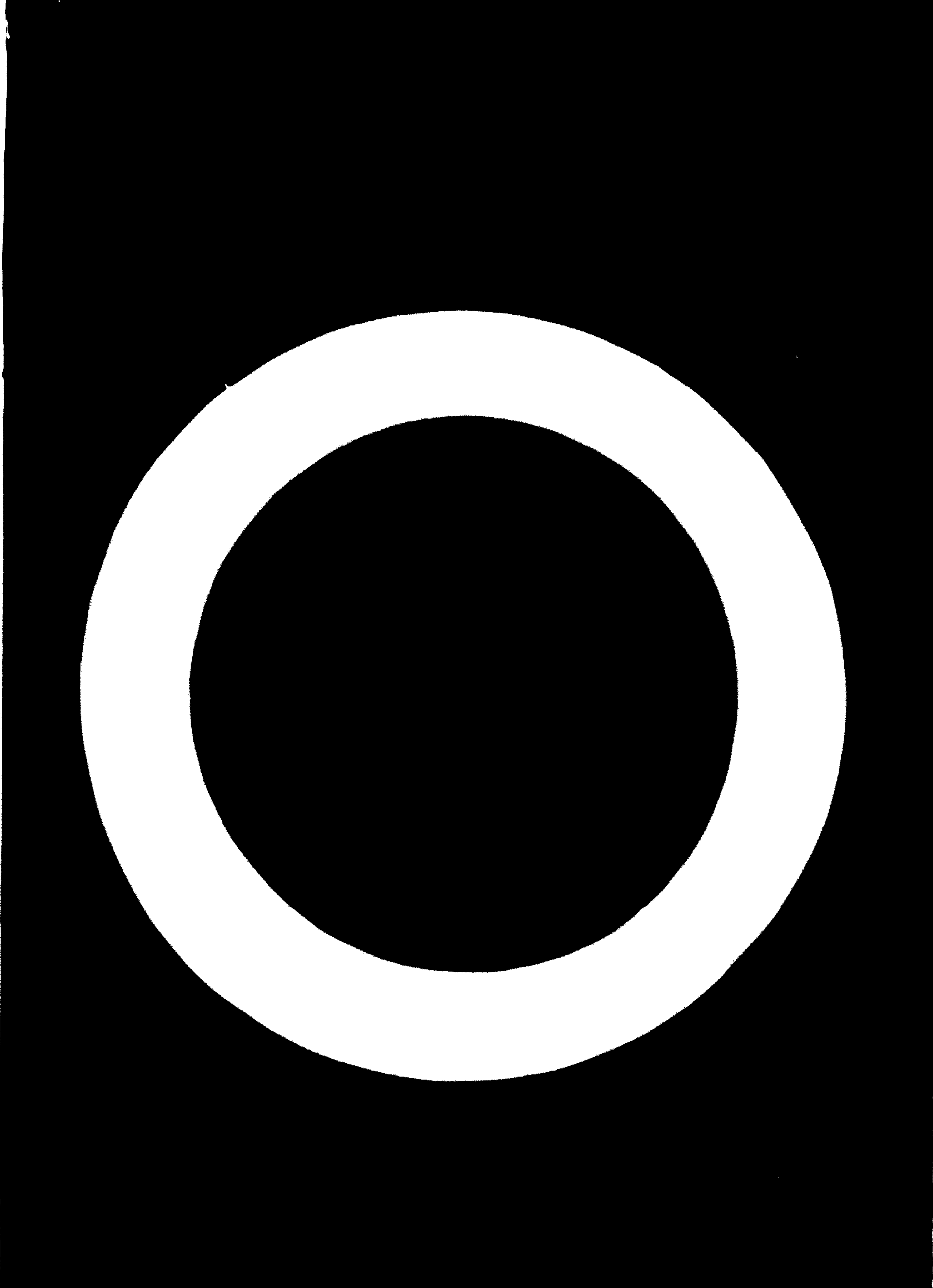


Chart II-4B



SOURCE: Tables II-1 and II-3.



II. NITROGENOUS FERTILIZERS BASED ON NATURAL GAS

Introduction

In countries where natural gas is at present being flared, efforts have been focused on utilizing this wasted and unreplenished natural resource. Products derived from natural gas are numerous although they have been concentrated mainly in the field of nitrogenous fertilizers and raw materials for plastics. The products discussed in this paper are ammonia, ammonium nitrate, ammonium sulphate and urea.

Data on investment and other inputs as well as illustrative cost structure are presented and analysed for these industries. These data are basically derived from the United States' experience and are obtained from engineering consultants. Some data incorporated in this part of the study were also based on surveys made by experts and consultants for establishing such industries in developing countries. Using these data as a background, an attempt is made to point out differentials that may be encountered when applying these data in developing countries.

The data used here are based on a given technology for each of these products. Alternative technologies, however, have been mentioned briefly in Section 1 of this study. It should be noted that consideration of one technology imposes a limitation on the scope of analysis when related to developing countries, in which case raw material and other input requirements as well as local market conditions may dictate the use of alternative technologies.

Section 1 of the study is devoted to a brief description of products, their uses and production processes. Section 2 presents statistical data covering recent trends on production, consumption and trade of these products. Section 3 is devoted to an analysis of fixed investment, labour and other inputs. In Section 4, an illustrative cost structure depicting the United States' experience is presented and analysed.

Section 1. Product description and processes

Ammonia (NH_3)

Synthetic ammonia is a basic chemical which is consumed mainly in the production of nitrogen fertilizers in addition to several other industrial uses. It is utilized in the production of such products as ammonium nitrate, ammonium sulphate and urea. In recent years the direct application of anhydrous ammonia to the soil is also coming into increasing use in the United States, as will be shown later in this study. The main reason for this rapid growth is that ammonia is the cheapest source of nitrogen for agriculture, once the methods of utilizing it directly were worked out. The fact that its direct application requires rather advanced farming techniques and additional investment on the part of the farmers would limit its use in the developing countries. Moreover, a solution of ammonia in water may also be produced and is often mixed with other nitrogenous solutions. These solutions may be injected directly into the soil. However, the need for specialized equipment, although not as expensive and technically advanced as for anhydrous ammonia, would still impose some limitations on its use in under developed countries. On the other hand, in these countries adding ammonia in the aqueous form to irrigation water may prove to be highly successful provided that proper care is used in its application.

As regards other industrial uses, large quantities of anhydrous ammonia are utilized for operating refrigeration machinery both in storage and in transportation, especially in the United States and in Europe. It is also very useful in the engineering industries for nitriding. Its chemical uses include the manufacture of soda ash by the ammonia soda process, the production of hydrogen cyanide, acrylonitrile, and other products.

Carbon dioxide is produced as a by-product in manufacturing synthetic ammonia and, when highly purified from traces of oil, can be used for the production of solid carbon dioxide, or "dry ice". This has considerable application in the refrigeration industry, notably for ice cream manufacture, as well as in atomic energy plants and in the engineering industries.

Ammonia can be synthetized by different routes, but all of them imply the use of a large amount of hydrogen for fixing the nitrogen extracted from the atmosphere. The choice of processes for recovering hydrogen depends essentially on availability of raw material. Most of the recently built ammonia plants, however, have natural gas as raw material. Producing ammonia from natural gas involves one of two processes, the steam-methane reforming process or the partial oxidation process; the former process is preferred because, *inter alia*, it does not have as many operating problems as the partial oxidation process, and for small and medium size plants it requires less amount of capital investment.

Ammonium nitrate (NH_4NO_3)

One of the most important nitrogen fertilizers is ammonium nitrate. It has a high nitrogen content (33.5 per cent)[1] and is a quick-acting fertilizer for crops. Its use as a fertilizer was limited because of its tendency to explode and it had the tendency to coalesce in large blocks ("tombstones") instead of remaining in a granulated form more suitable to feed crops. This inconvenience was overcome by granulating ammonium nitrate and coating the granules with clay or diatomacious earth. Ammonium nitrate is also the starting point of several explosives. Another use of ammonium nitrate is in the manufacture of nitrous oxide, which is also used as an anaesthetic.

[1] Pure ammonium nitrate has a content of 35.0 per cent of nitrogen.

The process to produce ammonium nitrate consists of two stages; the first involves the oxidation of ammonia to nitric oxide (NO), further oxidation of nitric oxide to nitric dioxide (NO_2), which is absorbed in water to form nitric acid. In the second stage, the nitric acid reacts with the required quantity of ammonia to produce ammonium nitrate.

UREA ($NH_2/CO/NH_2$)

It is a product of versatile use. Its major use, however, is as a fertilizer, where its advantage lies in its high nitrogen content, 46 per cent. It also has large application as raw material for thermoplastic resins; urea-formaldehyde compounds are used in glue and plywood manufacture.

There are many urea processes in operation. These include the I. G. Farben process, Du Pont, Imperial Chemical Industries, Montecatini, Dutch State Mines, Pechiney-Grace, Chemico and Inventa-Vulcan. Ammonia and carbon dioxide are combined under pressure to form ammonium carbamate. This is dehydrated to form urea and water. Unreacted ammonia and carbon dioxide are released, which are recycled or converted into by-products such as ammonium nitrate or ammonium sulphate

AMMONIUM SULPHATE ($(NH_4)_2\ SO_4$)

It is a widely used fertilizer and has been in use for many years. Ammonium sulphate presents some advantages in respect to other nitrogenous fertilizers; it is easy to handle and ship and does not set in bulk, as does ammonium nitrate. In preparing the conventional mixed fertilizers, ammonium sulphate is required in order to give these fertilizers the proper physical conditions.

Until twenty years ago, ammonium sulphate was manufactured in the United States almost entirely as a by-product of the coke plants of the steel industry. When the demand for nitrogenous fertilizers began to increase during the war at a steadily accelerating rate, new plants were built in which synthetic ammonia was combined with concentrated sulphuric acid to produce ammonium sulphate.

As is well known, natural gas may contain sulphur. This may be used as an alternative source to mined sulphur for use in production of ammonium sulphate. Certain countries have natural gas rich in hydrogen sulphide (the so-called "sour" gas), such as occurs in Arkansas, West Texas and Wyoming in the United States. Methods have been developed for removing hydrogen sulphide to purify the natural gas, and hydrogen sulphide thus obtained is utilized to make sulphur or sulphuric acid.

Where sulphuric acid is not available but there are convenient deposits of anhydrite or gypsum (calcium sulphate), ammonium sulphate can be made using either of these minerals as a source of sulphur; this alternative process is not used in the United States, but is employed on a large scale in Western Europe.

Section 2. Production, consumption and trade

The use of nitrogenous fertilizers has been increasing steadily along with other synthetic fertilizers. Table 1 below indicates world consumption of fertilizers for selected years in the last two decades. The consumption of nitrogenous fertilizers since 1947/48 has been increasing at an average of roughly 500,000 tons per year.

Table 1. World fertilizer consumption

(In thousand metric tons)[a]

Year	Nitrogenous (N)	Phosphate (P_2O_5)	Potash (K_2O)	Total
1937/38	2,485	3,678	2,960	9,123
1947/48	3,109	5,017	3,104	11,230
1950/51	4,191	6,208	4,514	14,913
1955/56	6,630	7,840	6,830	21,300
1959/60	9,220	9,530	8,380	27,130

SOURCE: Food and Agriculture Organization of the United Nations, "Long-Term Trends of World Fertilizer Consumption", *Monthly Bulletin of Agricultural and Economic Statistics* (Rome, February 1962), p. 1.

[a] In equivalents of plant nutrients (active components).

The rate of growth for the group of nitrogenous fertilizers during the post-war period has been faster than that of the other two groups, namely 8.4 per cent *per annum* as compared to 7.6 per cent and 4.9 per cent respectively for the potash and phosphate fertilizers. This resulted in an increase in the share of nitrogen at the expense of phosphate. Whereas in 1947/48 nitrogen's share was 28 per cent of total chemical fertilizers, and that of phosphate 45 per cent, by 1960 the consumption of the three major groups of fertilizers was shared roughly equally by the three types of fertilizers.

The various types of nitrogenous fertilizers are shown in table 2 (p. 33). Ammonium sulphate and ammonium nitrate share between them over half of the world total. Ammonium sulphate, however, has been losing its predominant position and its share is being gradually equalized to that of ammonium nitrate. Other fertilizers that have decreased their share in total consumption include ammonium sulphate nitrate, sodium nitrate, calcium nitrate and calcium cyanamide.

Urea, the newcomer to the field, and combined fertilizers, have been increasing their share of the market. The share of "other" fertilizers that include mainly anhydrous ammonia, aqua ammonia, ammonium nitrate-water solution, and a combination of ammonia, ammonium nitrate and urea dissolved in water, has also been increasing. Their use has been, however, confined mainly to the United States.

The important consumers of nitrogenous fertilizers are the advanced countries. Europe and North America (mainly the United States) shared roughly 73 per cent of the total world consumption in the two years 1959-1960. In the same period, Asia followed with 14 per cent, half of which was consumed by Japan alone and the remaining by other countries of the region. The Soviet Union accounted for 8 per cent of the balance and the rest of the world 5 per cent.

The unbalanced pattern of world consumption may also be indicated by the average consumption of nitrogen per hectare of arable land. Europe's estimated consumption in 1958/1959 was by far the highest, amounting to 24 kilogrammes per hectare, followed by North and Central America 10.5 kilos, Asia 4.1 kilos, and

Table 2. World production of nitrogenous fertilizer by product, 1954/55-1959/60

(Percentages of total output, unless otherwise specified)

Item	1954/55	1955/56	1956/57	1957/58	1958/59	1959/60
Ammonium sulphate	31.2	31.6	30.0	28.7	28.5	26.0
Ammonium nitrate	25.2	24.8	23.9	24.6	23.6	24.8
Urea	2.3	2.8	4.7	5.1	6.2	6.4
Combined fertilizers	5.1	6.0	7.9	8.3	8.7	9.5
Ammonium sulphate nitrate, sodium nitrate, calcium nitrate and calcium cyanamide	16.6	14.2	14.8	14.3	12.1	11.1
Other	19.6	20.7	18.8	19.1	21.0	22.3
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0
TOTAL, in thousand metric tons of (N)	5,600	5,932	6,469	7,030	7,689	8,007

SOURCE: Food and Agriculture Organization, of the United Nations, *An Annual Review of World Production, Consumption and Trade of Fertilizers*, 1959, 1960.

USSR 3.1 kilos; for the rest of the world, consumption ranged between 1.2 and 1.9 kilos.

International trade in nitrogenous fertilizers comprised an important part of world output; export averaged 28 per cent of the total production in the two years 1959-1960. Europe is predominant as the exporting region accounting for 65 per cent of total export in the same period, followed by North America 15 per cent, South America (Chile) 6 per cent and Asia (Japan) 13 per cent with the USSR handling the remaining 1 per cent. Europe imported in the same period 38 per cent of the total followed by North America 23 per cent, Asia 25 per cent, Africa 9 per cent with South America, Oceania and the USSR sharing the remaining 5 per cent of the market. Table 3 summarizes production, consumption and surpluses or deficits for two selected years by major regions.

Table 3. Production, consumption and surplus or deficit, 1955/56 and 1959/60

(In thousand metric tons (N))

Region	Production	Consumption	Surplus (+) or Deficit (—)
1955/56			
Africa	38	203	—165
America, North and Central	2,246	1,959	— 45
America, South	227	112	+109
Asia	813	1,075	—311
Europe	3,359	2,780	+440
Oceania	19	26	— 7
USSR	500[a]	479	+ 24
WORLD TOTAL	7,202	6,634	
1959/60			
Africa	59	230	—169
America, North and Central	2,860	2,845	—150
America, South	206	168	+ 12
Asia	1,110	1,269	—223
Europe	4,830	3,968	+897
Oceania	25	33	— 8
USSR[b]	740	709	+ 31
WORLD TOTAL	9,820	9,222	

SOURCE: Same as table 2.

[a] Estimate.

[b] Referring to July through December 1959.

An order of magnitude of possible future requirement for nitrogenous fertilizers in the developing regions has been estimated at 30 million tons by 1980.[2] This compares with a low volume of 4 million tons reported for these regions in 1960. By 1980 the world total was estimated at 70 million tons, assuming a moderate increase in the consumption of fertilizers for the rest of the world. Estimates for the developing regions were derived primarily as follows:

(i) Targets of food requirements were set at 174 to 219 per cent of a base year.[3] A moderate rate of growth in fertilizer consumption was assumed for countries that have already attained a high use of fertilizers such as Japan and China (Taiwan).

(ii) Average relationship between the value index of crop production and input of fertilizers used per arable hectare in forty-one countries in the years 1956-1958 was established. This average relationship was used as a basis for calculating the quantity of fertilizers needed to attain the set targets.

It should be emphasized that the figures given above are not projections of effective demand for fertilizers. They are estimates of *requirements* that may be needed to attain defined nutritional goals under given assumptions. These goals assume, *inter alia*, a sustained rate of growth in agricultural output ranging between a rate of about 3 per cent for Africa, and of 5 per cent for Asia and the Far East. To emphasize the magnitude of such a task, one may refer to the fact that a sustained 5 per cent growth in agricultural output has not been attained in the past by any of the world regions; and only a few countries have succeeded in attaining such high goals for a period extending over ten years. It may be mentioned at this point that these production

[2] F. W. Parker, "Fertilizers and Economic Development", paper delivered at the Fertilizer Workshop, American Society of Soil Science, Purdue University, February 1962. Estimates for developing countries include 5.0 million tons for China (mainland).

[3] *Set targets for 1980 (1960 = 100)*

Africa	174
Asia and Far East	219
Latin America	194
Near East	190

goals in agriculture compare favourably with those incorporated in the development plans of various developing countries.[4]

Section 3. Fixed investment and other inputs

Fixed investments: these include cost of processing equipment; auxiliary facilities that include utilities, such as power and steam supply, and cooling water facilities, etc., equipment for laboratories and workshops; buildings and structures; erection cost for equipment, building and structures; as well as miscellaneous costs that include design and engineering fees and allowance for contingencies.

The major components of fixed investment for the fertilizer plants under consideration are: process equipment sharing between 25 and 35 per cent of total investment, erection of process equipment between 10 and 15 per cent, utilities and auxiliaries between 10 and 20 per cent. Because most equipment is installed outdoors, buildings for these plants include mainly facilities for offices, control room, laboratory and workshop, and they share a small part of total investment, roughly between 5 and 10 per cent. The rest of fixed investment goes to design and engineering fees and investment overhead.

Table 4 indicates the fixed investment of new plants in the United States for the several products discussed in this paper. These costs represent plant investments[5] and they refer to the supply and erection of process equipment required to manufacture the products in given size plants. They refer to small to medium-size plants. The following are the additional costs that have to be faced:

(i) Purchase of land on which to erect the plant and its amenities;

(ii) Installation of foundations, drains, roads and fences;

(iii) Transportation of equipment from the place of purchase;

(iv) Installation of services, such as power and steam supply;

(v) Provision of cooling water facilities, including circulation towers, if necessary;

(vi) Construction and equipment of laboratories and workshops;

(vii) Administration offices and medical services;

(viii) Canteens and lavatories;

(ix) Storage and packing facilities.

As a general guide, it can be taken that plant investment should be about doubled to arrive at the total fixed investment of the factory.[6] If the site is in an isolated area, provision of housing and other amenities is required for the staff and workers.

Investment in the plants under consideration obviously involves economies of scale; that is, total investment increases less than proportionately to plant capacity. The investment figures derived from the capacity coefficient given in this paper indicate that quadrupling the capacity of an ammonia plant would require tripling total investment.

There are several reasons for this well known behaviour of fixed investment. Doubling the capacity of unit equipment, such as converters, heat exchangers and preheaters, would require less than double the steel, and labour requirements for producing larger units also increase less than proportionally, with a consequent decrease in unit cost of producing larger units of equipment. A substantial increase in plant capacity would also require a smaller expansion in some of the auxiliary facilities such as workshops and laboratories, and erection cost behaves in a similar way.

Table 4 gives the capacity exponent for several products. It should be emphasized that these exponents

Table 4. Plant investment in the United States

(Total and per ton of annual capacity)

Products[a]	*Annual capacity (in thousand tons)*	*Plant investment: Total (in million dollars)*	*Plant investment: Per ton of annual capacity (in dollars)*	*Capacity coefficient*[b]
Ammonia	60	4.1	62	0.88
Ammonium nitrate	50	2.5	50	0.71
Urea	40	2.6	65	0.67
Sulphuric acid	66	1.2	18	0.65
Ammonium sulphate	50	2.4	48	0.65

SOURCE: "Utilization of Natural Gas in Petrochemical and Other Industries"; paper prepared by the Division of Industrial Development in the Department of Economic and Social Affairs, United Nations, and presented at the Second Symposium on the Development of Petroleum Resources of Asia and the Far East, Teheran 1-15 September 1962.

[a] The *ammonia* plant is based on the steam-gas pressure reforming process, and it is assumed that gas engine driven compressors would be used. The major equipment required includes steam raising capacity, primary reformer, secondary reformer, CO shift reactor, CO_2 stripper, CO absorber, CO stripper, compressors, circulators, heat exchangers, NH_3 converter and ammonia storage facilities.

The *ammonium nitrate* unit includes a nitric-acid unit of high-pressure type. Ammonium nitrate is produced as prills. Major equipment included in the nitric acid plant is: air compressors, ammonia converters, waste heat boilers, absorption and bleaching columns, pumps and storage tanks. For the ammonium nitrate plant, a neutralizer, evaporator, prilling tower, drier, cooler and bagging equipment are required.

The *urea* unit is of the "total recycle" type, and includes facilities for prilling. Major equipment includes a reactor, first and second stage condensers, prilling tower, crystallizer, CO_2 compressor, condensator, dryer, NH_3 pre-heater, first and second stage distillers, urea solution concentrator, filler press, centrifuge, separators, pumps and drums.

The *ammonium sulphate* plant consists of two parts. In the first, sulphur is converted into sulphuric acid, which requires a sulphur burner, gas cooler, heat exchanger, sulphur dioxide converter, sulphur trioxide absorption system, acid storage tanks. The second plant requires vacuum crystallizer, centrifuge, drying and bagging equipment.

[b] This is an engineering coefficient. It is the same as elasticity of investment which implies a constant rate of growth for total investment in response to changes in capacity. The following formula defines the relationship with (a) as the constant elasticity, (C) as capacity and (I) total investment:

$$\left(\frac{C_x}{C_y} = \frac{I_x}{I_y}\right)^a$$

This functional relationship when plotted on a logarithmic chart shows itself as a straight line.

[4] Parker, op. cit.

[5] In the United States this investment is referred to as "battery limits". The investment figures given in the text are "turn key" and presented on a United States Gulf Coast basis.

[6] In the engineering and trade circles of the United States this is referred to as "grass roots investment".

are at best a first approximation and are in no way a substitute for a detailed investigation of any particular size plant under consideration. They are applicable only within a certain range of plant capacities.

Several points may be explored at this stage. It is well known that the increase in plant capacity that yields returns to scale cannot be expected indefinitely. There is a maximum capacity beyond which no return to scale is possible and a further increase in production can be achieved only by adding new units of production. The maxima plant capacity involved vary from industry to industry and change of course with the technology. The economically acceptable plant sizes impose a limit on the other extreme, since because of a steep rise in unit cost of equipment with decreasing capacity, there is a minimum below which it is not economically feasible to operate. Several capacities are illustrated for most products under consideration elsewhere in the paper, and they include both small and large scale operations based on United States experience. These, however, are not necessarily identical with the minimum or maximum scales in the United States. It will be kept in mind that these maxima and minima, particularly the latter, would vary from country to country, depending on the technological feasibilities as well as the economic and market conditions in each country and plant location.

To illustrate this, in the United States, unless under exceptional conditions, it would be extremely unlikely if a new ammonia plant were to be installed with a capacity of less than 180 tons per day, and this would apply to most Western European countries as well. Under different economic parameters such as exist in developing countries, a minimum capacity as low as 30 tons per day may prove to be economical.

Capital saving may be derived from the integration of several fertilizer plants on the same site. Such saving is attained as a result of the utilization of several common auxiliary facilities as well as of reduced installation cost. Fertilizer complexes may include facilities for production of ammonia, ammonium nitrate, ammonium sulphate, and urea. The factory would produce ammonia, part of which would be converted into ammonium nitrate, part into urea and part into ammonium sulphate, thus giving a complete range of nitrogenous fertilizers.

Two hypothetical examples of a large and a small complex of nitrogenous fertilizers grouped in one factory may be as follows:

Product[a]	I *Daily capacity (S. tons)*	II *Daily capacity (S. tons)*
Ammonia	140	520
Ammonium nitrate	150	500
Urea	60	300
Ammonium sulphate	150	500

[a] Ammonia required per ton of output: 0.460 tons for ammonium nitrate, 0.575 tons for urea, and 0.258 tons for ammonium sulphate.

A United States consultant firm that supplied the above information on these complexes estimated fixed investment at between 20 and 30 per cent less than when individual plants of the stated capacities are built on different sites.

So far investment has been analysed for an advanced country, namely the United States. A differential in investment will arise in under developed countries because of added ocean freight and insurance on imported equipment and materials, import profits and difference in cost of erection. As regards the latter, it is likely that the lower wage rates in under developed countries may be offset at least in part by the low factor performance. Furthermore, high cost of specialized engineers and technicians as well as skilled labour generally have to be imported for that purpose; the cost of services of these specialists is higher than in their own countries.

An indication of the order of magnitude of the differential in fixed investment may be taken from a survey prepared by a German consultant for the utilization of natural gas of an under developed country in the Middle East. The survey was based on the experience of the Federal Republic of Germany with adjustment to the conditions of the Middle Eastern country. Assuming the purchase prices of equipment are the same in both cases, the cost of ocean freight and insurance (between 13 and 15 per cent of equipment cost) was added to the cost of equipment in the Federal Republic to arrive at the equivalent cost in the Middle Eastern country. Whereas local wages were lower than in the Federal Republic, they were more than offset by the additional labour required because of lower labour performance. Cost of German personnel required for erection of these plants was more than twice that in the Federal Republic. Furthermore, it was estimated that building and construction unit cost for practically all components of construction was between 130 and 300 per cent higher in this under-developed country; the only exception was the cost of asphalted roads which was estimated at half the German cost.

The cost of investment for the Federal Republic of Germany was recomputed by adjusting for the ocean freight and insurance on equipment, labour and construction costs. The resulting figures showed that the cost of investment for the Federal Republic was between 10 and 15 per cent lower than that suggested for the under-developed country. The investment cost differential would be still higher than that suggested by these figures but for the fact that in computing the investment cost for the Federal Republic some items were left unadjusted—such as the cost of additional buildings required for equipment on account of the difference in climatic conditions in both countries.

Fixed investment discussed so far refers to direct investment in the plant proper; in developing countries additional investment may have to be incurred in economic and social infrastructure, such as housing and other social amenities for the labour force, transportation, power generating and water supply facilities. This type of investment would vary from one country or location to another and, in some cases, it may be rather substantial. Such investments, however, have been treated independently of direct investment elsewhere in this study, since it affects production cost through factors of production other than direct investment, i.e., cost of labour, power, transportation, water, etc.

Operating capital may also be mentioned at this stage. In developed countries this may amount to about between 25 and 30 per cent of fixed capital. High operating capital is needed because of the seasonal characteristic of demand for fertilizers. It is expected that this type of capital would be much higher in developing countries because of higher inventories and costs of such items as spare parts, raw materials, etc. The magnitude of the differential between developed and under-developed countries is not possible to ascertain and research into this aspect is needed.

Other inputs: Owing to the large degree of mechanization included in the design of such plants, the labour required for the actual operation of the plant itself is small. Table 5 indicates operating labour required for the various products under consideration. To arrive at total labour requirement one should add maintenance labour as well as labour needed in operating and maintaining the auxiliary activities. Total labour requirement is at least twice that of operating labour.

Another important feature of labour input is the economies of scale obtained with the increase in scale of operation. The number of operators varies only slightly with the capacity of the installation. Furthermore, supporting labour in the auxiliary activities, such as maintenance labour, increases less than proportionately to capacity.

Table 5. Operating labour requirement in nitrogenous fertilizer plants, United States

Plant	*Annual capacity (in tons)*	*Number of workers per 3-shift day*	*Man-hour per ton[a] capacity*
Ammonia	66,000	12	0.36
Ammonium nitrate	82,500	12	0.29
Urea	40,000	9	0.45
Ammonium sulphate	50,000	12	0.48

SOURCE: Same as table 4.

[a] Assuming 2,000 working hours per man per year.

It will also be noted that the possibilities of labour-capital substitution in these industries are not very great. The "core" operations in these plants require a highly specialized and automated equipment specifically designed for the chemical reactions needed. It is not possible to modify the equipment specifications without impairing the technical process or the quality of product so as to accommodate for more intensive utilization of labour at the expense of equipment. In the auxiliary activities, however (such as internal transport, maintenance) limited labour capital substitution may be possible. On the other hand, integration of several plants into a complex which leads to sharing of labour in the common auxiliary activities would reduce labour requirement.

So far as labour requirements in developing countries are concerned, it is unlikely that direct operating labour in the plant proper would differ significantly from what prevails in developed countries. Such plants are highly mechanized and the few men required should be as qualified as their counterparts in the industrialized countries, which is a question of training. Contractors supplying such plants are experienced in arranging training classes for operating and maintenance men; some of them would be trained on the job in similar plants to become familiar with the operations. Labour requirements in auxiliary activities, on the other hand, may be higher in developing countries because of generally lower levels of performance and of the possibility of some capital-labour substitution.

Other inputs include natural gas, utilities, water, catalysts, chemicals, and sulphur. In Table 6 below inputs required for these industries are given in physical units per ton of product. So far as these inputs are concerned, there are no economies of scale, such inputs being correlated directly with the increase in output.

Table 6. Consumption of certain major inputs per ton of output of indicated nitrogenous products

Product	*Natural gas feed[a] (in standard cubic feet)*	*Electricity (in kWh)*	*Water[b] (in gallons)*	*Steam (in tons)*	*Sulphur (in tons)*
Ammonia	23,100[c]	90.75	5,170	—[c]	—
Ammonium nitrate	—	49.5	1,980	2.8	—
Urea	—	33.0	3,850	1.5	—
Ammonium sulphate	—	27.5	1,100	—	0.263

SOURCE: Same as table 4.

[a] Natural gas with caloric value of 1,050 BTU per cubic foot.

[b] It is assumed that water used is recirculated; these figures then refer only to water lost in the operation (make-up water).

[c] An additional volume of 17,600 cubic feet of natural gas is used for fuel per ton of output.

Section 4. Production cost

Estimated costs of production have been constructed for the several products under consideration. These calculations are based on rough approximations and engineering coefficients taken from United States' experience. They do not reflect actual performance of any particular plant and are used here for illustration purposes.

It is intended to use these data as benchmarks to explore the differences in cost components that may arise in an under-developed as compared to a developed country, namely, the United States. Table 7 summarizes the share of the major cost components in production cost.

This table indicates that in the United States depreciation cost ranges between 23 and 28 per cent of production cost. As mentioned earlier, investment is likely to be higher in under-developed countries as compared to developed countries for the reasons enumerated above. If one assumes the same rate of depreciation and the same size of plants, then for a developing country, an additional cost of fixed capital of the order of 10 to 20 per cent would imply a rise in the cost of production of about 2 to 6 per cent.

Because of inadequate maintenance—due to lack of skills and organization—there will be a faster physical depreciation of equipment which will have to be reflected in a higher rate of accounting depreciation in the under-developed countries, and hence a higher production cost would ensue. On the other hand, in the longer run, an under-developed country that has a supply of labour at relatively low cost should be in a position by proper training of labour and organization and more intensive maintenance practices actually to lengthen the physical life expectancy of equipment and machinery. In the longer run, it may thus be expected that depreciation would be spread over a longer period with possible reduction in production cost.[7]

Another important aspect that may be mentioned is the possible low performance in production in under-developed countries as compared to production standards in advanced countries. This may be attributed mainly to poor management and labour practices. Such cases would result in an appreciable rise in unit production cost because fixed capital charges have to be allocated over a relatively small output.

[7] For a further treatment of depreciation in developing countries, see "Use of Industrial Equipment in Under-developed Countries" in United Nations *Bulletin on Industrialization and Productivity*, No. 4 (Sales No.: 60.II.B.2).

Table 7. Distribution of major cost components and total production cost in the United States

(Per cent of total)

Product	*Depreciation*	*Interest*	*Natural gas*	*Utilities*	*Operating labour*	*Supervision and plant general*	*Maintenance*	*Others*	*Total*	*Total (in dollars per ton)*
Ammonia	23.5	15.0	29.5[a]	3.6	5.1	6.9	8.5	7.9	100.0	34.63
Ammonium nitrate[b]	23.9	15.3	12.5[a]	15.5	6.1	8.7	9.7	8.3	100.0	37.14
Urea[b]	27.5	17.6	11.6[a]	7.7	6.6	9.4	11.4	8.2	100.0	50.09
Ammonium sulphate[b]	23.3	14.7	6.8[a]	1.8	7.7	10.4	9.7	25.6[c]	100.0	38.29

SOURCE: Data on fixed investment, labour and other input requirements used in the calculation are obtained from tables 4-6 and their source. Calculations of production unit cost were made as follows:

1. The capacities used are: ammonia 66,000 metric tons, ammonium nitrate 82,500, urea 40,000, and ammonium sulphate 50,000;

2. Computations were based on 90 per cent of full capacity, except for ammonia, 95 per cent;

3. Total fixed investment (grass roots investment) assumed at double the plant investment (battery limits);

4. Maintenance at 4 per cent of plant investment except for ammonia, three per cent. For the remaining investment, it was assumed at 1.5 per cent;

5. Supervision and plant general 80 per cent of total labour;

6. Depreciation at 10 per cent of plant investment and 2.5 per cent of other investment;

7. Interest, insurance and taxes have been calculated at 4 per cent for interest, 1 per cent for insurance and 1 per cent for taxes for plant investment; the same percentages were applied for other investment, except for insurance for which 0.5 per cent was used;

8. Production cost includes neither packages nor packing;

9. Price of natural gas 25 cents per 1,000 cubic feet;

10. Price of electricity 0.8 cents per kWh;

11. Price of water 10 cents per 1,000 gallons;

12. Price of ammonia $34.63 per ton;

13. Price of steam $1.65 per ton;

14. Price of sulphur $27.50 per ton;

15. Wages for operating labour assumed at $3.15 per man-hour and this includes fringe benefits.

[a] This includes natural gas used as feed stock and fuel. The percentages for fuel alone are: for ammonia 12.7 per cent, ammonium nitrate 5.4 per cent, urea 5.0 per cent, and ammonium sulphate, 2.9 per cent.

[b] Composite cost was calculated to introduce the capital, natural gas and other inputs carried over from the ammonia stage.

[c] Includes 18.9 per cent for sulphur.

The other important capital charge, namely interest, accounts for 15 to 18 per cent of production cost. The interest rate in the United States was assumed at 4 per cent; in a developing country this rate would be much higher possibly double if not triple that rate: this represents an increase in cost of the order of between 25 and 40 per cent.

As indicated in table 6, a large volume of natural gas is used only in the production of ammonia. For the purpose of this study the share of natural gas in the production cost of the other nitrogenous products was computed indirectly through their ammonia content. In the United States, the share of natural gas, both as raw material and fuel, constitutes a large proportion of production cost, 30 per cent for ammonia, about 12 per cent for ammonium nitrate and urea and 7 per cent for ammonium sulphate. In a number of developing countries with abundant supplies of natural gas, as a petroleum by-product, the cost of gas may be very low, particularly when the alternative cost concept is used. In each case, the cost of natural gas tends to pull production cost down. This would affect the production cost of ammonia rather significantly, although so far as the remaining products are concerned, the effect may be limited.

With regard to labour input in these products, it was mentioned earlier that wages in developing countries are, in general, lower than in advanced countries. However, during the early years of operation, it may be necessary to recruit foreign technicians, including some skilled labour at relatively higher salaries to operate the plants. Lower labour performance is another offsetting factor which will tend to result in a higher labour unit cost.[8]

As table 7 shows, plant maintenance may roughly amount to between 9 and 11 per cent of production cost. Proper plant maintenance in under-developed countries is an extremely important factor. Most of the plants that have been described in this paper should have an operating rate of utilization of 90 to 95 per cent at full capacity; any decline in this figure will result in a steep rise of production cost because of the high share of fixed cost.

In the longer run, if programmes of regular planned maintenance are organized and enforced, the wage cost of maintenance of the plant should actually be less than in developed countries once the skills have been acquired, because of the lower wage rates. An offsetting effect is the magnitude of the inventories of spare parts that must be carried to guard against an expensive shutdown; these are likely to be much higher in a developing country which is far from the sources of supply of equipment.[9]

The share of utilities in production cost varies with the products. It is relatively high in ammonium nitrate, 16 per cent, and to a lesser extent in urea, 8 per cent. In ammonium sulphate and ammonia, it is rather low, 2 per cent and 4 per cent, respectively. The items included under utilities in this study are fuel, power and water. Cost differential will vary greatly with each country. Countries having access to cheap fuel supply would obviously have a cost advantage; likewise countries endowed with hydropower potential would have a cost advantage in power provided that they have the advantage of economies of scale by operating moderately large-scale power facilities. On the other hand, in certain countries where economic overhead, including power, will have to be supplied by the plants themselves, the cost of power and other utilities will be relatively high because of the expected smaller scale of operation.

A brief mention of another type of input, namely transportation, is in order because it affects the cost of raw materials and finished goods. Certain plants may have to provide for their own transportation facilities. In such cases, the capital charge of infrastructures and the possible under-utilization of transport facilities may result in higher costs.

Other costs that are probably higher in developing countries as compared to advanced countries are catalysts and chemicals, particularly when imported. Their share in production cost, however, constitutes a fraction of one per cent for most of these products, and only a small per cent in the case of ammonium nitrate, roughly 2 per cent.

It is possible to obtain savings in production cost when related plants are integrated on the same site. Such savings are obtained through reduction of capital charges because of the lower fixed investment required for the fertilizers complex mentioned above, as well as reduced overhead per ton of product. Furthermore, transportation cost will be reduced substantially for raw materials when produced and used on the same site.

It may be concluded that economies of scale in the form of returns to scale in many components of production cost, namely, fixed investment, labour, maintenance, supervision and general plant expenses are a predominant characteristic in fertilizer production.

The importance of the scale of operation on cost in the developing countries cannot be overemphasized, since the generally limited local demand tends to impose limits upon the scale of production. Table 8 below indicates that the cost of production may vary by as much as between 20 and 30 per cent.

Table 8. Variation in average production cost, small vs. large capacity plants, United States[a]

(Unit co-efficient assigned to smallest capacity)

Capacity factor	*Ammonia*	*Ammonium nitrate*	*Urea*
1[b]	1.00	1.00	1.00
2	0.87	0.89	0.89
3	0.81	0.83	0.82
4	0.76	0.79	0.79
5	0.71	—	0.75
6	0.68	—	—

[a] For methods of computation and source, see table 7.

[b] Small capacities in tons per year: 30,000 for ammonia, 50,000 for ammonium nitrate and 20,000 for urea.

This cost differential, due to scale, may very well offset any advantages that may ensue from lower cost of natural gas, even if one considers its alternative cost as zero. It is important to select large enough capacity plants so that with a relative advantage in raw material costs, it would be possible for such projects to compete more effectively on the international market. It is very likely that local markets may not be large enough to sustain a moderately large scale plant for a particular country, but it may be possible to create big enough markets through pooling regional demand.

The economics of investing in a plant, the capacity of which for some years may be too large for the immediate demand for its products, present a number of problems, most importantly high production cost due to under-utilization of capacity. The selection of the optimum size of plant under conditions of growing demand is considered elsewhere.[10]

High transportation cost and still more inadequate distribution facilities for fertilizers may impose a serious limitation on the size of plant and hence limit the cost advantages obtainable from economies of scale. On the basis of unpublished material in the United Nations, transportation cost for nitrogenous fertilizer by railway averaged between 5 to 10 per cent of the price in a developing Asian country. But the inadequate services, such as irregular deliveries, posed a serious transport problem for the distribution of the product. This arose from the fact that fertilizers were to be delivered in bulk at an appropriate season. Several proposals to alleviate this problem were discussed, among which were, first, use of motor transport, secondly, installation

[8] In the longer run, through a programme of labour training and better management, the labour cost may be expected to be lower.

[9] For a further elaboration on problems relating to maintenance in developing countries, see *Bulletin on Industrialization and Productivity*, No. 4, op. cit.

[10] "Problems of Size of Plant in Industry in Under-developed Countries", in United Nations *Bulletin on Industrialization and Productivity*, No. 2 (Sales No.: 59.II.B.1).

of relatively small-scale plants and, thirdly, establishing transit stores at appropriate locations to replace the companies' storage, to be filled during the relatively slack periods of transportation.

In order to retain the production cost advantages obtained from relatively large-scale operations, the proposal of transit stores was preferred. Fertilizers shipped and stored during the slack transportation periods were to be sold to farmers during the proper season.

In conclusion, it may be stated that production cost in developing countries is likely to be higher than in advanced countries. The combined capital charges are high, roughly 50 per cent of production cost, and they are expected to be higher in developing countries. Further, the likelihood of operating at relatively low capacities tends also to extenuate the high production cost in the developing countries. An offsetting factor is the natural gas, the cost of which may be lower in some developing countries; the higher capital charges and the scale factor, however, may very well offset such an advantage.

In the longer run, however, as the developing countries gain more experience in production techniques and management, the differential in production cost may be gradually narrowed. Further, in developing countries where gas is being flared and large demand is obtaining either locally or through pooling regional demand, competitive production cost may ensue.

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Printed in U.S.A.
25740—January 1963—4,800

Price: $U.S. 0.75 (or equivalent in other currencies).

United Nations publication
Sales No.: 63.II.B.3
ST/ECA/75

23.7.74