CHOICE OF TECHNOLOGY IN THE PROCESS INDUSTRY IN A DEVELOPING ECONOMY

BY S.G. KIONGA KAMAU, M.Sc., D.I.S.

Thesis submitted for the award of the degree of Doctor of Philosophy of the University of London and for the award of the Diploma of Imperial College.

DEPARTMENT OF CHEMICAL ENGINEERING AND CHEMICAL TECHNOLOGY
IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
PRINCE CONSORT ROAD
LONDON SW7 2BY

APRIL 1979

ABSTRACT

Application of 'advanced' technology in the process industry in a developing economy is considered primarily in terms of its contribution to national welfare, and to the process of industrialisation. A general simplified method for assessing the performance of a process industry has been proposed which seeks to indicate performance of the industry with respect to several criteria including generation of 'direct income' to the nation, the distribution of generated income, employment effects, encouragement of growth of local technological capacity, etc.

The method is applied to a specific developing economy - Kenya - and factors that seem to influence choice of projects and/or technology are discussed. Samples of firms in the industry are used for study in most cases but wherever possible data on most of the industry have been used. The results from this section of the work indicate that project selection methods could be improved by incorporation of factors - externalities - not adequately handled in available methods. The results also suggest that less advanced technology could be more suitable to use in developing economies. The results also suggest a need to define the degree of sophistication or simplicity of processing systems and in this work a preliminary method for assessment of complexity of systems, in terms of levels of complexity, has been proposed.

ACKNOWLEDGEMENTS

Help and co-operation received from the following people and Institutions is gratefully acknowledged.

Dr. D. L. Pyle; for supervision.

Mrs. Sara Kionga Kamau; for graphic work and coffee.

Mrs. Helen Bastin; for typing.

Mechanical Engineering Department, University of Nairobi, for accommodation during my field trip to Kenya.

The Ministry of Commerce and Industry; The Central Bureau of Statistics; and the Central Bank of Kenya for information and data. Special thanks are due to Mr. Ndiho - Director of Commerce and Industry, and to Miss Kagane and Mr. Njonge - Central Bank.

The East African Oil Refineries Ltd., Bamburi Portland Cement Co. Ltd., East African Portland Cement Co. Ltd., Chemelil Sugar Co., The Pyrethrum Marketing Board; Sapa Chemical Industries Ltd.

Lastly, financial assistance from the Government of Kenya throughout my studies in the UK, including my undergraduate work and financial support for the field work, is acknowledged with thanks.

TABLE OF CONTENTS

		Page
ABSTRACT		i
ACKNOWLEDGEMENTS		ii
TABLE OF CONTENTS		iii
LIST OF FIGURES		vii
LIST OF TABLES		viii
CHAPTER 1	INTRODUCTION	1
CHAPTER 2	SIMPLE MULTI-OBJECTIVE CRITERIA FOR ASSESSMENT OF PAST PERFORMANCE OF PROCESS INDUSTRY IN A DEVELOPING ECONOMY	
I	Introduction	10
I.A	Income Generation	12
I.B	Distribution of Direct Income Generated by Industrial Firms Among the Various Sectors of the Economy	19
II	Employment as a Tool for Income Redistribution	23
III	Capital Resource and Efficiency of its Use in an Industry	27
III.A	Level of Self-Reliance of an Industry in Fixed Capital Financing	27
III.B	Relative Efficiency of Use of Capital Finance in an Industry	29
IV	Development Local Skilled Cadre	30
V	Contribution of Firms in the Process Industry to Transfer of Technology : Extent and Cost of Technology Transfer	34
V.A	Stimulation of Local Technological Capacity for Project Planning and Plant Construction	35
V.B	Stimulation of Local Linkages During the Life of a Plant	36
VI	Determinants of Choice of Technology	36
CHAPTER 3	BACKGROUND TO A SPECIFIC DEVELOPING ECONOMY AND SOURCES OF DATA USED TO ASSESS ITS PROCESS INDUSTRY	
I	Background to a Typical Socio-Economic System of a Developing Economy - Kenya	37
II	Sources of Data	39

		Page
CHAPTER 4	ASSESSMENT OF THE PROCESS INDUSTRY IN KENYA WITH PARTICULAR REFERENCE TO FIRMS UTILISING 'SOPHISTICATED' PROCESS TECHNOLOGY	
I	Income Benefits Arising from Operations of a Sample of Firms in the Processing Industry	42
I.A.I	Quantities and Prices of Output Products and of Raw Material Inputs	44
I.A.II	Correction of Export and Import Prices to Reflect Value of Foreign Exchange Earnings	65
I.A.III	Utilities Consumption by Firms in the Sample	68
I.A.IV	Direct Income Benefits Generated by the Sample of Five Firms in the Kenyan Processing Industry - Results	75
I.B	Direct Distribution of Direct Income Generated by a Sample of Firms in the Process Industry	83
I.B.1	Direct Income Accruing to the Rural and Modern Economies	83
I.B.1.A	Values of Variables and Constants	83
I.B.1.B	Results of Direct Income Accruing to the Two Economies	87
I.B.2	Income Distribution to Owners of Means of Production	88
II.A	The Employment Factor	89
II.B	Capital Investment and Employment	94
II.C	Employment Productivity per Capital Investment Unit and Feasibility of Satisfactory Growth of the Local Process Industry	96
III.A	A Level of Self-Reliance of the Industry for Capital Financing	99
III.B	Productivity of Capital in the Economy, in the Manufacturing Sector and in the Process Industry	100
IV	Contribution of Large Firms Utilising 'Sophisticated' Process Technology to Transfer of Technology: Development of Local Skilled Cadre	114
V	Contribution of Large Firms Utilising 'Sophisticated' Process Technology to Transfer of Technology: Costs and Extent of Transfer of Process Technology	121

		Page
V.A	Technology Requirements and Costs of Establishing Manufacturing Facilities Locally	121
V.B	Processing Plants Maintenance Requirements and Recurrent Annual Costs	126
CHAPTER 5	CHOICE OF INDUSTRIAL PROJECTS AND OF TECHNOLOGY IN KENYA, AND PROPOSED METHOD FOR CHOICE OF TECHNOLOGY IN A DEVELOPING ECONOMY	
I.A	Case History of an Investment Project in the Process Industry	130
I.B	Discussion on the Case Study of an Investment Project	137
II	Development Implications of Investments in Advanced Process Technology under Conditions of Technological, Financial, and Market Limitations	140
III	Technology Choice	143
CHAPTER 6	PROPOSED METHOD FOR ASSESSMENT OF COMPLEXITY OF PROCESS TECHNOLOGY IN RELATION TO CHOICE OF TECHNOLOGY	
	Complexity of Technology of Processing Systems	145
I	Equipment Engineering and Fabrication Complexity Levels	147
I.A	Operating Conditions Factors of Equipment Engineering and Fabrication	148
I.A.1	Temperature	148
I.A.2	Pressure	151
I.A.3	Corrosion	154
I.B	Equipment Geometry and Size Complexity Factors	157
I.B.1	Static Equipment Geometric Factors Consideration	158
I.B.2	Dynamic Equipment Geometric Factors Consideration	160
I.C	Size Factor	161

		Page
I.D	Examples of Equipment Complexity Levels due to Geometric and Size Factors	162
II	Complexity of Process Design of Equipment Units	170
II.A	Process Design Complexity Level for an Equipment Unit with Respect to Data Availability	172
II.B	Design Procedure Complexity Level for Equipment Unit	174
III	Process System's Design Complexity	179
IV.	Unit Process Design Complexity Levels and Equipment Engineering and Fabrication Complexity Levels for all Units in a System.	185
V.	Examples of Application of Technology Complexity Assessment Procedure to Processing Systems.	185i
V.A.	Technology of Ammonia Production by Steam Reforming of Naphtha.	185i
V.B.	Technology of a System for Production of Methane and Fertilizer from Biomass and Animal Waste.	185xii
CHAPTER 7	CONCLUSION	
I	Reorientation of Choice of Investment Projects and Technology in Developing Economies	186
II	Further Work	188
REFERENCES		190
APPENDICES		
	Appendix to Chapter 4	
A.4.III	Capital Investment Projects (1964 - 1976) and Form of Financing for a Sample of 7 Large Firms in the Kenyan Process Industry	222
A.4.III	Communication	228
	Appendix to Chapter 6	
A.6.I	Examples of Equipment Complexity Levels with Respect to Geometric and Size Factors	229
A.6.II	Examples of Equipment Units Design with Respect to Data Availability	236
A.6.III	Complexity of System's Design	244

LIST OF FIGURES

Figure		Page
1.1	Schematic Representation of the Project Implementation Process	7
4.1	Variation of Required Rates of Modern Sector Employment Growth with Change of Time Allowed Before all Increase in Labour Force is Absorbed by the Sector	91
4.2	Capital Productivity in the Economy, Manufacturing Sector, and in the Process Industry	108
4.2A	'Actual' and 'Calculated' Capital Formation in the Manufacturing Sector at Constant (1972) Prices	98v
4.3	Capital Productivity Variation with Size of Investment Project	112
6.1	Chemico Flowsheet for Ammonia Production from Naphtha	185ii
6.2	A Process Scheme for Biodegradation of Biomass, Crop Residue, and Animal Waste	185xiii
A.6.1	An Acyclic Processing System with N Units	244
A.6.2	A Recycling System of N Units	245
A.6.3	An Acyclic System (Computation Load)	248

LIST OF TABLES

Number		Page
2.IV.1		32
4.I.1	Quantity and Prices of Dry Flower Raw Material	45
4.I.2	Quantity and Value of Exports of Flower and Powder	45
4.I.3	Quantity and Value of Export Products	45
4.I.4		48
4.I.5	Local Raw Materials for Firm j = 2	50
4.I.6	Domestic Consumption of Products from Firm j = 2	51
4.I.7	Export of Products from Firm j = 2	51
4.I.8	Local Raw Materials for Firm j = 3	52
4.I.9	Domestic Consumption of Products from Firm j = 3	53
4.I.10		55
4.I.11		56
4.I.12		56
4.I.13		58
4.I.14	Refinery Products End Use Analysis	59
4.I.15	Actual Data Quantity and Value of "Home Use" Oil Products and Domestic Market Prices	61
4.I.16	Actual Data on Imports of Oil Products by Kenya and Tanzania from Overseas	63
4.I.17	Estimated Domestic Consumption and Prices of Oil Products from Local Refinery	64
4.I.18	Estimated Exports of Oil Products from the Local Refinery and Export Prices	66
4.I.19		70
4.I.20		72
4.I.21		73
4.I.22	Imports of Chemicals, Maintenance and Operation Services, etc.	74
4.I.23	Direct Income Benefits Generated by a Sample of Firms in Kenyan Processing Industry - Summary	76
4.I.23b	Sensitivity of Annual Income Generated by Sample to Changes in Foreign Exchange Premium: ϵ_p=0.02	79v
4.I.23c	Sensitivity of Annual Income Generated by Sample to Changes in Foreign Exchange Premium: ϵ_p=0.16	79vi
4.I.24	Straight 'Profit and Loss' Annual Account	80
4.I.25	Company 'After-Tax' Profits	81
4.I.26	Distribution of Direct Income Benefits Between the Rural and Modern Economies	86

Number		Page
4.II.1		90
4.II.2	Employment in the Process Industry	93
4.II.3	The Manufacturing Sectors Capital Formation and Employment Growth	95
4.II.3A	Capital Formation in the Process Industry and in Manufacturing Sector	98ii
4.II.4	'Actual' and 'Calculated' Capitalisation in the Manufacturing Sector at Constant (1972) Prices for the Period 1964-1977	98iv
4.II.4	"Expected" and "Most Optimistic" Forecasts of Capitalisation in the Manufacturing Sector	98vi
4.II.5	Expected and Optimistic Forecasts of Capitalisation at Constant 1972 and Constant 1975 Prices	98vii
4.III.1	Capital Investment and Borrowing Requirements for 7 Firms in the Process Industry	99
4.III.2	Capital Expenditure on New Plants and for Expansions in the Process Industry	102
4.III.3	Gross Product (at Factor Cost) for Firms in the Process Industry	103
4.III.4	Number of Firms in Each Industrial Group of the Process Industry	104
4.III.5	Capital Productivity in the Economy, in Manufacturing and in the Process Industry	106
4.III.6		110
4.IV.1	Manpower Structures for a Sample of Firms in the Process Industry	115
4.IV.2		117
4.V.1	Source of Technology for Process Industry's Investment Projects	122
4.V.II	Operation and Maintenance Services and Equipment Imports for Processing Plants	125
4.V.III	Annual Costs for Maintenance and Operation Services and Equipment	126
6.1	Permissable Design Stresses at Design Temperature for Ferrous Plates	150
6.2		151
6.3	Specifications for Materials of Construction for Unfired Vessels	153
6.4		154

Number		Page
6.5	Corrosion Properties of Ferretic Metals and Alloys	155
6.6		156
6.7	Axial and Centrifugal Compressors	163
6.8	Reciprocating Compressors	163
6.9	Classifiers	163
6.10	Heat Transfer Equipment	164
6.11	Tubular Furnace Heater - Indirect Fired Heaters	164
6.12	Continuous Through Circulation Dryers	165
6.13	Rotary Kilns	165
6.14	Plate and Packed Columns	166
6.15	Chemical Reactors	166
6.16	Jaw Crushers	167
6.17	Gyratory Crushers	167
6.18	Roll Crushers	167
6.19	Impact Breakers	168
6.20	Tumbling Mills	168
6.21	Ring Roller Mills	169
6.22	Hammer Mills	169
6.23		183
6.24		184
6.25	Operating Conditions for Ammonia Process	185iii
6.26	Ammonia Process' Equipment Engineering Complexity Levels	185vi
6.27	Overall Ammonia System's Complexity Level w.r.t. Equipment Engineering,etc.	185v
6.28	Equipment Unit Design Complexity Levels for the Ammonia System	185ix
6.29	"Biogas" Plant's Operating Conditions	185xii
6.30	Unit's Complexity Level w.r.t.Engineering...	185xiv
6.31	Unit's Complexity Level w.r.t.Unit Design	185xiv
6.32	Overall Biogas System's Complexity Level w.r.t. Equipment Engineering,etc.	185xv

TABLES IN APPENDICES

Appendix A.4.I

A.4.I.1	Actual Data on Exports of Oil Products by Kenya to East African Countries and Others	199
A.4.I.2	Exported Output Products, Firm j = 2	200
A.4.I.3	Local Raw Materials, Firm j = 1	201
A.4.I.4	Domestic Consumption of Output Product, Firm j = 2	202

Number		Page
A.4.I.5	Exported Output Product, Firm j = 2	202
A.4.I.6	Local Raw Materials, Firm j = 2	203
A.4.I.7	Domestic Consumption of Output, Firm j = 3	204
A.4.I.8	Local Raw Materials, Firm j = 3	205
A.4.I.9	Local Raw Materials, Firm j = 4	206
A.4.I.10	Domestic Consumption of Output, Firm j = 4	206
A.4.I.11	Exported Output Products, Firm j = 4	207
A.4.I.12	Imported Raw Materials, Firm j = 5	208
A.4.I.13	Domestic Consumption of Output Products, Firm j = 5	209
A.4.I.14	Exported Output Products for Firm j = 5	210
A.4.I.15	Income Benefits from Purchase of Process Water by Firm j	211
A.4.I.16	Benefits from Purchase of Electric Power by Firm j	212
A.4.I.17	Salaries Paid to Local Employees	213
A.4.I.18	Direct Distribution of Direct Income from Firm j = 1 to Rural Economy	214
A.4.I.19	Direct Distribution of Direct Income Generated by Firm j = 2 to Rural Economy	215
A.4.I.20	Direct Distribution of Direct Income from Firm j = 3 to Rural Economy	216
A.4.I.21	Direct Distribution of Income from Firm j = 4 to Rural Economy	217
A.4.I.22	Direct Distribution of Direct Income from Firm j = 5 to Rural Economy	218
Appendix A.4.II		
A.4.II.1	Employment in the Whole of the Modern Sector	219
A.4.II.2	Employment Growth in the Chemical Industry	220
A.4.II.3	Manufacturing Sector's Capital Formation and Employment	221
Appendix A.4.III		
A.4.III.1	Summary of Capital Investment Costs, Fixed Capital Investment Costs, and Project Financing for a Sample of 7 Firms in the Process Industry	226
A.4.III.2	Capital Formation and Gross Product in the Whole Economy and in the Manufacturing Sector only	227
Appendix A.6.III		
A.6.III.1	Relative Computation Load in Process Systems Design Calculations	247

CHAPTER ONE

INTRODUCTION.

For most of the third world, the real problem: ".... is one of poverty, and the real challenge is to raise the level of the majority of the population (sic) who have as yet benefitted little from past progress". (1)

It is generally held that to improve the overall economic level of countries in the third world industrialisation of some sort is a necessary precondition. But the question of the form that the industrialisation process must take in terms of technology 'instruments' to be employed has been, largely, only implicitly answered. At the 'macro-planning' level three approaches to industrialisation process are reported to have been adopted (2), viz:-

(a) A strategy that "assumes that the present patterns of modern sector industrialisation will be sustained into the future" and seeks to displace some of the elements of imported technology with locally generated technology.

(b) A strategy that takes "as given the existence of a modern large scale sector - but apart from some minor import substitution of technology, it assumes that this sector will continue to rely on imported technologies as in the past". Contribution of local technological development is seen here to be in "small-scale, low wage industries in the urban and rural economies and on the informal sector".

(c) A strategy based on creation of a more comprehensive industrial structure, including from the start production of capital goods and intermediates. At the same time it "emphasises the role of small-scale sectors supplying mass-demand for simple consumption goods on a regional basis". The strategy is said to aim at importing "a piece of technology" but only once.

The first approach has been criticised on the grounds that the control exerted by foreign technology suppliers would severely constrain the role of local technology in the industry and that the complexity of the technology might involve heavy social costs if foreign skills were substituted by local skills (Cooper and Hoffman (2)). Even

if the second criticism was proved unjustified and the first problem overcome, there remains serious doubts of the feasibility of either importing production technology operated by foreign or local skills at a rate that would be adequate, or developing production technology locally capable of substituting imports, to contribute significantly to the economic welfare of the majority of the population.

The second strategy also has been criticised on the grounds that it overlooks the existence of intersectoral links between small-scale local sectors and the modern sector (2). This criticism implies, correctly, that success of the strategy relies heavily on protection of the small-scale sector against incursions by the modern sector. The degree of protection would have to extend beyond price controls to the labour recruitment field to avoid its entrepreneurs and talent from gravitating towards the modern sector. A major problem with this approach could also be a low practical limit on supply of capital finance for the sectors as it would be competing with the modern sector which is undoubtedly more powerful.

Lastly, the third approach could be criticised on the ground that the task of capturing modern technology especially when extended to capital goods for the other industries would require a very large injection of financial capital and the feasibility of transferring modern technology at this level could prove a major constraint. In addition a capital goods industry would require a market. If slow growth of investments in non-capital goods industries occurred due to high cost of advanced technology it could be a long time before the corresponding capital goods industry could be justified.

In some cases stimulation of the industrialisation process is perceived to occur with attraction of foreign investments into a country. These would employ advanced technology unless economic considerations dictated otherwise.

The strategies outlined above implicitly assume that advanced technology which must - initially, at any rate - be imported will automatically benefit the majority of the population. Another implicit assumption is that the technology suppliers will in most cases be willing to facilitate proper transfer of the technology to the developing economy.

With regard to benefits from technology, clearly these depend on the amount of local inputs into industry and prices paid to local suppliers for them, the outputs from the industry and their prices to

the domestic consumers and in the case of imports of inputs, benefits would be affected by loss of foreign exchange and the effect of import prices on the final products prices. In the case of exports benefits from foreign exchange earnings depend on who normally needs foreign exchange. Thus where the welfare of the majority of the population is the main consideration there is need to establish that technology automatically improves the standards of living of this section of the population.

With regard to technology suppliers facilitating 'transfer of technology' it has been claimed that, under the prevailing technology market conditions, the process accentuates rather than alleviates aspects of 'under-development' (2), (3). Cooper and Hoffman convincingly argue that imperfections in the supply of technology assist firms ".... to appropriate technologies so as to secure quasi-monopolies" and that the producers have developed organisational forms which enable them to "control and exploit" quasi-monopoly (2). The most serious form of organisation is the practice of project and process packaged transactions that are claimed to enable the supplier to control use of technology. One effect of this is seen to be the depressing of local engineering capability through exclusion of use of the technology by other parties and through the supplier's control over strategic management functions (2), (4), (6). The other effect is the resultant "excessive profits" earned by technology suppliers (2), (3), (4), (5), (6). Although the analysis that the technology supplier's strong market position enables him to control use of technology is sound, the data base on which the analysis is based is restricted to a few countries especially in South America and India. This analysis suggests that the purchaser of technology is always unwilling to allow control of local production by the seller. There has been little attention paid to the study of the buyer's approach to acquisation of technology in the international market.

In a recent study, Teece (7) claimed that costs of 'transfer of technology know-how' incurred by a technology seller were often quite substantial - ranging from 2 to 22% of project costs in the "chemicals and petroleum refining" industry and 10 to 59% in the "machinery" industry. The author's interpretation is that these factors mainly determine the cost of a transfer, and warns "It is inappropriate, therefore, to make sweeping generalisations about the process of technology transfer and costs involved" (7).

Strategies on industrialisation seem to be loosely defined with

regard to the actual content of technology and the feasibility of implementation of the technology in terms of capital resource and skill demands. Thus a strategy might implicitly assume expansion of the modern sector using advanced technology invariably results in generation of local technological capacity. The evidence reported in the literature suggests that this cannot be taken for granted. For very simple technology that can be "accessible to virtually everyone" (8) it is hard to see how it could completely substitute more advanced levels of technology, and it could be argued that at very simple level the actual contribution to growth of local technological capacity would be small. It could, however, be advocated on the ground that it has the potential to improve the short term welfare of rural population, but that still leaves the problem of advanced technology and industrialisation unresolved.

Lack of proper definition of technology content is also reflected in methods developed for micro-project planning including those that attempt to measure the social benefits and costs of a project to a nation. These methods are widely known and include UNIDO guidelines (9), methods by Little and Mirrlees (10), and others (11), (12). A recognised weakness in these techniques is failure to treat externalities such as a project's impact on local technological capacity and the failure to recognise factors such as ownership and project financing in terms other than pure financial items. Gutierrez-Duran (13) points out that the methodstake technology as 'fixed' and demonstrates that utilisation of the flexibility that exists in design - such as change in operating conditions of a process - can result in different values of net aggregate consumption (the scaler objective maximising social welfare in financial terms using shadow pricing of inputs and outputs).

The apparent lack to relate to overall strategy on industrialisation by the micro-planning methods and in turn the apparent lack of clear definition of technology acceptable to the economy by common overall industrialisation strategy, seems to be a serious problem. The literature on 'transfer of technology' also introduces the problem of defining technology in such a way that purchasers with little technical background can have an idea of the content of technology. Descriptions of technology in terms such as 'sophisticated', 'simple', etc. are far too general.

In this work a number of problems related to use of 'advanced'

process technology in a developing economy are investigated and include the following:-

1. an attempt to establish the contribution of firms using advanced process technology to economic welfare of the 'majority' of the population as defined in Chapter 2 including an attempt to assess the distribution of benefits between the modern sector and the rural or 'traditional' - (small scale) - sector.

2. an attempt to assess the contribution of advanced process technology to employment. By assuming that rate of employment growth in the industry is maintained at the same level as the rest of the modern sector, feasibility of a stipulated adequate growth of the industry is estimated. Consideration is also given to alternative possible reasons for encouragement of growth of this industry, including its level of self-reliance in financing growth and the productivity of capital relative to capital productivity in other sectors of the modern economy.

3. an attempt to assess the extent of stimulation or creation of local technological capacity.

4. an attempt to assess the determinants of choice of advanced technology in the industry and to delineate factors that seem important in choosing technology for new projects.

5. an attempt to develop a simple method that could be used as a measure of 'complexity' of process technology systems. This could be used as an input to a method for investment projects appraisal.

In the context of this work technology is considered to consist of the following components:-

(i) Technology hardware: the actual hardware of industrial facilities such as plant and process equipment and instruments.

(ii) Technology software: the information and data pertaining to hardware technology and stored in retrievable forms such as books, flowsheets, and other blue-prints on hardware technology.

(iii) Technological expertise: relates to human skills to manipulate, exploit, or create the other components of technology as in (i) and (ii).

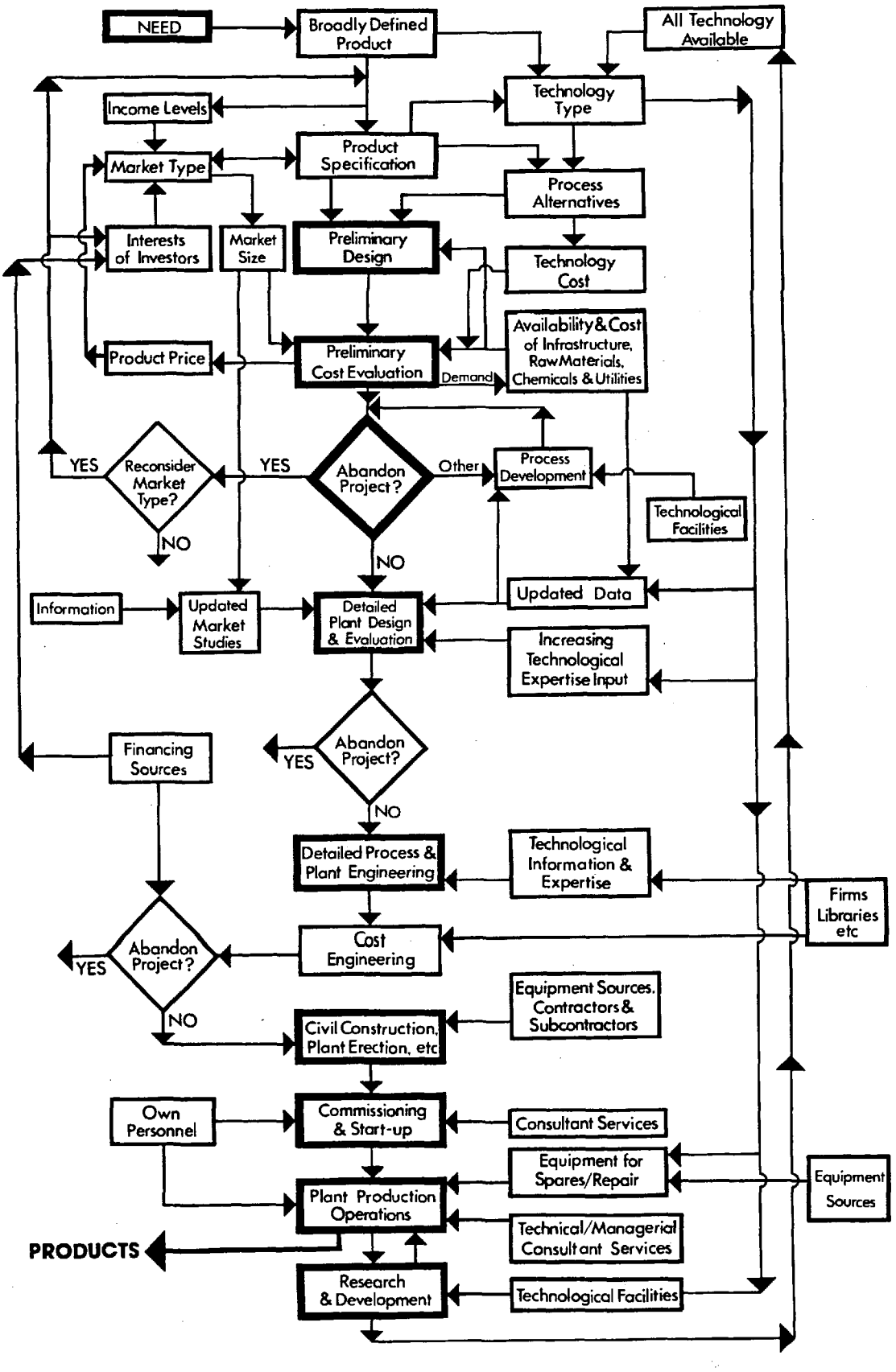
The concept of industrialisation implies the development or imputation, possibly in stages, of technology as considered above. It is possible to specify technology further by including the field of its application. In so far as 'technology transfer' between two environments cannot or does not take place en masse, it seems reasonable when dealing with the subject to make explicit the field and component of technology being transferred.

In chemical/process technology the degree to which a country has successfully acquired technology can be reflected, ceteris paribus, in the value of local inputs to a project that is being implemented. A project's implementation proceeds in stages or phases and each phase offers some opportunity for local acquisation of imported technology. Fig. 1.1 below shows a schematic presentation of a typical project implementation process.

Referring to Fig. 1.1 it can be seen that product specification is determined by choice of product market and available technology. Within the same type (or level of complexity) of technology, alternatives exist which are closely related; but within a broadly specified product different types of technology can be used to produce a commodity with significantly different specifications for meeting different market demands. Specification of these parameters constitutes the 'feasibilities studies' phase of every properly executed project. Once an investor's interests coincide with the existence of a need in a particular type of market, product specification and type of technology (complexity of) can be determined as dependent variables. During this phase preliminary plant designs enables rough estimation of fixed capital costs and production costs.

The crucial importance of this phase is the effect it can have on determining ultimately the products to be manufactured, the market to be served, and the technology to be employed. The skills required

Fig.1.1 SCHEMATIC REPRESENTATION OF THE PROJECT IMPLEMENTATION PROCESS



to execute this phase of a project seem of crucial importance in terms of socio-economic and industrialisation policies.

The other phases of the project implementation process include the following:-

2. Preliminary plant design and process development phase

Technological work involved here consists primarily of establishing the basis for design such as temperatures of cooling water, fuel to be used, etc. (14), preliminary flowsheeting and preliminary specification of operating conditions. During this phase laboratory tests and/or pilot plant studies are carried out to determine any critical data that are not available otherwise.

3. Detailed plant design and engineering phase

Detailed plant design involves refinement of phase (2). A comprehensive schedule of equipment is compiled and "special items put out to preliminary tender for pricing" (15).

Detailed plant engineering work involves preparation of necessary specifications and drawings needed to build the plant, and the procurement of plant items (16).

At the end of this phase tenders for erection and construction can be invited from contractors for quotations.

4. Plant construction and equipment erection phase

This phase is self-explanatory. A contractor with sub-contractors specialising in plant construction is normally hired to execute this phase.

5. Plant commissioning and start-up phase

Work involved here includes mechanical testing and inspection of equipment, and testing of the process operation. Design modifications have often to be made to achieve satisfactory operation of the new plant.

6. Plant operation and maintenance phase

This is self-explanatory. It is the phase at which attention of studies in 'technology transfer' is directed. Although through control of a firm's decision making processes this stage can affect other phases of project implementation, technological skills acquired here are not sufficient to ensure direct generation of a comprehensive

local technological capacity.

7. Research and development phase

Competitiveness in closely specified products makes access to product and process developments obligatory. This phase can be expensive to implement (17) and the results cannot be guaranteed to be useful, i.e. it is a risky undertaking.

A properly executed project proceeds through all the above phases at a cost and ease dependent largely on the type of project, its technology, and local technological infrastructure. A capital goods production project would have similar implementation phases. It can be seen that a strategy on capital goods production is not synonymous with a comprehensive industrialisation strategy. India has been quoted as an example of a country in which establishment of a capital goods industry has not "removed external technological dependency" (18).

This summarises the context in which 'transfer of technology' is considered in this work. In the next chapter simple criteria for assessing the performance of process industry in a developing economy are discussed.

CHAPTER TWO

SIMPLE MULTI-OBJECTIVE CRITERIA FOR ASSESSMENT OF PAST PERFORMANCE OF PROCESS INDUSTRY IN A DEVELOPING ECONOMY.

2.I INTRODUCTION

The purpose of this chapter is to define a simple and comprehensive method for assessing the past performance of an industry in the setting of a developing economy. Objectives behind a performance assessment could be:-

1. To establish the contribution of advanced imported technology in a particular industry to the economic and technological development of a country and hence implicitly to assess the feasibility of achieving desired industrial growth targets through use of the technology under existing, or past, institutional and economic setting.

2. To attempt to gain a qualitative measure of a likely set of opportunity 'costs' of adopting alternative technology policies.

3. To attempt to gain an understanding of the critical factors determining choices of industrial projects and technology in a specific institutional and economic setting. These could then be added to techniques of individual project appraisal by adding important dimensions to them.

Techniques for project appraisal include normal commercial profitability methods and social cost benefit analysis methods such as that proposed by UNIDO (9). Commercial criteria are normally criticised because of use of highly distorted market prices which do not reflect 'true' value of a commodity and take no account of nationally important considerations such as income distribution, foreign exchange values, etc. The social cost benefit methods using objective functions such as 'net aggregate consumption' and shadow prices for traded or non-traded commodities, employment, foreign exchange, and by incorporating factors such as propensity to save, and the investors preference for investment to consumption, assess the social value of a project in essentially quantitative financial terms. It has been recognised however, that the SCB methods have on the whole neglected treatment of externalities (19). Some of these externalities are not readily amenable to translation into financial terms. Thus in application of the principle of opportunity costs to valuation of labour, wage for skilled labour might incur a premium giving it a higher valuation (social wage price) than the market price because it is scarce. But experience gained by a worker

could later result in increased national consumption in another project or it could turn out to be of little national use. Clearly these possibilities cannot be quantitatively and accurately predicted. Similarly the contribution that a project could make to local generation of technological capacity is probably not possible to measure in the same numéraire as traded goods. In working out a simple method for performance assessment of an industry a single established appraisal method could be unsuitable although some aspects from several of them could be adapted for use in it. The proposed method given here is not meant to be a completely rigorous economic analysis but to provide an adequate way of handling readily accessible data and which could allow general conclusions on some consequences of the application of conventional western tailored technology to a third world situation to be made.

A nation could have several 'development' objectives such as increasing national income, intertemporal and interpersonal distribution of it, employment, etc. In addition the question of optimality of means to achieve these objectives is relevant to the level of their attainment. Available works such as those of Griffin and Enos (20), UNIDO (9), Squire and Van der Tak (11), Irvin (12), etc. give good accounts of these and other social objectives and of methods of their assessment at the micro-planning level.

A common objective is that of increase of 'net aggregate consumption' (9) and the distribution of consumption at a point in time and over time (11). At the sectoral level conventional indicators of consumption commonly applied by institutions such as the International Bank for Reconstruction and Development (IBRD) include level of "gross value added" in say the agricultural sector or the manufacturing sector of an economy (1). A method for assessment of performance of an industry should include a form of measure related to consumption, and its distribution.

Another important objective seems to be that of employment due to its distributive effects on consumption, and also because unemployed manpower is wasted natural resource.

Foreign exchange earnings can be a powerful tool in changing the levels of consumption through imports of consumption goods or of capital goods used to improve outputs from production.

Future consumption can be affected indirectly by the impact a project makes on an industry and the economy in terms of stimulation or creation of technological capacity locally.

Finally efficiency of scarce resource utilisation, e.g. utilisation of financial capital, with respect to levels of attainment of the most important national objectives is an important aspect of a method for assessment of industrial projects. This is particularly relevant at the macro-planning level where resources could easily be mobilised towards alternative schemes.

A simple multi-objective industrial performance assessment method is proposed in the following section which consists of quantitative and qualitative performance indicators relating to:-

(i) Contribution of an industry to national welfare in terms of its individual investments' direct effects on consumption - generation of income.

(ii) Contribution to direct employment generation in relation to a nation's unemployment problem over a period of time.

(iii) The level of self-reliance of the industry on its earnings for growth, i.e. proportion of investment costs paid for from the industry's retained profits. In addition the productivity of capital in the industry can be assessed in relation to national averages in order to assess relative efficiency of capital use.

(iv) Contribution to development of a local skilled manpower cadre required for operation and maintenance of production facilities in the industry - an aspect of national self-reliance.

(v) The use of operating capital in the local industry relative to what might be expected under different circumstances, e.g. relative to similar investments in environments with more highly developed technological infrastructures. This aspect could be connected indirectly to the extent to which investments in the industry facilitate effective transfer of technology.

Each of the above aspects of the method will be discussed in turn. In all cases 'industry' refers to the chemical/process industry.

2.I.A Income Generation

Assuming that in the absence of production goods now locally

produced would be imported and taking the commodity prices as constant over the period under consideration, it can be argued that local production increases the 'consumption welfare' of domestic consumers mainly from savings made through purchase of locally produced goods at domestic prices vis a vis import of the same commodities at prices that would entail. Both prices being exclusive of any tariffs and taxes and taking the numéraire as the domestic currency. The official rate of exchange can then be used to convert the possible imports into the domestic currency. The official exchange rate could be objected to on the grounds that it might not reflect the 'true value' of foreign exchange to the economy and in SCB methods foreign exchange rate value is normally adjusted in various ways (12).

Local production can also mainly or solely cater for the export market. In this case local production earns income, from sale of products, for the production owner only although it earns foreign exchange which might be scarce. In addition costs incurred by a local firm could mean income benefit to another group of the population, e.g. to wage earners or to physical material input suppliers. Clearly it is important to distinguish whose welfare is changed by engaging in local production of particular products using a particular type of technology.

Valuation of imports or importables and of exports or exportables can be crudely done as follows. Domestic and foreign currencies are assumed 'freely mobile' so that domestic money is freely convertible and can be invested locally or abroad - for example by the financial institutions. Now considering a local financial institution it could invest a sum of domestic money F, at any time locally, e.g. to industry, at the going rate of commercial interest, $r_{b\ell}$, in the domestic market or abroad at commercial rate of interest of r_{bf}. The marginal value after a unit of time of the sum of money when invested (or borrowed from) abroad instead of being invested in (or borrowed from) the domestic market and assuming equivalence of local and foreign currencies is then:

$$F_{xv} = F(r_{bf} - r_{b\ell}) \qquad (2.I.1a)$$

and the foreign exchange premium, ε_p, is approximated by:

$$\varepsilon_p = \frac{F_{xv}}{F} = (r_{bf} - r_{b\ell}) \qquad (2.I.1)$$

where:

F_{xv} = marginal value of (marginal interest on) F when invested abroad instead of locally. This is considered as the value of foreign exchange associated with exports and imports.

r_{bf} = annual commercial rate of interest on foreign loans.

$r_{b\ell}$ = annual commercial rate of interest on locally borrowed loans.

F, F_{xv} are both in domestic currency, which is freely convertible at the official rate of exchange.

Units of ε_p are domestic currency units per unit of domestic currency.

Another way of looking at the above valuation is by considering the position of a loan seeker who can borrow locally for purposes of importing capital equipment, on which no foreign exchange restrictions are imposed, valued at F units of domestic currency or its equivalent in foreign currency. The alternative to local borrowing is foreign borrowing. The corresponding rates of interests being $r_{b\ell}$ and r_{bf} for local and foreign borrowing. The difference in interest payments between foreign borrowing and local borrowing is then given by Equation (2.I.1a) and an approximation of value of foreign exchange is given by Equation (2.I.1).

Access to loan capital whether local or foreign is by no means always ready and the above treatment is an oversimplification to facilitate consistent numerical handling of the problem. Similarly, with respect to possible substitution of locally produced goods by imports, the availability of foreign exchange can affect the feasibility of substitution of some commodities depending on Government policies on trade. It has been assumed that for the type of goods produced by the local process industry and the size and nature of its market, foreign exchange availability constraint would not be significant.

On the supply side the industry can act as a market for production from other 'sectors' of the economy or for firms within the industry. This can mean an increased income to the input suppliers by the difference between what the firms pay for local input materials and what the same materials would fetch were they to be exported instead. There may be cases, for example, with certain agricultural produce where export is not feasible due to extreme deterioration in transit, or there are no known world markets for the commodity. This situation makes it necessary to process the material locally or alternatively not to produce or grow the 'raw material' at all. Provision of local inputs to the

process industry involves costs to the producers which ideally would set the minimum market value of the inputs. Some of these costs such as labour employment constitute benefits to the nation while others constitute necessary cash outflows from the country in form of payments for imported machinery, etc. Clearly a detailed analysis of all the components of costs entailed in production of local material inputs to the industry, is necessary to arrive at an accurate valuation of them. However, a simplification of the problem can be done by taking the price paid locally for the inputs by the processing firms as a measure of monetary contribution to national income. The error thus introduced is small where the inputs are supplied by several small scale farmers because of the labour intensity of that mode of farming, and higher in the case of plantation farming input sources. Some of this error is reflected in the income distribution calculations done as outlined in Section 2.I.B.

Local supply of maintenance equipment and consultant services can be treated in a similar manner to local raw material inputs.

Income from wage employment is a major contribution to national welfare by any industry. Valuation of its benefit has been much discussed in the cost-benefit analysis literature (see for example 6, 9, 10 and 11). Most developing economies experience acute unemployment problems. It is reasonable to assume, therefore, that the opportunity cost of labour is close to zero. With this assumption the income benefit from wage employment is simply the value of wages and salaries paid to manufacturing firms' employees. Zero opportunity cost of labour also implies that labour recruited by the industry has been unemployed. This is to ignore the mobility of labour and the method adopted here strictly applies to situations with overall growth of employment resulting from industrial investments. The wages and salaries earned by labour can be aggregated for simplification. Question of distribution among the individual employees has been ignored.

Now annual payments in respect of maintenance equipment imports, and for professional expertise hiring from overseas, under contractual or other basis, constitute a flow of foreign exchange from the country. These payments also constitute part of the operating costs of the industry. It can be argued that if foreign imports of skills and equipment were substituted by local skills and machinery - spare and repair - then the operating costs would remain virtually the same unless the domestic supply succeeded to undercut the foreign supply, or the

local supply was so inefficient as to cause effective overall losses in the industry. For the purpose of this study it can be assumed that the effective contribution of imports of repair and spare equipment and of maintenance skills, etc. to income generation is of loss of foreign exchange only. The value of foreign exchange has already been discussed under exports and this treatment can be applied to the negative foreign exchange earnings from annual imports. This effective adjustment applies also to raw material and intermediate products imports and to possible consumer product imports.

There are, of course, other inputs to the industry in the form of transportation and communications infrastructure and utility supplies from the public systems. The firms pay rates on these services. It might be argued that such rates do not truly reflect the cost of supplying the services. It could also be argued that the company taxes on profits are designed to balance out any differences between rates paid and costs of services supply, and that the Government is obliged to provide these services under the existing arrangements in order to attract investors into the industry. The position taken in this study is that rates paid in respect of transportation and communications infrastructures do not constitute a change in income level of the nation. The utilities - fuel, electricity, and water - can be treated as other material inputs. In the case of water and electricity consumptions by the industry, income generation effects are reflected in the difference between the prices paid by the industry vis a vis the prices paid by the general public for unit consumption of the same utility.

Accordingly, the annual income generated by an operating chemical processing firm, j, which accrues to a nation's consumers (through their wholesalers and product distributors), local raw materials and equipment suppliers, to workers and local consultants employed by the firm is given by:

$$W_j = \sum_{k=1} \left[DO_{jk}(p'_{Dk} - p_{Dk})\right] + \sum_{k=1} \left[EO_{jk} \cdot p_{Ek}(r_{bf} - r_{b\ell})\right]$$

$$- \sum_{i=1} \left[LR_{ji}(p'_i - p_i)\right] - \sum_{i=1} \left[IR_{ji} \cdot p_{Ii}(r_{bf} - r_{b\ell})\right]$$

$$+ \sum_{i=1}^{2} \left[U_{ji}(u_{mi} - u_{pi})\right] - MT_j(r_{bf} - r_{b\ell}) + LSB_j + RS_j \qquad (2.I.2)$$

and for the whole or part of the industry:

$$W = \sum_{j=1}^{\text{All firms}} W_j \qquad (2.I.3)$$

where, and using appropriate units:

W_j, W = annual income generated by the firm j and by the process industry respectively.

DO_{jk} = annual quantity of output product, k, (= 1, 2, ...) supplied in the domestic market from firm j.

EO_{jk} = annual quantity of output product, k, supplied to the export market from firm j.

LR_{ji} = annual quantity of raw material, i, (= 1, 2, ...) bought by firm j from the domestic market.

IR_{ji} = annual quantity of raw material, i, imported by firm j.

U_{ji} = annual consumption of process water, U_{j1}, or annual requirements for electrical energy, U_{j2} by firm j.

MT_j = total annual expenditure by firm j on imports of spare or repair equipment, technical and management services, etc., and on imports of chemicals such as catalysts and solvents.

LSB_j = annual expenditure by firm j on wages and salaries to local employees and consultants.

RS_j = annual expenditure on other locally supplied items.

r_{bf} = average annual commercial rate of interest on foreign loans.

$r_{b\ell}$ = average annual commercial rate of interest on locally borrowed finance.

u_{mi} = unit price of water, u_{m1}, or electrical energy, u_{m2}, charged to the process industry.

u_{pi} = unit price of water, u_{p1}, or unit price of electrical energy, u_{p2}, charged to small consumers (i.e. domestic consumers).

p_{Dk}, p_i = the unit price of an output product, k, in the domestic market (p_{Dk}), and the unit price of raw material input, i, in the domestic market (p_i). The unit prices are exclusive of any tariff. p_{Dk} is the ex-factory price and for exportable products it is the f.o.b. price. p_i for locally supplied raw materials is the price paid to local suppliers in respect of materials supplied

to a firm. For imported raw materials it is the price paid by the firm in respect of supplied raw material including commissions and freight charges.

p'_{Dk} = estimated import price of a product k, consumed in the domestic market and normally locally supplied by firm j. This is the estimated c.i.f. price for commodity k, corrected for loss of foreign exchange. Thus if the c.i.f. price is p''_{Dk}, then:

$$p'_{Dk} = p''_{Dk} \left[1 + (r_{bf} - r_{b\ell})\right] \qquad (2.I.4)$$

p'_i = estimated export price of a raw material i, normally supplied to firm j from local sources. This is the estimated f.o.b. price for commodity i, corrected for gain in foreign exchange. Thus if the f.o.b. price is p''_i, then:

$$p'_i = p''_i \left[1 + (r_{bf} - r_{b\ell})\right] \qquad (2.I.5)$$

The unit of currency, in all cases, is the domestic currency. In cases of exports and imports, the foreign prices or costs are converted into the domestic currency using the official rate of exchange.

It has been assumed that the retail prices of products consumed in the domestic market are related to the ex-factory prices or import prices (c.i.f.) in a rational manner so that variations in retail prices in different locations locally arise solely from internal transportation costs. This obviates the need for use of retail prices in measuring benefits accruing to domestic consumers.

The components of W_j and W would be expected to vary from year to year due to fluctuations in prices of inputs and outputs to and from the industry. They would also vary due to possible underutilization of plant capacities resulting from market or plant bottlenecks or capacity overutilization resulting from plant debottlenecking or minor plant modifications in an expanding market. For this reason values of W_j and W could be calculated for a few years in order to establish their averages.

Values of W_j or W so calculated do not make any distinction between group of beneficiaries noted above and refer to intratemporal direct income benefits generated in the productive life of the investments.

2.I.B Distribution of Direct Income Generated by Industrial Firms Among the Various Sectors of the Economy

Income distribution is a developmental problem concerned with intertemporal and intratemporal allocation of consumption as well as the distribution of consumption among different income groups and regions of a country. Here the assessment could be restricted to distribution of income generated by firms operating in the industry among the following economic groups:-

(a) The rural economy. Rural economy being defined as that part of the economy characterised by use of low scale sizes of operations, by simplicity of techniques generally used in production activities, and by simplicity of equipment employed in the sector. This is sometimes referred to as the 'traditional' sector of the national economy.

(b) The modern economy. Modern economy is the converse of rural economy in terms of the definition given above. Thus plantation farming is in the modern economy while small scale subsistence farming (with or without production of some 'cash crops') is in the rural economy. The process industry would largely be part of the modern economy.

(c) The owners of production in the process industry. UNIDO guidelines on project appraisal (9) refers to this economic group as the 'capitalist'. The owners of production would be in the modern economy but their position is unique because of the small size of the group (population) relative to the value of wealth that they command.

Direct distribution of direct income generated by a firm j among the two economies (a) and (b) is given by the following expressions:

$$W_{jR} = \sum_{k=1} \beta_{jk} \cdot DO_{jk}(p'_{Dk} - p_{Dk}) + \sum_{k=1} \xi_R \cdot EO_{jk} \cdot p_{Ek}(r_{bf} - r_{b\ell})$$

$$- \sum_{i=1} \gamma_{ji} LR_{ji}(p'_i - p_i) - \xi_R \cdot MT_j(r_{bf} - r_{b\ell}) + M_{jR} \qquad (2.I.6)$$

$$W_{jM} = W_j - W_{jR} \qquad (2.I.7)$$

where:

W_{jR} = value of income generated by firm j in one year, accruing to the rural economy.

W_{jM} = annual value of income generated by firm j, accruing to the modern economy.

β_{jk} = fraction of total output product k from firm j consumed in the rural economy.

ξ_R = proportion of foreign exchange reserves in the country earned by the rural economy.

ν_{ji} = fraction of total raw material i, supplied to firm j from the rural economy.

M_{jR} = value of miscellaneous income benefits from firm j accruing to the rural economy.

Notation for other variables is as in Section 2.I.A.

Some items of Equation (2.I.2) are not included in Equation (2.I.6) for the following reasons:-

(i) Benefits from consumption of electrical energy and of process water can be considered to affect directly only the modern economy. Most plants in the process industry are located in urban areas which are part of the modern economy. Even where the plants are in rural areas the electricity supplied to them is normally provided by modern economy's enterprises.

(ii) Similarly, income from direct employment by a firm j benefits the modern economy only. The firms in the industry normally recruit from this sector. In cases where labour is taken from the rural area the direct employment income effect can be considered to benefit the modern sector which now absorbs the firm's employees. It could be argued that a firm's operation might generate employment in the rural economy indirectly. This is possible but clearly difficult to measure since then one is dealing with marginal employment generation by a firm relative to other forms of land use.

Foreign exchange reserves gain or loss have been treated as

shown in Equation (2.I.6) because the argument that a country needs foreign exchange implies that all sectors of the economy need foreign exchange reserves. Where 'fair play' is the prime consideration the proportion of foreign exchange reserves 'belonging' to a sector would be equal to the country's foreign exchange reserves earned by the sector using only its own resources. Where equity is important then the proportion of share of foreign exchange reserves 'belonging' to a sector would be equal to the proportion of total population in that sector. Distribution of income benefits to the local owners of the means of production occurs through earnings of 'after-tax' profits P_j, by a firm j, i.e.

$$W_{jpo} = a\, P_j \qquad (2.I.8)$$

where:

W_{jpo} = annual income benefits from firm j accruing to local owners.

a = proportion of local ownership of firm j.

Benefits of 'net income' generated by a firm j and accruing to all foreign interests are given by:

$$W'_{jf} = (1 - a)\, P_j + (1 - \theta)\, MT_j + \tau ESB_j + \sum IR_{ji}\, (p_{Ii} - p''_{Ii})$$

$$+ \sum EO_{jk}\, (p_{Ek} - p''_{Ek}) \qquad (2.I.9)$$

where:

W'_{jf} = annual 'net income' benefits generated by firm j and accruing to all foreign interests (other than loan givers).

$(1 - a)$ = proportion of equity ownership held by foreign business interests.

P_j = annual 'after-tax profit' generated by firm j.

θ = ratio of annual costs MT_j, of imports of chemicals, maintenance equipment, maintenance and operation services, etc. for the plant owned by firm j, to average cost of providing these materials and services to a similar size and type of plant in the industrialised countries. (In the case of materials the relevant price is that of a

commodity in the 'world market'. If possible, equipment costs should be treated similarly). If annual costs in the industrialised country are denoted by MT_j', then θ is defined by:

$$\theta = \frac{MT'}{MT} \qquad (2.I.10)$$

τ = average proportion of salaries paid to expatriate employees of firm j which is repatriated.

p_{Ii} = the domestic price of imported raw material i, f.o.b. port of export.

p_{Ii}'' = the quoted 'world market' price of commodity i.

p_{Ek} = the export price of local product k, (f.o.b.).

p_{Ek}'' = the 'world market' price of commodity k.

In all cases the unit of currency is the domestic currency.

2.II. Employment as a Tool for Income Redistribution

Income redistribution from growth of the modern economic activity can be implemented through increased employment opportunities in the modern economy. Thus UNIDO guidelines on project evaluation (9) classifies labour into skilled and unskilled categories and weights each category differently to reflect income redistribution effects as a result of choosing a specified industrial project. Implicit in models for economic growth and for industrialisation is the assumption that increases in the growth of the labour force will all be absorbed, at one time, by the increasing employment in the 'modern economy' (and not in the 'rural economy'). For this to be realised certain conditions must hold. Stewart (4) gives an expression for the number of years from a base year when there no longer is an increase in number of those employed in the rural economy of a 'two economy' country, as follows (21):-

For all the increase in the labour force to be absorbed into the modern economy at any year, t:

$$\Delta E_m \geq \Delta E_p \qquad (2.II.1)$$

or setting $\Delta E_m = f_m \cdot E_m$ and $\Delta E_p = f_p \cdot E_p$ (taking the increases over a period of unit time (= 1 year)):

$$\frac{E_m}{E_p} \geq \frac{f_p}{f_m} \qquad (2.II.2)$$

Assuming constant values for f_m and f_p, for all time after t_o, the base year, and considering annual values of E_m and E_p, Stewart obtains the expression for the number of years t to elapse before all increases in the labour force can be wholly absorbed by the modern economy. That is, after time t:

$$E_m = E_{mo} (1 + f_m)^t \qquad (2.II.3)$$

and:

$$E_p = E_{po} (1 + f_p)^t \qquad (2.II.4)$$

so that the necessary condition to be fulfilled is:

$$\frac{E_{mo}\,(1 + f_m)^t}{E_{po}\,(1 + f_p)^t} = \frac{f_p}{f_m} \qquad (2.II.5)$$

where:

E_{mo} = number employed in the modern economy at base year (time t_o).

E_{po} = total labour force in the country at base year.

E_m = number employed in the modern economy at time t years after the base year.

E_p = total labour force in the country at a time t years from the base year.

f_m = constant rate of growth of employment per unit time (in this case one year) as a fraction of those employed in the modern economy at a time (t - 1) years from the base year.

f_p = constant rate of growth of population per unit time as a fraction of the population at time (t - 1) years from base year.

Thus, if E_{mo}, E_{po}, f_m, and f_p are known, the number of years, t, to elapse before all labour force increases are wholly absorbed in the modern economy can be calculated. For Kenya,Stewart found the value of t to be 200 years (21) - a very long time. In fact such a calculation can be misleading. Over 200 years the assumption of constancy of values of f_m and f_p is almost certainly violated. These growth rates cannot therefore, be taken as constant over a long period of time.

As an illustrative example the percentage growth rates per annum for Kenya in modern economy employment from 1966 to 1974 have been calculated (Appendix A.4.II.) and were seen to vary from 0.6% in 1966 to 8.5% in 1974. Using five year period moving averages, estimates of the employment's annual growth rates are approximately given by a linear function of time for f_m, over the period. ($f_m = 0.86\ t + 0.4$ where t = years since 1965).

It seems more useful therefore, to set a value for t, say 20 years, over which f_m might reasonably be assumed to be constant, then estimating f_p from demographic data and institutional policy on population growth, and estimating E_{mo} and E_{po} from statistical data, to evaluate the value of f_m necessary for the above condition to be fulfilled. Then

varying t under the relevant estimates of f_p, the feasibility of achieving the necessary value of f_m within reasonable time can be better examined.

Applying the same assumption of constancy of f_m and f_p the previous expression can be rearranged as:

$$f_m (1 + f_m)^t = \frac{E_{po}}{E_{mo}} \cdot f_p (1 + f_p)^t \qquad (2.II.6)$$

or:

$$\left[f_m^{1/t} (1 + f_m)\right]^t = \frac{E_{po}}{E_{mo}} \cdot f_p (1 + f_p)^t$$

or:

$$f_m^{1/t} (1 + f_m) = \left[\frac{E_{po}}{E_{mo}} \cdot f_p (1 + f_p)^t\right]^{1/t}$$

Thus:

$$f_m^{1/t} + f_m^{(t+1)/t} - \left[\frac{E_{po}}{E_{mo}} \cdot f_p (1 + f_p)^t\right]^{1/t} = 0 \qquad (2.II.7)$$

This equation can be solved for f_m. Performance of the process industry can be assessed using values of f_m for other sectors of the economy.

The redistribution effects of employment are assumed to arise from the earnings of formerly unemployed labour who were not receiving wages before entering the modern economy. Strictly the productivity of labour and its share of income generated from application of labour and capital should be considered in connection with the redistribution question. But such level of detail does not seem justified by the objectives of this work. Similarly, no effort has been expended on categorising types of employment and problems of defining underemployment in the rural economy are avoided by the above method. Opportunity cost of rural employment is assumed to be less than the modern sector wage rates so that there is no problem in persuading unemployed labour to take up modern economy unemployment. The other important assumption is that the economy can accommodate the rising number of employees absorbed from the rural sector growth of the labour force which may be much higher than

the growth of labour force already in the modern sector economy. If location of the sector is geographically in urban areas then this assumption is likely to invalidate the proposition that in all cases the growth of the labour force can be absorbed into the modern sector economic activity. This will be examined in the light of results under validity of the assumption. Growth of employment is, ceteris paribus, dependent on availability of adequate investment resources and past growth rates of the economy may not be feasible over the whole of the stipulated 20 years. This point can also be considered.

Another indicator of contribution to employment is by comparing numbers employed in the industry vis a vis numbers employed in the manufacturing sector per unit of capital invested. A similar approach was followed by the World Bank Mission to Kenya for different sectors. Accordingly, employment generation by capital invested in the process industry relative to manufacturing sector, REGC, is given by:

$$REGC = \frac{E_{IND}}{E_{MFG}} \cdot \frac{C_{MFG}}{C_{IND}} \quad , \quad \text{where } E_{IND} \subset E_{MFG} \qquad (2.II.8)$$

and:

E_{IND} = employment in the industry (numbers).
E_{MFG} = number employed in the manufacturing sector.
C_{IND}, C_{MFG} = fixed capital investment estimates in the industry and the manufacturing sector respectively.
REGC = employment generation by capital in the process industry relative to employment generated by capital in the manufacturing sector.

for REGC $\geq$ 1 employment in the industry is concormant with capital resources consumed by the industry relative to other industries in the economy.

2.III CAPITAL RESOURCE AND EFFICIENCY OF ITS USE IN AN INDUSTRY

2.III.A Level of Self-Reliance of an Industry in Fixed Capital Financing

A point often made in "equilibrium growth" economics is that over a period of time increase in 'capital stock', i.e. investment, denoted by ΔK and I respectively, must be a function of savings in a well balanced economy (22). Savings in turn are always a proportion of income generated by the economy, i.e. the value of output of the economy less costs of production other than salaries and wages. Thus, for a sector i, of an economy:

$$\Delta K_{Ti} \leq \sum_{t}^{T} S_{it}\, Y_{it} \qquad (2.III.1)$$

where:

T denotes time t = T years from time t = 0, over which increase in capital stock is considered over the level of stock at time t = 0.

t denotes any period (years) from base time t = 0.

S_{it} = proportion of output Y_{it} from industry i saved in the t^{th} year. (i = 1, 2, ...) and (t = 0, 1, 2, ...)

For the whole economy:

$$\Delta K_N = \sum_{i}^{M} \Delta K_{Ti} \leq \sum_{i}^{M} \sum_{t}^{T} S_{it}\, Y_{it} \qquad (2.III.2)$$

where M is the total number of industries or sectors in the economy and subscript N denoted 'whole economy' for time considered.

If an industry reinvests all its savings and its level of investment does not exceed its level of savings and considering a period T year from base year t = 0, then:

$$\Delta K_i = \sum_{i}^{T} I_i = \sum_{t}^{T} S_{it}\, Y_{it} \triangleq \sum_{t}^{T} p_{it} \qquad (2.III.3)$$

where p_{it} = profits earned by firms in industry i in year t.

The above expression applies to both new projects or expansions of existing facilities. The value of p_{it} would be that of profit after

payment of income tax. But earned profit need not be reinvested in the economy by industry i, and the industry might rely on other sectors of the economy to finance its investments. To allow for this possibility ΔK_i is generally given by:

$$\Delta K_i = \sum_t^T I_{it} = \sum_t^T pr_{it} + \sum_t^T bc_{it} \qquad (2.III.4)$$

where:

bc_{it} = value of loans borrowed to cover difference between reinvested profits and value of capital investments.

pr_{it} = value of reinvested earned profits.

Now since bc_{it} must ultimately come from the rest of the economy the degree of dependency of industry i on the rest of the economy is reflected in the value of $BCIR_i$ which is defined by:

$$BCIR_i = \sum_t^T bc_{it}/\Delta K_i \qquad (2.III.5)$$

where $BCIR_i$ = ratio of borrowed capital to total investment capital in industry i. $\sum bc_{it}$ can also be considered in terms of total investment in the whole economy in relation to the question of appropriateness of investing in this industry vis a vis other industries. This can be done very crudely as follows. δ_{2i} is defined as the proportion of capital available to the nation for investment that is transferred from other sectors of the economy to industry i, i.e.

$$\delta_{2i} = \sum_t^T bc_{it}/\Delta K_N \qquad (2.III.6)$$

Now, investing heavily or not investing at all in industry i could be justified on the grounds that incremental output per unit capital invested in the industry is higher or lower, respectively than the national average for the time considered, or:

$$ROK_i = \frac{(\Delta Y_i/\Delta K_i) - (\Delta Y_N/\Delta K_N)}{\left(\frac{\Delta Y_N}{\Delta K_N}\right)} \qquad (2.III.7)$$

For the borrowing to be justified $ROK_i \geq 0$ and vice versa where ΔY_i,

ΔY_N, ΔK_i, ΔK_N are incremental values of output of industry Y_i and the economy Y_N and of investments in industry K_i and the economy as a whole K_N, over the period T years from $t = t_o$.

A qualitative interpretation of values given by the above expressions is possible. Thus should δ_{2i} be greater than zero and ROK_i be less or equal to zero reasons for new borrowing in the industry must be justified on grounds other than purely economic ones. Conversely with very high values of ROK_i, higher values of $BCIR_i$ could be tolerated on economic grounds. Inclusion of δ_{2i} is for purposes of putting the value of $BCIR_i$ into its perspective by giving the relative impact of $\sum bc_{it}$ in the economy.

2.III.B Relative Efficiency of Use of Capital Finance in an Industry

Given the technology type in use in an industry, financial costs of industrial investments could nevertheless vary from one country to another due to factors quite external to the nature of the technology. Such differences could sometimes be attributed to seemingly inevitable technology transfer costs (7), or to inefficient planning and organisation of project investments at the implementation stages. Since capital availability is a major constraint on 'development' the question of performance of an industry with respect to capital costs relative to a 'standard' state seems important because it could lead to reduction of wastage in future projects.

The standard state could be taken as the state in a country or countries which are the origin of a substantial amount of technology in the developing economy, i.e. the highly industrialised countries. Costs here could be taken as representing a target norm of efficiency of capital utilization. The ratio of capital costs in an industrialised economy for a project to capital costs in the developing economy for a similar project can then be regarded as a crude indicator, χ, of relative efficiency of use of capital finance in the industry, i.e.

$$\chi = \frac{1}{J} \sum_{J=1} (C_j'/C_j) \qquad (2.III.8)$$

where:

J = total number of processing plants considered.

C_j = capital costs for processing plant j, with given design capacity, in a developing economy.

C_j' = capital costs for similar processing plant j, in a highly industrialised economy.

NB Similarity of plants could be based on the plant's design capacity.

A favourable value for χ is: $\chi \geq 1$, otherwise project costs in the developing economy are higher than in industrialised economies.

The components of fixed capital costs can be separated in hope of gaining knowledge of the specific areas of efficiency and inefficiency. This can be conveniently done by considering costs of implementing different phases of projects, and comparing as before. Thus:

$$\chi_{jf} = \frac{1}{M} \sum_j C_{jf}'/C_{jf} \qquad (2.III.9)$$

where:

χ_{jf} = relative efficiency of implementing phase f, of a project, for plant type j, in a developing economy relative to implementation of the phase in a highly industrialised economy for a similar plant.

C_{jf}', C_{jf} are costs of similar plants, for phase f, in the two economies.

M = total number of plants included in a study.

Other aspects connected with transfer of technology are considered in Sections 2.IV and 2.V.

2.IV Development of Local Skilled Cadre

Advanced technologies inevitably require highly skilled manpower inputs. A country intending to expand its local industry using this technology invariably has to confront the problem of development of local skilled cadre to man the industry. Unavailability of local skilled manpower can impose severe constraints on the feasibility of successful implementation of industrial development plans.

It could be argued that any locally unavailable skilled manpower can be imported and in practice developing economies rely on some import of skilled manpower. Import of skilled manpower seems feasible provided that the local demand for such skills is small, i.e. industrial

growth for section of the industry with highly skilled manpower input is severely restrained and made into an enclave, or when an industry is very young. However, the cost in foreign exchange of long term massive import of skilled manpower required for an expanding advanced technology industry would undoubtedly place a constraint to the industry's growth. Besides, as Hirschman (23) puts it:-

".... very few countries would even consciously wish to specialise in unskilled labour, while foreigners with a comparative advantage in entrepreneurship, management, skilled labour and capital take over these functions replacing inferior 'local talent' !"

The cost of acquiring such skills by local people is obviously equally important but it would seem that were such costs to be too high then the question would be reduced to one of alternative technologies or development activities available to a nation and not to an immediate conclusion that import of skills on a long term basis was inevitable.

It can be safely assumed therefore, that in terms of wider national industrialisation strategies, one of the major objectives for importing advanced manufacturing technology is to facilitate transfer of that technology into the local technological and social-economic structures. Development of local, highly skilled manpower cadre, would be part of the process of technology transfer. The skill requirements for the technology span the whole spectrum of a technological infra-structure, e.g. skills for equipment fabrication, skills for industrial projects analysis and planning, skills for industrial processes and plants design and engineering, etc. The various skills could be expected to be absorbed locally, progressively, with time.

Among the first skills that one would expect to be transferred are skills for operation, maintenance, and management of local production facilities. In looking at the performance of the process industry evidence of these skills being transferred can be sought. Time required for possible local development of these skills can be used in indicating success of such skill development provided that the specific skill requirements in an industry can be roughly defined.

Specific skill requirements for operation and maintenance of processing plants depend on such factors as the plant size, the level of sophistication - or complexity - of its processes, and the degree of automation. In general, however, input of highly skilled manpower is

regarded as high in the industry. Thus for United Kingdom the percentage distribution of skills in two subsectors of processing industry are as follows (24):-

TABLE 2.IV.1

Skill Category	Subsector and % distribution in 1975	
	General chemicals	Pharmaceuticals
Graduate engineers	3.2	0.5
Scientists	5.8	8.7
Technicians	12.0	14.8
Maintenance and construction crafts	23.0	8.8
Other skills	8.0	4.0
Production workers	36.6	39.0
Commercial and distribution	11.4	24.2

Depending on the total numbers employed in an industry it can be seen that skilled manpower - graduate engineers, scientists, and technicians - requirements could form a constraint to the growth of the industry in a developing economy. Skill requirements in the processing industry has roughly been found through an ILO study (25) to be as follows:-

(a) General Management - administrators, accountants, personnel managers, etc.

Typical requirements for top management include a university degree, a working knowledge in each of the functional areas of the plant, and at least five years experience in management positions.

(b) Production Staff

Production manager - typical qualification include a university degree in engineering, plus five - ten years practical experience working on similar plants as say an engineer.

Production supervisors - typical requirements are usually a

chemical engineering technician's certificate plus on-the-job training or long experience as a process operator with supervisory training.

(c) Maintenance Staff

Engineering manager - a relevant engineering degree plus a few years on-the-job training and experience.

Maintenance foreman or supervisor - requires a technician's qualifications and some experience.

Skilled maintenance workers - usual training for these skills is acquired in vocation schools or in apprenticeship programmes or some combination of the two lasting between 3 and 4 years.

(d) Quality Control - laboratories usually headed by a university graduate in chemistry who might be assisted by another graduate in chemistry. Technicians do not normally have university degrees.

It would appear from the above brief discussion that provided academically qualified local people are available, e.g. graduate engineers and scientists, school leavers with qualifications in physical sciences, etc. about ten years of deliberate on-the-job training would be adequate for a newly built plant to be fully manned by local personnel. In studying a firm, utilization of local manpower can be used to indicate the firm's contribution to development of local skilled manpower cadre.

Performance of the industry with respect to local skilled manpower utilization can thus be viewed in terms of the number of local people holding key production posts paying due attention to the time since the firm started production locally. The categorisation of skilled personnel for each firm can be made as follows:-

1. Years since firm started production (to be noted).
2. Number of local people (locals) versus total engaged in the top firm management level (excluding board of directors).
3. Number of locals versus total engaged in senior plant management level - scientists and engineers managing the firm's technological affairs.
4. Number of locals versus total engaged as senior plant supervisors or superintendents.

5. Number of engineers and scientists who are local versus total number engaged on a more or less pure non-management professional capacity (i.e. receiving directives from above but not directly responsible for execution of the technological solution to the problems they are asked to solve).
6. Number of locals versus total engaged as plant foremen or senior technicians.
7. Number of locals versus total engaged as plant skilled craftsmen and technicians.
8. Number of locals versus total engaged as semi-skilled craftsmen and operators.

The results can be tabulated for the firms in the industry whose data are available. Isolation of estimated earnings between the local personnel and the expatriate personnel might indicate the valuation of local manpower by the industry in monetary terms. This could be useful in estimating costs for imports of skills vis a vis costs for employing local manpower.

2.V Contribution of Firms in the Process Industry to Transfer of Technology: Extent and Cost of Technology Transfer

An industrialised state can be considered to be one in which all aspects of technological infrastructure are well inter-related or linked. Thus in such a state the final demand chemical products manufactured locally are linked to intermediate chemical goods from local sources or to local raw material supplies. Similarly, local plant construction for an industry would be linked to local capital goods industry and to local sources of plant and process design and engineering services.

In studying the process of technology transfer from industrialised to industrialising economies, the contribution of individual firms in an industry can be reflected in the firms' progressive use of local technological inputs starting at the preliminary project planning phase, to plant construction, to plant operation and maintenance phase and even up to process research and development phase. One method for tracing this process is by using costs of project implementation attributed to local material or service supplies.

2.V.A Stimulation of Local Technological Capacity for Project Planning and Plant Construction

Plant equipment supply costs for a new plant in the chemical industry in the industrialised countries vary between 20 and 40% of fixed capital costs. Instrumentation piping and electricals account for 8 - 30% of fixed capital costs. Using median values as in Peters (128) these items cost 52% of fixed capital costs. When plant is on-stream input of spare and repair equipment constitutes a significant recurrent cost of production. There is therefore, a strong enough incentive to provide these items locally. In assessing the contribution of firms using sophisticated technology to the process of technology transfer a dynamic indicator of performance could be the change in proportions of plant equipment supplied locally between a plant's latest expansion project and its initial project. These proportions can be considered in terms of equipment costs. The dynamic indicator of change can be denoted by Φ_j, for a firm j and defined by:

$$\Phi_j = \frac{c_{qtj} \cdot C_{fij} - c_{qij} \cdot C_{ftj}}{C_{fij} \cdot C_{ftj}} \qquad (2.V.1)$$

and for a sample of firms in an industry or for the whole industry:

$$\Phi_s = \frac{\sum_j c_{qtj} \cdot \sum_j C_{fij} - \sum_j c_{qij} \cdot \sum_j C_{ftj}}{\sum_j C_{fij} \cdot \sum_j C_{ftj}} \qquad (2.V.2)$$

where:

c_{qij} = cost of locally supplied equipment during initial construction of plant run by firm j.

c_{qtj} = cost of locally supplied equipment during the latest expansion of plant run by firm j.

C_{fij}, C_{ftj} = total fixed capital costs for initial and expansion plant construction projects for firm j.

Φ_s = dynamic indicator of equipment linkages generation by firms in the process industry.

Other inputs at the planning and plant construction stages of a project's implementation can be similarly treated.

2.V.B Stimulation of Local Linkages During the Life of a Plant

A progressive change in input of local maintenance equipment to a plant owned by firm j would, in theory, be observed culminating with the change in local equipment input during a major expansion programme relative to value of input when the plant's technology was first introduced into the country. A study of this process at the plant operation stage would be useful in giving a clearer picture of the dynamics of stimulation of local technological capacity.

Data on imports of maintenance equipment and of maintenance and operation services might be sufficient to indicate whether there is a significant contribution from local sources to a firm's equipment and service needs. This can be done on an annual maintenance costs basis relative to the fixed capital investment costs.

2.VI Determinants of Choice of Technology

Under 'phases of project implementation', the processes leading to, and taking place during and after, an industrial project's investment were outlined. In setting them out thus it was assumed that the investor had sufficient know-how and control to plan, organise, and direct the choice of technology and the implementation process. This text-book situation could be roughly applicable to major investments in the industrialised countries. The degree to which it applies to developing economy needs to be established, at least empirically. A convenient way of doing this would be by considering a case study of a major project from time of its inception through to the launching of its construction programme.

A study of this kind could be useful in determining the dominant factors influencing the choice of technology in developing economies.

In the following chapter a specific developing economy is introduced. This economy's process industry will be used to study the role of sophisticated technology in contributing to economic welfare of the majority of the population in the country and to the industrialisation process. It will also be used to study some of the institutional factors that might influence choice of this type of technology.

CHAPTER THREE

BACKGROUND TO A SPECIFIC DEVELOPING ECONOMY AND SOURCES OF DATA USED TO ASSESS IT'S PROCESS INDUSTRY.

3.I BACKGROUND TO A TYPICAL SOCIO-ECONOMIC SYSTEM OF A DEVELOPING ECONOMY - KENYA

Kenya is an agricultural country. 85% of the population is rural based. The main economic activity is agricultural production for subsistence by small scale farmers. However, there is a modern sector of the economy which includes commercial and industrial enterprises, large scale farming and Government institutions such as the civil service. This is the sector in which 15% of the population is active and on which much attention is normally focussed.

The country is not rich, with a gross domestic product in 1970 and 1974 at constant (1964) prices of 485 million K£[1] and 607 million K£ respectively. Of this, gross fixed capital formation was 95.5 million K£ and 99.3 million K£ respectively. Gross domestic product per capita for the two years were K£ 43.2 and K£ 47.0 respectively (26). In the same years agriculture accounted for 34% and 32% respectively of the total gross domestic product, while the manufacturing industry followed with a share of 11% and 13% respectively to take second place. The importance of both industries is indubitable. In the past there has been a marked interdependence between these two sectors such as in food processing industry. While diversification in the future will no doubt progressively mask this interdependence, growth of the manufacturing[2] sector and specifically of chemical and processing industry must be based on the inputs and outputs to and from the agricultural sector.

Growth of the manufacturing sector seems important for the improvement of material standards of life. At present the sector is quite small both in terms of its contribution to the national income and to employment. Ideally its growth should be steady and self-sustaining and its benefits should accrue to the nation with a socially just distribution. In practical terms that means more involvement by the 85% of the population currently outside the modern sector.

In 1974 the population of persons aged between 14 and 54 years

---

[1] In 1974 rate of exchange was about: 1 US$ ≡ 0.357 K£ : 1 £ Sterling ≡ 0.75 K£. K£ = Kenya pound.

[2] Manufacturing sector as used in this work includes such industries as the chemical processing industry, food, textile, metal products, electrical machinery, motor vehicle body building industries, etc.

was estimated (from 1969 census) to have been about 6 million people. The number employed in the modern sector and in the public service was only 830,000, (27), i.e. less than 15% of the population fit for work. Even taking account of those still in school and training institutions, the figure for those needing alternative employment was still very high.

In 1974 the whole of the manufacturing sector employed 100,000 (28). The conventional process industry's[1] share of persons engaged in the sector was 10,400 persons or about 10% of those engaged in manufacturing industries (see Table A.4.II.3 in Appendix A.4.II), and ~1.3% of total engaged in the whole of the monetary economy. The contribution of the conventional process industry to gross domestic product in 1974 was 26.8 million K£ at current prices (Table 4.III.3 in Chapter 4.III), i.e. 23% of the manufacturing sector's gross product[2]. This contribution was made by firms in the following industrial groups:-

Manufacture of paints, varnishes and lacquers.
Manufacture of cleansing preparations and cosmetics.
Petroleum refining.
Cement production.
Soda ash production.
Wattle extraction.
Extraction of oleo resin from pyrethrum.
Manufacture of basic industrial chemicals.
Manufacture of pulp and paper.
Production of sugar from cane.
Manufacture of vegetable and animal oils.

This industry can, therefore, be seen to play an important role in the manufacturing sector.

When value of GDP is considered the country can be seen to be among the poorest in the world. The manufacturing sector and the industries comprising it are still at an infant stage. The economy,in

---

[1] The process industry as considered in this work does not include the textile industry (normally weaving), foods and drinks processing, e.g. flour mills, breweries, etc., leather treating industry, and similar non-chemical processing industries.

[2] The sectors gross product at current prices in 1974 was 118.7 million K£ (29).

the sense of monetary measures is a developing one, and has been selected for study using methods described in Chapter 2.

3.II Sources of Data

The mass of data required for study of the Kenyan process industry was obtained from several sources including the following:-

National Accounts publications.
Company reports.
Field work - including questionnaires to and personal interviews with a few firms in Kenya; examination of records made available by the Central Bank of Kenya, and the Ministry of Commerce and Industry (Kenya); and unpublished data from the Central Bureau of Statistics. Use of these primary sources was made under research permit number OP.13/0C1/709/7.

In Appendix A.4.III a copy of communications attached to data made available by the Statistics Office (Nairobi) is shown for purposes of illustration of the limitations of the data referred to but also to demonstrate the position in the country with regard to publication of data in a form that identifies a particular company without the company's consent. Most of the data obtained during the field work was given in confidence and the identity of the companies for which such data refers cannot regretably be revealed.

The method used for some of the field data reported in Chapter 3 can be briefly outlined:-

Section 4.I

Data on imports, by a sample of firms in the process industry, of chemicals, spare/repair equipment, management and other service fees were obtained from records on applications for authority to purchase foreign exchange kept in the Central Bank. This involved identifying the applications made by firms in the sample among all the applications recorded for the country, noting the exchange authority licence numbers and confirming the nature of the imports for which authority was given by referring to copies of the application forms kept by the bank. Complete records available went only back to July, 1974 and data were gathered in the first 7 months of 1977. The data included here were

covered by licence numbers lying between licence number 154,000 (July, 1974) and 323,000 (December, 1976). Data here included imports of physical materials only. For "technical and management fees" reference was made to file EC 15/01641.

Sections 4.II, 4.III and 4.V

Data on capital costs for plant expansions and on which summary in Appendix A.4.III was based were supplied by the companies involved and supplemented/confirmed by reference to files on the companies kept in the Central Bank.

Section 4.IV

Data on firm manpower structures were given by the firms included in the sample survey. A copy of a questionnaire was sent to each firm and on their return the firms senior personnel gave interviews to clarify the manpower structures and other data.

Section 5.I

The case history outlined in Chapter 5(I) is based on documents kept in the Ministry of Commerce and Industry and the Central Bank on the project. The records examined included files IND11/01/pA, IND11/01/pB, IND11/01, IND11/04 and CB/15/02151A.

The application of method described in Chapter 2 to the process industry in Kenya follows in Chapters 4 and 5. Wherever possible most of the industry has been included but in some cases it was practically possible to consider only samples of a few important firms that use 'sophisticated' technology for local production. Each sample included at least one firm producing solely for the domestic market or for the export market using domestic raw materials, and at least one firm using imported raw materials.

A measure of the importance of the firms in the sample can be illustrated by considering the sample considered in Section 4.I in terms of its contribution to the gross domestic product. Gross product (in 1974) for firms in industrial groups:-

Petroleum refining.
Pyrethrum processing.
Cement manufacture.
Sugar cane processing.

amounted to 13.1 million K£ (Table 4.III.3). This amounts to about 50% of the industrial groups in the process industry as defined earlier in this chapter and to 11% of total gross product from the whole of the manufacturing sector. Of the samples considered in Chapter 4 the sample of firms in Section 4.I was the smallest.

CHAPTER FOUR

ASSESSMENT OF THE PROCESS INDUSTRY IN KENYA WITH PARTICULAR REFERENCE TO FIRMS UTILISING 'SOPHISTICATED' PROCESS TECHNOLOGY.

4.I Income Benefits Arising From Operations of a Sample of Firms in the Processing Industry

The annual income generated by a firm j, and accruing to a nation's consumers, local raw materials and equipment suppliers, and to local workers and consultants employed by the firm, is denoted by W_j (for any year), and given by:

$$W_j = \sum_k \left[DO_{jk}(p'_{Dk} - p_{Dk})\right] + \sum_k \left[EO_{jk} \cdot p_{Ek} (r_{bf} - r_{b\ell})\right] - \sum_i \left[LR_{ji} (p'_i - p_i)\right]$$

$$- \sum_i \left[IR_{ji} \cdot p_{Ii} (r_{bf} - r_{b\ell})\right] + \sum_{i=1}^{2} U_{ji} (u_{mi} - u_{pi})$$

$$- MT_j (r_{bf} - r_{b\ell}) + LSB_j + RS_j \qquad (2.I.2)$$

where, and in appropriate units:

DO_{jk} = annual quantity of firm's output product, k, (= 1, 2, ...) sold in the domestic market.

EO_{jk} = annual quantity of firm's output product, k, sold in the export market.

LR_{ji} = annual quantity of raw material, i, (= 1, 2, ...) bought by firm j from the domestic market.

IR_{ji} = annual quantity of raw material, i, imported by firm j.

U_{ji} = annual consumption of process water, U_{j1}, or annual requirements for electrical energy, U_{j2}.

MT_j = total annual expenditure on imports of spare or repair equipment, technical and management services, etc. and on imports of chemicals such as catalysts and solvents.

LSB_j = annual expenditure by the firm on wages and salaries to local employees and consultants.

RS_j = annual expenditure on other locally supplied items.

r_{bf} = average annual commercial rate of interest on foreign loans.

$r_{b\ell}$ = average annual commercial rate of interest on locally borrowed finance.

u_{mi} = unit price of water, u_{m1}, or electrical energy, u_{m2}, charged to the process industry.

u_{pi} = unit price of water, u_{p1}, or unit price of electrical energy, u_{p2}, charged to small consumers (i.e. domestic consumers).

p_{Dk}, p_i = the unit price of an output product, k, in the domestic market, p_{Dk}, and the unit price of raw material input, i, in the domestic market, p_i. The unit prices are exclusive of any tariff. p_{Dk} is the domestic ex-factory price of output products. p_i for locally supplied raw materials is the price paid to local suppliers in respect of materials supplied to the firm. For imported raw materials it is the price paid by the firm in respect of supplied raw material including commissions and freight charges.

p_{Ek} = the f.o.b. price of domestic export product, k.

p'_{Dk} = estimated import price of a product, k, consumed in the domestic market and normally locally supplied by firm j. This is the estimated c.i.f. price for commodity, k, corrected for loss of foreign exchange. Thus if the c.i.f. price is p''_{Dk}, then:

$$p'_{Dk} = p''_{Dk}\left[1 + (r_{bf} - r_{b\ell})\right] \qquad (2.I.4)$$

p'_i = estimated export price of a raw material, i, normally supplied to a firm, j, from local sources. This is the estimated f.o.b. price for commodity, i, corrected for gain in foreign exchange. Thus if the f.o.b. price is p''_i, then:

$$p'_i = p''_i\left[1 + (r_{bf} - r_{b\ell})\right] \qquad (2.I.5)$$

p_{Ii} = the f.o.b. price of imported raw material product, i.

The unit of currency in all cases is the domestic currency. In cases of exports and imports, the foreign prices or costs are converted into domestic currency using the official rate of exchange. 1 K£ is equivalent to about 1.33 £ sterling.

For this section of this work, a sample of five important firms in the process industry in Kenya have been selected for study.

The selected firms own the following types of processing plants:-

1. Pyrethrum flower extraction and refining plant.
2. Portland Cement manufacturing plant.
3. A second Portland Cement manufacturing plant.
4. A crude sugar extracting and refining plant based on sugar cane as raw material.
5. A crude petroleum oil refining plant.

Expression for income generated by a firm j, i.e. W_j in Equation (2.I.2) gives values of total income accruing to the specified beneficiaries on an annual basis only. Normally W_j would be evaluated for several years and an average value of W_j obtained for purposes of assessing the performance of a firm j with respect to local income generation. It has been possible to evaluate values of W_j for the above plants, for 3 years only including the years 1974, 1975 and 1976. This is because records from which data on imports of equipment for repair or spare purposes, imports of technical, management, and marketing services, and of chemicals, could be obtained went back to 1974 only. After a certain period of time these records are normally destroyed. All of the above firms had been operating in the country for more than 9 years in 1976 and it seems reasonable to assume that the 3 years' data would give a fair representation of the situation for most of the life of a particular plant. Before presenting the results it is useful to outline the basic data used for calculation of W_j for the above plants. This can be done firm by firm for the items considered.

4.I.A.1 Quantities and Prices of Output Products and of Raw Material Inputs

1. Pyrethrum Processing Plant (Firm j = 1)

(a) Raw Material Input

Both the quantity and value of dry flower delivered to the plant for processing are published annually in the company's annual report and accounts. For 1974 - 1976 the relevant publications are references (30), (31) and (32). This gives values for LR_{j1} and for p_1, where subscript 1 denotes dry pyrethrum flower.

Estimates of 'would-be' export prices for dry flower can be

TABLE 4.I.1
QUANTITY AND PRICES OF DRY FLOWER RAW MATERIAL

Year	Dry flower delivered to plant, LR_{j1} mt	Domestic unit price p_1 K£/mt	Estimated export price p_1'' K£/mt
1974	13,722	292.96	330
1975	15,035	286.80	340
1976	14,267	310.44	350

Sources of Data: References (30), (31) and (32)

TABLE 4.I.2
QUANTITY AND VALUE OF EXPORTS OF FLOWER AND POWDER

Year	Quantity, EO_{j1} mt	Value, $(EO_{j1} \times p_{E1})$ K£	Unit price, p_{E1} K£/mt
1974	4094.0	1,112,880	272
1975	4593.4	1,296,386	282
1976	3664.9	1,201,094	328

Sources of Data: References (30), (31) and (32)

TABLE 4.I.3
QUANTITY AND VALUE OF EXPORT PRODUCTS

Year	Quantity of		Value of	
	Extract, EO_{j2} (mt)	Marc, EO_{j3} (mt)	Extract, $(EO_{j2} \times p_{E2})$ (K£)	Marc, $(EO_{j3} \times p_{E3})$ (K£)
1974	474.664	6187.7	4,559,886	175,187
1975	313.913	5076.0	3,506,286	181,142
1976	506.304	1626.2	5,726,774	60,645

Sources of Data: References (30), (31) and (32)

made by using the firm's realised prices for export of flower and powder. Pyrethrum powder contains a lower content of pyrethrin than the dry crop delivered by the farmers to the firm. Thus in 1972, 4,323 tonnes of powder were made from 2,993 tonnes of dry flower delivered to firm (33), giving a dry flower to powder ratio of 100 : 144 by weight. Similarly, in 1974, 3,900 tonnes of powder were made from 2,659 tonnes of dry flower delivered to firm (30) giving a dry flower to powder ratio of 100 : 147. Thus if the f.o.b. price of powder is p_{E1}, a close approximation - ignoring blending costs - for the f.o.b. price of dry flower, p_1'', (before correction for gain of foreign exchange) is given by:

$$p_1'' = 1.44\ p_{E1} \qquad (4.I.1)$$

Available data gives export quantities and value (f.o.b.) of "pyrethrum flower and powder" and it is not possible to deduce from the data the exact amount of unprocessed dry flower exported by the firm as such and hence of the powder exported. However, since in 1974, 3,900 tonnes of powder were made (30) and only 4,094 tonnes of "pyrethrum flower and powder" were exported (34), the bulk of this product consists of powder and the approximation above would be still roughly applicable. The presence of dry flower in the "pyrethrum and powder" would raise the coefficient '1.44' if this was taken into account.

Equation (4.I.1) above is used to estimate the "would-be' f.o.b. export prices of dry flower, p_1'', had the material all been exported instead of being supplied to the local firm j = 1. Table 4.I.2 gives the quantity and values (f.o.b.) of 'flower and powder' exported in the years 1974, 1975 and 1976. These values allow calculation of p_{E1} for each year and hence of p_1''. The value of p_1'' obtained by the calculation is then adjusted to allow for some powder grinding and blending costs and in order to make the estimate conservative. For 1974 the estimated value of p_1'' used later in this work is 61 K£/mt lower than that given by the approximation Equation (4.I.1). Similarly, the 1975 and 1976 estimated values of p_1'' are lower than those given by Equation (4.I.1) by 65 K£/mt and 122 K£/mt, respectively.

Table (4.I.1) shows the annual quantity of raw material delivered to the firm, the actual price paid for it by the firm to

local suppliers and the estimated 'would be' f.o.b. export price for the raw material. The years 1974 - 1976 are covered.

Dry pyrethrum flower is the only raw material to this processing plant.

(b) Output Products

Output products from the plant are (1) a crude oleo resin extract, some of which is further refined to increase the concentration of pyrethrin , (2) marc, which is the residue remaining after extraction of pyrethrin., and (3) pyrethrum powder, which is ground dry pyrethrum flower blended with marc.

Domestic consumption of the products is small compared to the exported products. Thus total company revenue from sale of extract and pyrethrum powder and flowers was 6.384 million K£ in 1974* (30); 5.357 million K£ in 1975 (31); and 6.389 million K£ in 1976 (32). For the same annual accounting periods, revenue from export of the same products were 5.092 million K£ in 1974* (35); 5.346 million K£ in 1975 (35); and 5.092 million K£ in 1976 (36). The firm is also in an influential world market position for its products and can influence commodity prices. It is unlikely, therefore, that products consumed in the domestic market and supplied by the firm would be at a greatly differing price from that which would obtain if local supply was substituted by imports - ignoring the transportation costs which are not significant for the extract product. Because of the problem of estimation of quantities of products consumed by the domestic market, these have been neglected in the study.

For the export market data are readily available and shown on Tables 4.I.2 and 4.I.3 for the three products.

2. Portland Cement Manufacturing Plants (Firms j = 2 and j = 3)

(a) Raw Materials

In terms of cost the important raw materials for portland cement manufacture are gypsum and limestone. Requirements for each per tonne of cement manufactured are as follows (37):-

---

* 1974 financial year being from October, 1973 - September, 1974 and similarly for the other years. Data later used in applying Equation (2.I.2) for firm j = 1 are, however, for the calendar year.

Limestone requirements = 1.3245 mt/mt cement
Gypsum requirements = 0.04255 mt/mt cement

Both of these materials are locally supplied. The prices at which they are supplied are, however, unavailable. For gypsum the domestic price paid by the local firms are assumed to be the same as the prices paid for export of surplus gypsum from the country. For the three years the amount of gypsum exported were 2,967 tonnes (34), 3,093 tonnes (38), and 3,315 tonnes (39) in 1974, 1975, and 1976, respectively. The corresponding revenues from those quantities of exports were K£ 12,389, K£ 31,596 and K£ 49,431, which gives gypsum prices of 4.2 K£/mt in 1974, 10.2 K£/mt in 1975 and 14.9 K£/mt in 1976.

For limestone nominal domestic prices of 1.0 K£/mt in 1974, 2.0 K£/mt in 1975, and 2.5 K£/mt in 1976 were assumed. The same prices were assumed for would-be export prices.

The companies involved in cement production are also involved in quarrying operations locally and it is likely that the prices assumed above are low thus favouring supply of the materials to the local cement factories.

(b) Output Products from the Cement Manufacturing Plants

Portland cement production by the two plants owned by firms j = 2 and j = 3 for the three years were as follows (40):-

TABLE 4.I.4

Year	Total Production (mt)/annum	Annual Domestic Consumption (mt)/annum
1974	854,555	326,350
1975	892,054	341,945
1976	986,874	358,438

Firm j = 3, up to 1976 had a plant whose capacity was 250,000 tonnes per annum and the plant operated at 68% of this capacity, throughout the 1974 - 1976 period (41). Thus production of cement by firm j = 3 was constant at about 170,000 tonnes per annum. Production of cement by firm j = 2 is then the difference between this figure and

the ones given above for annual total production by the two firms, assuming disposal of total annual production in the same year.

As for the markets of the cement outputs from the two firms, firm j = 3 supplies the domestic market only (42) and its plant's location is in the interior of the country. Plant owned by firm j = 2 is located on the coast catering mainly for the export market but also supplying the domestic market. The size of the domestic market is shown on Table 4.I.4 above. Hence annual exports and domestic sales for each firm can be calculated.

Domestic Prices of Output Product - Unit Prices of Cement, p_2

Actual domestic prices are not available but Tanzania imported substantial quantities of cement from Kenya and from other countries during the 1974 - 1976 period. It is assumed that Kenya exported to Tanzania at the same prices as the prices in the domestic market during this time when the East African Community Organisation was in existence. For the 1974 - 1976 period Tanzania imports of cement from Kenya and the revenues from them were 37,553 tonnes at a total cost of 522,908 K£ in 1974 (34); 38,359 tonnes at a total cost of 631,986 K£ in 1975 (38); and 27,392 tonnes at a total cost of 436,459 K£ in 1976 (39). From this domestic unit price of cement is estimated as p_{D1} = 14 K£/mt in 1974; p_{D1} = 18 K£/mt in 1975; and p_{D1} = 16 K£/mt in 1976. The estimated prices p_{D1} are slightly higher than the Tanzania prices, this is because the wholesale price in Nairobi in February 1977 was about 26 K£ per tonne rising to 32 K£ per tonne in Kisii (43). The would-be import prices are also estimated on the basis of Tanzania imports from countries outside East Africa. Data from references (34), (38) and (39) for quantities and values (c.i.f.) of Tanzania imports of cement give import c.i.f. prices of cement as 15.04 K£ per tonne in 1974; 23.80 K£ per tonne in 1975 and 22.88 K£ per tonne in 1976. On this basis the Kenyan would-be unit price of cement import, p_{D1}'', is estimated at 15 K£ per tonne in 1974; 20 K£ per tonne in 1975 and 19 K£ per tonne in 1976. (1 K£ ≡ 1 Tanzania £).

Data on quantities and values (f.o.b.) of cement exports to countries within and outside East Africa are readily available for the period 1974 - 1976. The total quantities of cement exports, including exports to East African countries, and the f.o.b. values of those exports were 528,205 tonnes at a total cost of 4,505,400 K£ for 1974 (34); 550,109 tonnes at a cost of 6,013,200 K£ in 1975 (38); and 628,436 tonnes at a cost of 8,069,708 K£ in 1976 (39). This gives export unit prices for

TABLE 4.I.5

LOCAL RAW MATERIALS FOR FIRM j = 2

Year/material	Quantity of raw material, LR_{ji}	Domestic price, p_i	Export price, p_i''
units	(mt)	(K£/mt)	(K£/mt)
LIMESTONE			
1974	LR_{j2} = 909,210	p_2 = 1.0	p_2'' = 1.0
1975	LR_{j2} = 956,740	p_2 = 2.0	p_2'' = 2.0
1976	LR_{j2} = 1,081,930	p_2 = 2.5	p_2'' = 2.5
GYPSUM			
1974	LR_{j3} = 29,210	p_3 = 4.2	p_3'' = 4.2
1975	LR_{j3} = 30,740	p_3 = 10.2	p_3'' = 10.2
1976	LR_{j3} = 34,760	p_3 = 14.9	p_3'' = 14.9

TABLE 4.I.6
DOMESTIC CONSUMPTION OF PRODUCTS FROM FIRM j = 2

Year	Quantity, DO_{jk}	Domestic price, p_{Dk}	Import price, p_{Dk}''
units	(mt)	(K£/mt)	(K£/mt)
PORTLAND CEMENT			
1974	DO_{j1} = 156,350	p_{D1} = 14	p_{D1}'' = 15
1975	DO_{j1} = 171,950	p_{D1} = 18	p_{D1}'' = 20
1976	DO_{j1} = 188,440	p_{D1} = 16	p_{D1}'' = 19

TABLE 4.I.7
EXPORT OF PRODUCTS FROM FIRM j = 2

Year	Quantity, EO_{j4}	Price, p_{E4}	Value, (EO_{j4} x p_{E4})
units	(mt)	(K£/mt)	(K£/annum)
1974	EO_{j4} = 530,120	p_{E4} = 8.54	4,505,000
1975	EO_{j4} = 550,410	p_{E4} = 10.93	6,013,200
1976	EO_{j4} = 628,440	p_{E4} = 12.84	8,069,708

TABLE 4.I.8

LOCAL RAW MATERIALS FOR FIRM j = 3

Year/material	Requirement (mt)	Domestic price, p_i (K£/mt)	Export price, p_i'' (K£/mt)
LIMESTONE			
1974	LR_{j2} = 225,160	p_2 = 1.0	p_2'' = 1.0
1975	LR_{j2} = 225,160	p_2 = 2.0	p_2'' = 2.0
1976	LR_{j2} = 225,160	p_2 = 2.5	p_2'' = 2.5
GYPSUM			
1974	LR_{j3} = 7,234	p_3 = 4.2	p_3'' = 4.2
1975	LR_{j3} = 7,234	p_3 = 10.2	p_3'' = 10.2
1976	LR_{j3} = 7,234	p_3 = 14.9	p_3'' = 14.9

TABLE 4.I.9

DOMESTIC CONSUMPTION OF PRODUCTS FROM FIRM j = 3

Year	Production (mt)	Domestic consumption DO_{jk} (mt)	Domestic price p_{Dk} (K£/mt)	Import price $p\acute{\acute{}}_{Dk}$ (K£/mt)
PORTLAND CEMENT				
1974	170,000	DO_{ji} = 170,000	p_{D1} = 14	$p\acute{\acute{}}_{D1}$ = 15
1975	170,000	DO_{ji} = 170,000	p_{D1} = 18	$p\acute{\acute{}}_{D1}$ = 20
1976	170,000	DO_{ji} = 170,000	p_{D1} = 16	$p\acute{\acute{}}_{D1}$ = 19

Source of Data: Tables 4.I.5 to 4.I.9 inclusive are summaries of data and information given, for portland cement manufacturing plants owned by firms j = 2 and j = 3, under the heading of "Quantities and prices of output products and of raw material inputs" above.

cement, p_{E4}, of 8.54 K£ per tonne in 1974; 10.94 K£ per tonne in 1975 and 12.84 K£ per tonne in 1976.

Tables 4.I.5 through to Table 4.I.9 above summarise the information contained in the discussion on cement production with respect to quantities and prices to be used in application of Equation (2.I.1) to firms j = 2 and j = 3.

3. Sugar Factory (Firm j = 4)

(a) Local Raw Materials for the Sugar Factory

During the process of crushing of cane to extract raw sugar and subsequent refining the plant considered here is assumed to have a cane to sugar ratio of 10 to 1. Refined sugar production outputs for firm j = 4 were 39,230 tonnes, 39,920 tonnes and 46,090 tonnes in 1974, 1975 and 1976 respectively (47). Cane processed by the plant is then estimated by multiplication of these figures by 10 for each year.

Actual average cane prices for cane deliveries to sugar factories in the country were 3.089 K£/tonne, 4.474 K£/tonne and 5.226 K£/tonne in 1974, 1975 and 1976 respectively (44).

Estimation of would-be export prices is made difficult by the fact that unprocessed cane would be unsuitable for exportation in bulk due to rapid deterioration with storage. However, it is possible to extract crude sugar in very small units by small groups of farmers who could then export the crude sugar for refining. Value of raw sugar exports less extraction costs would then give a rough indication of the value of 'cane exports'.

Raw sugar requirements, for a conventional refining plant, say, in America, per tonne of refined sugar is 1.06 tonnes (45). Exports of raw sugar from Kenya or Tanzania were as shown on Table 4.I.10. below.

The would-be export price, p_i'', for cane is then assumed to be half the price of 'cane equivalent' in raw sugar export for any year. This is a crude estimation method. However, it seems likely that prices paid for local cane during the 1974 - 1976 period were lower than prices dictated by world market in refined sugar. The annual average prices for refined sugar in New York are reported to have been 270 K£/tonne (= 757 US$/tonne) in 1974; 247 K£/tonne (= 691 US$/tonne) in 1975; and 167 K£/tonne (= 469 US$/tonne) in 1976 (46). These figures show prices of sugar going down over this period while the prices of cane paid to the Kenyan farmers were going up as shown above.

TABLE 4.I.10

Reference	Year	Raw sugar quantity (mt)	Raw sugar value (K£)	Price of cane equivalent (K£/tonne cane)
(34)	1974	126	12,958	10.3
(38)	1975	12,002	1,680,339	14.0
(39)	1976	21,629	3,567,694	16.5

TABLE 4.I.11

Year	Raw material (cane) quantity, LR_{j3} (mt)		Domestic price, p_3 (K£/mt)	Estimated 'export' price, p_3'' (K£/mt)
1974	392,300	(47)	3.09	5
1975	399,200	..	4.47	7
1976	460,900	..	5.23	8

TABLE 4.I.12

Source	Year	Quantity of molasses (mt)	Value (K£)	Export price, p_{Ek} (K£/tonne)
(34)	1974	24,257.2	189,928	7.83
(38)	1975	43,258.3	313,870	7.26
(39)	1976	14,943.5	511,352	34.22

In summary, for firm j = 4, the quantity and prices for local raw materials were as shown on Table 4.I.11. above.

(b) Output Products from the Sugar Factory

One of the products - refined sugar - has already been mentioned. All of this product is consumed in the domestic market. Domestic price, p_{Dk}, can be assumed to be the same as the import price. This is because Kenya was a net importer of refined sugar (in 1974 the country imported 70,703 tonnes of sugar; in 1976 it imported 45,501 tonnes of sugar (44)). It seems reasonable to assume that local ex-factory prices would be fixed at the c.i.f. price p''_{Dk}, of imports or higher, depending on the form and degree of protection of the sugar industries. For refined sugar then, $p_{Dk} = p''_{Dk}$, which for the period considered were 126 K£ per tonne in 1974 (34), 150K£ per tonne (estimate) in 1975 and 164 K£ per tonne in 1976 (39).

The other important product of sugar factories is sugar molasses. This product is mainly exported as shown on Table 4.I.12. above.

Output of sugar molasses can be calculated by using a cane to molasses ratio of 1 to 0.035. Thus for the cane delivery figures shown earlier amount of molasses produced is estimated at 13,720 tonnes for 1974; 13,960 tonnes for 1975 and 16,135 tonnes for 1976.

Notation applicable to Equation (2.1.2.) for the products of firm j = 4 is as follows:-

DO_{j2} = refined sugar for domestic consumption.
p_{D2} = domestic price of refined sugar.
p''_{D2} = would-be import price of sugar.
EO_{j5} = molasses for export.
p_{E5} = export price for molasses.

The outputs' quantities and prices are as given above.

4. Petroleum Oil Refining Plant (Firm j = 5)

(a) Raw Materials

Crude petroleum oil is the raw material for firm j = 5. All of the raw material was imported from the Middle East during the 1974 - 1976 period. Data on crude oil's annual import quantity, IR_{j1}, and of its c.i.f. value, $(IR_{j2} \times p_{I1})$, where p_{I1} is the unit f.o.b. price of crude oil at any one year, are readily available. For the 1974 - 1976 period,

these values were as follows:-

TABLE 4.I.13

Year	Crude oil quantity IR_{jl} (mt)	f.o.b. value (IR_{jl} x p_{Il}) (K£)
1974	2,807,700	67,027,000
1975	2,825,500	86,822,000
1976	2,490,000	93,470,000

Sources of Data: for 1974, reference (34); for 1975, reference (38); and for 1976, reference (39).

There was no local supply of raw material for the refinery.

In terms of litres of crude oil, imports in 1974 were 3.3254 x 10^9 litres; in 1975, 3.2845 x 10^9; and in 1976, 3.038 x 10^9 litres (49). For purposes of estimation of electrical energy requirements later, the plant production capacity is taken as constant for the three years at 3.3 x 10^9 litres per annum.

(b) Output Products from the Refinery

The refinery output products include the following:-

Liquefied petroleum gas (LPG)
Motor spirit
Turbo-fuel
Kerosene
Gas oil
Diesel oil
Fuel oil
Bitumen
Residue (including heavy residual fuels such as bunker C, and acid sludge)

All of the residue is exported to countries outside East Africa.

TABLE 4.I.14
REFINERY PRODUCTS END USE ANALYSIS

Product and year	Refinery output production	QUANTITY OF EXPORTED PRODUCT			Domestic consumption DO_{jk}
		East Africa	Others	Total EO_{jk}	
LPG	tonnes	tonnes	tonnes	EO_{j6} (tonnes)	DO_{j3} (tonnes)
1974	17,300 (d)	2,662.80 (34)	1,457.80 (34)	4,120.60	12,400 (c)
1975	17,700 (d)	2,571.50 (38)	2,290.40 (38)	4,861.90	13,400 (c)
1976	19,200 (d)	2,376.10 (39)	2,549.10 (39)	4,925.20	14,700 (c)
Motor Spirit	litres x 10^3	litres		EO_{j7} (litres x 10^3)	DO_{j4} (litres x 10^3)
1974	498,447 (a)	186,958	- (34)	186,958	311,489 (b)
1975	491,808 (a)	166,834	- (38)	166,834	324,974 (b)
1976	491,390 (d)	157,837	- (39)	157,837	333,553 (b)
Jet fuel	litres x 10^3			EO_{j8} (litres x 10^3)	DO_{j5} (litres x 10^3)
1974	344,600	25,719 (34)	-	25,719	318,881 (b)
1975	412,819	35,777 (38)	-	35,777	377,042 (b)
1976	310,778	6,614 (39)	-	6,614	304,164 (b)
Kerosene	litres x 10^3			EO_{j9} (litres x 10^3)	DO_{j6} (litres x 10^3)
1974	135,054	66,765 (34)	- (34)	66,765	68,269 (b)
1975	152,715	78,163 (38)	3,690 (38)	81,853	70,862 (b)
1976	150,978	80,616 (39)	2,310 (39)	82,926	68,052 (b)
Gas oil	litres x 10^3			EO_{j10} (litres x 10^3)	DO_{j7} (litres x 10^3)
1974	466,651 (a)	-	-	168,752	297,899 (b)
1975	489,883 (a)	-	-	186,165	303,718 (b)
1976	489,300 (d)	-	-	148,494	340,806 (b)
Diesel oil	litres x 10^3			EO_{j11} (litres x 10^3)	DO_{j8} (litres x 10^3)
1974	180,209 (a)	20,575.447 (34)	97,017.467 (34)	117,592.914	47,599 (a)
1975	158,665 (a)	14,204.975 (38)	78,365.263 (38)	95,570.238	38,640 (c)
1976	116,480 (d)	8,473.041 (39)	50,509.816 (39)	58,982.857	52,609 (b)
Fuel oil	litres x 10^3			EO_{j12} (litres x 10^3)	DO_{j9} (litres x 10^3)
1974	845,610 (a)	101,098.293 (34)	333,357.383 (34)	434,455.676	437,098 (b)
1975	821,860 (a)	70,703.283 (38)	275,301.236 (38)	346,004.519	464,295 (b)
1976	781,700 (d)	56,922.014 (39)	114,348.309 (39)	171,270.323	534,010 (b)
Bitumen	tonnes			EO_{j13} (tonnes)	DO_{j10} (tonnes)
1974	36,600 (d)	7,634.6 (34)	414.3 (34)	8,048.9	27,104 (b)
1975	40,700 (d)	5,936.2 (38)	3,066.8 (38)	8,703.0	30,200 (b)
1976	42,200 (d)	5,141.7 (39)	2,187.4 (39)	7,329.1	31,204 (b)
Export residue	litres x 10^3			EO_{j14} (litres x 10^3)	
1974	607,268 (a)	-	-	582,635.406 (34)	-
1975	527,287 (a)	-	-	393,032.241 (38)	-
1976	363,260 (d)	-	-	560,503.947 (39)	-

Source of Data: Reference (a) refers to Table 153 of Reference (44)
Reference (b) refers to Table 157 of Reference (44)
Reference (c) refers to Table 10.4 of Reference (50)
Reference (d) refers to Table 10.3 of Reference (50)

NB Production and exports/domestic consumption figures in some cases do not agree. This would be due to market supply and demand fluctuations

For all of the other products, each product is partly consumed in the domestic market, partly exported to other East African countries, and except for motor spirit, kerosene and jet fuel exported to countries mainly in the Central Africa region such as Zaire, Zambia and Rwanda. In addition the companies in the local oil distribution business import some of the products to supplement the output from the refinery and to satisfy the demand of the extensive market of this region of Africa. Fortunately, data on the refinery product outputs and of domestic consumption of oil products are available from a number of publications. Data on all import and export commodities are also annually published in the "Annual Trade Report" for the East African countries, i.e. Kenya, Uganda and Tanzania up to 1977 and for Kenya only from 1978. By use of these publications for the years 1974 to 1976 it has been possible to obtain or deduce quantities of each product from the refinery consumed in the domestic market, the East African (Tanzania and Uganda) market or in other export markets. Table 4.I.14 tabulates these figures. For ease of reference later, the notation of variables of Equation (2.I.2) has been indicated where applicable. In this case, DO_{jk}, i.e. quantity of output product k, consumed in the domestic market, and EO_{jk} the quantity of output product k, which is exported. Figures in brackets indicate that data entry has been obtained from the referred publication. It might be useful to note that normally LPG, fuel oil, and diesel oil are entirely supplied from the local refinery, i.e. are not supplemented by imports.

Domestic and Export Prices of the Refinery's Output Products

Domestic prices, p_{Dk}, for refinery output products are estimated from the published quantities and values (monetary) of oil products recorded as products for "home use" in "Annual Trade Report" publications for the relevant year, e.g. reference (34). For the years of interest the locally produced petroleum products were subject to an excise duty rate equal to the rate of import duty levied on imports of these products (34). In some cases local production is supplemented by imports and the quantities and values under "home use" would include the imported element in the statistics of the annual report. Although the values thus recorded are free of tariffs they include freight and handling costs for that portion of a product which is imported. Nevertheless, the monetary values thus recorded indicate the valuation of the products by the oil companies (several oil companies rent the

TABLE 4.I.15

ACTUAL DATA QUANTITY AND VALUE OF "HOME USE" OIL PRODUCTS AND DOMESTIC MARKET PRICES

Year	1974			1975			1976		
Output product	Quantity of oil product	Value (K£)	Domestic price, P_{Dk}	Quantity	Value (K£)	Domestic price, P_{Dk}	Quantity	Value (K£)	Domestic price
LPG	(mt) 12,919.0	535,870	(K£/mt) 41.48	(mt) 13,997.8	926,816	(K£/mt) 66.21	(mt) -	-	(K£/mt) -
Motor spirit	litre x 10^3 315,251.754	9,609,235	K£/litre x 10^3 30.48	313,755.591	12,120,237	K£/litre x 10^3 38.63	1,076.577	69,804	K£/litre x 10^3 64.84
Jet fuel	litre x 10^3 314,416.32	8,659,530	K£/litre x 10^3 27.54	385,351.443	15,737,052	K£/litre x 10^3 40.84	40,292.684	1,722,221	K£/litre x 10^3 42.74
Kerosene	litre x 10^3 81,478.490	2,690,413	K£/litre x 10^3 33.02	77,051,527	3,013,551	K£/litre x 10^3 39.11	4,981.220	264,914	K£/litre x 10^3 53.18
Gas oil	litre x 10^3 311,711.95	9,151,397	K£/litre x 10^3 29.36	270,580.34	9,121,524	K£/litre x 10^3 33.71	4,774.816	203,872	K£/litre x 10^3 42.70
Diesel oil	litre x 10^3 99,669.414	2,328,802	K£/litre x 10^3 23.37	110,513.290	3,539,228	K£/litre x 10^3 32.03	-	-	K£/litre x 10^3 -
Fuel oil	716,301.45	15,290,384	21.35	683,538.825	17,715,950	25.92	-	-	-
Bitumen	(mt) 21,366.8	757,279	(K£/mt) 35.44	(mt) 30,384.3	946,535	(K£/mt) 31.15	(mt) 3,148.5	228.947	(K£/mt) 72.72

Source: Data for 1974 are from "Annual Trade Report", Reference **(34)**
Data for 1975 are from "Annual Trade Report", Reference **(38)**
Data for 1976 are from "Annual Trade Report", Reference **(39)**

NB Data for 1974 and 1975 include locally produced oil products as well as imports consumed in the domestic market. Data for 1976 include only imports which are consumed in the domestic market.

refinery for processing of crude imported by them. They maintain ownership of the output products from processed crude and market the products to wholesalers and others. Only four of the seven or eight oil companies involved locally in products distribution and crude oil purchase actually hold shares in the oil refinery itself. Thus the refinery performs a purely processing role) and could, therefore, be taken as the ex-factory prices, i.e. p_{Dk}.

The 'would-be' import prices, p''_{Dk}, are estimated from actual imports of oil products, which are separately shown on the 'Annual Trade Report' for any year. Where imports of a product for Kenya is small relative to imports of the same product to Tanzania or Uganda from countries other than Kenya, the 'would-be' import price p''_{Dk}, for Kenya is then an estimate based on calculated prices for the largest quantity of import by any of the East African countries. Exception to this is taken when smaller import quantities in one of the countries are priced lower than larger quantities of imports by another East African country. The lowest price is then used as the basis.

Table 4.I.15 above shows recorded quantities and values of oil products entering the Kenyan domestic market. The quantities include products of the oil refinery and some imports. There is no distinction between amounts of oil product imported and that which is locally produced. For 1974 and 1975, prices shown on the table could be assumed as the domestic prices, p_{Dk}, for oil products. For 1976 the data do not include quantities and value of locally produced oil products and show the quantities and values of imports for the domestic market. The prices calculated from the data are often different from the prices calculated from quantities and values of imports before classification according to whether the imports are for "home-use", i.e. domestic market, or for re-export. It seems reasonable to assume that even for 1976 the domestic prices approach those shown on Table 4.I.15. Except for kerosene and bitumen the 1976 prices have been assumed, therefore, close to those of Table 4.I.15. In cases where there are no data on "home-use" products estimates can be made by observing general trend between c.i.f. import prices for "unclassified market" products and the "home-use" product prices in the other years. Prices of Kenya exports to other East African countries are also useful as a guide in making these estimates.

Table 4.I.16 below shows quantities and values of actual imports of some oil products by Kenya and Tanzania for the 1974 - 1976 period.

TABLE 4.I.16

ACTUAL DATA ON IMPORTS OF OIL PRODUCTS BY KENYA AND TANZANIA FROM OVERSEAS

Oil product/ year	IMPORTS BY KENYA			IMPORTS BY TANZANIA		
	Quantity	Value (c.i.f.) (K£)	Price	Quantity	Value (K£)	Price (K£)
Motor spirit	litre x 10^3		K£/litre x 10^3	litre x 10^3		K£/litre x 10^3
1974	49,941.303	1,579,888	31.63	-	-	-
1975	4,616.742	274,875	59.54	-	-	-
1976	61.999	4,007	64.64	16,194.76	797,833	49.26
Jet fuel						
1974	85,538.392	1,744,095	20.39	-	-	-
1975	4,986.907	210,339	42.18	14,587.816	498,966	34.20
1976	49,407.892	2,283,881	46.22	-	-	-
Kerosene						
1974	20,118.633	472,911	23.51	-	-	-
1975	4,161.067	154,402	37.11	-	-	-
1976	6,350.413	320,475	50.46	-	-	-
Gas oil						
1974	83,898.432	1,936,850	23.08	78,247.389	1,781,257	22.76
1975	-	-	-	75,682.119	2,686,211	35.49
1976	-	-	-	105,630.389	4,715,061	44.64
Bitumen	(mt)	(K£)	(K£/mt)	(mt)	(K£)	(K£/mt)
1974	1,574.4	122,508	77.81	251.7	15,605	62.00
1975	3,222.1	229,296	71.16	3,210.0	182,843	56.96
1976	750.0	75,147	100.20	5,713.2	369,227	64.63

Source: Annual Trade Reports; Reference (34) for 1974
Reference (38) for 1975
Reference (39) for 1976

TABLE 4.I.17

ESTIMATED DOMESTIC CONSUMPTION AND PRICES

OF OIL PRODUCTS FROM LOCAL REFINERY

Product/ year	Quantity DO_{jk}	Domestic price p_{Dk}	Import price p_{Dk}	Notation of product's quantity
LPG	mt	K£/mt	K£/mt	DO_{j3}
1974	12,400	41.5	25.0	
1975	13,400	66.2	45.0	
1976	14,700	70.0	60.0	
Motor spirit	litre x 10^3	K£/litre x 10^3	K£/litre x 10^3	DO_{j4}
1974	311,489	30.5	31.6	
1975	324,974	38.6	40.0	
1976	333,553	55.0	49.3	
Jet fuel				DO_{j5}
1974	318,881	27.5	20.4	
1975	377.042	40.8	34.2	
1976	304,164	42.7	46.2	
Kerosene				DO_{j6}
1974	68,269	33.0	23.5	
1975	70,862	39.1	37.1	
1976	68,052	55.0	50.5	
Gas oil				DO_{j7}
1974	297,899	29.4	23.1	
1975	303,718	33.7	35.5	
1976	340,806	42.7	44.6	
Diesel oil				DO_{j8}
1974	47,599	23.4	20.0	
1975	38,640	32.0	30.0	
1976	52,609	42.0	40.0	
Fuel oil				DO_{j9}
1974	437,098	21.4	16.0	
1975	464,295	26.0	25.0	
1976	534,010	33.0	30.0	
Bitumen	mt	K£/mt	K£/mt	DO_{j10}
1974	27,104	35.4	40.0	
1975	30,200	31.2	45.0	
1976	31,204	50.0	55.0	

Estimates for prices, p''_{Dk}, of 'would-be' imports, i.e. without a local refinery can be based on this table. In the case of diesel oil, liquefied petroleum gas, and fuel oil which were not substantially imported, prices of Kenya's exports to Uganda and Tanzania could be used as a basis for estimates.

On Table 4.I.17 above data for domestic consumption, DO_{jk}, domestic prices, p_{Dk}, and estimated would-be import prices, p''_{Dk}, are shown together ready for use in Equation (2.I.2).

Prices of Exports

Table A.4.I.1 in Appendix A.4.I shows actual exports of oil products from Kenya to the East African market (Tanzania and Uganda) and to other countries. The prices shown are calculated from the given data. In addition, average export prices for the total quantities exported can be readily calculated.

Data shown on Table A.4.I.1 however, includes exports of locally produced oil products and in most cases also substantial quantities of imports which are re-exported.

Exports of locally produced oil products only, and average export prices calculated from Table A.4.I.1 are shown on Table 4.I.18. below.

4.I.A.II Correction for Export and Import Prices to Reflect Value of Foreign Exchange Earnings

In using import or export prices in Equation (2.I.2), the prices denoted by double prime notation, e.g. p''_i, have to be corrected to reflect loss or gain of foreign exchange earnings. In this work this correction is done by use of estimated average rates of interest for borrowed finance in the domestic money market and in foreign commercial institutions, i.e. $r_{b\ell}$ and r_{bf} respectively.

In the domestic market the rate of interest on borrowed finance capital from financial institutions and banks was steady over the period under consideration. Thus interest rates on the Central Bank's advances against Kenya Government securities and on Bills and notes was 6.5% per annum in 1967 through to 1973. The Commercial Bank's rates of interest on loans and advances for the period was constant at 7% per annum (51).

Foreign borrowing, however, attracts interest rates varying according to both the nature of the lending institution and the duration of the loan. Long-term loans attract lower interest rates but are much more difficult to procure than short-term loans which can attract interest

TABLE 4.I.18

ESTIMATED EXPORTS OF OIL PRODUCTS FROM THE LOCAL REFINERY AND EXPORT PRICES

Local refinery product/year	Quantity exported EO_{jk}	Export price P_{Ek}
LPG	mt	K£/mt
1974	EO_{j6} = 4,120.6	23.84
1975	EO_{j6} = 4,861.9	55.23
1976	EO_{j6} = 4,925.2	64.71
Motor spirit	litre x 10^3	K£/litre x 10^3
1974	EO_{j7} = 186,958	28.84
1975	EO_{j7} = 166,834	39.76
1976	EO_{j7} = 157,837	48.98
Jet fuel		
1974	EO_{j8} = 25,719	34.17
1975	EO_{j8} = 35,777	46.02
1976	EO_{j8} = 6,614	48.42
Kerosene		
1974	EO_{j9} = 66,765	22.38
1975	EO_{j9} = 81,853	36.35
1976	EO_{j9} = 82,926	54.46
Gas oil		
1974	EO_{j10} = 168,752	25.87
1975	EO_{j10} = 186,165	35.35
1976	EO_{j10} = 148,494	41.84
Diesel oil		
1974	EO_{j11} = 117,592.914	20.44
1975	EO_{j11} = 95,570.238	30.78
1976	EO_{j11} = 58,982.857	39.37
Fuel oil		
1974	EO_{j12} = 434,455.676	14.78
1975	EO_{j12} = 346,004.519	24.53
1976	EO_{j12} = 171,270.323	31.63
Bitumen	mt	K£/mt
1974	EO_{j13} = 8,048.9	17.72
1975	EO_{j13} = 8,703.0	42.90
1976	EO_{j13} = 7,329.1	59.22
Residue	litre x 10^3	K£/litre x 10^3
1974	EO_{j14} = 582,635.406	16.42
1975	EO_{j14} = 393,032.241	23.91
1976	EO_{j14} = 560,503.947	19.54

rates of up to 25%. For foreign loans, interest rates of between 9% of borrowed capital per annum and 23% of borrowed capital per annum could be expected.

For this work interest rates on borrowed finance are assumed as follows:-

Rate of interest on loans from domestic money market, $r_{b\ell} = 7\%$

Rate of interest on loans from foreign commercial sources, $r_{bf} = 16\%$

It is now possible to evaluate the terms in Equation (2.I.2) which deal with the domestic consumption of output products, exported output products, and with local and imported raw materials. Table A.4.I.2 through to Table A.4.I.14 in Appendix A.4.I summarise the calculations of these income generation terms. The five firms are considered in turn and the notation adopted in this section is adhered to in the Appendix. In considering the results shown in the Appendix it is useful to note that the correction for gain or loss of foreign exchange in prices is done according to the definition:

$$p' = p''\left[1 + (r_{bf} - r_{b\ell})\right] \tag{4.I.2}$$

For convenience of tabulation of results later the terms referred to here can be redefined as follows:-

$$DOT_j = \sum_{k=1}^{10} DO_{jk}\,(p'_{Dk} - p_{Dk}) \tag{4.I.3}$$

$$EOT_j = (r_{bf} - r_{b\ell}) \sum_{k=1}^{14} EO_{jk} \times p_{Ek} \tag{4.I.4}$$

$$LRM_j = \sum_{k=1}^{4} LR_{ji}\,(p'_i - p_i) \tag{4.I.5}$$

$$IRM_j = IR_{j1} \times p_{I1} \tag{4.I.6}$$

where subscript j denotes firm j = 1, 2, ... 5, and:

DOT_j = income generated from domestic consumption of output.

EOT_j = income generated from exported output (gain of foreign exchange).

LRM_j = income loss from use of local material which could in theory be exported.

IRM_j = income loss from import of raw material (reflects loss of foreign exchange).

Other notation are as previously defined.

4.I.A.III Utilities Consumption by Firms in the Sample

1. Pyrethrum Extraction Plant (Firm j = 1)

Solvent extraction process for pyrethrum closely resembles processing of cottonseed oil by expression and solvent extraction. Electrical energy requirements for pyrethrum plants can, therefore, be approximated by requirements of electrical energy in the cottonseed processing facilities. These are given as 29.4 Kwh/200 lb of cottonseed processed (52). Thus a pyrethrum plant handling 15,000 mt of dry pyrethrum flowers can be expected to have electrical energy requirements of 5.0×10^5 Kwh/annum.

2. Cement Factories (Firm j = 2 and j = 3)

For wet processes electrical energy consumption per 376 lb of cement production is 24.1 Kwh (37). Thus for the following plant capacities the electrical consumption can be estimated:

Capacity (mt cement)		Electrical energy/year
9.0×10^5	≡	1.27×10^8 Kwh
1.5×10^5	≡	2.12×10^7 Kwh

Process water requirement is US gal 30 per 376 lb cement. Thus:

Capacity (mt cement)		Process water
9.0×10^5	≡	1.61×10^8 US gals
1.5×10^5	≡	2.68×10^7 US gals

3. Sugar Factories (Firm j = 4)

Process water requirements for the refining section of a sugar factory is about 600 lb H_2O per 100 lb of refined sugar produced (53). Neglecting the raw sugar extraction section, total water requirement for a plant operating at 50,000 mt/annum capacity of refined sugar is 300,000 mt of water/annum or about 3×10^5 m^3/annum.

Electricity from external sources can be taken to be 2.1 Kwh/mt of cane processed (54). Thus, total electrical energy requirements from external sources for the 50,000 mt/annum refined sugar plant (equivalent to 500,000 mt cane/annum) is 1.05×10^6 Kwh/annum.

4. Oil Refining (Firm j = 5)

Process water requirements for crude distillations are negligible consisting mainly of make-up water for cooling purposes and for steam. Electrical energy consumption is 0.4 Kwh/barrel of crude oil processed (55). Thus for a plant processing 3.3×10^9 litres of crude/annum (where 1 bbl ≡ 158.99 litres) the electrical energy requirements are of 8.3×10^6 Kwh per annum.

4.I.A.IV Rates of Charge for Process Water and Electric Power

Electrical Energy Charges

In 1974 the price of electrical energy for industrial purposes varied according to loading factor as follows (56):-

Loading factor	1974 Prices 0.05 x K£/Kwh
90 %	0.12
75 %	0.13
67 %	0.14
25 %	0.21

In 1975 at a loading factor of 67% the cost was 0.009 K£/Kwh rising to about 0.0115 K£/Kwh in early 1977 (57).

It is reasonable to assume the charges for electrical energy supplied to sample of firms in this study were as in Table 4.I.19 below.

Small consumers' electrical energy tariffs for 1974 to 1976 can be estimated from those of 1979. For "ordinary consumers whose consumption does not exceed 7,000 units per meter reading period" the

TABLE 4.I.19

Year	Consumption level $\leq 5 \times 10^6$ Kwh/annum	Consumption level $> 5 \times 10^6$ Kwh/annum
unit	(0.05 x K£/Kwh)	(0.05 x K£/Kwh)
1974	0.14	0.12
1975	0.18	0.15
1976	0.21	0.18

tariff structure at the beginning of January 1979 were as follows (58):-

(a) A fixed charge of 0.75 K£.

(b) 0.011 K£ per unit for the first 30 units and 0.025 K£ per unit for all additional units.

1 unit is equal to 1 Kwh. Thus for power consumption of 30 Kwh per meter reading period the rate of charge is 0.036 K£ per Kwh and for consumption of 7,000 Kwh per meter reading period the rate of charge is 0.025 K£ per Kwh. Assuming that the majority of domestic consumers consume about 100 Kwh per meter reading period the average rate of charge at the beginning of 1979 was equal to:-

0.566 x 0.05 K£ ($\triangleq$ 0.57 x 0.05 K£/Kwh)

Now, assuming that for the period January 1974 to January 1979 the rates of charge increased at an average annual rate of 10% (considered here as on the high side), the estimated rates of charge for various years are then:

Year	Rate of charge (0.05 x K£)/Kwh
1974	0.35
1975	0.39
1976	0.43

Water

Rates for water for industry vary from location to location. In 1974 the rates for industrial water were 1.85 x 0.05 K£/m^3 in one of the major industrial locations and only 0.24 x 0.05 K£/m^3 in another. In 1976 the former had risen to about 2.36 x 0.05 K£/m^3. In the sample firms considered the rates for the three locations relevant here have been estimated as shown in Table 4.I.20. below.

TABLE 4.I.20

Year	Location 1 (firm 2) (0.05 x K£/m^3)	Location 2 (firm 3) (0.05 x K£/m^3)	Location 3 (firm 4) (0.05 x K£/m^3)
1974	1.9	0.9	0.25
1975	2.1	1.2	0.35
1976	2.4	1.5	0.50

Corresponding estimates of rates of charge for domestic consumers are:

TABLE 4.I.21

(K£ x 0.05)

Year	Location 1	Location 2	Location 3
1974	3.5	2.0	1.0
1975	3.9	2.5	1.2
1976	5.0	2.9	1.4

The foregoing information allows calculation of terms in Equation (2.I.2) dealing with income generation through consumption of electrical energy and of process water by firms j = 1, 2, ... 5. Tables A.4.I.15 and A.4.I.16 of Appendix A.4.I summarise the results of the calculations using WUB_j to denote annual income benefit generated by firm j through purchase of process water and PUB_j to denote annual income benefit generated by firm j through purchase of electrical energy. In terms of notation of Equation (2.I.2) these quantities are defined by:

$$WUB_j = U_{j1} \times (u_{m1} - u_{p1}) \qquad (4.I.7)$$

and:

$$PUB_j = U_{j2} \times (u_{m2} - u_{p1}) \qquad (4.I.8)$$

Benefits from Salaries Paid to Local Employees

Calculation of these benefits can be based on the number of employees of the firm and on the reported average salaries in the manufacturing sector. These calculations are given in Table A.4.I.17 of Appendix A.4.I.

Imports of Chemicals, Maintenance, Operation and Marketing Equipment and/or Services

Data on expenditure on imports of chemicals, maintenance equipment, etc. were gathered from the field as explained in Chapter 3.

TABLE 4.I.22

IMPORTS OF CHEMICALS, MAINTENANCE AND OPERATION SERVICES, ETC.

(K£)

Year	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5
July - December 1974 (Actual)	340,790	972,970	249,950	415,350	718,410
1974 (Estimate)	400,000	1,500,000	450,000	500,000	1,000,000
1975 (Actual)	151,730	1,960,730	786,370	658,080	1,187,610
1976 (Actual)	74,810	2,648,460	461,180	331,160	1,171,930

Source: Field

In Equation (2.I.2) these items are denoted by MT_j, where subscript j denotes a firm. The values of this variable are as shown in Table 4.I.22. above.

From this data value of foreign exchange connected with import of spare/repair equipment and services, MET_j, for a firm j, can be calculated, i.e.:

$$MET_j = MT_j\ (r_{bf} - r_{b\ell}) \qquad (4.I.9)$$

All the terms of Equation (2.I.2) can now be evaluated.

4.I.A.IV Direct Income Benefits Generated by the Sample of Five Firms in the Kenyan Process Industry - Results

For the five firms, j = 1, 2, ... 5, the results of application of Equation (2.I.2) can be presented in tabular form. For ease of tabulation, the following notation can be adopted for the terms in Equation (2.I.2):

1. $$DOTS = \sum_{j=1}^{5} DOT_j = \sum\sum_{jk} DO_{jk}\ (p'_{Dk} - p_{Dk}) \qquad (4.I.10)$$

2. $$EOTS = \sum_{j=1}^{5} EOT_j = \sum\sum_{jk} EO_{jk} \times p_{Ek}\ (r_{bf} - r_{b\ell}) \qquad (4.I.11)$$

3. $$LSBS = \sum_{j=1}^{5} LSB_j \qquad (4.I.12)$$

4. $$WUBS = \sum_{j=1}^{5} WUB_j = (u_{m1} - u_{m2}) \sum_{j=1}^{5} u_{j2} \qquad (4.I.13)$$

5. $$PUBS = \sum_{j=1}^{5} PUB_j = (u_{m2} - u_{m2}) \sum_{j=1}^{5} u_{j2} \qquad (4.I.14)$$

6. $$LRMS = \sum_{j=1}^{5} LRM_j = \sum\sum_{ji} LR_{ji}\ (p'_i - p_i) \qquad (4.I.15)$$

7. $$IRMS = \sum_{j=1}^{5} IRM_j = (r_{bf} - r_{b\ell}) \sum\sum_{ji} IR_{ji}\ p_{Ii} \qquad (4.I.16)$$

8. $$METS = \sum_{j=1}^{5} MET_j \qquad (4.I.17)$$

TABLE 4.I.23

DIRECT INCOME BENEFITS GENERATED BY A SAMPLE OF FIRMS IN KENYAN PROCESSING INDUSTRY - SUMMARY

K£ x 10^3

Firm/Year	DOT_j	EOT_j	LSB_j	WUB_j	PUB_j	$-LRM_j$	$-IRM_j$	$-MET_j$	W_j
Firm 1									
1974	-	526.3	205.5	-	−5.3	− 919.4	-	−36.0	−228.9
1975	-	448.5	255.2	-	−5.3	−1,264.6	-	−13.7	−579.9
1976	-	629.0	300.1	-	−5.5	−1,027.2	-	− 6.7	−110.3
Firm 2									
1974	367.4	409.5	304.6	−48.8	−1,495.0	− 92.9	-	−135.0	− 690.2
1975	653.4	541.4	349.2	−54.9	−1,560.0	−200.5	-	−176.5	− 447.9
1976	887.6	726.2	378.0	−61.0	−1,625.0	−295.4	-	−238.4	− 228.0
Firm 3									
1974	399.5	-	64.1	− 5.5	−195.5	− 23.0	-	− 40.5	199.1
1975	646.0	-	73.5	− 6.5	−324.0	− 47.2	-	− 70.8	271.0
1976	800.7	-	79.5	− 8.5	−337.5	− 61.5	-	− 41.5	431.2
Firm 4									
1974	431.5	9.7	320.4	−10.5	− 11.6	− 925.1	-	− 45.0	− 230.6
1975	558.9	9.1	368.3	−12.0	− 11.6	−1,260.8	-	− 59.2	− 407.3
1976	691.4	49.7	331.4	−13.5	− 12.1	−1,608.9	-	− 29.8	− 591.8
Firm 5									
1974	−3,950.5	2,768.7	169.2	-	− 87.2	-	− 6,032.4	− 90.0	−7,222.2
1975	2,841.1	3,537.4	205.1	-	− 87.2	-	− 7,814.0	−106.9	−1,424.5
1976	4,087.6	3,440.2	231.2	-	− 91.3	-	− 8,412.3	−105.5	− 850.1
	DOTS	EOTS	LSBS	WUBS	PUBS	− LRMS	− IRMS	− METS	WS
1974									
1974	−2,752.1	3,714.2	1,063.8	− 64.8	−1,794.6	−1,960.4	− 6,032.4	− 346.5	−8,172.8
1975	4,699.4	4,536.4	1,251.3	− 73.4	−1,988.1	−2,773.1	− 7,814.0	− 427.1	−2,588.6
1976	6,467.3	4,845.1	1,320.2	− 83.0	−2,071.4	−2,993.0	− 8,412.3	−421.9	−1,349.0

DOTS, EOTS, LSBS, etc. denote values of DOT, EOT, LSB, etc. for the whole sample. All other notations have been defined already in this section. The individual firm's values of DOT_j, EOT_j, LRM_j, and IRM_j have been worked out and presented in Tables A.4.I.2 to A.4.I.14 inclusively, in Appendix A.4.I. Similarly, values of WUB_j, PUB_j and LSB_j are worked out and presented in Tables A.4.I.15 to A.4.I.17 inclusively in Appendix A.4.I. Values of MET_j can be worked out from values of MT_j given in Table 4.I.22 above and using Equation (4.I.9).

The results of the calculations covering the three years (1974 - 1976) are presented in Table 4.I.23 above.

Discussion of Results of Table 4.I.23

Table 4.I.23 shows that of the sample of five firms considered, one firm (j = 3) had a positive value of W_j - direct income generated by a firm to the nation's consumers of locally manufactured products, workers, raw material suppliers, consumers of electrical energy and water, and to the nation's foreign exchange reserves. These groups of beneficiaries could be described as the 'nation' and their welfare the 'national welfare'. The other four firms had negative values of W_j with firms j = 2 and j = 5 performing relatively more poorly.

Examination of the results shows that firm j = 3 performed well basically because it catered solely for the domestic market at prices that place a heavy premium on imports of their product. In addition the firm had a relatively low component of imports. Another characteristic of this firm is that it operates the smallest plant in the sample both in terms of annual turn-over and the plant capacity. The plant also uses domestic raw materials which in the calculations were priced at the same value as that of actual or 'would-be' exports. This probably biased the results. But firm j = 2, using the same raw materials, shows negative values of W_j which means that other factors are equally strong in influencing the W_j value.

Firm j = 1 also operates a small plant - compared to the refinery - and shows negative value of W_j. It also has the smallest value of imported inputs. However, the raw material factor here is dominant. The adverse effects of the firm's operations seem to arise from what might be described as 'under-paying' the raw material producers for their crop. Change of the values of LRM_j to half its 1974 - 1976 levels would give positive values of W_j. The problem connected with this would be the feasibility of price increases and the growers ability

to encourage higher prices for their product. In 1974 and 1975 the firm's tax on their profits amounted to only 33,850 K£ and 100 K£ (59) respectively indicating that either (a) the processing operations cost too much due to inefficiencies or (b) the firm's product was underpriced in export market. It has been reported that the firm experiences severe competition in the export market coming from producers of synthetic substitutes to their natural product (31). This factor could act as a stimulant to the firm's search for means of improving the product's quality and as the firm has not established process development facilities locally it would have to rely on other sources for process technology development[1]. Thus control of processing and process development costs can be difficult.

Firm j = 4 also utilises local agricultural materials but produces primarily for the domestic market. Again, the most significant feature is the apparent 'underpricing' of locally supplied raw materials. Refined sugar is also imported for the domestic market and this could influence the quality of products demanded by the market and which the local factory must try to achieve. In terms of processing technology this would be reflected by search for process improvement which necessarily must be imported[2]. Quality demands are fixed by the market type and the assumption made in the previous statement is that the factory serves the same market as that served by imports.

Firm j = 2 primarily serves the export market. Its performance on the basis of criterion adopted here is among the worst in spite of favourable raw material price estimates. The firm has the highest expenditures on process water and electrical energy consumption[3] as well

---

[1] The extraction plant process licence was obtained from an overseas company in 1951. In 1969 another licence for an improved process was negotiated between the local company and the former licensor. This new process replaced the old process later. Source of information: field work (see Chapter 3).

[2] In a recent (1977) minor process modification project to "improve product quality" and costing K£ 0.1335 million the import costs component was 80.5% of total cost. This was so despite use of some old process equipment - mainly heat exchangers and pipes from the unit that was being replaced. Source of data: field work - personal interview.

[3] During this period the firm was consuming about 10% of the total national electrical energy supply based on the estimates of electrical energy consumption by the firm.

as being the heaviest importer of chemicals, maintenance equipment, etc. It is large - its plant was 3 times the capacity of plant owned by firm j = 3. It would seem that where the technology used by a firm demands high inputs of power water and maintenance and operation services/ equipment imports the plant is less likely to have favourable values of W_j.

Lastly firm j = 5 has the worst results of all the firms considered. The dominant feature here is that adverse effects of raw material imports heavily outweigh the benefits from local production. This would seem to be due to lack of 'savings' between the domestic prices and the import prices for most of its products. The pricing of products would seem not to be directly influenced by technology of processing, and relative to other expenditures, imports of maintenance equipment and services is insignificant. The results might be explained in terms of the seven marketing firms who buy crude oil, process it and then market it together with other imported oil products. The issue then would seem to be one of ownership of both the processing plant and the crude petroleum oil and the owners' desire to share profits generated from value added to the crude as a result of processing. Assuming that businesses by definition maximise profits, a desire to share with consumers would seem optimistic. Prices could be made more 'competitive' if the marketing firms do not have a monopoly of the market or form cartels. In the case of the oil business, agreements between multinational companies seem common (60). The local trade in oil is largely handled by multinationals and it is likely that they would have a high degree of freedom in determining prices of oil products. It is interesting to note that in 1974 the value of W_5 was much worse than in the other two years. This corresponded with the 1973 - 1974 oil crisis where apparently the domestic consumer paid heavily for the crisis.

The most significant components of income generation to the 'nation' can be discussed for each firm in turn.

For the pyrethrum firm (j = 1) the local raw material supply term $-LRM_1$, is the most dominant component of W_1 as shown by Table 4.I.23. This component is sensitive to the 'would be export' price that would be expected if local material was exported instead of being sold to the local processing firm. However, even when 'would be export' price is assumed equal to the actual domestic price of the raw material, the values of $-LRM_1$ are -4.1×10^5 K£, -3.9×10^5 K£, and -4.0×10^5 K£ for the years 1974, 1975, and 1976 respectively. These values obtain

because of the foreign exchange earnings that would result from exports. A premium is attached to such earnings. Under condition of equal 'would be export' and actual domestic prices the values of income generated by the firm, W_1, are 2.8 x 10^5 K£ (1974), 3.0 x 10^5 K£ (1975) and 5.2 x 10^5 K£ (1976), which are favourable values. The validity of the assumed 'would be export' prices therefore needs to be established.

With regard to the method used to estimate these prices the first point to be made is that in both the dry flower raw material and the actual exported "flower and powder" the essential ingradient is the pyrethrin content. The price for either of these commodities at any time is thus proportional to the pyrethrin content of the commodity. The dry pyrethrum flower always contains a higher percentage of pyrethrin per unit weight than "pyrethrum flower and powder" which is exported. It is therefore quite reasonable to expect a higher price of dry flower than that of "flower and powder" in the same market. In 1974 and 1975 the prices paid to the local supplying farmers were 293K£/mt dry flower and 287K£/mt dry flower respectively. The corresponding export prices for "flower and powder" were 272K£/mt and 282K£/mt in 1974 and 1975 respectively. However, in 1976 the domestic price of dry flower was only 310K£/mt dry flower compared to export price for "flower and powder" of 328K£/mt, suggesting that dry flowers supplied to the local firm could be 'undervalued'.

In terms of pyrethrin content the price of dry flower, if exported, should be higher than that of "flower and powder" and the relation between the two should be as given by eqn. 4.I.1. In this equation it is implicitly assumed that (a) the average pyrethrin content in dry flower and in "flower and powder" are constant over the three years: and (b) the essential difference between dry flower and "flower and powder" is the pyrethrin content of the commodities. The estimated 'would be export' price for dry flower was however adjusted to take account of the possibility that assumption (b) is invalid so that blending costs - other materials, labour, and machinery - contributed to the prices of "flower and powder". Estimates of blending costs were then substracted from values of "would be export" prices of dry flower calculated from eqn 4.I.1.

The assumption of constancy of pyrethrin content in "flower and powder" can be examined using 1972 and 1974 data. The pyrethrin content of dry flower delivered to the processing plant was 1.34% on weight basis in 1972 and 1.363% in 1974. The amounts of dry flower

converted to flower and powder were 2993 mt (1972) and 2659 mt (1974). The corresponding amounts of "flower and powder" made were 4323 mt (1972) and 3900 mt (1974). The average pyrethrin content in "flower and powder" were therefore 0.93% w/w in 1972 and 0.93% w/w in 1974. The basic figures used to calculate the average pyrethrin content in "flower and powder" here are given in the relevant annual report and accounts of the firm. These figures suggest that the pyrethrin content of powder over the 1974-76 period could have been constant at around 0.93% on weight basis. The pyrethrin content of flower delivered to the firm for the three years were however 1.363% w/w in 1974; 1.334% w/w in 1975 and 1.315% in 1976. This gives a variable coefficient on the right hand side of equation 4.I.1 of 1.47 in 1974, 1.43 in 1975 and of 1.41 in 1976 (which gives the average coefficient of 1.44 in eqn. 4.I.1).

Now, it is possible to make "powder and flower" without the pyrethrin extraction process by blending the dry flower of high pyrethrin content with the flower's inerts and homogenising, if the market price for 'processed' "flower and powder" is higher than for the higher pyrethrin content dry flower. Under such circumstances the effective price of dry flower in the export market is the equivalent price of "flower and powder" less blending costs. This is the procedure followed in estimating 'would be export' prices of dry flowers.

The main uncertainty in the estimates of 'would be export' prices lies in estimation of the blending costs. These were estimated at 61K£/mt dry flower in 1974, 65K£/mt in 1975 and 120K£/mt in 1976. The estimates were stated without proof and can be checked as follows.

The fixed capital costs for replacing and expanding the extraction capacity of the plant including the blending section, laboratories, and administration buildings during the 1972-75 period was 1.5 million K£ (137). Taking a plant life of 10 years and fixed capital costs of the blending section as 0.7 million K£ (which is extremely high) gives annual costs of blending machinery of 0.07 million K£. Taking labour costs for blending as half the labour costs for the whole plant as in Table 4.I.23 gives blending labour costs of 0.10 million K£ in 1974, 0.13 million K£ in 1975 and 0.15 million K£ in 1976. Using the "flower and powder" sales figures and the above costs gives annual blending costs of 42K£/mt "flower and powder" in 1974 and similarly 44K£/mt and 60K£/mt in 1975 and 1976 respectively. In terms of dry flower converted to "flower and powder" the blending costs are 62K£/mt dry flower for 1974, 63K£/mt for 1975 and 85K£/mt for 1976. These costs are not higher than the estimates used in the calculations for the $-LRM_1$ term of Table 4.I.23.

On the basis of this discussion it would seem that in fact the 'would be export' prices for the local raw material to this firm are extremely conservative. In particular the 1976 'would be export' price estimate could reasonably be increased by about 30 K£/mt while still maintaining the bias on the side of caution. The value of W_1 for 1976 would then be -5.7×10^5 K£. The likely movement of 'would be export' prices would be up which would have the effect of making the values of income generated worse than shown in table 4.I.23.

The results in table 4.I.23 are also sensitive to changes in the foreign exchange premium i.e. ε_p of eqn. 2.I.1. The rate of interest on locally borrowed finance was constant at about 7% per annum while that of overseas commercial loans was considered to be variable within the limits of 9 - 23% p.a. Tables 4.I.23 (b) and 4.I.23 (c) below give the results of sensitivity analysis using values of foreign exchange premium of $\varepsilon_p = 0.02$ and $\varepsilon_p = 0.16$. The situation for the pyrethrum firm does not improve except for the year 1976 with value of $\varepsilon_p = 0.16$. As stated above the value of 'would be export' price for local raw materials could be justifiably increased by 30 K£/mt. Increasing this value by only 10 K£/mt with $\varepsilon_p = 0.16$ would in fact change the value of income generated in 1976 to -1.4×10^5, which is unfavourable.

Table 4.I.23.b

SENSITIVITY OF ANNUAL INCOME GENERATED BY THE SAMPLE TO CHANGES OF FOREIGN EXCHANGE PREMIUM: $\epsilon_p = 0 \cdot 02$

FIRM/YEAR	Domestic Consumption Term, DOT_j	Exports Term, EOT_j	Salaries Term, - LSB_j	Process Water, WUB_j	Electricity, PUB_j	Local Raw Material, $-LRM_j$	Imported Raw Material, $-IRM_j$	Imported Maintenance Equipment/ Services, $-MET_j$	Annual Income Generated, W_j
	$K£ \times 10^3$								
PYRETHRUM									
1974	-	117	206	-	-5	-599	-	-8	-289
1975	-	100	255	-	-5	-902	-	-3	-555
1976	-	140	300	-	-6	-664	-	-1	-231
CEMENT j=2									
1974	203	91	305	-49	-1,459	-21	-	-30	-996
1975	413	120	349	-55	-1,560	-45	-	-39	-817
1976	637	161	378	-61	-1,625	-64	-	-53	-627
CEMENT j=3									
1974	221	-	64	-6	-196	-5	-	-9	69
1975	408	-	74	-7	-324	-10	-	-16	125
1976	575	-	80	-9	-338	-13	-	-9	286
SUGAR									
1974	99	2	320	-11	-12	-789	-	-10	-401
1975	124	2	368	-12	-12	-1,066	-	-13	-609
1976	151	11	331	-14	-12	-1,350	-	-7	-890
OIL REFINERY									
1974	-6,365	615	169	-	-87	-	-1,341	-20	-7,029
1975	-957	786	205	-	-87	-	-1,736	-24	-1,813
1976	-796	764	231	-	-91	-	-1,869	-23	-1,784
ALL FIRMS	DOTS	EOTS	LSBS	WUBS	PUBS	-LRMS	-IRMS	-METS	WS
1974	-5,842	825	1,064	-66	-1,795	-1,414	-1,341	-77	-8,646
1975	-12	1,008	1,251	-74	-1,988	-2,023	-1,736	-95	-3,669
1976	567	1,076	1,320	-84	-2072	-2,091	-1,869	-93	-3,246

Table 4.I.23.c

SENSITIVITY OF ANNUAL INCOME GENERATED BY THE SAMPLE TO CHANGES OF FOREIGN EXCHANGE PREMIUM: $\epsilon p = 0{\cdot}16$

FIRM/YEAR	Domestic Consumption Term, DOT_j	Exports Term, EOT_j	Salaries Term, - LSB_j	Process Water, WUB_j	Electricity, PUB_j	Local Raw Material, $-LRM_j$	Imported Raw Material, $-IRM_j$	Imported Maintenance Equipment/ Services, $-MET_j$	Annual Income Generated, W_j
	$K£ \times 10^3$								
PYRETHRUM									
1974	-	936	206	-	-5	-1,233	-	-64	-160
1975	-	797	255	-	-5	-1,618	-	-24	-595
1976	-	1,118	300	-	-6	-1,363	-	-12	37
CEMENT j=2									
1974	532	724	305	-49	-1,495	-165	-	-240	-388
1975	894	963	349	-55	-1,560	-356	-	-314	-79
1976	1,138	1,291	378	-61	-1,625	-516	-	-424	181
CEMENT j=3									
1974	578	-	64	-6	-196	-41	-	-72	327
1975	884	-	74	-7	-324	-84	-	-126	417
1976	1,027	-	80	-9	-338	-107	-	-74	579
SUGAR									
1974	791	17	320	-11	-12	-1,063	-	-80	-38
1975	990	16	368	-12	-12	-1,457	-	-105	-212
1976	1,209	88	331	-14	-12	-1,867	-	-53	-318
OIL REFINERY									
1974	1,581	4,922	169	-	-87	-	-10,724	-160	-7,461
1975	6,608	6,289	205	-	-87	-	-13,892	-190	-1,067
1976	8,983	6,116	231	-	-91	-	-14,955	-188	96
ALL FIRMS	DOTS	EOTS	LSBS	WUBS	PUBS	-LRMS	-IRMS	-METS	WS
1974	320	6,597	1,064	-66	-1,795	-2,502	-10,724	-616	-7,720
1975	9,376	8,065	1,251	-74	-1 988	-3,515	-13,892	-759	-1,536
1976	12,357	8,613	1,320	-84	-2,072	-3,853	-14,955	-751	575

For the pyrethrum firm therefore the indication is that local processing could be unattractive. It could be argued however that the stipulated 'would be export' prices would not actually obtain in the case of exports of locally processed materials. This objection could be valid where the raw material supply exceeded its demand. In the case of pyrethrum this would seem an unjustified conclusion judging by the trend of low pyrethrin content "flower and powder" export prices. In addition, crop production could be controlled so that there was not a glut in the market.

For the cement exporting firm j = 2 the most dominant income generation component is the electrical energy term as shown in Table 4.I.23. The value of income generated by this firm is very sensitive to change in foreign exchange premium as shown by Tables 4.I.23, 4.I.23(b) and 4.I.23(c) above. The performance of the firm improves with higher valuation of foreign exchange earning.

Considering the electrical energy term, the values for energy charges used are those reported by the firm supplying electric power in the country. The firm is largely owned by the Government. For the values of W_2 in Table 4.I.23 to become zero or positive the unit charge for electrical energy needs to change by 88% for 1974, 46% in 1975, and by 20% in 1976. Thus as the volume of output increases the increased benefits from exports and domestic consumption primarily obtain from added foreign exchange earnings and savings which rapidly move towards offsetting the decreasing value of benefits from PUB_2. This is shown by considering price increases required to change value of W_2 to equal to or greater than zero when the foreign exchange premium ϵ_p is 0.02 as in Table 4.I.23(b). In this case the required increases are of 128% for 1974, 84% for 1975 and of 54% for 1976. Similarly when $\epsilon_p = 0.16$, Table 4.I.23(c) shows that the 1976 value of W_2 becomes positive.

It could be argued that lower charges for electrical energy supplied to large consumers like firm j = 2 actually constitute increased benefits to the 'nation' if energy supply is greater than the demand. The first point to be made about this and with regard to firm j = 2 is that where energy consumption is at off-peak periods as is bound to happen from time to time, the charges are then much lower than the values used in this work. If this had been taken into account the values of W_2 would have been worse than shown by Table 4.I.23. The second point is that in a developing economy demand is strongly dictated by prices. By lowering the rates of charge to the ordinary small consumers the demand would be expected to increase sufficiently to absorb all of the supply.

Nevertheless, it is possible to have temporary over-supply but this argument would not be applicable to processing firms whose planning horizon is always of at least 7 years.

In calculating the income component - LRM_2 connected with local raw materials it was assumed that the materials were supplied at prices that would obtain if they were exported. In the case of gypsum actual export prices were used while in the case of limestone arbitrary prices of 1K£/mt, 2K£/mt and 2.5K£/mt were assumed for 1974, 1975, and 1976 respectively. Although 'would be export' prices were assumed equal to domestic prices the value of $-LRM_2$ is non-zero due to foreign exchange premium attached to 'would be export' price. A case can be made against the feasibility of exporting quantities of limestone as large as used by the cement firm. Under such circumstances the procedure of using 'would be export' prices to obtain values of $-LRM_j$ could lead to theoretical complications. In this case the 'error' introduced by the method could be roughly estimated by according to the raw materials the same treatment accorded to electrical energy and water where scale of consumption by a single firm results in unit price of the commodity. From Tables 151(a) and 151(b) of reference (44) it can be verified that the unit prices of limestone in the domestic market was 8.1K£/mt in 1972, 7.0K£/mt in 1973, 4.3K£/mt in 1975 and 27.8K£/mt in 1976 for total quantities of 23,000mt (1972), 32,000mt (1973), 200,000mt (1975) and 30,000mt (1976). Considering the year 1975 and taking unit prices of limestone to the small consumer and to large consumers as 7k£/mt and 5K£/mt the corresponding income benefit is given by the product of quantity consumed by the cement firm j = 2 multiplied by the difference between unit price of limestone to the firm and unit price to small consumers. This is equal to - 1.5×10^6K£ for 1975. If this figure is substituted for - LRM_2 in Table 4.I.23 it can be seen that value of W_2 for the year deteriorates remarkably.

Again it could be argued that the supply is greater than the current demand. In the case of a mineral deposit it is possible to limit exploitation of the mineral deposit until the large scale consumers are willing to pay the same price as the small scale consumers. In addition or alternatively production of products requiring the raw material in several small production plants could be encouraged. In taking such a decision several other considerations would also be important which could suggest allowing a lowering of unit prices for large consumers. Such factors might include foreign exchange earnings and employment generation. The factors would not invalidate the procedure for assessing a firm's performance adopted in this work.

Considering the other cement factory firm j = 3 which caters solely for the domestic market, the value of W_3 is favourable for all the three years and increases with increase of foreign exchange premium as shown by Tables 4.I.23, 4.I.23(b) and 4.I.23(c) above. The main reason for these favourable results is the value of benefits connected with domestic consumption of cement product. Although the domestic prices are in fact higher than local export prices of cement, estimated import prices are substantially higher than either. This factor together with the adverse effect on foreign exchange reserves of 'would be imports' combine to offset the income "losses" connected with raw materials and utilities consumption, or imports of maintenance equipment and services. Because of the volume and weight of cement, transportation costs are very high, make the c.i.f. 'would be import' price high, and therefore result in a high value of benefits connected with domestic consumption of local cement product.

The results for firm j = 3 are also sensitive to the valuation of local raw materials particularly that of limestone. If this material was actually supplied to the local firm at a price of say 5 K£/mt (see discussion on firm j = 2 above) instead of at the small consumer's domestic price of 7 K£/mt it could be argued that in 1975 the contribution of consumption of limestone by the firm, - LRM_3, to income benefits was of - 450,000 K£ which would make the value of W_3 in Table 4.I.23 equal to - 132,000 K£ instead of the given positive value. The positive values of W_3 in Table 4.I.23 should therefore be treated with caution. Valuation of raw material benefits in this way would again raise the question of supply and demand. But again the objection is valid only where the firm's consumption of the local raw material occurs only under a condition of prices lower than the small consumer prices and at valuation of unconsumed material at prices lower than those offered by the local processing firms. There seems to be a good case for considering the value of an unperishable commodity per se to be the highest unit value that a market offers at the time of consideration. Concessions on unit price can then be made either on the basis of valuation of other benefits contributed by the purchaser as a result of the purchase or on the basis of valuation of contribution that revenue from 'extra' sale of the commodity would make to the welfare of the seller (nation). In this section of this work such contributions are considered in terms of foreign exchange earnings or savings and of employment salaries and wages.

With the sugar firm j = 4, the contribution of local raw material to income generation is again dominant. This is sensitive to estimated 'would be export' prices of cane and the method used to estimate these prices is fully described on page 54 of this work. It was assumed that costs of processing cane into raw sugar in small units were 5 K£/mt cane, 7 K£/mt cane, and 9 K£/mt cane for the years 1974, 1975, and 1976 respectively. Thus for annual amounts of cane processed of 500,000 mt the production costs, exclusive of cane costs, would be 2.5 million K£ (1974), 3.5 million K£ (1975) and 4.5 million K£ (1976). Quite clearly these costs are grossly exaggerated. Their adjustment to more likely figures of 1 - 2 K£/mt cane and application to calculations for - LRM_4 would make the value of W_4 in Table 4.I.23 worse than shown.

It could well be argued that in the event of local farmers being unable to organise the processing of cane in small simple units for purposes of exporting the product for further processing, low domestic cane prices relative to export prices, then represent the true worth of their crop.

By the same argument very high domestic prices of cane vis a vis 'would be export' prices would reflect the worth of the cane crop. But since the quality and unit quantity of the crop is constant the two price sitations at given time represent a theoretical sacrifice by or benefit to the local farmer. On this basis the question of local suppliers' ability to achieve given prices for his produce would not invalidate the procedures used in this work.

Considering now the oil refinery firm j = 5, the results for the firm are dominated by the benefits from domestic consumption of outputs, by exports and by raw material imports. Valuation of imports and exports are sensitive to foreign exchange premium and Tables 4.I.23(b) and 4.I.23(c) show the sensitivity of these components to charges in ϵ_p. It is clear that income generated while improving with higher valuation of foreign exchange does not become positive within the limits of ϵ_p considered appropriate. The sources of the data used for the calculations are fully given on pages 57 - 65. Of the data used in this section these are the most completely reliable and are largely based on actual domestic, export and import prices. The commodities can be and are imported and they can be and are exported.

The accuracy of the data here is totally dependent on the accuracy of the data in official statistics records and it is not possible here to estimate how accurate these records are.

From the above discussion, it is clear that strictly, values of W_j entered in Tables 4.I.23, 4.I.23(b) and 4.I.23(c) should be read as 'equal to or less than' shown value of W_j.

At this point the results of Table 4.I.23 can be compared with straight 'profit and loss' annual account for the firms. This is given by

$$STP_j = \sum_{k=1} DO_{jk} \cdot p_{Dk} + \sum_{k=1} EO_{jk} \cdot p_{Ek} - \sum_{i=1} LR_{ji} \cdot p_i$$

$$- \sum_{i=1} IR_{ji} \cdot p_{Ii} - \sum_{i=1}^{2} U_{ji} \cdot u_{mi} - LSB_j - MT_j \qquad (4.I.10)$$

where

STP_j denotes profit before deductions of tax, depreciation, and miscellaneous local costs. Other notations are defined as before.

TABLE 4.I.24

STRAIGHT 'PROFIT AND LOSS' ANNUAL ACCOUNT FOR THE SAMPLE

Year \ Firm	1	2	3	4	5
	K£	K£	K£	K£	K£
1974	1,218,980	3,069,090	1,443,880	3,005,600	3,731,345
1975	260,360	3,535,040	1,467,550	3,462,220	7,055,661
1976	2,179,320	3,591,770	1,258,100	5,018,480	15,314,002

The results obtained on application of Equation (4.I.10) to the available data are presented in Table 4.I.24. These results indicate that the firms with the worst values of W_j have the highest margin of revenue available to cover depreciation of processing facilities, any local work not included above, and company profits. Firm j = 1 has a low figure for 1975 mainly because although the plant capacity was maintained sales were low and stocks appear to have been carried over to 1976.

Data on reported company 'after-tax profits' for firms j = 1, 2, and 3 are available for the 1974 and 1975 years. These are shown on Table 4.I.25 below. Thus the firms show a profit to their owners. In the case of firm j = 1 it is not likely that it would make a loss either because the prices paid to farmers for their product are fixed by the firm according to the surplus revenue realised on sales of its products less charges on processing of the dry flower, marketing, etc.

TABLE 4.I.25

COMPANY 'AFTER-TAX' PROFITS

Year \ Firm	1	2	3
	(K£)	(K£)	(K£)
1974	41,370	433,580	320,080
1975	120	737,840	242,760

Source: Firm 1, Ref. (59); Firm 2, Ref. (61); Firm 3, Ref. (62)

It would seem unlikely that the multinational firms involved in firm j = 5 would be operating at a commercial loss although data here is unavailable.

The above results indicate that production for the overseas export market, as is the case of firms j = 1 and j = 2 or for the domestic or regional (neighbouring countries) markets with product quality demands approaching those of the overseas export market, might

impose on the local production facilities, product quality demands necessitating process developments outside local capability or availability, and hence encourage seemingly permanent technological dependency on imports. The effect of this would be to increase processing costs which would be passed on either to the consumer or to the raw material supplier or both depending on who has the weakest bargaining powers. The other effect might be to hinder the process of local technological capacity creation or development. This aspect is treated in Section 4.IV below.

It would also seem that larger plants - firms j = 2 and j = 5 - tend to have more adverse effects on generation of direct income to the 'nation' than smaller plants. This could be due to the higher proportion of equipment and maintenance and operation services imports and/or the greater probability of low capacity utilisation which makes higher product prices necessary. In addition large firms would tend to discourage entry into the market by other firms thus creating a monopoly situation which is generally considered undesirable.

The results of firm j = 5 would tend to indicate that involvement of large, well-established and experienced multinational companies in purchase of raw material inputs and of marketing of products does not necessarily lower prices in the domestic market than might be expected under alternative arrangements.

Based on the results of this sample it would seem that the choice of investment projects in the local process industry cannot be necessarily assumed to benefit the nation as a whole in terms of direct income generated by the firms: and that production of products demanding high quality specifications, e.g. export products, could have far reaching consequences on 'process technology links with the initial technology sources'.

It might be argued that firms such as considered could still be encouraged on the basis of external effects such as redistribution of income, employment generation, transfer of advanced technology, etc. The performance of the above firms with respect to income redistribution effects and of other, often larger, samples of firms in the local process industry with respect to these externalities are considered in the following sections.

4.I.B Direct Distribution of Direct Income Generated by a Sample of Firms in the Process Industry

The income distribution effects of the production activities of firms j = 1, 2, ... 5 in Section 4.I.A can be considered. The relevant 'sectors' of the economy as explained in Section 2.I.B are the 'rural economy', the 'modern economy' in general, local owners of means of production, and foreign business interests. In terms of income generated by firm j as given by Equation (2.I.2) only the two 'economies' are relevant. Distribution of this 'income' between them can be considered first.

4.I.B.1 Direct Income Accruing to the Rural and Modern Economies

4.I.B.1A Values of Variables and Constants

Income accruing to the two economies is given by Equations (2.I.6) and (2.I.7). For ease of reference these equations for firm j, are:

$$W_{jR} = \sum_{k=1} \beta_{jk}\, DO_{jk}\, (p'_{Dk} - p_{Dk}) + \sum_{k=1} \xi_R \cdot EO_{jk} \cdot p_{Ek}\, (r_{bf} - r_{b\ell})$$

$$- \sum_{i=1} \gamma_{ji}\, LR_{ji}\, (p'_i - p_i) - \xi_R \cdot MT_j\, (r_{bf} - r_{b\ell}) + M_{jR} \qquad (2.I.6)$$

$$W_{jM} = W_j - W_{jR} \qquad (2.I.7)$$

where:

W_{jR} = value of income generated by firm j in one year, accruing to the rural economy.

W_{jM} = annual value of income generated by firm j accruing to the modern economy.

β_{jk} = fraction of total output product k from firm j consumed in the rural economy.

ξ_R = proportion of foreign exchange reserves in the country earned by the rural economy.

γ_{ji} = fraction of total raw material i supplied to firm j from the rural economy.

M_{jR} = miscellaneous annual income benefits from firm j, accruing

to the rural economy.

Other notations are as defined at the beginning of Section 4.I.

Most of the variables in the above equations have already been considered in Section 4.I.A. Valuation of M_{jR} is difficult in some cases. For the sugar and pyrethrum firms, value of M_{jR} would be greater than zero because the firms spend money on agricultural services offered to farmers. Expenditure data on these services are not available. In the case of the other firms, value of M_{jR} is zero. In this work M_{jR} has been neglected for all firms.

The value of foreign exchange to the rural economy on the basis of the rural economy's population would be about 80% of the foreign exchange reserves. In terms of foreign exchange earnings the rural economy contributes a major proportion. Thus in the 1974 year, exports of agricultural products alone accounted for 42% of total exports while combined exports of agricultural products and "food, beverages, and tobacco" accounted for 52% of total exports (63). For the purposes of calculations in this section, ξ_R can be taken as 0.5.

The other variables introduced in this section are estimated for each firm as follows:

1. Pyrethrum Processing Plant - Firm j = 1

$\gamma_{11} = 0.9$

γ_{11} is estimated from flower deliveries to the firm in 1973 and 1974. Flower deliveries from small scale farmers, for these two years, amounted to 12,539 tonnes and 9,539 tonnes respectively while deliveries from the large scale farmers amounted to 1,872 tonnes and 1,744 tonnes in 1974 and 1975 respectively (64).

2. Cement Manufacturing - Firm j = 2

$\beta_{21} = 0.2$

Data on consumption of cement in the rural economy is not available. It is fairly obvious, however, that most buildings using cement are commonly found in the modern economy. As the processing

plant owned by firm j = 2 is located on the coast and caters for both export and domestic markets, it seems reasonable to assume that only a small proportion of its product reaches the rural areas in the interior of the country. The value of β_{21} has therefore been assumed equal to 0.2.

$\gamma_{22} = \gamma_{23} = 0.8$

Local limestone and gypsum are natural deposits found in the country. Proportion 'belonging' to the rural economy can be considered equal to the proportion of the total population engaged in the rural economy, i.e. 85%. For the purpose of calculations in this work γ_{22} and γ_{23} can be taken equal to 0.8.

3. Cement Manufacturing - Firm j = 3

$\beta_{31} = 0.3$

Because of location in the centre of the country and concentration on the domestic market one would expect the proportion of cement from firm j = 3 reaching the rural economy to be somewhat higher than that of firm j = 2. Accordingly, β_{31} has been assumed equal to 0.3.

Coefficients for domestic raw materials can be treated exactly as those of firm j = 2, i.e. $\gamma_{32} = \gamma_{33} = 0.8$.

4. Sugar Factory - Firm j = 4

$\beta_{42} = 0.6$

Refined sugar consumption data in the rural economy is not available. Consumption can however, be assumed widespread in the whole of the economy with the modern sector consuming a higher quantity per head than that consumed in the rural economy. Because of the size of the rural based population a value of β_{42} equal to 0.6 would seem reasonable.

Local raw material supply data based on area under sugar cane cultivation are available. In 1977 area under cane cultivation for supply to the sugar factory and owned by small scale farmers (with farm

TABLE 4.I.26

DISTRIBUTION OF DIRECT INCOME BENEFITS BETWEEN THE RURAL AND MODERN ECONOMIES

Year	1974		1975		1976	
Sector	Rural	Modern	Rural	Modern	Rural	Modern
Firm, j	(K£ x 10^3)		(K£ x 10^3)		(K£ x 10^3)	
1	— 582.3	353.4	— 920.7	340.8	— 613.4	503.1
2	136.4	— 826.6	152.8	— 600.7	185.1	— 413.1
3	81.2	117.9	120.7	150.3	170.3	260.9
4	— 36.3	—194.3	— 68.0	— 339.3	— 57.9	—533.9
5	—2,082.0	— 6,090.8	—1,858.4	— 730.2	—2,119.8	— 769.9
Total	—2,483.0	— 6,640.4	—2,573.6	—1,179.1	—2,435.7	—952.9

holdings of $\leq$ 100 acres) was 28% of total area under cane cultivation (47), i.e. $\gamma_{44} = 0.3$.

5. Petroleum Oil Refinery - Firm j = 5

$\beta_{56} = 0.3$, $\beta_5 = 0.2$, $\beta_5 = 0.2$

Some estimates of petroleum oil products consumption in the "rural areas" have been reported by Githinji as follows(74):-

Liquefied petroleum gas	= 15% of total domestic consumption
Aviation spirit	= 10% of total domestic consumption
Motor spirit	= 10% of total domestic consumption
Kerosene	= 50% of total domestic consumption
Diesel fuel	= 40% of total domestic consumption
Gas oil	= 40% of total domestic consumption

It would seem that the estimates include large scale farms and possibly small towns in rural areas, which are considered in this work as part of the modern economy. For calculations here, consumption of products is assumed to be restricted to kerosene, gas oil, and diesel fuel with coefficients of $\beta_{56} = 0.3$, $\beta_{57} = 0.2$ and $\beta_{58} = 0.2$.

4.I.B.1.B Results of Direct Income Accruing to the Two Economies

Evaluation of W_{jR} of Equation 2.I.6 can now be done using data from Section 4.I.A as well as the data presented in Section 4.I.B.I.A. The results for each of the five firms are presented in Tables A.4.I.18 to A.4.I.22 inclusively of Appendix A.4.I. In the tables the coefficients β_{jk}, γ_{ji} etc. are described as the income distribution coefficients. Using those values of W_{jR}, values of W_j from Table 4.I.23 (Section 4.I.A), and Equation (2.I.7) above, the distribution of direct income generated by the sample of five firms can be calculated. The results are tabulated on Table 4.I.26. below.

From the results of Table 4.I.26 firm j = 1 can be seen to take from the rural economy to give to the modern economy. Similarly, firm j = 5 takes more from the rural economy than from the modern economy in spite of the fact that the rural economy consumes only three of its eight products considered here. Even firm j = 3 which has positive

values of W_j benefits the modern economy more than the rural economy. Results for firm j = 4 illustrate that where the rural economy is a substantial consumer it can suffer lower maldistribution effects than when it does not consume a firm's products. Firm j = 2 illustrates the firm's dependency on power and electricity for which the small consumers in the modern economy would pay more than the firm does. It also illustrates the effect of the assumption made in the calculation. This was that the value of foreign exchange 'belongs' to both economies equally. In fact the rural economy normally uses little foreign exchange so that its benefits from firm j = 2 would actually be lower than shown if this had been taken into account. The same could not be said about the expenditure of foreign exchange by the firm; for the rural economy, through its exports of agricultural products such as coffee and tea, earns the country a major portion of its foreign exchange and when the reserves are reduced the rural sector would not likely be exempt from pressure to export more.

The point demonstrated by this subsection is that the rural economy is, on the basis of this limited study, directly linked to the modern economy. This link seems to be such that the firms in the modern economy and occasionally other sections of the modern economy as defined above are maintained at the expense of the rural sector. This is a tentative conclusion which is worth further investigation using larger samples of the industry and of the manufacturing sector as a whole.

4.I.B.2 Income Distribution to Owners of Means of Production

Data on company profits are available only for three firms and for two years as on Table 4.I.25. It seems reasonable to assume that for the other two firms the value of after tax profit would be positive.

As for distribution of income to foreign interests, some of the variables of Equation (2.I.9), i.e. τ, θ, p''_{Ii}, and p''_{Ek} could not be evaluated due to lack of sufficient data or information allowing reasonable estimation. A qualitative treatment of the foreign component in local production activities is given later under transfer of technology (Sections 4.IV and 4.V).

4.II.A The Employment Factor

1. Required Annual Rate of Growth in the Modern Economy

The required rate of growth of employment in the modern sector to absorb all increase of the labour force in the whole economy, can be calculated using different values of time, t, when this state could be achieved. The equation for this was given in Chapter 2.II.A as:

$$f_m^{1/t} + f_m^{(t+1)/t} - \left[\frac{E_{po}}{E_{mo}} \cdot f_p \cdot (1 + f_p)^t\right]^{1/t} = 0 \qquad (2.II.7)$$

Taking the base year as year 1974, the constants in the equation are as follows:-

f_p = 0.033 from Ref. (65)

E_{mo} = 8.26×10^5 from Ref. (66)

E_{po} = 6×10^6. This is the number of people aged between 14 and 54 years in 1974 based on the population census conducted in 1969: data is from Ref. (67).

Values of t are varied from 10 years to 130 years and the corresponding values of f_m solved for in the above equation by iterative trial and error method. The results are tabulated on Table 4.II.1. below. These results are plotted on Fig. (4.1). below.

From the curve on Fig. (4.1), it can be seen that:-

(a) The required rate of growth of employment in the modern economy for total increase in the labour force to be wholly absorbed by the modern economy, f_m, rises very steeply as the given period in years for this to occur is reduced from about 35 years to 10 years.

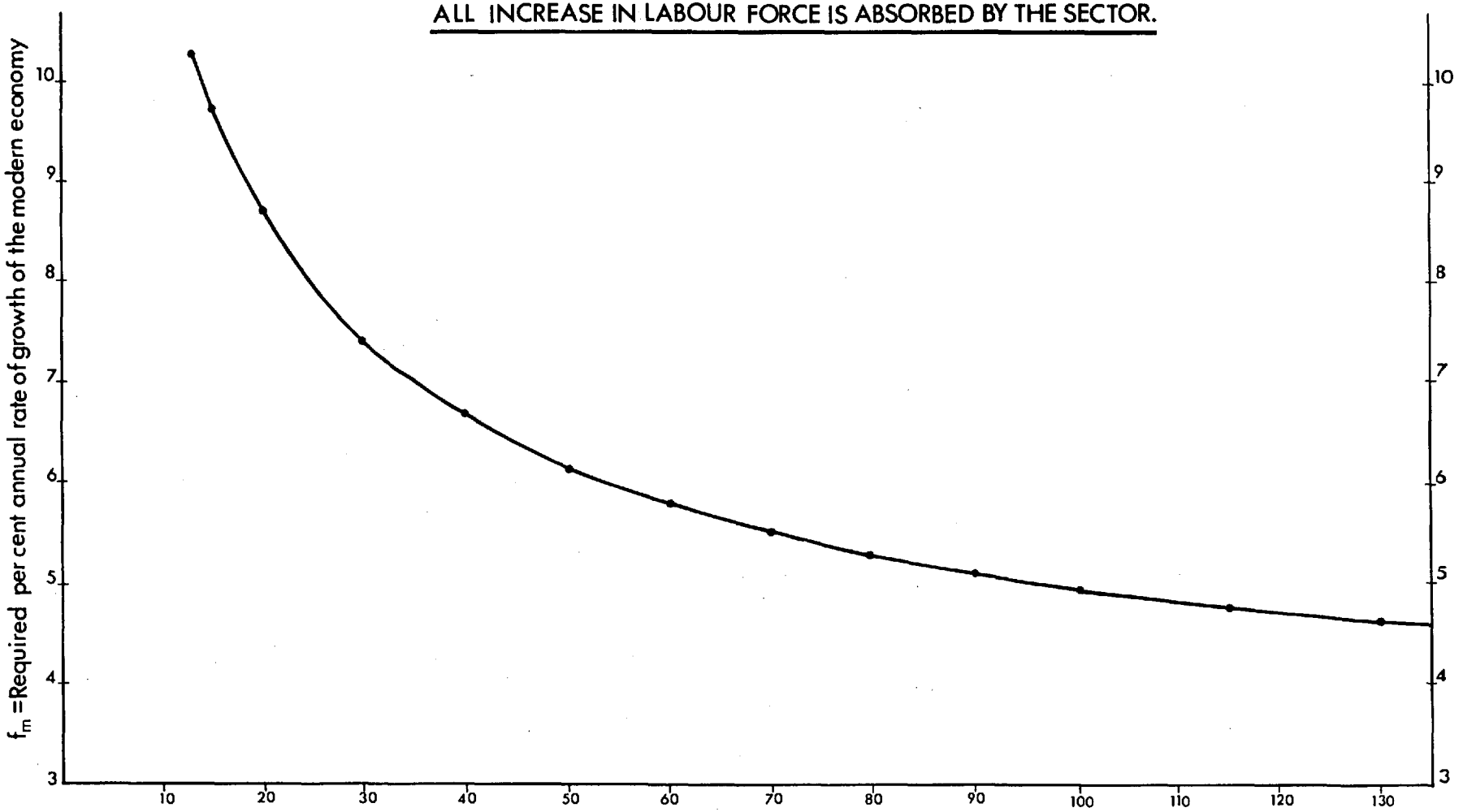
(b) The required rate of employment growth, f_m, decreases only slowly when the given time for complete absorption of the increases of labour force by the modern economy, t, is varied from 60 years to 100 years and very slowly beyond this time region.

From the curve it is also evident that a minimum employment growth rate in the modern economy of 5% would be necessary for the

TABLE 4.II.1

t(years)	10	20	30	40	50	60	70	80	90	100	115	130
f_m (%)	11.33	8.68	7.42	6.66	6.12	5.78	5.50	5.27	5.10	4.94	4.76	4.62

Fig. 4.1 VARIATION OF REQUIRED RATES OF MODERN SECTOR EMPLOYMENT GROWTH WITH CHANGE OF TIME ALLOWED BEFORE ALL INCREASE IN LABOUR FORCE IS ABSORBED BY THE SECTOR.



stipulated condition to obtain within 100 years, provided that the population growth rate does not increase. An 'optimal' period of 25 to 35 years would require an average annual growth rate, f_m, of between 7% and 8%.

2. Actual Growth Rates in the Modern Economy

Employment in the modern economy as a whole for the years 1965 - 1974 inclusive is shown on Table A.4.II.1 of Appendix A.4.II. From this table it has been calculated that:-

(a) The arithmetic mean annual rate of employment growth for the whole of the modern economy is equal to 4%.

(b) The corresponding moving average annual rate of employment growth in 1974 was equal to 7.3%.

3. Rate of Growth of Employment in the Process Industry

Employment figures for most of the chemical/processing industry in Kenya is shown on Table A.4.II.2 of Appendix A.4.II. These figures do not include food processing or the beverage manufacturing establishments, but represent a major portion of the chemical processing firms. The results are summarised on Table 4.II.2. below.

Thus arithmetic average annual growth rate of employment for the manufacturing groups represented is 6.02%. As shown in the Appendix, figures for sugar factories and refineries over the period 1964 - 1967 were not available. However, employment figures for large scale (employing more than 50 persons per establishment) "bakery products, sugar and sugar confectionery" firms given in national statistics for this period were (Stats. Abst. 1970):-

	1964	1965	1966	1967	1968
Number engaged	2,664	2,393	2,889	2,576	2,986

Error introduced by omission of sugar refineries and factories over this period is, therefore, relatively small.

For the Kenyan processing industry, therefore, the arithmetic annual rate of employment growth is about 6%, starting at a low employment base of about 3,000 people. The rate of growth of employment between

TABLE 4.II.2
EMPLOYMENT IN THE PROCESS INDUSTRY

Year	Total number engaged	Annual increase (number)	% growth for year
1964	3,212	-	-
1965	3,029	— 183	—5.70
1966	3,276	247	8.15
1967	3,293	17	0.52
1968	3,568	275	8.35
1968	6,877	-	-
1969	7,836	959	13,95
1970	8,024	188	2.40
1971	8,809	785	9.78
1972	9,903	1,094	12.42
1973	9,460	— 443	—4.47
1974	10,392	932	9.85
1975	11,532	1,140	10.97
		Total	66.22

Source: Table A.4.II.2, Appendix A.4.II

1969 and 1975 was 7.8% annual arithmetic average.

It would seem, therefore, that provided the current rates of growth of employment in the modern economy as a whole and in the processing industry are maintained and provided that population rate of growth does not exceed its current level it is feasible within about 40 years to transform the employment pattern of the economy so that the role of the traditional 'rural' sector as an employer would be greatly diminished or eliminated.

The crucial factor in determining feasibility of the current rates of employment growth being maintained would be availability of financial capital and the cost of industrial investments. Capital availability would in turn depend on the type of market the investors are largely interested in and the size of that market.

4.II.B Capital Investment and Employment

Calculation of:

$$REGC = \frac{E_{IND}}{E_{MFG}} \cdot \frac{C_{MFG}}{C_{IND}} \qquad (2.II.8)$$

(REGC = relative employment growth per unit of capital invested)

requires knowledge of total number of employees for the whole of the processing industry, E_{IND}, and for the whole of the manufacturing sector, E_{MFG}. Also required are the respective capital investment figures, C_{IND} and C_{MFG}. Data for an exact value of REGC are extremely difficult to obtain and instead a sample of a number of firms in the processing industry has been taken to represent the industry while data for capital investment in the manufacturing sector has been taken from published data for capital formation in the sector for a number of years (in this case from 1968 to 1976). Thus it is the average increases in both capital investment and employment over a given period of time that can be considered. In all but one of the firms in the process industry sample, expansion capital projects or recent capital projects were involved and this validates the approach.

The number engaged in the manufacturing sector over the period 1968 to 1976 and the value of capital formation (in current prices) over the period are given in Table A.4.II.3 of Appendix A.4.II. To bring the currency to the same base year (1976) value, a discount rate of 5% per

annum is discounted on capital formation values for the years before 1976. This is an attempt to account for inflation which was quite low for the period under consideration in Kenya. The relevant results are shown in Table 4.II.3 below.

TABLE 4.II.3

THE MANUFACTURING SECTORS CAPITAL FORMATION AND EMPLOYMENT GROWTH

Year	Annual increase in number engaged	Values of capital formation (discounted at 5% p.a.)	
		Undiscounted K£ x 10^6	Discounted K£ x 10^6
1968	3,110	14.1	20.8
1969	4,430	11.5	16.2
1970	9,880	13.9	18.6
1971	7,060	17.8	22.7
1972	8,470	28.7	34.9
1973	9,650	30.5	35.3
1974	6,880	29.9	33.0
1975	— 600	31.2	32.8
1976	8,050	43.7	43.7
1968 - 1976	56,930		258.0

Source: Table A.4.II.3, Appendix A.4.II

Sample of Firms in the Process Industry

The sample of firms considered here include firms discussed in Section 4.I. The numbers engaged in direct production are shown in Table A.4.I.17 which gives a total number of persons engaged by these firms of about 2,344 for the 1975 - 1976 period.

Estimates of value of capital investments for this sample are based on actual costs of recent major expansion projects (during the

1972 - 1976 period). The data here were obtained in the field (see Chapter 3) and applies to four of the five firms. Cost of such expansions is then divided by the increased manufacturing plant capacity and then multiplied by the total capacity for each plant after completion of the expansion project, to give the estimated replacement value of the investments in 1976. Values of investment costs so obtained do not represent the actual cost of the existing facilities since in all cases the initial plants were built well before 1976 at lower cost per unit capacity than the cost in 1976. Thus investment cost for a crude petroleum oil refinery with a 4.2 million tonnes/annum throughput of crude would be estimated at 25 million K£, a cement factory of 0.5 million tonnes/annum cement output capacity would be estimated to cost 7 million K£, and so on. Investment costs for the fifth firm are estimated as the actual initial plant's cost discounted at a rate of 5% per annum from the on-stream date to the end of 1975. This firm had not expanded its plant's capacity up to 1976.

Estimate of total capital investment costs, at about 1975 prices, so obtained is equal to 62 million K£ for the five firms. Thus:

$$C_{IND} = 62 \times 10^6 \text{ K£} \quad , \quad C_{MFG} = 258 \times 10^6 \text{ K£}$$

$$E_{IND} = 2{,}344 \quad , \quad E_{MFG} = 56{,}930$$

and hence:

$$REGC = \frac{2{,}344}{56{,}930} \times \frac{258}{62} = 0.2$$

Thus capital investment in the sample of process industry firms generates about 20% of employment that would be generated by investing the same finance capital in an 'average performing' industry of the manufacturing sector, 'average performing' here being understood to mean the productivity of capital investment with respect to employment generation.

4.II.C Employment Productivity per Capital Investment Unit and Feasibility of Satisfactory Growth of the Local Process Industry

From Fig. (4.1) an employment growth rate in the modern sector of about 10% per annum would be adequate to transform the economy such that the role of the rural sector would be significantly diminished

within 10 to 15 years. Assuming that this target period is desirable for economic or political reasons, and assuming that the type of investments represented by the above sample from the process industry also experiences the same growth rate some intertemporal considerations can be made.

Taking the growth period of 15 years from 1975, the rate of employment growth in the process industry as 10%, and the number of persons employed in the whole of the Kenyan process industry as 12,000 in 1975, then:-

Number of persons engaged in process industry at end of the 15 year period $= 12{,}000\ (1.1)^{15}$

For investments similar to those of the sample firms, the capital to number engaged ratio is equal to 62 million K£ : 2,344 persons engaged.

Thus total required investment capital over the 15 year period at constant 1976 prices, C_{NEW}, would be given by:

$$C_{NEW} = \frac{62 \times 10^6 \times 12{,}000}{2{,}344}\left[(1.1)^{15} - 1\right] \text{K£} = 317.4 \times 10^6 \times 3.177 \text{ K£}$$

$$\triangleq \underline{1010 \text{ million K£}}$$

In addition it is estimated in Section 4.V.B below that the current rate of imports of maintenance and operation equipment and services, for plants similar to those in the above sample, amounts to 7% of capital cost per annum. If this situation were also to continue the added expenditure over the period, on imports of equipment and services alone, C_{MTI}, would amount to:

$$C_{MTI} = 0.07 \times 317 \times 10^6 \left[\sum_{i=1}^{15}(1.1)^i - 15\right] \text{K£}.$$

$$\triangleq \underline{440 \text{ million K£}}$$

The above estimates are at about 1975 prices.

It is worth noting that the financial capital requirement of 1000 million K£ is for covering the initial cost of new plants similar in size and technology to those in the sample. If industrial growth occurs partly in form of expansions of existing - at any year within the stipulated period-plants, the ratio of capital to number of persons engaged would tend to increase with the number of expansions. The total capital requirement for covering the initial costs of new plants and expansions would then be expected to be significantly greater than the sum of 1000 million K£ given above.

The sum of 440 million K£ constitutes part of the recurrent costs associated with the new investments. This component of recurrent costs would account for imports of maintenance equipment and services, and for operation and marketing service imports only. The costs would be met from revenue earned by the operating plants but are important in that they would affect prices at which produced commodities would be supplied. They would therefore have to be taken into account at the planning stages of industrial projects.

Feasibility of the stipulated industrial growth can be considered in terms of potential capitalisation in the process industry using historical growth of capitalisation.

Table 4.II.3a below shows values of capital formation in the process industry and in the manufacturing sector for the period 1964 to 1977. The ratio of capital formation in the process industry to capital formation in manufacturing sector has also been calculated. The average values for this ratio over the periods 1964-1976 and 1967-1976 are 0.23 and 0.25 respectively. As explained in section 4.III data for up to around 1966/67 are more uncertain than for the subsequent years. The ratio of 0.25 can therefore be considered as the more reliable proportion of capital formation in the manufacturing sector accounted for by capitalisation in the process industry over the period 1967 - 1976 and over the period of projection of the data below (1975 - 1990). For forecasting purposes the manufacturing sector is more convenient to use because it has a more recognisable trend. Values of capitalisation at constant prices must be used in order to reflect 'real' trend in capital formation.

For the manufacturing sector table 4.II.3a shows that available data are based on 1964 and 1972 constant prices. It is desirable to bring all values to those obtaining at constant 1972 prices. Price changes can be measured in terms of Paasche index-numbers of prices with the base year i.e. 1964 or 1972 having a Paasche index number of 100 (134). Accordingly,

Table 4.II.3a

CAPITAL FORMATION IN THE PROCESS INDUSTRY & THE MANUFACTURING SECTOR, (1964–1977)

YEAR	CAPITAL FORMATION AT CURRENT PRICES		$\frac{\Delta K_{PRS}}{\Delta K_{MFC}}$	Manufacturing Sector Capital formation at constant	
	Process Industry ΔK_{PRS} (K£x10^6)	Manufacturing Sector ΔK_{MFG} (K£x10^6)		1964 prices (K£x10^6)	1972 prices (K£x10^6)
1964	1·10	5·82	·19	5·82	
1965	0·86	6·63	·13	–	
1966	1·01	8·09	·12	–	
1967	1·63	9·96	·16	9·05	–
1968	2·02	12·12	·17	10·87	–
1969	2·48	9·46	·26	8·42	–
1970	4·59	12·95	·35	12 31	–
1971	4·69	18·47	·25	15·60	–
1972	5·82	28·02	·21	19·96	28·19
1973	7·27	(29·03)31·84	·23	(18·88)	27·72
1974	19·03	29·86	·64	–	20·88
1975	6·02	31·23	·19	–	17·68
1976	3·78	45·96	·08	–	20·94
1977		60·67	N.A.	–	24·14

Data Source: For the manufacturing sector–

1964–1970(at current prices) from Table 52 of Ref. (133);
1971–1973(" ") from Table 47(a) of Ref(28);
1974–1977 (at current and constant prices) from Table 2.10 of Ref.(136);
1967–1970(at constant 1964 prices) from Table 52(b) of Ref.(131);
1971–1973 (" " ") from Table 47(b) of Ref.(28);
1972–1974 (" 1972 ") from Table 51(b) of Ref.(44).

For the process industry–

Table 4. III.2. below

N.B. A dash,(–) indicates that data is not available for the entry.

the price index number for 1972 on the basis of 1964 prices i.e. Paasche index number for 1964 = 100, is given by

$$(28.19/19.96) \;/\; (5.82/5.82) \;=\; 1.41$$

i.e. there was a 41 per cent increase in prices between 1964 and 1972. Price changes in terms of 1964 prices can similarly be calculated for the other years between 1966 - 1972 using capital formation values shown in table 4.II.3a. Thus price index, at 1964 prices, for the year 1967 = 1.10, for 1968 = 1.11,...., for 1972 = 1.41 and so on.

Revaluation of figures for capital formation in terms of 1972 constant prices can be accurately done only by revaluation of all the components of capital formation for the years considered. As this information is not readily available an approximate revaluation to 1972 prices can be done by assuming that price changes from year to year occur at the same rate for all components of capital formation. The price index on 1972 basis for any year is then given by:

$$\text{(a year's price index on 1972 basis)} = \frac{\text{(1972 price index on 1964 basis)}}{\text{(the year's price index on 1964 basis)}}$$

Multiplication of the year's capital formation value at current prices with the year's calculated price index on 1972 basis then gives the estimated capital formation value at constant, 1972 prices. This method of estimation gives values of capital formation for 1973 of 26.65 million K£ compared to the reported actual value of 27.72 million K£. The values reported for this year at current prices are themselves different i.e. 29.02 million K£ and 31.84 million K£ presumably due to reclassification of some items. The 5% error in estimation using the above procedure would therefore seem within the limits of accuracy of the published data.

Applying the above procedure to the data covering the period 1967 - 1971, and using published data for 1972 - 1977 period, capitalisation in the manufacturing sector for the period 1967 - 1977, at constant 1972 prices, is as shown in Table 4.II.4 below. Figures for 1965 and 1966 are estimates based on capital formation data at current prices and using price index numbers for capital formation in the whole economy (on 1964 basis) for these two years. Thus table 4.II.4 covers a period of 14 years between and including 1964 and 1977. This table has been used for preliminary exploration of the most appropriate form of a curve reflecting the trend of capitalisation in the manufacturing sector. This was done

by examination of slopes, using seven-yearly moving averages of the data and the methods given in Gregg et al (135).

Explorative calculations showed that a "logistic" form of trend curve would fit the data for the whole period. The trend curve is of the form

$$\frac{1}{y} = a + br^t \qquad (4.II.1)$$

where,

y = value of capital formation for any year, t years from a base year,

and

a,b,r, are constants with $0 < r < 1$.

For the trend curve fitting, only data for the 1967 - 1977 period were considered because of their higher reliability. Gomes method which involves use of tables of "J functions" and found in Gregg et al (135) was used. The appropriate equation was found to be

$$\frac{1}{y} = .041 + .057\ (.725)^t \qquad (4.II.2)$$

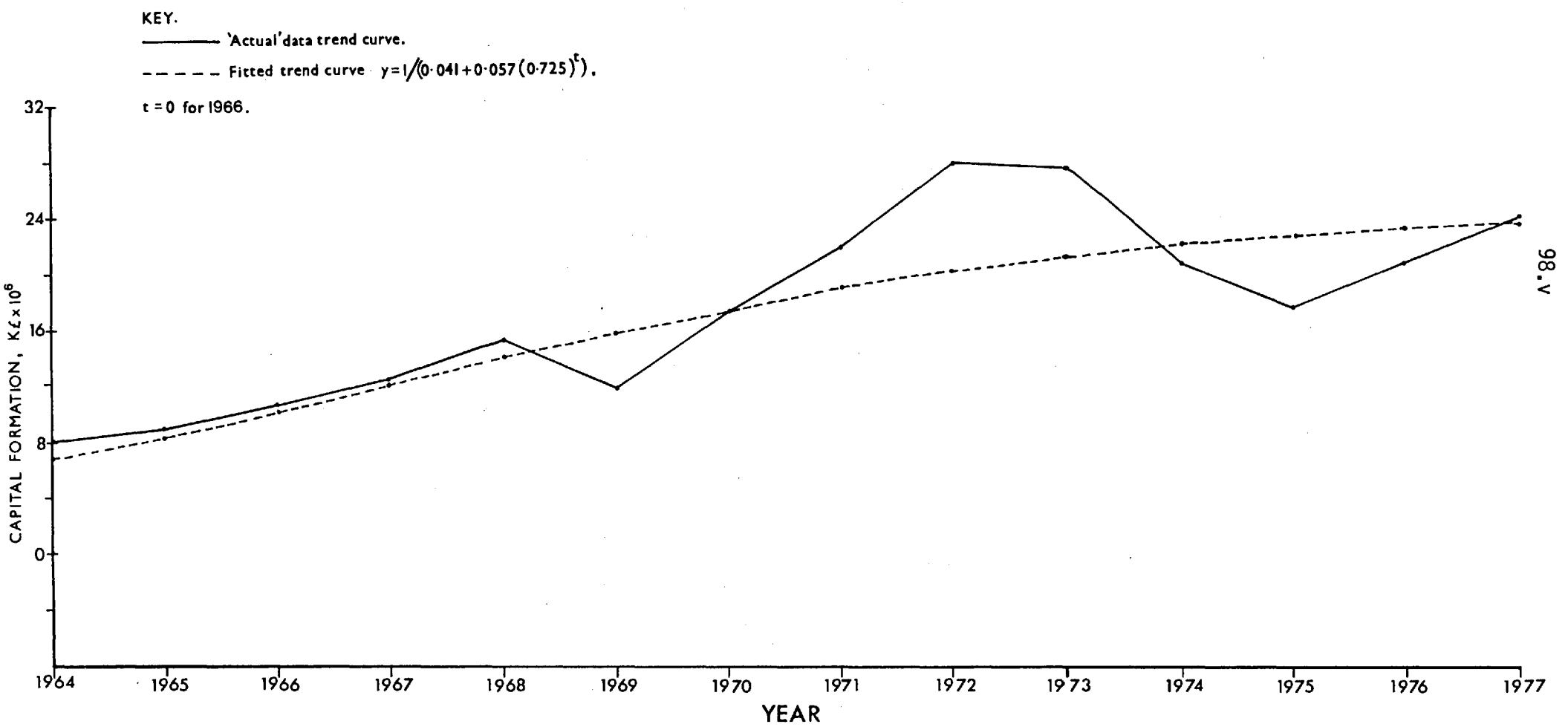
The following table 4.II.4 shows values of capital formation at constant 1972 prices in the manufacturing sector given by application of the above equation - 'calculated' values. Also shown are 'actual' data used to derive the trend curve (in the case of 1967 - 77 data). Value of t was taken as t = 0 for the year 1966.

Table 4.II.4 'Actual' and 'Calculated' capitalisation in the manufacturing sector at constant 1972 prices for the period 1964 - 1977.

YEAR	CAPITAL FORMATION		YEAR	CAPITAL FORMATION	
	'Actual' K£ x 10^6	'Calculated' K£ x 10^6		'Actual' K£ x 10^6	'Calculated' K£ x 10^6
1964	8.2	6.7	1971	22.1	19.1
1965	9.1	8.4	1972	28.2	20.3
1966	10.9	10.2	1973	27.7	21.3
1967	12.7	12.1	1974	20.9	22.1
1968	15.4	14.1	1975	17.7	22.6
1969	11.9	15.9	1976	20.9	23.1
1970	17.4	17.6	1977	24.1	23.4

Fig. 4.2.A.

'ACTUAL' AND 'CALCULATED' CAPITAL FORMATION IN THE MANUFACTURING SECTOR AT CONSTANT (1972) PRICES.



In Fig. 4.2A above the values of capital formation in the manufacturing sector shown in table 4.II.4 have been plotted to show the graphical representation of eqn. 4.II.2 and of the 'raw' data.

Now eqn. 4.II.2 can be used to give forecasts of annual values of capital formation in the manufacturing sector for 15 years from 1975 i.e. 13 years from 1977, for purposes of considering the feasibility of capitalisation in the process industry at the level stipulated earlier. Gregg et al (135) also give a method for estimation of 90% confidence limits for the fitted curve. The confidence limits are given by the product of the standard deviation of the points about the fitted curve and a complex function of r and of the number of years in the period considered in the trend curve fitting. The results of application of eqn. 4.II.2 in extrapolation of the 'logistic' curve and of estimation of 90% confidence limits for the extrapolated years are given in Table 4.II.5 below. In the table only the 'expected' values and the 'most optimistic' predicted values within 90% confidence limits are considered. The values of capital formation are all at constant, 1972 prices.

Table 4.II.5 "Expected" and "Most Optimistic" forecasts of capitalisation in the manufacturing sector (1978 - 1990).

YEAR	CAPITAL FORMATION (K£ x 10^6)		YEAR	CAPITAL FORMATION (K£ x 10^6)	
	Expected	Most Optimistic		Expected	Most Optimistic
1978	23.7	31.5	1985	24.3	35.5
1979	23.9	32.5	1986	24.3	35.5
1980	24.0	33.1	1987	24.4	35.9
1981	24.1	33.7	1988	24.4	35.9
1982	24.2	34.4	1989	24.4	35.9
1983	24.2	34.8	1990	24.4	36.0
1984	24.3	35.2	TOTAL 1978-90	314.6	449.9

From table 4.II.5 and actual data for the years 1976 and 1977, it is clear that the most likely value of capital formation in the manufacturing sector at constant 1972 prices, is of 360 million K£ for the whole of the 1976 - 1990 period.

The most optimistic prediction at 90% confidence limits gives a value of capital formation over the 1976 - 1990 period, at constant 1972 prices,

of 495 million K£.

These values can be adjusted to 1975 values for purposes of comparison. From table 4.II.3 it can be seen that between 1972 and 1975 prices of capital formation components changed by 77%.

Thus expected and most optimistic levels of capitalisation in manufacturing sector and in the process industry over the 1976 - 1990 period at constant 1975 prices can be summarised as follows:-

Table 4.II.6 Expected and optimistic forecasts of capitalisation at constant 1972 and constant 1975 prices.

Base Year for Constant Prices	Projected Capital Formation (1976 - 1990)			
	Manufacturing Sector		Process Industry	
	Expected K£ x 10^6	Most Optimistic K£ x 10^6	Expected K£ x 10^6	Most Optimistic K£ x 10^6
1972	360	500	90	125
1975	640	880	160	220

From table 4.II.6 above, it seems evident that an average growth rate of about 10% for the process industry - assuming that the sample is a reasonable representative of the industry - would not be financially feasible.

The implications of these calculations would seem to be that in terms of employment generation, investments represented by the sample considered would tend to perform badly. Adequate growth of such investments might not be possible if employment is considered a prime consideration in choice of projects.

However, even within the industry labour intensity varies both with plant size and with type of processing operation. In general, the more expensive a plant is the more intensive it tends to be and the more 'complex' are the processing operations.

Growth of an industry in terms of employment could also mean growth of local technological capacity. This form of growth would seem desirable.

This section thus highlights the possible importance of careful selection of technology used in developing the process industry. The next section considers the existing process industry in terms of conventional economic considerations.

4.III.A Level of Self-Reliance of the Industry for Capital Financing

Increases in capital stock, i.e. investments in the industry and in the economy have been considered for the period 1964 - 1976. Seven major firms in the processing industry have been selected to represent the industry as a whole. The financing pattern for these firms has been briefly sketched in Appendix A.4.III which also shows how the values for the given estimates were arrived at.

Denoting incremental capital stock for firm k, over period of time t, by Δk_{kt} and the level of borrowing by the firm over the same period of time, by bc_{kt}, the summary of these values for the period t = T, i.e. 1963 - 1976, for the seven firms are given on the following table. These values are taken from Table A.4.III.1 of Appendix A.4.III.

TABLE 4.III.1

CAPITAL INVESTMENT AND BORROWING REQUIREMENTS FOR 7 FIRMS IN THE PROCESS INDUSTRY

K£ x 10^6

Firm	k1	k2	k3	k4	k5	k6	k7	k1, k2, ... k7
Δk_{kT}	6.2	1.5	19	2.7	15	30	3.5	$\sum \Delta k_{kT} = 77.9$
bc_{kT}	6.1	1.3	13	2.0	12	24	2.9	$\sum_{k=k1}^{k7} bc_{kT} = 61.3$

Source: Field data

From these figures average ratio of borrowed capital to total investment capital, $BCIR_i$ for the sample is:

$$BCIR_i = \sum_{k=k1}^{k7} bc_{kT} \Big/ \sum_{k=k1}^{k7} \Delta k_{kT} = 0.79$$

Capital investment in the whole of the economy can be taken as the value of "capital formation" for the economy as given in national statistics publications. These figures - which include spare and replacement equipment costs - have been reproduced in Table A.4.III.2 of Appendix A.4.III for the period 1964 - 1976. The value of total capital formation,

i.e. capital investments Δk_N, calculated from Table A.4.III.2 is:

$$\Delta k_N = 1{,}740 \text{ million K£}$$

Since the sample of 7 firms in the processing industry considered here had an estimated borrowing requirement of 61.3 million K£, the ratio of borrowed capital for these firms to total expenditure on capital projects for the whole country, δ_{2s}, is:

$$\delta_{2s} = \frac{61.3}{1{,}740} = 0.035$$

In other words the sample's estimated borrowing requirements amounted to 3.5% of total value of new capital investments in the country.

A level of borrowing of 70 - 80% and amounting to an estimated 3 - 4% of total capital finance available for investments (in fixed assets), by a sample of seven firms in one small industry would seem significant. Firstly, it would indicate that there is a strong case for assessment of new industrial projects outside the normal confines of production facilities owners' commercial interests and secondly, it is interesting to study, on the basis of conventional indicators of performance, whether or not investment projects such as included in the sample are the most productive.

A single most important characteristic factor of the firms in the sample considered (Table 4.III.1) is the value of capital expenditure on projects, ranging between 1.5 - 30 million K£. Now, it is common for most plants to be of relatively small sizes compared to common sizes in the industrially advanced countries. The relatively high value of capital expenditure would, therefore, be as much a reflection of the cost of the projects' technologies as of the plants' sizes. In the following section this comment is investigated further in relation to 'capital productivity' in the Kenyan processing industry.

4.III.B Productivity of Capital in the Economy, in the Manufacturing Sector and in the Process Industry

For the purpose of this work, annual investments, i.e. annual increase in capital stock, for the whole economy or for the manufacturing sector only can be taken equal to the annual 'capital formation' for the economy or the manufacturing sector as reported in annual National

Statistics publications. In these publications the "Figures on Capital Formation measure expenditures on fixed assets which represent a gross addition to the stock of capital in the economy. .... No deduction is made for capital used by depreciation, obsolescence or unforeseen damage" (68).

Value of outputs in the economy can be taken as the 'Gross Domestic Product' for the whole economy, where "The figures on Gross Domestic Product measure the value of outputs of goods and services each year. .... The figures are gross because no deduction has been made to allow for consumption of fixed capital assets in the production of the output .... " (68). For the manufacturing sector the term applicable is 'Gross product' defined as for the economy with the exception that it is restricted to this sector only.

Productivity of capital invested in the economy as a whole and in the manufacturing sector can be reflected by the ratios of incremental gross domestic product to incremental total capital formation in the economy and of incremental gross product to incremental capital formation in manufacturing sector, over a specified period of time. For the period 1964 to 1976 inclusively Table A.4.III.2 of Appendix A.4.III shows annual data on gross domestic product, gross product, and capital formation for the whole economy and for the whole of the manufacturing sector respectively.

For the process industry it was necessary to obtain data from the Central Bureau of Statistics directly because available publications do not disaggregate the data sufficiently. The data made available are shown below on Tables 4.III.2 - 4 inclusively. Table 4.III.2 gives values of capital expenditure on new plants and/or expansions for all firms in the industry employing 50 persons or more and which fall into any of the following types of industrial production groups:-

Manufacture of paints, varnishes and lacquers,
Manufacture of cleansing preparations and cosmetics,
Petroleum refining,
Cement production,
Soda ash production and/or crude soda extraction,
Production of extracts from wattle bark,
Production of extracts from pyrethrum flowers,
Manufacture of basic industrial chemicals,
Manufacture of pulp and paper,
Production of refined and crude sugar from sugar cane,
Manufacture of vegetable and animal oils.

TABLE 4.III.2

CAPITAL EXPENDITURE ON NEW PLANTS AND/OR EXPANSIONS IN THE PROCESS INDUSTRY

Value (K£ x 10^6)

YEAR	INDUSTRIAL GROUP											INDUSTRY TOTAL
	1	2	3	4	5	6	7	8	9	10	11	
1963	-	0.126	0.220	0.212	0.029	0.007	0.001	0.068	0.048	0.119	0.113	0.963
1964	-	0.124	0.096	0.101	0.004	0.009	0.001	0.043	0.473	0.164	0.088	1.103
1965	-	0.256	0.031	0.017	0.019	0.004	0.022	0.097	0.276	0.138	-	0.860
1966	-	0.284	0.050	0.010	0.002	0.009	0.012	0.254	0.186	0.161	0.037	1.005
1967	-	0.519	0.075	0.041	0.064	0.023	0.072	0.099	0.097	0.599	0.038	1.627
1968	-	0.165	0.062	0.101	-	0.023	0.008	0.105	1.016	0.485	0.054	2.019
1969	0.022	0.150	0.099	0.082	0.047	0.020	0.022	0.089	0.691	1.212	0.042	2.476
1970	0.026	0.221	0.152	0.091	0.165	0.058	0.019	0.176	0.447	3.177	0.054	4.586
1971	0.046	0.398	0.306	0.071	-	0.063	0.033	0.028	0.237	3.443	0.064	4.689
1972	0.029	0.247	0.257	0.057	0.011	0.132	0.039	0.047	0.265	4.610	0.127	5.821
1973	0.036	1.728	3.914	0.043	0.018	0.003	0.017	0.059	0.011	1.344	0.096	7.269
1974	0.049	0.142	5.685	-	1.478	-	0.022	0.160	10.774	0.611	0.105	19.026
1975	0.026	0.601	2.615	0.021	0.059	0.001	0.063	0.127	0.026	2.305	0.175	6.019
1976	0.045	2.150	0.232	0.037	0.231	0.003	0.062	0.569	0.094	0.073	0.285	3.781

TABLE 4.III.3

GROSS PRODUCT (AT FACTOR COST) FOR FIRMS IN THE PROCESS INDUSTRY

K£x10^6

YEAR	INDUSTRIAL GROUP											INDUSTRY TOTAL	ANNUAL CHANGE
	1	2	3	4	5	6	7	8	9	10	11		
1963	-	0.455	0.469	0.231	0.446	0.207	0.183	0.539	0.171	0.980	0.901	4.582	-
1964	-	0.665	0.553	0.202	0.306	0.293	0.232	0.590	1.840	1.219	0.943	6.843	2.261
1965	-	0.723	0.703	0.228	0.313	0.365	0.253	0.630	2.050	1.611	0.970	7.846	1.003
1966	0.041	0.709	1.491	0.220	0.186	0.438	0.178	0.706	2.113	1.715	0.973	8.770	0.924
1967	0.043	0.576	1.158	0.205	0.223	0.239	0.163	0.811	2.465	1.791	0.987	9.048	0.279
1968	0.040	0.983	0.549	0.328	0.236	0.264	0.175	0.854	2.298	1.981	0.991	8.699	— 0.349
1969	0.041	1.094	0.719	0.280	0.201	0.332	0.209	1.142	2.659	2.334	0.993	10.004	1.305
1970	0.298	1.652	1.436	0.451	0.170	0.375	0.228	1.293	2.278	2.715	0.998	11.894	1.890
1971	0.253	1.514	1.370	0.555	1.266	0.408	0.364	1.283	2.947	3.172	1.049	14.181	2.287
1972	0.350	1.273	2.489	0.594	1.082	0.487	0.412	1.343	2.971	3.089	1.029	15.119	0.938
1973	1.394	1.992	2.530	0.423	0.421	0.493	0.415	2.391	1.270	4.147	2.105	17.581	2.462
1974	1.963	3.687	3.859	0.458	1.390	0.498	0.855	3.867	3.943	4.117	2.148	26.785	9.204
1975	2.430	5.449	3.588	0.519	1.473	0.593	0.621	3.089	4.988	5.522	1.966	30.238	3.453
1976	4.745	8.795	7.251	0.634	1.510	0.778	0.884	5.071	5.135	6.798	2.146	43.747	13.509

TABLE 4.III.4

NUMBER OF FIRMS IN EACH INDUSTRIAL GROUP OF THE PROCESS INDUSTRY

Number of firms in a group/year

Year	INDUSTRIAL GROUP										
	1	2	3	4	5	6	7	8	9	10	11
1963	1	2	4	2	1	3	3	3	1	2	1
1964	1	2	5	2	1	3	4	3	1	2	1
1965	1	1	5	3	1	2	4	4	1	2	1
1966	1	2	4	2	1	2	2	4	1	2	1
1967	1	3	5	2	1	2	2	4	1	2	1
1968	1	4	4	3	1	2	2	4	1	2	1
1969	1	4	6	2	1	2	2	4	1	2	1
1970	1	4	7	4	1	2	2	4	1	2	1
1971	3	5	7	4	1	2	2	4	1	2	1
1972	3	6	8	1	1	2	11	4	1	2	1
1973	4	6	11	1	1	2	6	5	1	2	1
1974	7	6	11	1	1	2	7	6	1	2	1
1975	6	8	12	1	1	2	2	7	1	2	1
1976	6	9	10	2	1	2	3	7	1	2	1

Source of data in Tables 4.III.2, 4.III.3 and 4.III.4: Central Bureau of Statistics, Ministry of Finance and Planning, Private Communications.

NB Numbers 1, 2, 3, ... 11 at the top row of the tables represent the industrial groups as listed earlier. The listing order, however, does not correspond to the order of numbering of the industrial groups on the tables. This is done in order to protect the anonymity of those firms which are singly or in pairs, found in a group. Communications attached to the data from the Statistics Bureau and shown in Appendix A.4.III indicates why this has been done.

Table 4.III.3 gives the values of gross products for the firms included in the above classification, while Table 4.III.4 shows the number of firms represented in each group. As can be seen from the communication reproduced on page 228 of Appendix A.4.III relating to the data there is a degree of uncertainty as to the accuracy of some of the data. For some firms considered elsewhere in this work it is possible to deduce whether data for their group on capital expenditure on new plants and expansions are reliable or not. Thus firm k = 1 on Appendix A.4.III belongs to group 2 – the firm came on stream in 1968 which corresponds to the increase in number of firms in that group for the year. However, fixed capital expenditure could not have been less than K£ 1.0 million as shown on Table 4.III.2, given the size and nature of the processing plant. Data from other sources on which estimates of capital investment costs shown on Appendix A.4.III are based confirm this. The firms for which actual data were unavailable seem, therefore, to be those in group 2. Comparison of Table 4.III.2's data with data for firms included in samples studied in other parts of this work indicate that the data for the other groups are reasonably accurate. This comparison has been done for firms in group 3, 5, 9 and 10. Overall then, the data can be regarded as accurate as data published for the whole economy and for the manufacturing sector. The summed up figures on capital expenditure on new plants and/or expansions now treated as capital investment, and the gross product for the process industry are shown together with data for the economy and for the manufacturing sector on Table 4.III.5 below. On this table annual incremental output value of products and services for the economy is denoted by ΔGDP, for the manufacturing sector by ΔGP_{MFG}, and for the process industry by ΔGP_{PRS}. The corresponding annual investments are denoted by Δk, Δk_{MFG} and Δk_{PRS} respectively.

Table 4.III.5 also shows calculated values of capital productivity in the economy, in manufacturing sector, and in the process industry. In these calculations capital invested in one year is assumed to start being productive in the following year. For the economy as a whole and particularly in relation to small scale investments - such as small businesses or in rural sector agriculture - the capital investment would have only a few months gestation period. For large firms in the processing industry and in manufacturing sector in general, gestation periods would vary between one and two to three years during which plants are constructed. It seems that, for some

TABLE 4.III.5

CAPITAL PRODUCTIVITY IN THE ECONOMY, IN MANUFACTURING, AND IN THE PROCESS INDUSTRY

Year	WHOLE ECONOMY			MANUFACTURING SECTOR			PROCESS INDUSTRY		
	Δk (K£x10^6)	ΔGDP (K£x10^6)	$\frac{\Delta GDP}{\Delta k}$	Δk_{MFG} (K£x10^6)	ΔGP_{MFG} (K£x10^6)	$\frac{\Delta GP_{MFG}}{\Delta k_{MFG}}$	Δk_{PRS} (K£x10^6)	ΔGP_{PRS} (K£x10^6)	$\frac{\Delta GP_{PRS}}{\Delta k_{PRS}}$
1963							0.96	4.58	
1964	45.14	20.86		6.95	4.75		1.10	2.26	2.35
1965	46.54	7.74	0.17	7.55	3.57	0.51	0.86	1.00	0.91
1966	61.24	51.40	1.10	9.51	5.16	0.68	1.01	0.92	1.07
1967	81.30	21.90	0.36	14.90	3.29	0.35	1.63	0.28	0.28
1968	90.06	35.45	0.44	12.70	4.80	0.32	2.02	— 0.35	— 0.21
1969	93.73	34.31	0.38	9.46	6.85	0.54	2.48	1.31	0.65
1970	112.71	42.61	0.45	12.95	5.32	0.56	4.59	1.89	0.76
1971	144.20	51.12	0.45	18.47	9.52	0.74	4.69	2.29	0.50
1972	160.37	78.46	0.54	28.02	12.67	0.69	5.82	0.94	0.20
1973	181.46	91.60	0.57	31.84	10.25	0.37	7.27	2.46	0.42
1974	203.76	156.18	0.86	29.86	24.47	0.77	19.03	9.20	1.27
1975	242.54	133.27	0.65	31.23	8.06	0.27	6.02	3.45	0.18
1976	298.04	223.79	0.92	43.65	24.20	0.77	3.78	13.51	2.24

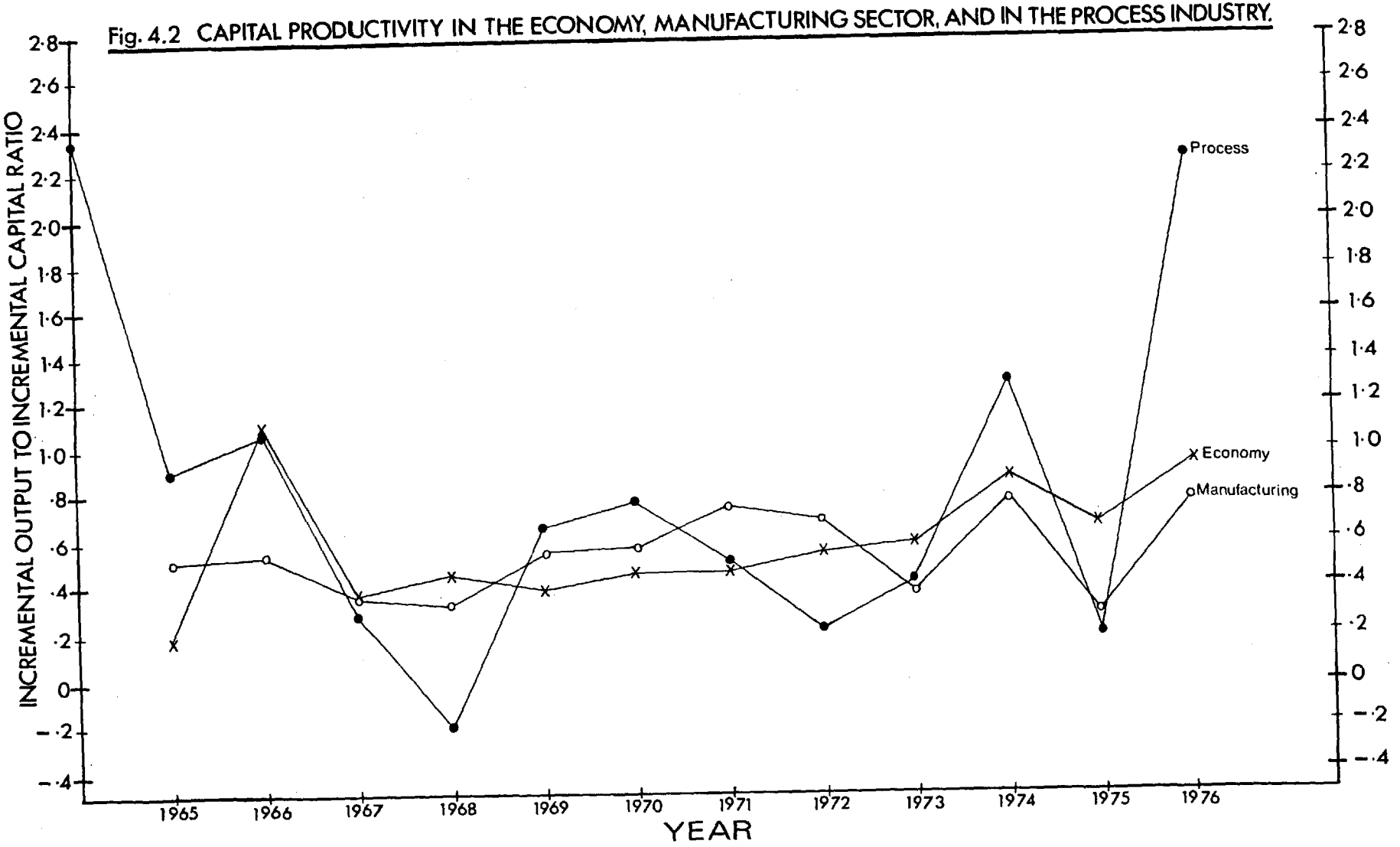
Source: Calculated from tables referred to above

large firms at least, data on capital formation are entered in official statistics record in the year the capital projects are completed. Thus for firm in group 5 of Table 4.III.2 the project for which capital formation data is given, for the 1974 year, was actually started in 1972 and completed in 1974. In other cases, such as that of firms in group 10 over the period 1967 - 1973, the expansion projects involved were actually completed in 1967 - 1968 and it would seem that loans were being repaid over the period given on the table.

Ratios of incremental outputs to incremental capital investment have also been plotted on Fig. (4.2) below for the whole economy, i.e. plot 'economy', the manufacturing sector, i.e. plot 'manufacturing' and the process industry, i.e. plot 'process'.

Considering plots for the economy and for manufacturing sector, on Fig. (4.2), it is clear that the productivity of capital invested in the economy as a whole exhibits a gentle but steady upward trend, particularly over the 1967 to 1976 period. The plot for the manufacturing sector shows a higher degree of oscillation. This could be explained by the fact that the number of investments in manufacturing sector is small compared to the total number of investments in the whole economy. Industries in the manufacturing sector make major investments at different times and differences in productivity of capital between industries could then be reflected in the plot for the manufacturing sector. Thus from Table 4.III.2, in 1974 value of investments in the process industry was K£ 19 million out of a total of K£ 30 million for the whole of the manufacturing sector. In spite of the oscillations, plot 'manufacturing' shows a rough trend. For the period 1967 to 1976, productivity of capital in manufacturing sector up to 1972 was higher than the national average but remained below the national average over the rest of the period. As can be seen from Table 4.III.5 the investment figures for the sector vis a vis the whole economy show a reversal of this trend. Thus for the period 1967 - 1971 value of capital investments in the sector was 13% of total capital investments in the economy, increasing to 15% over the 1972 - 1976 period. This might be justified on the ground that the sector's value of capital productivity particularly over the 1969 to 1972 period was better than that of the economy as a whole. But, it has since then ceased to be significantly more attractive than the average for the whole economy. It could, therefore, be argued that in general, financial requirements for continued growth of the manufacturing sector should be met largely by

Fig. 4.2 CAPITAL PRODUCTIVITY IN THE ECONOMY, MANUFACTURING SECTOR, AND IN THE PROCESS INDUSTRY.



profits generated by the sector itself, i.e. borrowing requirements should be kept low. Some industries or industrial groups in a particular industry could, however, exhibit higher productivity of capital than the average, and the importance of the above results lies in that they indicate a need for scrutiny of investments in the sector at the industrial and/or group level to isolate those that are most promising for enhanced development.

Now considering the plot for the process industry, plot 'process', the immediately noticeable feature is the much greater degree of oscillation here compared to the other plots in Fig. (4.2). This can again be explained in terms of the small number of investments in the process industry compared to those both in either the manufacturing sector as a whole or the whole economy. In this case, the oscillations could be highlighting differences in capital productivity between the industry's 'industrial groups' or even individual firms. Errors in the data can also be more pronounced here where the number of firms involved is much smaller than in the case of the whole economy and of the manufacturing sector.

Plot 'process' indicates from the excursions of the value of capital productivity from one year to another that the difference between industrial groups and, or firms in the industry can be very significant. One could expect that the plot would exhibit a gentle trend upwards as new plants' capacity utilisation rises over the years and a trend downwards if several plants are scrapped before their replacement. The combination of these factors might then give roughly constant values of capital productivity for random scrapping of plants and improved capacity utilisation in the industry. The magnitude of the peaks and crests on plot 'process' suggest that this could not have been a major reason for the shape of the plot. Uneven growth between industrial groups with different capital productivity values seems to be the major cause for the oscillations. A crude analysis of capital productivity could be done on the basis of the data available.

Ignoring the data for the period prior to 1967 where the degree of uncertainty in the data's accuracy is high as explained in the communications shown on page 228, Appendix A.4.III, Tables 4.III.2 - 4 can be used to estimate variation of capital productivity with size of capital project. Table 4.III.6 below shows estimated values of capital investments, gross product before and after the investments, and capital productivity values for the process industry. These values

TABLE 4.III.6

INDUSTRIAL GROUP (number)	CAPITAL INVESTMENTS			GROSS PRODUCT			CAPITAL PRODUCTIVITY
	Reference period (year)	Number of new firms	Capital invested (K£ million) Δk	Reference years	Output value as gross product, GP (K£ million)	ΔGP ($K£ \times 10^6$)	$\frac{\Delta GP}{\Delta k}$
1	1970 - 1972 1973 - 1976	2 2	0.10 0.16	1972 : 1969 1976 : 1973	0.350 : 0.041 4.745 . 1.394	0.309 3.351	3.06 21.50
2	1971 - 1973 1974 - 1976	1 3	2.37 2.89	1974 : 1970 1976 : 1975	3.690 : 1.650 8.800 : 5.450	2.040 3.350	0.86 1.16
3	1973 - 1975	1	12.21	1976 : 1972	7.250 : 2.490	4.790	0.39
4	1969 - 1971	2	0.24	1972 : 1969	0.594 : 0.280	0.314	1.31
5	1974	1	1.48	1976 : 1973	1.510 : 0.420	1.090	0.74
8	1968 - 1970 1975 - 1976	1	0.37 0.70	1970 : 1968 1976 : 1974	1.293 : 0.811 5.071 : 3.867	0.482 1.204	1.30 1.72
9	1968 - 1970 1974	Modification Expansion	2.15 10.77	1972 : 1968 1976 : 1972	2.970 : 2.300 5.140 : 2.970	0.670 2.170	0.31 0.20
10	1967 - 1973 1974 - 1976	Expansion Expansion	14.87 2.92	1974 : 1966 1976 : 1974	4.120 : 1.720 6.800 : 4.120	2.400 2.680	0.16 0.92

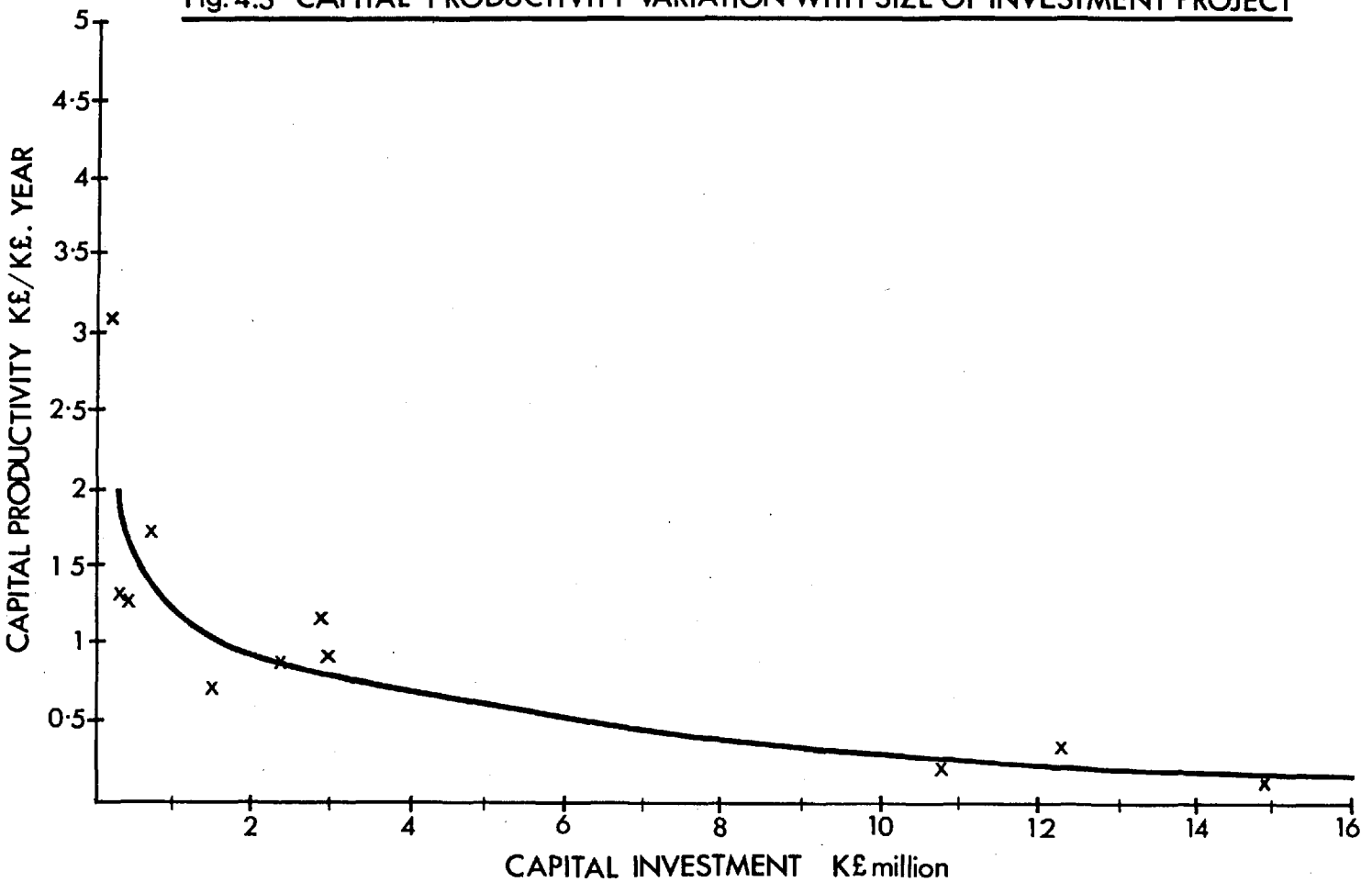
are taken or calculated from Tables 4.III.2 - 4 above. In the table a relation between capital productivity and value of capital investment for a project, i.e. project size, is indicated. Fig. (4.3) below is a plot of capital productivity against capital investment using data shown on Table 4.III.6. The number of data points on the plot is too small to allow definite quantitive conclusions to be drawn from the plot. However, it seems clear that projects with high values of investment capital tend to have low capital productivity values and vice versa. From Fig. (4.2) a capital productivity value of 0.6 K£/K£ per annum could be taken as the average for the economy and for the manufacturing sector over the 1967 - 1976. On this basis, and subject to confirmation of the curve on Fig. (4.3) by data on capital projects costing between 3 and 10 K£ million, capital projects in the industry costing more than K£ 5 million are not optimal. With less costly projects the industry would seem to offer above average productivities of capital.

It is significant that the three projects in groups 2, 9 and 10 with capital expenditures of K£ 12.21 million, K£ 10.77 million, and K£ 14.87 million respectively consumed 66% of total capital expenditure by the firms in groups 1, 2, ... 11 inclusively over the 1967 - 1976 period, while total expenditure by the firms in groups 2, 9 and 10 was 78% of total by all the groups for the period. Calculations based on the 1976 year show that these three groups' contribution to the total gross product by all the groups 1, 2, ... 11, was only about 44%.

For projects with capital investments ranging from K£ 1.5 million to K£ 30 million the sample study of Section 4.III.A shows that capital financing by loans is estimated at around 70% (weighing the estimate on the side of caution). As these projects evidently consume a higher proportion of total capital expenditure in the industry than their share of gross product, it could be argued that by pre-emptying capital resources which other, evidently more productive (for projects costing less than 4 - 5 million K£), investments could employ, their continued growth could effectively slow down the overall growth of both the process industry and of the economy.

The low productivity of capital for major investments could be due to lower plant capacity utilization with larger firms, to relatively high costs of plant construction and operation services arising from greater need for imported services due to the level of sophistication of the plants, to lower labour intensity thus being unable to take full advantage of relatively cheap labour supply, etc.

Fig. 4.3 CAPITAL PRODUCTIVITY VARIATION WITH SIZE OF INVESTMENT PROJECT



The productivity of capital being relatively low for larger investments it would seem that their ability to attract capital financing loans could not be due to pure 'semi-macro' economic reasons. It is suggested here that the larger projects can attract foreign investors interested in equipment sales, construction, and related services or in participation in a commodity's production locally more easily than the smaller projects. Firstly, because the capital investment would yield greater amount of net income revenue and secondly, because the foreign firms interested in local production often use the technology hardware they sell for commodity production elsewhere (2). In turn, it is easier for well-established large foreign firms to arrange for capital financing loans locally or abroad than for local would-be entrepreneurs (129).

4.IV Contribution of Large Firms Utilising 'Sophisticated' Process Technology to Transfer of Technology : Development of Local Skilled Cadre

In this and the following section attention is directed to the observed effects of use of sophisticated or/and foreign owned or/and foreign controlled production technology locally on the process of industrial progress. These effects could be classified as some of the external effects on the basis of which a project with low or unfavourable immediate financial benefits - from the point of view of the nation as a whole - might still be encouraged. Industrial progress in the context of this work can be understood to mean the process of creation of a local technological capacity capable of competently dealing with most of the demands imposed by technological projects (in the process industry) continuously being implemented locally, i.e. local development of skilled manpower, hardware and software of technology, for execution of the phases in a technological project. Development of local skilled cadre for plant operation and maintenance can be considered first.

The performance assessment of the local process industry can be based on a sample of firms in it. The sample considered here consists of five firms[1] which had been operating manufacturing plants locally for periods of 10, 14, 19, 20, and 24 years by the year 1977 when data was collected. The employment structure for firms in this sample is shown on Table 4.IV.1 below. Also shown on the table is the proportion of local ownership in terms of shareholding. From the table it can be seen that for four out of the five firms majority shareholding is by local interests. Majority local ownership for the firms occurred at different periods in the history of the firms. Thus for the 20 year old plant it occurred in 1974, for the 19 year old plant in 1964, for the 14 year old plant in 1972 and for the 10 year old plant in 1974.

In Chapter 2.IV, it has been argued that provided university graduates and other academically qualified people are available, ten years of deliberate 'on-the-job' training should be adequate for most of the local process industry to be manned by local people in operation and maintenance positions. Table 4.IV.1 clearly shows that in up to

---

[1] Data collection for this section was through questionnaires answered by firms included in the sample out of seven to whom the questionnaires were sent, and supplemented by personal interviews with the management personnel of the firms that responded. The firms wish for anonymity has been respected.

TABLE 4.IV.1

MANPOWER STRUCTURES FOR A SAMPLE OF FIRMS IN THE PROCESS INDUSTRY

Firm	1		2		3		4		5	
Plants age (1977), years	24		20		19		14		10	
Firm equity ownership (% local)	< 30		> 60		> 70		51		> 70	
	Number		Number		Number		Number		Number	
PERSONNEL STATUS	Nationals	Total	Nationals	Total	Nationals	Total	Nationals	Total	Nationals	Total
OVERALL FIRM										
Top firm management	2	10	2	5	4	6	2	8	1	4
PLANT STRUCTURE										
Plant personnel in top firm management	1	5	-	1	1	2	1	6	-	2
Other senior plant management personnel (heads of plant departments, etc.)	11	22	-	5	1	4	-	4	-	3
Plant's middle management (graduate or equivalent senior engineers, etc.)			1	4	8	17	2	4	3	5
Other graduate engineers and scientists on more-or-less non-management positions	10	10	2	2			10	10	8	8
Senior plant supervisors, foremen and senior technicians	8	15	15	15	-	4	3	7		
Section (process, mechanical, etc.) supervisors, foremen and technicians	67	87			12	12	36	36	496	496
Skilled craftsmen or equivalent			67	67	400	400	81	81		
Semi- and non-skilled craftsmen and operatives	567	567	51	51			92	92		
Total	666	716	138	150	426	445	227	248	508	518

Source: Field data

24 years duration this has not been fully achieved in the local process industry. Local manpower participation would seem to be largely restricted to non-management positions and, specifically, to the unskilled, semi-skilled, and the lower ranks of skilled labour. It seems significant that local personnel, with university degrees in science or engineering, are often isolated from the mainstream of the management hierarchy. This management hierarchy seems to progress downwards to 'plant middle management - graduate or equivalent senior plant personnel' and from there directly to 'senior plant supervisors, foremen, and technicians' etc. A 'side-branch' connects the non-management graduate engineers to a position under the middle plant management. This is a very crude summary of personnel structures employing different titles for similar positions in different firms and with differing definitions of the points of demarcations between hierarchical levels. The overall indication of the results in Table 4.IV.1 is that local process industry is heavily dependent on imports of skilled manpower.

Another indicator of the extent of this dependency on foreign skilled manpower for plant operation, maintenance, and management can be given by the frequency of management, marketing, and technical services agreements between the local and foreign firms. In 1977 the situation for the firms considered on Table 4.IV.1 is shown on Table 4.IV.2.

The management and technical services agreements can allow the foreign firms to appoint senior personnel of the companies. A typical management and technical services agreement signed in 1975[1] between a foreign minority equity shareholder and a newly formed local firm with 65% equity shares held by local interests provided that the contract granted "day to day control of the company's business" to the foreign managing firm with powers to execute functions including:-

1. "to do all things except borrow money, pledge assets, or assign rights or obligations of the company ....

2. "to procure senior staff for management, administration, accountancy, and technical services and to fix terms of

---

[1] This firm is not included in the sample considered above. The information given here was made available by representatives of the local majority shareholder.

TABLE 4.IV.2

Local firm	Nature of agreement with foreign firm(s)		
	Marketing	Management	Technical
Firm number 1	With parent company	Parent company	Parent company
Firm number 2	Minority foreign owner	Minority foreign owner	Minority foreign owner
Firm number 3	Unassociated foreign firms	-	-
Firm number 4	Minority foreign owner	Minority foreign owner	Minority foreign owner
Firm number 5	Unassociated foreign firm	Unassociated foreign firm	Unassociated foreign firm

Source: Field

service, remuneration, allowances, and bonuses and to determine their duties ....

3. "to have power to appoint, suspend, or remove all other employees and agents of the company and to fix their terms of service or otherwise ....

4. "to advise on prices of products produced locally ....

5. "to advise on type and quantity of production and on the processes of manufacture and quality control ....

6. "to manage the plant maintenance including equipment and machinery ....

7. "to assist and advise on marketing and distribution of products and on the appointment and removal of marketing agents and distributors and in fixing their terms .... "

The same foreign firm was also given jurisdiction over the marketing activities of the local firm through a separate marketing agreement. The powers granted to foreign management firms can, therefore, be extensive and the degree of local dependency high.

The slow mobility of local personnel up the ladders of industrial hierarchy might be explained, at least partially, by the temptation of foreign managing firms to reserve top management and technological positions to their own (expatriate) employees, whose abilities are known and predictable instead of taking risks in trying local academically qualified personnel for these positions. As business institutions, the foreign firms would be unlikely to overlook the fact that the slower the upward mobility rate of local personnel the longer can be the period over which services of foreign firms would be required. The high number of local graduates of engineering and science outside the mainstream of the management hierarchy could be explained by the above factor and partially also by the practice - known to be true of at least one firm - of recruiting more than one local graduate for only one opening in the management structure. This inevitably creates 'failures'.

Appointment of expatriate personnel apart, the foreign

management firms make their technical services available whenever required by the local firms as clients and also serve to keep the local firmsinformed of new developments in technology of the products and processes used by the local firms. This was confirmed for four firms included above during the interviews with their senior personnel.

Existence of service agreements vis a vis degree of local ownership would appear to be the dominant factor in determining the rate of development of local senior management and technical personnel. Ownership is, however, important as shown by the employment pattern of firm number 1 which is largely owned by foreign business interests. In the case of the 19 year old firm with majority local ownership and no existing (1977) management and technical agreements, the pattern of employment is similar to the other firms except for the few top management positions. This might be partially explained in terms of acute shortages of qualified personnel in the early 1960s when the firm became largely locally owned and partially in terms of the tendency to perpetuate manpower recruitment methods started at that time. The example of a typical management agreement, given above, was for a new company whose plants were scheduled to come on stream in 1978/79. In this case total foreign dependency seems inevitable, which indicates that local owners of production facilities have total confidence in foreign controlled plants and little confidence in local skilled manpower. While this could well be true, evidence from a case history of recent investment project in the process industry, given in Chapter 5, shows other forces to be equally or more active in encouraging foreign control of local production facilities.

The argument that locally skilled manpower is simply unavailable is much weakened by the fact that the industry is extremely small and over 10 - 15 years it would not have been difficult to recruit graduates of the right calibre for on-the-job training. Most of the engineers included on Table 4.IV.1 under 'other graduate engineers ....' had experience between two and eight years; the chemical engineers had been trained abroad. Output of engineering graduates from the local university in the period 1969 to 1977 was of 190 graduates. Although this is a small number the above industries offer some of the best employment benefits in the country and recruitment problems could not reasonably be anticipated.

The financial implications although perhaps not the most important aspect of the pattern of employment in the industry can be

briefly indicated. The table above implicitly gives the number of expatriate personnel. For them, it could be reasonably assumed that they would be paid salaries commensurate with those paid in their countries of origin, for similar jobs. Now since expatriates hold mostly senior management and technical positions an annual salary of K£ 4,000 (equivalent to sterling £5,300) would be very conservative, for 1977. Local salaries could be taken as the average for the manufacturing sector based on the 1976 figure of K£ 530 per annum (69), and taken as £580 per annum for 1977. Then for the firms included in Table 4.IV.1, in 1977:-

Estimated total value of salaries earned by expatriate personnel	= 4,000 x 112 K£ p.a. = 448,000 K£/year
Estimated total value of salaries paid to local employees	= 580 x 1965 K£ p.a. = 1,139,700 K£/year

The proportion of wages consumed by expatriate personnel is thus roughly 30%. In other words, 5% of the employees consume 30% of total salaries paid by the local firms. In addition services agreement fees and charges are annually paid to foreign firms in connections with operation and maintenance of the local production facilities, and the marketing activities. These factors could contribute substantially to higher production costs than would be expected to occur if the imported services element could be competently replaced locally.

Dependency on imports of advanced skills in plant operation, maintenance, management, etc. has been recognised by several authors including the World Bank (70) and the data presented in Table 4.IV.1 could be considered as typical. What the results above indicate is that the scarcity of highly skilled and/or experienced manpower that might encourage "continued purchase of foreign skills in the key sectors of development .... " (70) could also act as a retarding catalyst in the process of development of these skills locally. The results also indicate that the question of ownership and/or control of local production facilities cannot be assumed to be irrelevant to the problem of local development of a skilled cadre.

In the following section the contribution of different samples of firms in the industry to other aspects of technology transfer is considered.

4.V Contribution of Large Firms Utilising 'Sophisticated' Process Technology to Transfer of Technology: Costs and Extent of Transfer of Process Technology

4.V.A Technology Requirements and Costs of Establishing Manufacturing Facilities Locally

Some project investment data for a sample of firms in the processing industry is shown in Table 4.V.1 below. The table shows the proportion of expenditure in fixed capital investment by a firm F, accruing to either local or foreign technology sources.

In all cases the projects[1] referred to were executed or under construction during the period 1973 - 1978, and therefore represent the most recent practice for the industry in Kenya, for these and similar firms. All of the projects except one consisted of expansions of existing plants which had been built in or before 1963. Thus there has been a 10 - 15 years over which technology could have been theoretically transferred within the firms - in the case of preliminary design phase and some detailed design - or within the country as a result of growth of total technology hardware locally. The last project involved a new local firm but the technology used there is very similar to the technologies used on the other firms' facilities. The capital costs for the projects varied from 1.75 million K£ to 23 million K£. Total capital costs for the five projects was 49 million K£. This figure does not include capital financing costs which although significant do not constitute part of fixed assets of technological services. The phases of project implementation considered are restricted to more or less pure process technology and such items like civil work, site preparation, and buildings have been neglected. The results are shown on Table 4.V.1. below.

Although the data given in the table is not complete due to lack of differentiation of the split between local and foreign expenditures on some items, it is known that, in the case of the packaged plant erection contract and the equipment supply and erection contracts for firms F5 and F4 respectively, all of the process and

---

[1] Data used in this section were supplied by companies running the plants in the case of firms F1, F2 and F3 and from the offices of a major shareholder in the case of firms F4 and F5.

TABLE 4.V.1

SOURCE OF TECHNOLOGY FOR PROCESS INDUSTRY'S INVESTMENT PROJECTS

PHASE OF PROJECT	CAPITAL EXPENDITURE AS PER CENT OF FIXED CAPITAL INVESTMENT									
	LOCAL BENEFICIARIES					FOREIGN BENEFICIARIES				
	Firm F1	Firm F2	Firm F3	Firm F4	Firm F5	Firm F1	Firm F2	Firm F3	Firm F4	Firm F5
Phase 1	-	-	2.0	-	-	-	-	-	-	-
Phase 2										
(a)	-	-	-	-	-	4.2	4.5	17.0	16.8	
(b)	0.2	0.5	-	-	-	-	-			
Phase 3									A few equipment supply and erection contracts 72.1	Single package contract 93.2
(a-i)	-	-	6.5	-	-	38.6	38.0			
(a-ii)	1.4	NAS	NA	NA	NA	4.2	NAS			
(b-i)	0.5	-	NA	NA	NA	16.4	12.5	58.9		
(b-ii)	0.6	NAS	NA	NA	NA	2.0	NAS			
Phase 4	-	19.0	NA	NA	NA	-	12.0	4.0	NA	
Phase 5	-	-	-	-	-	0.6	2.0		NA	1.8
Total	2.7	19.5	8.5	NA	NA	66.0	69.0	79.9	88.9	95.0

Source: Field data

where: NA = not available
NAS = not available separately, i.e. included in other given data

and:

Phase 1 = preliminary process and plant design, pilot studies, etc.
Phase 2
(a) = detailed design and engineering of process and plant
(b) = drafting and reproductions
Phase 3
(a-i) = process equipment purchase
(a-ii) = process equipment installation
(b-i) = auxiliary equipment purchase (including instruments)
(b-ii) = auxiliary equipment installation
Phase 4 = equipment erection and plant construction including supervision not separated as in Phase 3, i.e. total installation costs for process and auxiliary equipment
Phase 5 = plant commissioning and start-up

auxiliary equipment were purchased from abroad and, that erection supervision and erection equipment were from overseas sources. Plant and process design and engineering was similarly done by foreign firms. Clearly Table 4.V.1 shows that the bulk of technology for design, engineering, plant erection supervision, and plant commissioning and start-up, required for establishing manufacturing facilities similar to those of the firms under consideration, are supplied from foreign sources.

Firm F3 shows some local supply of process equipment. In fact this situation occurred because some equipment from a scrapped local plant was used in the expansion project; while the values for auxiliary equipment as in firm F1 consisted of some piping obtained from a local supplier. In the instance of preliminary studies work done by firm F3, the local firm was a subsidiary of a foreign firm and one could expect a high degree of assistance from the parent company - as evidenced by the proportion of fee paid to the local firm which was transferred to its overseas parent directly[1].

A sixth example is of a minor project consisting of modification of a section of the processing plant through incorporation of a new process. This project was for firm F6 and cost K£ 0.14 million. For the project, percentage of cost attributed to imports of process equipment (including freight) and auxiliary equipment was 58.8% while old process equipment re-used was valued at 7.2%; old process pipework and electricals, and local erection labour were valued at 12.2%. Erection supervision was done by a foreign firm and cost 6% of the project cost. The balance of 15% was payment for process licence. Again even at this level the percentage of foreign payments for fixed capital investments exceeds 65%.

Evidence thus available portrays a situation in Kenya where erection labour is the main local contribution to the execution of project technological phases. Significantly the evident lack of stimulation of local development of technological capacity required to implement above technological phases, suggests that for this type and level of technology, effective transfer has not been accomplished.

In terms of costs of acquisition of plant equipment and

---

[1] In most cases it was possible to check the information supplied by the firms through other independent sources such as a firm's applications for "foreign exchange authority" to the Central Bank.

erection of plants. the limited data given above tends to indicate that the costs of equipment and plant construction in Kenya are higher than would be expected in the industrialised countries. Apart from freight costs no common reason can be attributed to this for purchasing arrangements of equipment and machinery, supervision of equipment erection and plant construction, and commissioning and start-up are all done by personnel of foreign firms.

Estimates of process equipment costs, erection costs, process materials costs, i.e. concrete substructures, piping, electricals, insulation, instrumentation, etc., given by Perry for plants in America, vary as follows (71):-

	Cost as percentage of fixed capital investment
Process equipment	25.0 - 40.0
Process equipment erection labour	1.5 - 4.5
Process materials	8.0 - 18.0
Process materials labour	4.0 - 12.0

Comparison with figures on Table 4.V.1 confirm that costs in Kenya are higher. This might be used to support the argument that sale of technology to developing economies offers opportunities for extraction of 'monopoly rents' profits through over-pricing of technology exports. In one consignment of five storage tanks[1] for a major project under construction in 1977, over-pricing of invoice was by sterling £25,811 the 'correct' cost being sterling £106,489. Thus over-pricing was as much as 24%. This does not prove that all equipment imports are over-priced or that all foreign companies are involved in this practice. It does, however, illustrate the existence of both the opportunity and the temptation for over-invoicing, and this factor could be a major one in determining the ultimate cost of investments in the country, especially where 'true' cost is difficult to establish.

---

[1] These tanks had been ordered by firm F4 in Table 4.V.1. The consignment referred to here was one in a list of 'over-priced' consignments for several other firms in the country sent to the Central Bank of Kenya by the General Superintendence of Inspection, Geneva, in 1977.

TABLE 4.V.2

OPERATION AND MAINTENANCE SERVICES AND EQUIPMENT IMPORTS FOR PROCESSING PLANTS

Item / Year/firm	Equipment imports	Services imports	Total	Fixed capital costs for plant	Total imports as percentage of fixed capital investment
	K£ x 10^3	K£ x 10^3	K£ x 10^3	K£ x 10^3	%
Actual 1974 (July - December)					
1	413.90	-			
2	128.60	NA			
3	142.00	70.06			
4	7.90	-			
5	938.00	33.53			
6	233.30	10.00			
1974 (Annual estimated)					
1	500.00	40.00	540.0	5,500	9.8
2	150.00	150.00	300.0	2,000	15.0
3	250.00	140.00	390.0	16,000	2.4
4	20.00	30.00	50.0	3,000	1.7
5	1,400.00	160.00	1,560.0	17,000	9.2
6	400.00	15.00	415.0	4,000	10.4
1975 (Actual)					
1	535.50	105.90	641.4	5,500	11.7
2	163.40	177.10	340.5	2,000	17.0
3	298.00	185.30	483.3	16,000	3.0
4	52.73	49.53	102.3	3,000	3.4
5	1,331.20	227.50	1,558.7	17,000	9.2
6	710.80	19.70	730.5	4,000	18.3
1976					
1	241.60	60.70	302.3	5,500	5.5
2	265.20	215.90	481.1	2,000	24.1
3	422.50	161.70	584.2	16,000	3.7
4	34.42	37.23	71.7	3,000	2.4
5	1,253.00	547.60	1,800.6	17,000	10.6
6	405.90	18.70	424.6	4,000	10.6

Source: Field data

4.V.B Processing Plants Maintenance Requirements and Recurrent Annual Costs

A sample of six firms has been considered. Estimated fixed capital costs for the plants operated by these firms are shown on Table A.4.III.1 of Appendix A.4.III (firms K1, K2 .... K6). The relevant costs exclude financing costs and include initial fixed capital costs estimates as well as fixed capital costs for the expansions.

Some maintenance equipment data are available covering a period of 2.5 years from July, 1974 to December, 1976. These data are only for imports of equipment and equipment parts designated as "repair, replacement, or spare" equipment by the firms themselves during application for foreign exchange authority to remit payments abroad[1].

Services consisting of management, operation, and marketing consultancy, together with "professional services" - interpreted here as occasional, i.e. non-long term contract services on plant debottlenecking - are also often imported. Data on charges on imported services and maintenance equipment imports, and the estimated fixed capital investment for the plants are shown on Table 4.V.2 above. Also shown are the values of equipment and service imports for these firms as a percentage of fixed capital investments.

From Table 4.V.2 it can be seen that average expenditure on maintenance equipment for the sample expressed as a percentage of fixed capital investment were as shown on Table 4.V.3.

TABLE 4.V.3
ANNUAL COSTS FOR MAINTENANCE AND OPERATION SERVICES AND EQUIPMENT

Year	1974	1975	1976
Expenditure (% of fixed capital investment)	7	8.1	7.7

[1] Data here was made available by the Central Bank of Kenya and the total annual figures summed up from several entries each month for the six firms as explained in Chapter 3.

The figures relate to total annual expenditure by the sample as a percentage of its total fixed capital investments. Individual firm's figures show a wide range of variation roughly between 3% and 15% of fixed capital costs.

Assuming that the above figures are representative of the situation in the whole industry and taking a figure of 7.5% as typical, it is clear that for imports of spare parts and consultancy services alone the costs are very high. With reference to estimates of manufacturing costs for the chemical industry in industrialised countries a figure of 4% of fixed capital investment per annum is normally used to allow for (a) maintenance materials, (b) manpower required for installation and, (c) overheads for supervision and maintenance scheduling (72). For a cement manufacturing plant in France, for example, value reported for expenditure on maintenance is 3.0% (73); in Kenya it is about 10%; for sugar plants in Japan figures of 1.1% and 4.3% have been reported (73): the figure for Kenya is between 6% and 12%.

The Kenyan figures may have been inflated by inclusion of spare parts which would not be used immediately but assuming that this stock is maintained the actual expenditure on imports of maintenance equipment and services would remain roughly unchanged. One of the causes for such high values must be freight charges. However, other significant factors include payments of commission for purchases of equipment by foreign firms with whom the local firms have marketing agreements. These charges are normally over and above the contractual annual payments. Firm 4,with the lowest expenditures,is known not to have long term agreements of this kind while all the other firms have such agreements[1]. Another possible factor could be undetected over-pricing of equipment imports which escape examination, if valued at under 1,000 K£, by the authorities. Even for imports valued at greater than K£ 1,000 over-invoicing is still possible as evidenced by reports of General Superintendence of Inspection - Geneva - to the Central Bank of Kenya, who often send these reports with up to 36% over-invoicing. Firm 4 excluded, the above firms all have at one time or another been reported to have claimed f.o.b. value of equipment which included an element of

---

[1] This information was supplied by the firms who returned questionnaires. Other field sources show that purchasing commission excluding "invoice cover charges" for firms F1, F2, F3, F5 vary between 3 - 5% of imported material's cost.

over-invoicing. This can easily be verified by reference to "clean report finding" reports on foreign exchange applications to the Central Bank.

Considering the evidently high maintenance equipment and service imports it would not be unreasonable to expect low local linkages of these establishments with local equipment suppliers and consultancy services. A survey of the sample through personal interviews with the firms revealed that occasionally one firm tries out local tanks on its plant, another one uses local tanks, and a third has tried some local rollers but found them unable to meet the specifications. Thus this part of the industry as depicted by these firms does not stimulate growth or creation of local equipment production or supply linkages.

Turner (60) has studied two refineries in Nigeria the first of which was closely associated with Shell-BP multinationals with BP being the more active partner in Nigeria. BP had been appointed "the operator" at the investment stage of the refinery and had ".... supplied materials and personnel for all stages including design, fabrication, erection, commissioning and operation ...". Writing on the activities of BP the author adds ".... BP has buying agreements with 'brother' companies which are often subsidiaries or UK-owned. Nigerian refinery demands were directed towards these firms while local linkages were neglected .... BP was reluctant to reduce its operating role by replacing expatriate staff with trained Nigerian personnel .... The terms of transfer discouraged the development of local research and development facilities. BP called on head office resources to solve the most elementary problems .... very few local suppliers of materials and services were patronized by the BP management with the result that after almost a decade the refining company had established virtually no linkages with the Nigerian economy" (60).

The results reported in this work for Kenya are rather similar to Turner's observations. Like with skilled manpower development, at the initial stage of capital investments the availability of advanced technological capacity to design, engineer, fabricate, construct, etc. equipment and plants in the process industry is extremely limited.

The technology used for local manufacture of chemical products under the industrial structure exhibiting financial, economic, employment, ownership, control of production means and technology transfer patterns illustrated in this chapter has all been imported from the highly industrialised countries. It is basically of the same type or level as would be used in those countries for manufacture of products manufactured

locally (including product quality specifications). A survey of five firms with recent plant expansion projects showed that no attempt was made to adapt the technologies to local conditions. The technology level and organisation of large firms in the process industry seems to encourage creation of a process technology enclave with strong technological bonds to the initial technology sources but with insignificant impact on local technological capacity.

The problems illustrated here have been recognised before by several authors such as Cooper and Hoffman (2), Stewart (4), etc. The investors in the developing countries would be expected to be aware of some of these problems. Yet projects such as the one cited in Section 4.IV in Kenya are very recent. In the following chapter some of the dynamic forces that could influence choice of investment projects and of technology in a real situation are studied using a case history of a major (capital investment of > 20 million K£) project in the process industry.

CHAPTER FIVE

CHOICE OF INDUSTRIAL PROJECTS AND OF TECHNOLOGY IN KENYA, AND PROPOSED METHOD FOR CHOICE OF TECHNOLOGY IN A DEVELOPING ECONOMY.

5.I.A Case History of an Investment Project in the Process Industry[1]

1966 A local subsidiary of two European multinationals (A) conducted a study on possible project in the country and catering for the whole of the East African (EA) market.

1967 A local subsidiary of multinationals (A) was planning to build a factory in the country and immediately sought Kenya Government protection, through controlled import licensing, against competing imports. This request was favourably received.

1968 Early in the year an ad hoc committee in the relevant Government ministry was formed to look into the question of local production of the product. Meanwhile a new foreign multinational (B) expressed its interest in building the factory thus competing with multinational firm A. Another multinational firm (C) offered to build the factory as well as offering agricultural services. Still another (D) offered to supply a small plant mounted on skids. This offer was not acceptable because the firm was not interested in equity participation.

1969 Multinational company A abandoned plans to build the intended factory. The Government now wanted a detailed study of the products industry and market before embarking on any decision and charged its Industrial Promotion Advisory Committee with the responsibility. An international organisation, viz. UNIDO offered a joint study of the product's industry under its special Industrial Services programme. Also the E.A. Development Bank (EADB) conducted a study on the subject and in 1970 the Economic Commission for Africa (ECA) conducted a study too.

---

[1] This case study is for a project that was recently being implemented. Information given here was kindly made available by the Government of Kenya. The projects investment pattern does not necessarily reflect the pattern followed in all projects in which the Government has interests. More likely, the project reflects some of the worst aspects and problems of joint ventures with some multinational firms. The process technology for the project is advanced by local or international standards.

1970 The preliminary studies by international organisations ECA and UNIDO concentrated their attention on the project as an East African venture vis a vis a Kenyan one. The EADB itself recommended a joint venture between the East African partner states. At the same time, offers from equipment supplying firms for supply of plant equipment partly on loan basis were made, while a multinational consulting firm offered to conduct an investment study at a fee.

ECA's preliminary study suggested that local production of a certain specific intermediate was feasible coupled with further processing to various finished products.

1971 The Government decided to concentrate on a study based on development of the industry in Kenya and again sought UNIDO's help in preparing a detailed study.

Several new foreign companies continued to make enquiries about the project but most of them only offered to carry out parts of the plant construction work; to conduct feasibility studies; to manage the plant and market the product once it was on stream. Several of these companies were from the Indian sub-continent, but a new European multinational (E) joined in.

1972 Early in the year UNIDO informed the Government that a joint UNIDO/FAO/World Bank working group had suggested an investment study for plants processing imported intermediate products into a number of finished products. As for a detailed study by UNIDO, United Nations Development Programme (UNDP) Office argued in mid year that the studies by Maxwell Stamp Associates, Tennessee Valley Authority (TVA) financed by USAID, International Bank for Reconstruction and Development (IBRD) and by the ECA Planning Committee were "reasonably adequate". These studies all contemplated a project organised on an East African regional basis. In addition UNDP thought that the World Bank had already started a study similar to the one requested from UNIDO. The response by UNDP seemed to want to take the initiative out of the hands of the Kenyan Government, and in its apparent lack of regard for the Government's interests in this matter served to eliminate a major International Organisation as a positive influence on the ultimate choice of an important

investment project.

Towards the end of the year alternative sources of co-operation in the study appeared from a European Government through its local Embassy, which arranged for a technical mission to go to Kenya to conduct the study. The Government's terms of reference for the detailed study included, inter alia, the following:-

(i) to review, update and refine TVA's preliminary study.
(ii) to recommend the ideal size of plant for a stipulated intermediate product.
(iii) to outline in detail capital costs for plant equipment.
(iv) to outline programme for establishment of the intermediate product's processing in the country.
(v) to make recommendation on organisation of marketing within and outside the country.

While the Government was arranging for this study it received responses from two interested foreign private companies in Europe. One was from the Technical Mission's country and offered to conduct a study on the project and suggested that project financing could be arranged. The Government naturally awaited the results of the proposed study.

1973 Early in the year the Technical Mission started project study work in Kenya and by mid year had completed it.

During the year a large European multinational (F) with a subsidiary firm in the country submitted proposals for a project to be implemented in four phases stretching over a period of ten years. Company E also submitted their independent study and proposals on the project. Still another, (G), expressed interest in a joint venture with the Government. Their project proposal excluded local production of the intermediate product. Firm F stated that it would consider becoming a shareholder provided full Government support would be accorded and a detailed study revealed an economic viability of the project, while a new firm (H) was also very interested.

These companies understood that the Government was interested in minority shareholding.

1974 Early in the year the Government's concern was over the siting of the factory and in deciding which possible "know-how" partners (multinationals) would be chosen to co-operate with the Government. The oil crisis was affecting prices of product imports and had a stimulating effect on the resolve to invest in the project. Accordingly, the Government invited interested firms to submit detailed proposals for participating in the project. It also supplied the results of the Technical Mission's study after adjusting for glaring inaccuracies in market and product-mix figures. The Government advised that in evaluating the proposals its principle considerations would include inter alia the following:-

(i) Preference that the project include the intermediate product production from a by-product of a local processing plant sited near the new project's location.

(ii) The technical and financial partners providing expertise and management should hold a major portion of equity, the Government preferably holding 50% or less of share capital. Equity to loan ratio preferred being 1 : 2.

(iii) Sponsors should have experience in production and distribution preferably including experience in developed countries.

(iv) Sponsors should indicate type and cost of production facilities they considered appropriate and suggest sources of financing capital including source of share capital.

The response to this invitation was positive but details of the multinational firms' proposals were not quite so favourable. Company F promptly responded with an updated version of their previous proposal, in the light of the Government's study, but maintained that all intermediate products going into manufacture of the finished products would be imported. It offered to participate in 51% of share ownership with the remaining 49% of the shares being released to financial and other institutions; but it added that the ratio of participation would "probably be reduced in time". Their equity to loan ratio was 3 : 7.

Company C which had featured in 1968 expressed renewed interest in the project and offered to participate under "certain conditions of equity, management, prices, import restrictions, etc.". But it did not propose to include local production of the stipulated intermediate because the intermediate's production "requires sophisticated machinery. To maintain them there should be a secondary industry". It felt that such an industry did not exist in Kenya and ".... will take quite some time before it will be built". Companies A and G too made project proposals roughly similar to that of Company F.

Company E also made a detailed project proposal based on import of intermediates and emphasised that the local market was too small to justify local intermediate production and referred to UNIDO's recommendation of satellite plants. They offered to arrange for capital financing of the project if selected.

Company H sent a proposal offering to engineer and build the plants including the intermediate product production and the recommended finished products. It also offered to assist in personnel training and plant management services and to arrange for financing of design and plant construction services provided by H. The problem seemed to be their refusal to participate in equity ownership.

As a result of conflicting production schemes suggested by respondents the Kenya Government sought comments by IBRD (the World Bank) on suitable production processes, size and type of plants. Another financial institution - International Financing Corporation (Washington) - after examining the feasibility studies supported the claim that there was a case only for a project that eliminated production of any intermediates. This was also the judgement of IBRD.

Thus again there was a conflict between the interests of the Kenya Government on the one hand, and the wealthy foreign multinational firms supported by multilateral aid agencies on the other. Such a situation probably prompted the Government to start to seriously consider sponsoring the project without foreign companies equity participation. Such a move would have necessitated foreign borrowing and created a problem of how to

manage and operate the facilities once the plant was on stream. With respect to the latter, management, technical and marketing services would presumably be provided by an experienced firm in the business which necessarily would be foreign owned. With no equity stake in the business, the latter arrangement would be a second best solution. Nevertheless, it seems possible that the Government sought new sources of co-operation in the worlds major financial and technological capitals.

Towards the end of the year Companies C and F presented a joint revised proposal. This still excluded local production of the intermediate but had an improved finished product-mix formulation that corresponded closely to the Government's requirements. In addition they detailed a financing scheme with each company owning 20% of equity (originally F had proposed 51% share of equity ownership) with a debt to equity ratio of 7 : 3 as before but outlined the financial sources which included F's parent company. The plant was to be constructed by F's parent company on turn-key basis and both C and F would be responsible for plant management and for providing technical expertise.

Company E too revised its proposal to include local intermediate product production by use of a different feedstock from one stipulated in the Government's study. Availability of this new feedstock was crucially dependent on another project whose implementation was under way, but not complete. E urged decision on the project be delayed in order to ascertain feedstock availability. In addition its proposed final product-mix omitted some finished products desired by the Government. Financing was to be arranged by E but details of its equity interest were not made clear.

As these new developments were being evaluated a new relatively small American multinational Company X sent a very roughly outlined proposal but committed themselves to production of the intermediate as originally envisaged by the Government, and a product-mix formulation that would be close to the Government's requirements.

1975 Company X further elaborated their proposal which included construction of the complete plant on turn-key basis, at a

project price lower than that of Company F, an equity participation of 35%, and offered to arrange for financing capital of 75 - 80% of price from Europe. X, therefore, successfully outbidded all other companies.

The consequences of this was a heavily packaged deal including management, technical and marketing agreements, grant by the Government of right of first refusal to X of any future proposals to manufacture more of the products, or more intermediates such as had been previously envisaged by Company E in 1973, of protection measures, exemption from taxes on all their earnings, guarantee on price levels that would fix X's minimum earnings, etc. A local joint venture firm was formed.

Company X's detailed proposal for the plant which was the basis of the contract was later found to have some serious design deficiencies because in order to produce some of the proposed products some plant sections had to lie idle. Towards the end of 1975, X suggested a modified plant configuration which was formulated in a sub-contract between the local company and one of Company X's sub-contractors. However, this configuration could not meet production flexibility demands stipulated in the original contract. At the signing of the sub-contract the local firm was unaware of the shortcomings of the modified plant configuration due to 'mis-information' by Company X when introducing the sub-contract to the local firm (of which X owned 35% of equity shares).

1976 A consultant for the Government proposed a major modification to the plant to make it as flexible as had been originally intended. Differences of opinion between the local company and the foreign Company X arose from this issue because of the substantial extra expenditure that would be incurred. However, towards the end of the year Company X proposed to modify the section of the plant that had created the rift. Meanwhile, some construction work was proceeding very slowly.

1977 Construction costs were escalating and scheduled plant construction dates exceeded and extended from 1977/78 to 1978/79.

1978 This project was abandoned.

5.I.B Discussion on the Case Study of an Investment Project

From the case study presented above and with regard to factors that could influence choice of local industrial projects and of process technology, the following points can be made:-

1. Local investments in major projects can take a long time (in the above case 9 years) between the time of inception to the time of firm decision to implement a project. This could be due to the many conflicting forces that bear on the implementation process. Thus in 1966 the Government was apparently not under pressure to invest in the project referred to above (hereafter referred to as project CS) and although willing to give protection to a new factory it was not anxious to participate financially in the venture at this stage. It is probable that the multinational company A abandoned its plans to build a factory due to insufficient protection from the Government. While the multinational firm A was interested in an East African market the Government was concerned with domestic market.

2. At the feasibility studies level the case study suggests that, in 1969, there was limited local manpower for carrying out these studies or that the Government had little confidence in the ability of those that existed (if any). This indicates a need for establishment of competent local cadre to handle this phase of the project implementation process.

3. International 'non-commercial' sources of finance such as IBRD, USAID, and other international organisations such as UNIDO, FAO, ECA, etc. were in agreement in supporting a production scheme based on regional co-operation between the East African states. When the Government later (1971) decided to take account of political boundaries and requested UNIDO's assistance in conducting a detailed study based on domestic market, the response was clearly negative insisting that earlier studies by multinational firms, i.e. TVA and Maxwell Stamp Associates, were "reasonably accurate". As a result alternative sources of co-operation in conducting feasibility studies had to be sought. This factor strengthens the case for local development of technological capabilities required here.

4. Multinational firms involved in technology sale are naturally interested in technology markets. It would appear that they cannot be relied on, by the potential purchaser, to consider the suitability of the technology to the environment of a developing economy. This is a decision to be made by the customer under pressure from sellers of technology.

5. Major investments involving large injection of capital introduce severe constraints on technology choice by local interests. In the case study the Government had proposed with aid of a foreign Government (through a mission composed of employers of a major multinational firm engaged in technology sale internationally) production of a specific intermediate that might form a backward link with a local intermediate (primary intermediate)/consumer product. However, some multinational firms interested in the project proposed omission of this intermediate. In one case, the multinational firm proposed to import this intermediate from an ".... assured supplier from Saudi Arabia where a 'Firm'[1]/Saudi venture is being negotiated which will produce 'the intermediate'[2] and 'other products'[2] in two very large plants ...."[3]. Another multinational firm proposed to import the intermediate from the Persian Gulf where they are involved in its production[3]. This also illustrates global market incentives that might prompt multinational firms to invest locally - confirming a point that has been made by Kaplinsky (42), Turner (60), and many others.

6. The case study also suggests that a government could, contrary to 'transfer of technology' literature (2), (3), welcome packaged transactions in technology. In the case study the Government specifically referred, inter alia, to "technical and financial partners providing expertise and management ....". This could have been in anticipation of an inevitable condition but the point emerging is that market and financial forces tend to dominate project and technology selection.

---

[1] Here 'Firm' is substituted for actual name of the mutlinational firm referred to.

[2] Similarly 'intermediate' and 'other products' are substitute names for actual chemicals referred to.

[3] This information was part of the communications by the firms to the Government relating to project CS.

7. Capital finance required by a project is largely covered by borrowing. In insisting on an equity capital to loan ratio of 1 : 2 the Government acknowledges this. This conforms to results obtained in Chapter 4.III of this work.

8. Where local interests need multinational firms' participation the multinational firm agrees to participate under "certain conditions of equity, management, prices, import restrictions, etc." Although there is competition between the firms the conditions remain basically the same. The main difference seems to arise from the concessions on product mix required by the local interests that different firms make. The case study suggests that the more concessions on product mix and on arranging financial loan made by a firm the greater is the loading of the project package in terms of "certain conditions ....".

From the case study it is apparent that there was pressure precipitated by the oil crises for the Government to start local production of the products envisaged. The market survey data on which production capacities were planned were based largely on 'modern sector' consumption and not on actual national need. One of the companies interested had mentioned that "Kenya should not expect cheaper 'products' ...." after project CS was implemented. Under such conditions local production would be justifiable on grounds such as employment generation and other externalities. In this project the externalities would have been very long term.

The technology for this project was advanced. Technology considerations seem to have been ignored in favour of sole market considerations.

This case history suggests that the role of foreign investments as a major force in the industrialisation process could be limited or limiting. In addition the study suggests that it is important for the country to have a cadre of skilled manpower able not only to manage a production plant but also able to assess the technologies or the market competently. Chances of developing such local skills are increased by dealing with less sophisticated technology.

Considerations of financing sources also seem extremely important. Clearly, technologies that are less sophisticated are also cheaper and thus offer an added degree of freedom to local investors in controlling the pattern of industrialisation. Cheaper projects could

mean more local participation by private investors who currently do not significantly participate (in Kenya) in large projects.

5.II Developmental Implications of Investments in Advanced Process Technology under Conditions of Technological, Financial, and Market Limitations

The results of Chapter 4 suggest:-

1. that based on a criteria that considers the welfare of the domestic consumers, domestic raw material suppliers, local labour, etc. considered as a group, firms utilising advanced technology do not on the whole generate satisfactory levels of direct income. In particular the distribution effects are somewhat regressive: they take income from the rural economy (assuming that the rural sector does not consume much foreign exchange) to the modern economy and, specifically, from the group considered to the owners of production.

Low levels of salaries in the manufacturing sector also mean that the rural economy subsidises the modern sector through provision of 'underpriced' agricultural products[1]. This is clearly seen by noting that industrial consumer goods are highly priced - relative to levels of income from wages. High prices result from use of technology and production patterns similar to those used in the highly industrialised countries or because they are imported at prices corresponding to the wage levels in countries from which imports originate.

The imbalance in income redistribution could be corrected (considering Equation (2.I.6)) by production of commodities which the rural economy both needs and can afford; and by use of rural economy's raw materials supplied at competitive prices.

2. Production for the export market and a small domestic market demanding the same standards of quality or brand names, as those of imported commodities, could severely restrict the production technology that could be used, forces the local firms to compete with the most

---

[1] It is common knowledge in Kenya that a lot of employees in the modern sector have interests in the rural sector as a means of supplementing their wages. In addition, the prices of agricultural products are, compared to, say, UK prices, low.

advanced technologies for the product elsewhere in the world, and thereby imposing on the local firm a condition of keeping abreast with the developments of that production technology. This in turn creates or strengthens a dependency relationship between the local firm with some firms in the highly industrialised countries which created, own and supply, and/or continue to develop the production technology. As a result of such dependency relationships, control of technological, managerial, and marketing functions can be surrendered to foreign firms. There seems to be no incentives for such foreign firms to effectively train local manpower to manage and maintain production facilities or to encourage local development of the technology. Since technology is continuously developing in the industrialised countries such ties of dependency could be permanent.

3. The results of this work also suggest that expensive advanced technology has lower capital productivity than simpler (less expensive) technology (Chapter 4.III). In addition the indication is that use of this technology tends to pre-empt capital available for alternative investments either in the manufacturing sector or the economy. This is suggested by the relatively high borrowing requirements - exemplified by the sample of firms considered in this work.

4. The cost of advanced technology makes it accessible only to the Government or to foreign firms. The complexity of the technology makes it manageable largely only by foreign firms. The tendency of foreign controlled production facilities is to slow the growth of local technological capacity generation through "learning by doing". The recurrent costs of running such facilities are also high.

5. In terms of stimulation of local growth of a comprehensive technological capacity adequate to cope with all the other technological phases of project implementation viz. plant and process evaluation, process and plant design and engineering, plant construction planning and supervision, commissioning and start up; and in terms of stimulation of growth of a local equipment industry capable of creating links with the process industry, the industry has been a failure.

It is considered here that this failure could be accounted for by the small size of the process industry thus being unable to attract large multinational construction firms to start permanent offices

locally dealing with supply of the above technological services, or to invest in capital goods industry designed to supply the local process and allied industries. It seems likely that it is not in the best commercial interests of foreign firms to encourage local growth of a technological capacity that would substitute technological services now wholly imported. Although the initiative should lie on local business interests, the current dependency structure in most of the large manufacturing establishments makes it extremely difficult to break into this market. The high and rigid specifications for equipment inputs into the industry makes this task additionally difficult.

The Role of Foreign Investments in Growth of the Process Industry

The financial burden imposed by expenditure of a half of the sum stipulated in Chapter 4.II to finance a substantial growth of the process industry using advanced technology would be too great for the developing economy to bear. Therefore, it seems likely that the country would not invest in the industry to a significant extent. It might be argued, however, that provided the 'climate' was right it would be possible for the industry to grow through foreign investments.

It seems unlikely that such investments would constitute a significant portion of the required growth rate. In Kenya, there are few abundant cheap raw materials that would attract further foreign investments such as crude petroleum oil, or natural mineral resources. Processing of the few materials that exist such as soda, cement, or pyrethrum flowers, etc. has already been invested in. The domestic market that can afford industrial goods is quite small and with the tendency of the neighbouring countries to duplicate each other's production of industrial goods - because all want to industrialise and import substitution of products from neighbouring countries is generally the easiest first stage of industrial expansion - regional markets are uncertain. Lastly there is a practical limit - which is considered low here - to the number of projects in which foreign investors and creditors can be assured of a sufficiently profitable return on their investments through freedom to fix price levels of local products, the freedom to control the local production facilities, and through protection from local or other foreign competition. Too many investments by foreign firms under these conditions would probably bankrupt the country through imports of equipment and services and then the chance of any foreign firm making any profit would be eroded. The multinationals could be

expected to anticipate this.

For the foreseeable future, then, the local process industry can only hope to grow through investments by local interests such as businessmen and the Government. In the case of the Government its contribution could be constrained by its commitments to other areas of the nation's economy, and by the difficulties of borrowing financial capital from foreign financing institutions or aid donors.

5.III Technology Choice

In terms of an industrialisation strategy the results obtained in this work suggest that the probability of local growth of a technological capacity, defined in the broadest sense, could be increased by use of less sophisticated technology. With this type of technology, local investors and other interests would be asked to take lower risks in allowing local skilled manpower to manage it and, because it would most likely be less severe in equipment specification demands, it would also allow scope for experimentation with equipment from potential local capital industry. In the context of this work planning for a local capital goods industry would not be a complete strategy by itself. It would be part of a strategy of industrialisation incorporating also development of facilities and services required in designing and building manufacturing plants as well as their operation and maintenance.

The degree of simplicity or complexity of technology clearly needs to be defined for a number of reasons. Firstly, because it could happen that a technology that is too simple would do little to develop the technological infrastructure of a specific developing country, in the same way that very advanced technology might fail to develop the local technological infrastructure. Secondly, and as a consequence of the first reason, different countries have achieved different levels of industrialisation and the degrees of simplicity of technology appropriate to each socio-economic system therefore differ. In Chapter 6 a method for defining technology complexity of a processing system is proposed. With proper development this method might reach a level where it could be used as an aid to technology buyers with little technical background in estimating - crudely - the worth of the technology (assuming that the design is technically optimal).

It might be argued that technology per se, given product specifications, is fairly well defined and inflexible. This could hold in several cases and the implicit assumption in the exercise on technology

assessment for industrialisation purposes, is that product specifications would be defined as broadly as possible (126).

In the case of developing countries this could be possible for the low income consumption products-for the majority of the population.

Simplicity of technology alone would not be a sufficient condition for development of local technological capacity as demonstrated in this work in the case of skilled manpower for plant operation and maintenance using advanced technology. Other factors need to be incorporated in choice of projects at the micro-project planning level. It is suggested that these factors should include consideration of ownership patterns, financing requirements (whether or not capital financing demands impose extra constraints on control of technology), and product suitability in terms of national welfare.

Pyle has described an approach to project selection which attempts to take account of such factors (127). The approach uses the idea of a "technology-attribute matrix". Each design has a certain set of input characteristics, e.g. 'know-how', capital, services, scale, and other inputs; and a set of output characteristics such as products, skill development, 'environmental' impact variables, etc. The appropriateness of the technology is then judged by the way it measures up to the objectives set by policy-makers, those involved in technology operation, and so on. The set of inputs and outputs can thus be measured against a set of evaluators used to define the technology of each project alternative in terms of a point in a multidimensional attribute space. The work is still incomplete, as he has pointed out, because problems of measurement of evaluators and definition of objectives remain to be resolved. In the following chapter a method for assessment of technological complexity of process systems is proposed.

CHAPTER SIX

PROPOSED METHOD FOR ASSESSMENT OF COMPLEXITY OF PROCESS TECHNOLOGY IN RELATION TO CHOICE OF TECHNOLOGY.

6. COMPLEXITY OF TECHNOLOGY OF PROCESSING SYSTEMS

That different processing systems or plants have varying degrees of complexity is intuitively obvious. The problem arises, however, when one seeks to rationalise the idea of process complexity so that it is given a definite and tangible meaning. The subject has been of some interest mainly in preliminary cost estimations of refinery capital costs. Thus Nelson (75) has defined a refinery complexity number in terms of ".... the number of times a refinery is more complex than a crude distillation refinery ....". After this definition a refinery incorporating viscosity breaking is twice as complex; one incorporating catalytic cracking is 4 times as complex; one with coking facilities is 8 times as complex and so on (76). The method for obtaining these complexity figures has not been given.

Process technology complexity is reflected in the absolute level of difficulty and relative time requirements in executing any of the technological phases of an industrial project's implementation. Complexity can, therefore, be implicitly reflected in the cost of implementing such projects. Process technology complexity can strongly affect the process of technology transfer to industrialising countries. The differences between the technology complexity of a project being implemented and the technology availability in the country of consideration, could allow "quasi monopoly rents" on technology. The more complex the technology, the more easily can highly industrialised countries capture, or withhold the know-how and block the technology's effective transfer.

The degree of technology complexity sets the minimum levels of technological skills, facilities and infrastructure necessary for realisation of a particular project; and thus can be used as a characteristic of a processing system that defines these technological demands and which indicates qualitatively the probability of an effective transfer of the project's technology to the technological system of an industrialising country. Market prices for tradeable goods are sensitive to commodity demand and availability, among others. An objective view of the content of process technology offered for sale can help the purchaser to assess the likely price trends over his planning horizon and therefore aid in taking the necessary decision on that technological project. Alternatively, knowledge of the technology content can be used by a purchaser to improve his bargaining position in cases where he is not familiar with the project's technology.

The problem as stated above is of defining the technology content of a particular processing system. A method is developed here which is designed to reflect the relative ease with which such systems can be developed, designed, engineered and the relevant equipment fabricated and erected. It is clear that ease of design and fabrication often implies ease of maintenance and operation of the process system. Technology content of a processing system is then considered to be proportional to the system's complexity level; and this system's complexity is seen to result from the individual and combined effects of the system's equipment units complexity and the interactions between those equipment units. Thus:

System's Complexity Level = f [Equipment engineering and fabrication complexity level, Process and equipment design complexity level, System design complexity]

These three factors of complexity, i.e. in relation to equipment engineering and fabrication, equipment and process design, and in relation to the effects of intrasystem's interactions, can be considered in turn.

The basis of the method is of classifying complexity into five levels corresponding to the following classes of service or equivalent demands:-

Level 1 ≡ Light duty
Level 2 ≡ Medium duty
Level 3 ≡ Heavy duty
Level 4 ≡ Severe duty
Level 5 ≡ Extreme duty

Under each of the factors, a methodology for classification into levels as above has been proposed below. However, there is a subjective element involved in the method difficult to eliminate in some cases, but which is clearly identifiable. The method proposed here could, nevertheless, form an important stage towards evolution of a more objective criterion for measurement of the complexity or the content of technology of processing systems.

6.I Equipment Engineering and Fabrication Complexity Levels

Ease of equipment fabrication is facilitated mainly by an abundant supply availability of materials of equipment construction, by low levels of strength demands on materials used in fabrication, by the simplicity of the geometrical shape of equipment, and by low scales of equipment sizes. These factors have direct bearing on the complexity level of an equipment unit. Construction material availability can be implicitly considered by basing the treatment of the other factors on the most common and cheapest material of construction. Levels of complexity for an equipment unit can then be assigned for each of the three factors of engineering and fabrication requirements, viz:-

(a) Equipment service demands, i.e. operating conditions,
(b) Equipment geometric factors,
(c) Equipment size factors.

It is considered that the overall complexity of an equipment unit reflected in the equipment's degree of difficulty in engineering, fabrication, and maintenance is a result of 'forces' exerted by the above factors in combination. (a), (b) and (c) are complexity factors, with respect to engineering and fabrication aspects of technology. The complexity factors can, therefore, be treated as vectors which give a resultant complexity of the equipment unit with respect to engineering, fabrication, and maintenance difficulties. The resultant complexity factor denoted by, EF_i, where subscript i denotes equipment unit i, is then given by:

$$EF_i = \sqrt{\left[(PC_i)^2 + (EG_i)^2 + (ES_i)^2\right] \frac{1}{3}} \qquad (6.1)$$

The factor $\sqrt{1/3} = 5/\sqrt{75}$ is included to scale down the value of EF_i to between 1 and 5 corresponding to the five levels of complexity adopted earlier. The notations for the factors are:-

EF_i = Complexity level of equipment unit i with respect to overall engineering and fabrication requirements.
PC_i = Complexity level for equipment unit i with respect to severity of operating conditions.
EG_i = Complexity level for equipment unit i with respect to

geometric factors of the equipment.

ES_i = Complexity level for unit i with respect to size of unit,

and:

$$1 \leq EF_i , PC_i , EG_i , ES_i \leq 5 \qquad (6.2)$$

Procedure for obtaining numerical values for the above variables is discussed in the following section.

6.I.A Operating Conditions Factors of Equipment Engineering and Fabrication

Equipment has to be able to withstand mechanical, thermal, chemical and other stresses anticipated in the life of its service. From equipment reliability studies, it is known that equipment failure rates change radically with changes in levels of stresses imposed on equipment of a given rating (77). Because of uncertainties both in the stresses which an equipment unit must withstand in service, and of the equipment production processes, the higher the service rating for the equipment the more demanding and 'complex' are the fabrication and engineering requirements.

In the process industry, the major stresses encountered by equipment are dominated by chemical (i.e. corrosion) and thermal stresses and by stresses due to operating pressures. Thus important service demand considerations are those of operating temperature, operating pressure, and of the corrosiveness of equipment's environment. The severity of each of these conditions can be classified into one of five levels - level 1, 2, ... , or 5. Each level applies over a range of values of an operating condition. The procedure for specifying the range of values of an operating condition represented by a level can be considered for the three operating conditions in turn as follows.

6.I.A.1 Temperature

Classification can be based on carbon steel and alloy steels because they are the cheapest, most common, and versatile metals in the process industry. Compared to carbon steel, higher standards of specifications in material fabrication are required in the making of alloy steels and in its treatment to improve metal properties.

Arranged in order of 'complexity' of material fabrication and treatment, specifications by the British Standards Institute (78) for maximum allowable tensile stresses at specified design temperatures (for which recommended design equations are applicable) have been reproduced on Table 6.1. below. The specifications are for design of fusion welded pressure vessels using carbon and alloy steels. Pressure vessels often produce a structural envelope for many functions, including heat exchange. separation processes, chemical reaction, mixing and blending, etc. They, therefore, render themselves convenient for use as a basis of studying temperature effects.

Similar tables for ferrous bars, sections, forgings, and castings in pressure vessel design show the same trends of allowable stress with increase in temperature. Carbon steel of 26 - 32 tons/in^2 tensile strength is only suitable for construction of vessels with maximum shell plate thickness of $\frac{5}{8}$ in excluding corrosion allowance(78).

Perry gives a safe operating temperature for wrought iron, under mechanical loading, of 343^{o}C (79) corresponding roughly to semi-killed carbon steel. Further processing required in producing semi-killed carbon steel and in producing other types of materials increases with service temperature and indicates complexity in production of suitable construction materials. Using Table 6.1 , varying temperature effects on material of construction can be seen to be marked for the temperature ranges: up to 149^{o}C, 150 - 342^{o}C, 345 - 400^{o}C, 400 - 450^{o}C, 450 - 500^{o}C, 500 - 510^{o}C after which none of the above alloys are suitable for construction purposes.

The codes, by the American Society of Mechanical Engineers, for pressure vessels for service at 15 lb/in^2 - 3000 lb/in^2 pressure make provisions for construction of vessels up to 649^{o}C for carbon and alloy steel, and up to 815^{o}C for stainless steel (82). At high temperatures material properties such as resistance to rupture and creep, decrease very rapidly making special demands on, and restrictions to, alloys suitable for equipment construction. At low temperatures possibility of brittle fracture further restricts the range of suitable materials for construction and necessitates further material treatment. A.S.M.E. code for pressure vessels (Section VIII, Division 1) allows use of many steels down to - 20^{o}F without a check on toughness. Under these conditions some vessels can be operating below the lower limit of ductility (83).

TABLE 6.1

PERMISSIBLE DESIGN STRESSES AT DESIGN TEMPERATURE FOR FERROUS PLATES

Material	Tensile strength ton/in^2	Permissible stress lb/in^2 at design temperature of:							
		Up to 149^{o}C	342^{o}C	371^{o}C	399^{o}C	454^{o}C	495^{o}C	510^{o}C	538^{o}C
Carbon-steel	26 - 32.0	14,500	-	-	-	-	-	-	-
Carbon steel (semi-killed)	26 - 31.5	14,500	14,500	14,300	12,700	-	-	-	-
Carbon-Manganese steel (semi-killed)	28 - 33.5	15,700	15,700	15,200	13,400	-	-	-	-
Carbon-Manganese steel (silicon killed)	26 - 31.5	14,500	14,500	14,300	12,700	8,700	4,900	3,350	-
Carbon-Molybdenum steel	27 - 33.0	15,100	15,100	15,100	15,100	13,800	12,200	9,000	3,800

Source: Ref. (78)

Recommendation of suitable metals for low temperature service are given in Perry (84) and the temperatures of transition are $-50^{o}F$, $-75^{o}F$, $-150^{o}F$ and $-320^{o}F$.

A suitable classification of temperature ranges reflecting progressive complexity of construction material demands can thus be made as shown on Table 6.2.

TABLE 6.2

Duty Designation	Light	Medium	Heavy	Severe	Extreme
Temperature range ^{o}C (below $0^{o}C$)	0 — 140	140 — 300	300 — 450 0 to —30	450 — 650 —30 to —50	> 650 < —50
Complexity level of Equipment, T_i	1	2	3	4	5

6.I.A.2 Pressure

Pressure vessels have been classified into the following categories (85), based on classification by British Standards Institute:-

1. Severe duty vessels

Vessels containing toxic or lethal substances at temperatures above their self-ignition temperature. Also included in this category are fired vessels for pressures exceeding 100 lb/in^2.

2. Light duty vessels

Unfired vessels whose plate thickness does not exceed $\frac{5}{8}$ in and for working pressures not exceeding 50 lb/in^2 vapour pressure or 250 lb/in^2 hydrostatic pressure at temperatures less than $300^{o}F$.

3. Medium duty vessels

Unfired vessels for service at conditions intermediate of conditions in (1) and (2).

4. Sub-atmospheric pressure vessels and which are liable to embrittlement at temperatures below $0^{o}C$.

The American Society of Mechanical Engineers code requirements covered by Section VIII of "Boiler and Pressure Vessel Code (1962)" are restricted to pressures between 15 lb/in^2 and 3000 lb/in^2 (86). Specific code requirements for different services reflect degrees of complexity of the vessels. Thus different classes of vessels are restricted with respect to allowed temperature ranges, pressure ranges, service or contents of vessel, and with specifications for welded joints, stress reliefing and radiography test.

Table 6.3 on the following page shows some of these specifications from Table 24.2 of Perry (80).

Pressures above 750 lb/in^2 can be considered to be in the high pressure region (87). As vessel service pressures increase and vessel sizes increase a practical forging limit is approached. This is of about 100 tons weight. Beyond this weight vessel sections have to be forged and then welded together to complete the fabrication. Even this is practical for small diameter vessels only.

Increasing vessel design pressures introduces fabrication problems due to increasing wall thicknesses; problems with enclosures are introduced due to size, clearances and effective gasket seals; and nozzle design gets more difficult due to abrupt changes in section. As higher strength is demanded of the materials, fabrication difficulties increase with alloy content and welding difficulties increase. Extension of solid wall thickness ranges requires large presses and furnaces and welding requires either low-hydrogen electrodes or electro slag welding.

Classification of the pressure ranges over which equipment complexity, with respect to fabrication and engineering, changes is shown on Table 6.4. below.

TABLE 6.3

SPECIFICATIONS FOR MATERIALS OF CONSTRUCTION FOR UNFIRED VESSELS

Service/Contents	Construction material		Design temperature	Design pressure	Stress relief	Radiography
	Class	Specs[1]				
	Carbon Steel					
Non-lethal and non-nuclear	UC5	SA7113	$-20^{o}F$ to $650^{o}F$	-	NR	NR
Non-lethal, non-nuclear and non-flammable	UC1	SA278				
Gases	UC1	SA278	$450^{o}F$ and below	160 lb/in^2 max	NR	NR
Liquids	UC1	SA278	$350^{o}F$ and below	160 lb/in^2 max	NR	NR
Liquids, Gases, Steam and other Vapours	UC1	SA278	$650^{o}F$ and below	250 lb/in^2 max	Stress relief anneal required about $450^{o}F$	NR

[1] Specs. = Specification code of metal : NR = Not required

Source : Table 24.2 of Perry (80)

TABLE 6.4

Duty	Light	Medium	Heavy	Severe	Extreme
Pressure lb/in^2	0 - 150	150 - 400	400 - 1000	1000 - 2000	> 2000
Complexity level P_i	1	2	3	4	5

6.I.A.2 Corrosion

Ferrous metals because of their wide application can be taken as the basis for classification of equipment complexity with respect to corrosion resistance demands imposed by the service media. General corrosion properties of some metals and alloys have been given in Perry (88). Some of the data relating to ferrous metals is given in Table 6.5 below.

Classification of corrosiveness of equipment's environment can thus be done as shown on Table 6.6 below.

6.I.A.3 By treating the separate influences of temperature, pressure, and corrosion as vectors the complexity level of equipment unit with respect to operating conditionsis the resultant of the complexity levels of individual operating or environmental variables, i.e.:

$$PC_i = \sqrt{\frac{1}{3}\left[T_i^2 + P_i^2 + C_i^2\right]} \qquad (6.3)$$

where: PC_i = Complexity level of equipment unit i with respect to severity of service conditions.

T_i = Complexity level of equipment unit i due to operating temperature demands.

P_i = Complexity level of equipment unit i due to operating pressure demands.

C_i = Complexity level of equipment unit i due to severity of corrosiveness of the equipment's environment.

and: $$1 \leq PC_i \, , \, T_i \, , \, P_i \, , \, C_i \leq 5 \qquad (6.4)$$

TABLE 6.5

CORROSION PROPERTIES OF FERRETIC METALS AND ALLOYS

	Cast Iron	14% Silicon Iron	Mild Steel, also Low Alloy Irons and Steel	Stainless Steel Ferritic 17% Cr.
Non Oxidising or reducing media				
Acid solutions, excluding hydrochloric	Poor - Fair	Excellent	Poor - Fair	Fair
Neutral solutions, e.g. non-oxidising salt solutions, chlorides and sulphates	Fair - Good	Excellent	Fair - Good	Good
Alkaline Solutions — Caustic and mild alkalies excluding ammonium hydroxide	Good	Fair	Good	Good
Alkaline Solutions — Ammonium hydroxide	Good - Excellent	Good - Excellent	Good - Excellent	Excellent
Oxidising Media - Solutions				
Acid solutions, e.g. HNO_3	Unsuitable	Excellent	Unsuitable	Good - Fair
Neutral or alkaline solutions	Good	Excellent	Good	Excellent
Pitting media, acid ferric chloride solutions	Unsuitable	Fair - Good	Unsuitable	Unsuitable
Natural Waters				
Static or slow-moving fresh water supplies	Good	Good - Excellent	Good	Good
Turbulent fresh water supplies	Fair - Good	Good - Excellent	Fair - Good	Excellent
Static or slow-moving sea water	Good	Good - Excellent	Good	Poor - Fair
Turbulent sea water	Fair	Good - Excellent	Fair	Good
Gases				
Steam - moist condensate	Good	Excellent	Good	Good - Excellent
Steam - dry at high temperature promoting slight dissociation	Good	Good	Good	Excellent
Furnace Gases with Incidental Sulphur Content				
Reducing, e.g. heat treatment furnace gases	Poor - Fair	Good	Poor - Fair	Fair - Good
Oxidising, e.g. flue gases	Poor - Fair	Fair - Good	Poor - Fair	Fair
Ambient air - city or industrial	Fair - Good	Excellent	Fair - Good	Good
Moist halogens and derivatives	Unsuitable	Unsuitable	Unsuitable	Unsuitable

Source: Perry, 5th. ed. Table 23-4.

TABLE 6.6

Duty Classification	Light	Medium	Heavy	Severe	Extreme
Environments	Ammonium hydroxide solution Oxidising neutral or alkaline solution	Fresh water Steam	Sea water Neutral non oxidising or reducing solutions e.g. chlorides and sulphates Caustic and mild alkalies excluding NH_4OH	Oxidising acid solution, e.g. HNO_3 Furnace gases with incidental sulphur content	Moist halogens and their derivatives Pitting oxidising solution media e.g. ferric chloride solution
Complexity level due to corrosion, C_i	1	2	3	4	5

In some cases accounting for the effects of temperature and pressure alone during equipment engineering and fabrication can prove adequate in dealing with any corrosion problems that may be inherent in a process. Equation (6.3) above could, in some cases, obscure the dominant effects of temperature and pressure. To avoid this the following equation could be used:

$$PC_i = \sqrt{0{\cdot}5\left[T_i^2 + P_i^2\right]} \qquad (6.3a)$$

This equation applies under any of the following conditions

$P_i, T_i = 5$, and $C_i \leq 3$;

$P_i, T_i = 1$, and $C_i \geq 4$;

$P_i, T_i \leq 3$, and $C_i = 5$;

$P_i, T_i \geq 2$, and $C_i = 1$;

$P_i, T_i \leq 2$, and $C_i \geq 4$, where $P_i \neq T_i$

6.I.B Equipment Geometry and Size Complexity Factors

Both geometry and size factors can be considered sequentially and then together to give an overall effect on equipment complexity with respect to engineering, fabrication and maintenance difficulties. With regard to geometry, clearly a simple storage tank for given service conditions is of lower complexity than that of a shell and tube heat exchanger at similar operating conditions; a single stage centrifugal compressor is less complex than a multistage centrifugal compressor for similar service. The essential element in these and similar cases is that the number of equipment constituent parts increases with complexity. As number of parts increase so also does the probability of failure of whole equipment and where the additional parts are different additional skills and facilities are demanded for both fabrication and maintenance.

Equipment size can have the effect of limiting the sources of the equipment because transportation limits are exceeded, or requiring bigger or/and stronger fabricating machinery such as large presses and furnaces required for fabrication of large solid wall thicknesses in pressure vessels. In addition, process operating charactistics are often influenced by equipment size. Thus stability of chemical reactors can be dependent on reactor volume; and in design of packed tower columns, height to diameter ratio of the column must be considered.

In assessing complexity levels of various equipment types with respect to geometry and size the problem of specification of each level can be difficult. This is due to the huge number of equipment types and to the large number of configurations within each type. In addition, equipment geometry is often greatly influenced by equipment 'capacity size'. Thus multistage compressors are designed so that they can accommodate more gas, with or without increase of discharge pressure, and thus increasing the equipment size as well as changing the equipment geometry. Because of the differences in construction of various equipment given size ranges cannot be taken to apply equally to all types of equipment and each type therefore needs to be considered separately. This greatly magnifies the problem and the amount of work involved.

Nevertheless, a rational approach can be made which with further refinement might be developed into a precise measuring method. The premises of such an approach are outlined as follows below.

Equipment types for the process industry fall into two broad categories:-

(1) Static and (2) Dynamic

- In static equipment, processing operations occur with equipment parts remaining essentially inactive. Some parts of equipment might be moving in order to promote a processing operation, e.g. a stirrer, but processing can still occur even without the moving parts. Examples of this type are a simple stirred reactor, mixing tanks, or storage vessels.

- In dynamic equipment, process operations occur with mobility of equipment parts being of the essence so that without movement of the mobile parts the necessary process operation could not be accomplished. Examples of this category of equipment are compressors and crushers.

- In cases where an equipment unit may be a single stage or multistage one, complexity changes due to geometry can implicitly be included into complexity changes due to size variation, i.e. for a type of equipment such as centrifugal compressors, single stage equipment would have the same complexity level as multistage equipment where factors due to geometry are considered. However, the size factor is assumed to include some effects of geometric changes accompanying such an increase of equipment stages.

- In many cases such as in drying equipment, the whole unit consists of a number of different equipment units which can be designed and fabricated separately such as fans and heaters. In such cases the different equipment units, i.e. those that can be used on their own under different circumstances, can be treated as separate equipment units and assessed as such. The whole equipment unit could then assume the complexity value of the part with the highest complexity, raised to another level as suggested in subsection 6.I.B.1.

6.I.B.1 Static Equipment Geometric Factors Consideration

A great number of processing functions occur in a structural envelope in the form of a pressure vessel. Vessels without any internals can, therefore, be taken to constitute the lowest level of equipment

complexity in terms of equipment geometry. Complexity level can then be seen to increase with the relative number of internal parts and with the shape and form of those internals. Keeping to the five levels of complexity adopted earlier, definition of geometric forms corresponding to each level can be made as follows:-

Level 1 Equipment approaching single chamber structure, i.e. shells without, or with negligible, internals. The vessel may be lined or unlined and of any shape. An example of Level 1 equipment is a storage vessel.

Level 2 Equipment consisting of a chamber and a few internal attachments. Examples clarifying this statement are:-

(a) Single tube in a shell heat exchange equipment.
(b) Less than five solid integral parts encased in a chamber such as is the case of parts in the compression chamber of reciprocating pumps and compressors.
(c) Impeller blades or other solid attachments supported by a single shaft and the whole being confined to a single chamber such as in single stage fans and compressors and stirred vessels.

Level 3 Vessels consisting of single chamber with either several geometrically simple attachments or with several solid packings of simple design and fabrication requirements. Examples are multi-tube, multi-pass shell and tube heat exchangers, and mill chamber equipped with pebbles in tumbling mills. Other equivalent equipment are vessels with more than one internal shaft equipped with attachments such as ring roller crushers.

Level 4 Equipment consisting of a shell with several internal packings or attachments of a highly specialised design and fabrication nature. Also equipment as in Level 3 but also having integrated, extra internal facilities of complexity level of 2 or 3. An example of equipment at this level is packed and plate columns.

Level 5 Equipment as in 4 but with integrated additional facilities with complexity level of 2 or 3. This is the case in packed columns equipped with internal intercoolers.

The above description of equipment forms at various levels serves as a guideline to complexity level assessment with regard to geometric influences on fabrication and maintenance of equipment in their static state. During individual equipment assessment a degree of subjectivity is unavoidable because of the looseness of the guidelines. Errors so introduced can be minimised by a deep understanding of the mechanical construction of equipment used in the process industry.

6.I.B.2 Dynamic Equipment Geometric Factors Consideration

Equipment with moving parts have added complexity factors introduced by the parts that transmit power to the processing equipment parts. The mobility of moving parts increases possible sources of mechanical failure due to generated stresses between the moving parts or between moving parts and material being processed. Another complication arises from heavier sealing requirements along the boundaries of the moving parts where this is vital. These two 'dynamic' factors are treated briefly as follows.

Mechanical power transmission equipment factors

Where the movement required is simple such as circular motion, relatively simple transmission equipment is required, such as belts or simple gear drives. In addition solid coupling might be applicable where the driver and driven shafts operate at the same speed. Solid coupling have the effect of eliminating shaft bearing. Use of solid coupling can, however, result in shaft misalignment at high speeds and under such conditions flexible coupling are necessary. Higher speeds correspond to higher capacities of the equipment, highlighting the close relation between size factors and geometric ones.

Similarly, where required movement is more complicated such as vibratory motion in conjunction with axial rotation the fabrication requirements of say, gear drives and couplings get more severe. At high speeds friction increases and special gear tooth profiles must be designed and fabricated to provide the rolling action necessary to minimise friction. In providing better rolling action shaft alignment

and gear spacing become critical factors.

The effect of mechanical transmission requirements on overall equipment complexity has been assumed to have the effect of raising its equipment complexity level by 1 or 2 depending on the simplicity of the transmission requirements as briefly set out above.

Sealing factors

Sealing requirements are heaviest where processing takes place under substantial pressure. Packings are easier to fabricate and install - although they demand heavier maintenance - than mechanical seals which are precision components demanding careful handling and installation. Accordingly, where these sealings are used, packings and mechanical seals are assumed to raise the overall complexity level of equipment by 1 or 2 respectively.

Thus equipment with moving parts have their complexity level raised over their static state level by these considerations. The incorporation of these additional factors into the overall equipment complexity level is rather arbitrary but it has the effect of simplifying the method adopted here.

6.I.C Size Factor

As convenient indicators of size vary with different equipment, and partially to compensate for oversimplification of the method of accounting for geometric factors, specification of size ranges covering a size level cannot be generalised. Thus in most dynamic equipment types horsepower required to drive the moving parts is a convenient indicator of size while in most static equipment types material flowrate to the equipment might be a suitable size indicator. As with other factors, size is divided into 5 levels which are specified under each equipment type.

The complexity level of equipment unit with respect to geometry considerations and assessed in the way described in Section 6.I.B is then denoted by EG_i, where subscript i denotes equipment unit i.

Complexity level of equipment unit i with respect to size consideration is denoted by ES_i. Specification of the size ranges over which the levels apply can be done for all common equipment units in the process industry. The specification can be based on the size ranges

found in equipment market for the process industry. The most common size range in a highly industrialised country can be considered to be at complexity level 3 (it is assumed that the most common equipment sizes used in the highly industrialised countries would be considered relatively large when used in a developing economy). Data on past changes in the largest fabricated sizes over a period of say, 30 years, could also be useful in specifying the size ranges.

In Appendix A.6.I a number of equipment common to the process industry have been considered and the procedure given above for specification of EG_i and ES_i applied. Attempt has been made to show how information on process equipment could be used to specify these two variables. The results of assessment for the equipment considered are summarised below on Tables 6.7 - 6.22 inclusively.

At this point it is, therefore, possible to give numbers to the expression:

$$EF_i = \sqrt{\frac{1}{3}\left[PC_i^2 + EG_i^2 + ES_i^2\right]} \qquad (6.1)$$

6.I.D Examples of Equipment Complexity Levels due to Geometric and Size Factors

A number of commonly used process equipment units have been assessed for complexity levels due to geometric and size factors. These serve as an illustration of the results that can be expected on application of the method outlined above. Other process equipment units resemble the examples shown on the following pages.

TABLE 6.7

AXIAL AND CENTRIFUGAL COMPRESSORS (SEE APPENDIX A.6.I - A)

Geometric Complexity Level = 5

Complexity level due to size is variable according to:-

Complexity Level		1	2	3	4	5
Size Ranges Capacity ft^3/min	Centrifugal	≤ 800	800 - 2,000	2,000 - 10,000	10,000 - 100,000	> 100,000
	Axial	-	40,000 - 70,000	70,000 - 150,000	150,000 - 300,000	> 300,000

TABLE 6.8

RECIPROCATING COMPRESSORS

Geometric Complexity Level = 5

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges Capacity ft^3/min	≤ 300	300 - 800	800 - 1,500	1,500 - 2,500	> 2,500

TABLE 6.9

CLASSIFIERS (SEE APPENDIX A.6.I - 8)

Geometric Complexity Level = 3

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges Motor horsepower	< 10	10 - 60	60 - 160	160 - 350	> 350

TABLE 6.10

HEAT TRANSFER EQUIPMENT (SEE APPENDIX A.6.I - C)

Includes equipment for cooling, heating, condensing, evaporating, etc. particularly the floating head type shell & tube heat exchangers

Geometric Complexity Level = 3

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges					
* Shell Diameter (ft)	≤ 2	2 - 4	4 - 6	6 - 8	> 8
* Tube Length (ft)	≤ 6	6 - 10	10 - 15	15 - 25	> 25

* Effective level = $\frac{1}{2}$ (Diameter level + length level)

TABLE 6.11

TUBULAR FURNACE HEATER - INDIRECT FIRED HEATERS (SEE APPENDIX A.6.I - D)

Geometric Complexity Level = 3

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Duty					
10^6 BTU/hr	< 5	5 - 75	75 - 150	150 - 300	> 300

TABLE 6.12

CONTINUOUS THROUGH CIRCULATION DRYERS (SEE APPENDIX A.6.I - E)

Geometric Complexity Level = 3

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges					
* { Width	< 4 ft	4 - 6 ft	6 - 8 ft	8 - 10 ft	> 10 ft
* { Length	< 10 ft	10 - 30 ft	30 - 40 ft	40 - 60 ft	> 60 ft

* Effective level = $\frac{1}{2}$ (Width level + length level)

TABLE 6.13

ROTARY KILNS (SEE APPENDIX A.6.I - F)

Geometric Complexity Level = 4

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Capacity per 24 hr operation 376 -lb bbl	< 300	300 - 800	800 - 1,500	1,500 - 2,500	> 2,500

TABLE 6.14

PLATE AND PACKED COLUMNS (SEE APPENDIX A.6.I - G)

Geometric Complexity Level = 4

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges					
* Diameter (ft)	$\leq$ 3	3 - 5	5 - 10	10 - 16	> 16
* Height (ft)	$\leq$ 20	20 - 40	40 - 70	70 - 100	> 100

* Effective level = $\frac{1}{2}$ (Diameter level + height level)

TABLE 6.15

CHEMICAL REACTORS (SEE APPENDIX A.6.I - H)

Batch and continuous stirred tank reactors geometric complexity level = 2

Continuous staged stirred reactors geometric complexity level = 3

Multitubular reactors geometric complexity level = 3

Catalytic bed reactors and fluidised bed reactors geometric complexity level = 4

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges					
* Diameter (ft)	$\leq$ 2	2 - 4	4 - 6	6 - 8	> 8
* Height (ft)	$\leq$ 5	5 - 10	10 - 15	15 - 25	> 25

* Effective level = $\frac{1}{2}$ (Diameter level + height level)

TABLE 6.16

JAW CRUSHERS (SEE APPENDIX A.6.I - I)

Geometric Complexity Level = 3

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (tons/hr)	< 15	15 - 70	70 - 180	180 - 280	> 280
Motor power (hp)	< 10	10 - 50	50 - 100	100 - 160	> 175

* Either capacity or motor power requirement could be used

TABLE 6.17

GYRATORY CRUSHERS (SEE APPENDIX A.6.I - J)

Geometric Complexity Level = 4

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (tons/hr)	< 15	15 - 60	60 - 140	140 - 300	> 300
Motor power (hp)	< 15	15 - 60	60 - 120	120 - 200	> 200

* Either capacity or motor horsepower could be used

TABLE 6.18

ROLL CRUSHERS (SEE APPENDIX A.6.I - J)

Geometric Complexity Level = 4

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (tons/hr)	< 25	25 - 70	70 - 170	170 - 230	> 230
Motor power (hp)	< 20	20 - 60	60 - 120	120 - 200	> 200

* Either capacity or motor horsepower could be used

TABLE 6.19

IMPACT BREAKERS

Geometric Complexity Level = 3

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (tons/hr)	< 50	50 - 100	100 - 250	250 - 600	> 600
Motor power (hp)	< 50	50 - 100	100 - 200	200 - 350	> 350

* Either capacity or motor horsepower could be used

TABLE 6.20

TUMBLING MILLS (SEE APPENDIX A.6.I - K)

Geometric Complexity Level = 5

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (tons/hr)	< 1	1 - 5	5 - 12	12 - 30	> 30
Motor power (hp)	< 10	10 - 50	50 - 150	150 - 300	> 300

* Either capacity or motor horsepower could be used

TABLE 6.21

RING ROLLER MILLS (SEE APPENDIX A.6.I - L)

Geometric Complexity Level = 5

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (tons/hr)	< 0.5	0.5 - 1	1 - 10	10 - 20	> 20
Motor power (hp)	< 10	10 - 50	50 - 150	150 - 300	> 300

* Either capacity or motor horsepower could be used

TABLE 6.22

HAMMER MILLS

Geometric Complexity Level = 4

Complexity level due to size is variable according to:-

Complexity Level	1	2	3	4	5
Size Ranges* Capacity (lb/hr)	< 500	500 - 1,600	1,600 - 3,500	3,500 - 5,500	5,500
Motor power (hp)	< 5	5 - 15	15 - 30	30 - 60	> 60

* Either capacity or motor horsepower could be used

6.II Complexity of Process Design of Equipment Units

For the purpose of this work, process design can be understood to mean: the procedures for specification of process variables such as pressure, temperature, horsepower, etc. and of equipment unit variables such as length, diameter, volume, amount of packing, number of contacting plates, etc. required to accomplish material transformation from a given physical and/or chemical state to another.

The task of process design involves two inter-related steps, viz. accumulation of required design data and application of the data to the design equations. The nature of data and particular form of design equations depend on the processing operation, nature and properties of materials being processed, and on the type and form of processing equipment unit. These factors are often interdependent so that the type of processing operation, for example, can suggest the types of equipment that can be used. In general a fundamental design equation for a transformation process can be written in form of a rate equation. The equation shows the rate at which chemical or physical or other processes take place. Above factors enter into the rate equation as dimensional and time factors, operating variables, physical-chemical properties, and numerical factors normally correcting for the influences of geometric shape of equipment independent of size (89).

Process design complexity for a particular unit operation derives from the relative difficulty of obtaining design data and from the complexity of the design procedure reflected by methods and effort required to solve all the design equations, given ready availability of data. For either of these tasks the level of difficulty (or complexity) varies with the number and type of simultaneous processes involved in an equipment unit's operations. For similar basic process operation equipment's process design varies according to the type and number of phases - gaseous, liquid, or solid - and of material components active in the process. Flexibility of equipment operation 'mode' means that an operation can be designed to be in one of a number of equipment modes, i.e. it could be designed as a single stage operation, as a series of single stage operations, as continuously interfacial contacting phases, or as a multistage operation all in one equipment unit. This can also influence process equipment design complexity. In mathematical language:

Equipment unit's design complexity = $f\left[f_1(\text{Complexity due to data availability}),\right.$
$\left.f_2(\text{Complexity due to design procedure demand})\right]$

and $f, f_1, f_2 = f_i(op, np, cm, qm)$, $i = 1, 2$

where:

op denotes type of process(es) involved.
np denotes number of material phases.
cm denotes number of active material components.
qm denotes type and 'mode' of equipment.

The required data and information for design of various equipment units has not yet been generalised and the number of possible equipment configurations is so large that the above formulations of f_i and f_2 can have only qualitative meaning.

As was the case with aspects relating to equipment units engineering and fabrication the two factors are assumed to be vectors which when combined give a resultant equipment unit complexity level, with respect to process design, given by:

$$ED_i = \sqrt{\frac{1}{2}\left[(DT_i)^2 + (DP_i)^2\right]} \qquad (6.5)$$

and:

$$1 \leq ED_i \ , \ DT_i \ , \ DP_i \leq 5 \qquad i = 1, 2, ... \qquad (6.6)$$

where:

ED_i = complexity level of unit i with respect to unit process design considerations.
DT_i = complexity level of equipment unit i with respect to availability of design data in the open literature.
DP_i = complexity level of equipment unit i with respect to design procedures.

Procedure for obtaining numerical values for the above variables is suggested in the following section.

6.II.A Process Design Complexity Level for an Equipment Unit with Respect to Data Availability

The interpretation of process design complexity in terms of facility of obtaining data for design and of the design procedure means that all types of equipment can be assessed on the same basis. Although the amount of data required for design varies between equipment types some general data, such as physical properties of pure substances, can reasonably be assumed to be readily available. In design, specific data dependent on the process operation and equipment is also needed and it is this sort of data which is of concern, i.e. specific data that constitute part of the basic design relations. Method for evaluating data availability level is suggested as follows,

Data Level 0 — When design data can be obtained in the open literature in form of generalised correlations of high accuracy according to reputable authorities in the field. High accuracy is defined as within an error range of ± 20% between the correlations or theoretical predictions and experimental results for industrial equipment.

Data Level 1 — When open literature generalised correlations or predictive methods for data can be in error by over ± 20% but less than ± 60% or specific correlations are available covering a wide range of commonly encountered situations, e.g. data for most types of tower packings, and where the correlations are accurate to within ± 30%.

Data Level 2 — Where data have been correlated for only a few special cases or where general correlations and predictive methods are available but of doubtful accuracy.

Data Level 3 — Where the required data are so specific that the designer must evaluate them from own experimental or pilot-plant studies: or where design data for equipment

are hardly available in the open literature.

The design parameters considered important with respect to data availability and under which the equipment design data availability is evaluated are:

1. The mass transfer coefficients or their equivalents,

2. Overall heat transfer coefficient or its film resistances equivalents.

3. The chemical reaction rate constants.

4. Data for evaluation of relations governing the physical behaviour of the materials in the equipment unit, under 'static' conditions, e.g. the equilibrium behaviour of gas-liquid systems, or the pressure-volume-temperature curves for a given substance.

5. Data for evaluation of relationships relative to pressure drop due to fluid friction, and related fluid flow parameters.

6. Other data important for equipment design and which is not covered above or without an equivalent above, e.g. catalyst activity in catalysed bed reactors, or plate efficiencies in packed columns.

Where design relation requirements are not covered by the above list in most chemical engineering operations it is possible to find their equivalents. Then data complexity level is given by:

$$DT_i = f_1 = 1 + \frac{4}{3} \times \frac{1}{6} \sum_{i=1}^{6} d_k \qquad (6.7)$$

where:

$DT_i = f_1$ = equipment units design data complexity level and whose value lies between 1 and 5; i denotes equipment unit i.

d_k = data unavailability level for an aspect k of design as listed above, e.g. mass transfer coefficients, reaction constants, etc. Inclusion of all items has the effect of indicating relative 'complexity' of the equipment by number of items for which data is required. Value of d_k is $0 \geq d_k \leq 3$.

6.II.B Design Procedure Complexity Level for Equipment Unit

The effort required to carry out the design procedure - given availability of data - can constrain the feasibility of an equipment unit's design if either or both of skilled manpower availability and computing facilities are limited. In certain design problems the numerical methods of solutions to the design equations can be extremely cumbersome and time consuming without the aid of a computer. In some others, by use of graphs and simple calculating machines and a combination of analytical and numerical methods of solutions, it is practically feasible to do without a computer. Only rarely can analytical methods be used entirely in design of equipment units and then the equipment is very simple.

A suitable method for measuring the design procedure's complexity would be to find the number of computations that must be done in order to fully solve the design problem. In practice trial and error methods are almost always necessary for at least part of the design. This means that the number of computations necessary for each equipment would also vary according to the experience of the designer and the specific circumstances of the process operation. However, examination of the design procedures for common process equipment units shows that some generalisation of the factors influencing design complexity could be made.

For a given type of processing operation the equipment design complexity tends to vary with:

1. The 'mode' of process operation for which the equipment is designed. Thus for a distillation process operation, equipment design for operation of flash distillation is much simpler than the design for multistage distillation in a plate separation column. Similarly, single stage equipment design for extraction processes is easier than the design for several extraction units operating in series.

2. The number of material phases in contact and actively involved in the process operations. Thus design procedures for a homogeneous phase chemical reaction involves less work than for heterogeneous chemical reactions.

3. The number of material components taking part in the process operations, e.g. binary distillation design methods involve simple computation methods compared to design methods for multicomponents (> 3) distillation. Again in chemical reaction processes, ease of integration of the rate equations depends on the number of reactants influencing the reaction.

4. The number of physico-chemical transformations, i.e. operations taking place in the equipment unit and included in the design work. Thus, calculations and data requirements for heat transfer in a single shell-single tube exchanger where only conductive and convective heat transfer modes are involved are simpler and fewer than for design of a simple furnace where convective, conductive, and radiative heat transfer modes are involved as well as the chemical reactions for the burning fuel.

Accordingly, the design procedure complexity level, f_2, based on the above observations can be evaluated for an equipment unit i by:

$$DP_i = f_2 = \frac{5}{3} \times \frac{1}{4} \sum_{k=1}^{4} p_k \qquad (6.8)$$

Thus:

$$1 \leq f_2 = DP_i \leq 5 \qquad (6.9)$$

where:

p_k = design level with respect to a single item k, where the items are (1) through to (4) above, i.e. mode of equipment, number of phases, etc.

DP_i = complexity level of equipment i with respect to units process design procedure.

Value of p_k is equal to either 1, 2 or 3 for each p_k assigned as follows:-

1. For equipment operation mode, assignment of value to p_1 is made according to the criteria:

   $p_1 = 0$, for vessels without packings.

   $p_1 = 1$, for equipment unit equivalent to a single stage unit such as a flash drum, a single stage compressor, a single stirred tank reactor, etc.

   $p_1 = 2$, for multistaged equipment consisting of single stage units connected in series, e.g. multipasses, multi-tubular shell and tube heat exchangers, a battery of multiple effect evaporators, etc.

   $p_1 = 3$, for equipment designed for continuous contacting of phases through numerous packings or equivalent, such as multistaged contacting distillation columns: or for equipment incorporating more than two different units under the same casing which could exist as autonomous processing units elsewhere in the processing system, e.g. tray dryers where the dryer is assembled by use of a blower, a heater, and trays on a cabinet all enclosed in the same casing.

2. For the number of phases in contact and actively involved in process operations, value of p_2 is given by:

   $p_2 = 1$, for single phase process operations.

   $p_2 = 2$, for two-phase or three-phase processes.

   $p_2 = 3$, for more than three phases actively participating in the process.

   N.B. Catalyst bed counts as one phase.

3. For the number of active material components p_3 is given by:

   $p_3 = 1$, for up to 3 components including temperature as a component where temperature changes cannot be ignored

such as in adiabatic reaction processes, separation processes, etc.

$p_3 = 2$, for 4 - 5 active components including temperature.

$p_3 = 3$, for greater than 5 active components.

Pressure changes are common to most flow processes as pressure drop. Where pressure changes due to the nature of process operation, e.g. in chemical reactions or in heat transfer processes, the changes are very simply handled by the simple gas relations. Pressure is thus ignored.

4. For physico-chemical transformations, the most common in process engineering are the following processes:-

(i) Heat transfer processes.

(ii) Interfacial physical mass transfer processes between phases.

(iii) Chemical reaction processes.

(iv) Phase separation processes utilizing phenomenon of flow through obstacles, e.g. filteration operations.

(v) Momentum transfer processes between fluid phases and mechanical devices such as in mixing, compression, and turbine operation processes.

(vi) Momentum transfer between mechanical devices and solid phase or phases as in crushing and grinding operations.

In most processes more than one process operations take place and for design purposes some operations can be ignored. Thus, in physical mass transfer processes some heat transfer takes place as well. However, there are cases when the thermal effects can be ignored in equipment design. In considering

the number of process operations involved in equipment design only the dominant and significant ones should be considered. Values of p_4 can then be assigned as follows:-

$p_4 = 0$, for operations in simple vessels eg. storage or phase separation.

$p_4 = 1$, for one dominant process operation.

$p_4 = 2$, for two or three dominant process operations taking place simultaneously.

$p_4 = 3$, for more than three dominant process operations taking place simultaneously.

By using the procedures of Sections 6.II.A and B, numerical values can be assigned to DT_i and DP_i and thus from Equation (6.5) to ED_i, where i denotes an equipment unit. In Appendix A.6.II illustrations of the application of the above procedure to some of the most common and industrially important equipment are given for clarification of the procedure.

6.III Processing System's Design Complexity

In processing systems, flowsheeting of the energy and material balances constitutes a major part of the preliminary design work. These flowsheets are also in constant use when the system is operating. Further work specific to the system as a whole stems from economic considerations which dictate that the system be optimised so as to minimise overall equipment capital and operating costs while maximising production of the desired products.

During the system's (plant's) operation the performance of the individual units is monitored and the 'debottlenecking' of the system often involves consideration of the system as a whole. Because uncertainty in equipment design cannot be completely removed a priori, debottlenecking work is unavoidable even in the best designs. This work often leads to equipment modifications or replacement.

Systems can be of a type (a) where all units are connected in series, (b) where units are connected in recycle loops and (c), a mixture of (a) and (b). Systems with serially connected units are acyclic systems and the other type of systems can be referred to as recycling systems.

Complexity of tasks involved in systems design and operation is greatly influenced by the number of units in the system and the number, type and nature of interconnections between the units in the system. The influences of these factors is demonstrated in Appendix A.6.III.

A. Acyclic Systems

It can be shown that for an acyclic system, optimisation procedure using dynamic programming techniques involves a number of computations given by:

$$C_{ompta} = \sum_{i=1}^{N-1} \left[t_s^{s_{i+1}} \cdot t_d^{D_i} \right] + t_d^{D_N} \qquad (6.10)$$

where,

N = number of units in the system.

s_i = number of state variables constituting information flows between units i and $(i + 1)$.

t_s, t_d = number of trial points that adequately span the range of each of the state variables and design variables respectively.

D_i = number of design variables for unit i.

State variables are those variables in a unit reflecting the operation of the process in the unit and which are dependent on the operation's nature, e.g. concentration of components and temperature of exit stream from a unit. Design variables are those variables that the designer or plant operator is free to manipulate in optimising process operation or system design, e.g. amount of heating area of an exchanger, or coolant rate, or equipment pressure, etc. Each unit offers its own design variables. State and design variables can in some cases be interchangeable.

The number of state variables will depend on such factors as the number of components participating in a unit's processing operation, the number of phases involved, and the type of the operation and of equipment unit used. Similarly, design variables applicable to a unit depend on the equipment unit considered. These factors in turn influence the number of trial and error increments necessary to obtain a satisfactory answer to the optimisation problem. In considering individual unit's complexity level with respect to design procedure (Section 6.II.B), it is essentially these factors that are taken into account. Thus for equipment unit denoted by i, in an acyclic system the complexity level of the equipment with respect to its design procedure, DP_i, could be considered proportional to the number of trial points in a search and to the number of variables to be searched, or:

$$DP_i \alpha t^{s_{i+1}} . t_d^{D_i} \tag{6.11}$$

and for the Nth equipment unit in the acyclic system of N units:

$$DP_N \alpha t_d^{D_N} \tag{6.12}$$

By comparison with Equation (6.13), the complexity of design of the acyclic system with N units is seen to be reflected by a number C_{xya}, given by:

$$C_{xya} = \sum_{i=1}^{N-1} DP_i + DP_N \qquad \text{or}$$

$$C_{xya} = \sum_{i=1}^{N} DP_i \tag{6.13}$$

where by definition, $1 \leq DP_i \leq 5$, and therefore $C_{xya} \geq 1$.

B. Recycling Systems

For a recycling system, the computation load is further increased due to the fact that the whole system must be optimised as a single 'unit' by direct search methods. Dynamic programming techniques whereby sequential optimisation of each unit in the system is sufficient to optimise the whole system cannot be applied. It has been observed (90) that the difficulty of search for an optimum using direct search method for a unit or system treated as a unit varies according to the Equation:

$$W_{DS} = a\ (b)^y \tag{6.14}$$

where:

W_{DS} = number of trials required to isolate the optimum.
y = number of variables being searched.
a = parameter whose value depends on the efficiency of the "search plan".
b = parameter whose value depends on the nature of the problem to be solved.

Considering a recycling system of N units with v_i variables being searched per unit i, the above equation takes the form of:

$$W_{DS} = a \left[b_1^{v_1} \times b_2^{v_2} \times b_3^{v_3} \ldots\ldots b_N^{v_n} \right] \tag{6.15}$$

where b_i is taken as number of trials adequately spanning each variable v_{ij} ($j = 1, 2, \ldots.$) for unit i, i.e.,

$$W_{DS} = a \prod_{i=1}^{N} b_i^{v_i} \tag{6.16}$$

Thus taking $b_i^{v_i}$ as directly proportional to a single unit's complexity level with respect to design procedure, i.e.,

$$b_i^{v_i} \alpha DP_i \tag{6.17}$$

the complexity of a recycling system with respect to system's design procedure is seen to be reflected by a number C_{xyr}, given by:

$$C_{xyr} = \prod_{i=1}^{N} DP_i \quad , \quad 1 \leq DP_i \leq 5 \tag{6.18}$$

C. Any System

In practice systems have recycling and acyclic elements in them. The overall complexity of system design in such cases can then be reflected by a number C_{xym}, given by:

$$C_{xym} = \sum_{k=1}^{K} DP_k + \sum_{j=1}^{R} \prod_{i=1}^{n_j} DP_{ij} \tag{6.19}$$

where:

subscript k denotes unit k (= 1, 2 ....) outside any recycle loops,
subscript i denotes unit i (= 1, 2 ....) inside the jth recycle loop in the system.

n_j = total number of equipment units in the jth recycle loop.
K = total number of equipment units outside recycle loops.

D. Processing Systems Design Complexity in Terms of Complexity Levels

Considering several recycling systems each containing N equipment units of the same complexity level DP_i, and where both N and DP_i are variables, the number C_{xyr} reflecting the complexity of a system, with respect to its design procedure, can be computed as shown on Table 6.23 where the elements in the matrix represent C_{xyr} for systems defined by the (N, DP_i) coordinates.

As would be expected, the value of C_{xyr} increases very rapidly with the number of units for higher values of DP_i and vice versa. A similar general trend but with much lower values would be obtained if the computations were repeated for the acyclic systems.

The above values can be used to give a translation of a processing

TABLE 6.23

N \ DP_i	1	2	3	4	5
	System Complexity Reflecting Number C_{xyr}				
1	1	2	3	4	5
2	1	4	9	16	25
3	1	8	27	64	125
4	1	16	81	256	625
5	1	32	243	1,024	3,125
6	1	64	729	4,096	15,625
7	1	128	2,187	16,384	78,128
8	1	256	6,561	65,536	390,625
9	1	512	19,683	262,144	1,953,125
10	1	1,024	59,049	1,048,576	.
11	1	2,048	177,147	4,094,304	.
12	1	4,096	531,441	.	.
13	1	8,192	1,594,323	.	.
14	1	16,384	.	.	.
15	1	32,768	.	.	.
16	1	65,536	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
20	1	1,048,616	.	.	.

system's complexity with respect to system's design, in terms of the five levels adopted as the basis of classifications in this work. Examination of common industrial processing systemsshows that major recycle loops rarely contain more than 7 or 8 equipment units (excluding pumps, pipes, and instruments) although the overall number of process equipment units can be in excess of 40.

For a whole processing system, with both acyclic and recycle parts, ranges of values of C_{xym} which would seem to reasonably reflect different levels of complexity of a system with respect to its design (and hence operation, research and process development) are as shown on Table 6.24. These classifications are based on Table 6.23 and some examination of number of units in typical processing systems.

TABLE 6.24

System's design complexity level	1	2	3	4	5
Range of values of C_{xym}	<100	100 - 500	500 - 1000	1000-2000	>2000

6.IV Unit Process Design Complexity Levels and Equipment Engineering and Fabrication Complexity Levels for all Units in the System

The ultimate objective for considering individual equipment units might be to be able to assess the overall complexity of the processing system with respect to its technology content. It might be considered that more useful information is gained by keeping the three 'components of technology complexity' in a system, separate.

Accordingly, the overall effect of the individual units on the complexity of the system with respect to individual equipment units engineering and fabrication (etc.) could be treated as follows:

Equipment units complexity levels with respect to engineering, etc. could be plotted against the frequency of occurrence of each level (between 1 and 5), i.e. denoting an individual equipment complexity level with respect to engineering and fabrication by EF, for any equipment unit i; and the frequency of occurrence of a level by q_{EF}, a plot of EF versus q_{EF} gives the distribution of complexity levels in the system with respect to this 'component.'

The mean complexity level with respect to equipment engineering and fabrication can, therefore, be found which could be taken as the representative complexity level for the system with respect to engineering, fabrication, maintenance, etc. difficulty.

Complexity of the system with respect to equipment unit process design can be treated similarly.

Thus mean complexity levels of the whole system with respect to:

1. Unit process design complexity;
2. Unit engineering and fabrication complexity;
3. System's design complexity,

can be accorded numerical values each lying between 1 and 5.

For any country depending on local technological capacity and on planned field of expansion, appropriate designs can be considered as those lying between two levels appropriate to that environment. For example, a country just beginning to create a local technological capacity might decide that the boundaries required are between 1 and 1 (i.e. level 1) for system design complexity; between 1 and 2 for unit process design; and between 1 and 1 for unit engineering and fabrication complexity. Another country, at a different technological infrastructure development stage, might have boundaries (2 - 3), (3 - 4), and (2 - 4) respectively.

6. V EXAMPLES OF APPLICATION OF THE ABOVE TECHNOLOGY COMPLEXITY ASSESSMENT PROCEDURE TO PROCESSING SYSTEMS

To illustrate the method of assessment of complexity of technology for processing systems, two different 'types' of technologies have been selected. These consist of technologies involved in (a) production of ammonia by steam reforming of naphtha and (b) production of organic fertilizer and methane gas by biodegradation of animal waste and, or, crop residue.

6. V.A. TECHNOLOGY OF AMMONIA PRODUCTION BY STEAM REFORMING OF NAPHTHA

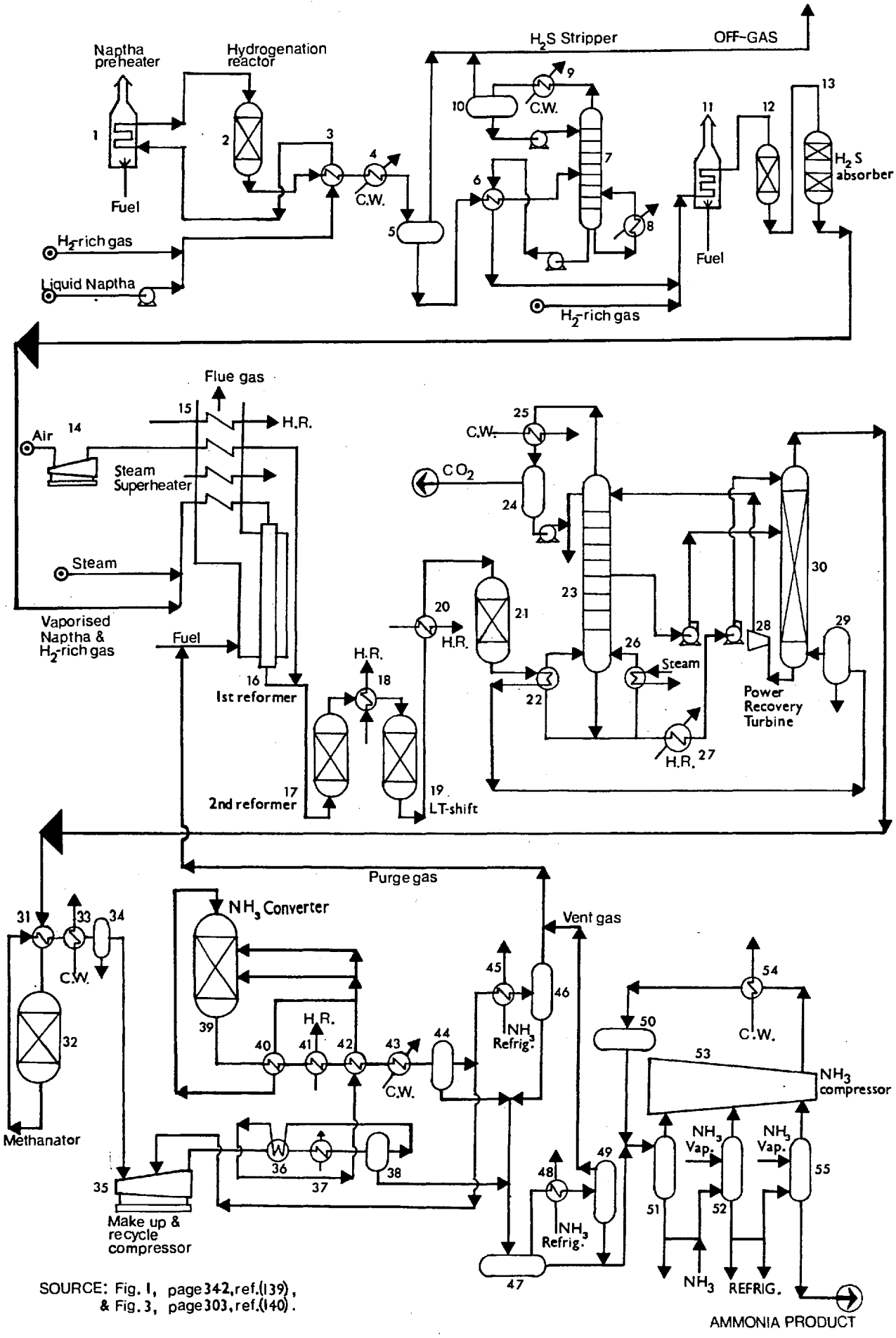
Figure 6.1 below shows a typical flowsheet for the ammonia process. For ease of reference numbers have been assigned to each unit. Slack and James (ed.) (138) give some of the data required for assessing the system's complexity e.g. temperature, pressure, type of units, etc. These data are not detailed enough to allow a very rigourous application of the procedure. Thus on the whole, heat exchangers have been assumed to be of the shell and tube type although in practice some exchangers would be of a different type. However the data given are sufficient to illustrate how the method can be used. In Table 6.25 below operating temperature and pressure data for units shown in Figure 6.1 are given. In the table, T_i and P_i denote complexity levels of unit i with respect to operating temperature and pressure respectively.

(i) Equipment Engineering and Fabrication complexity

Using the classification of operating conditions severity given in Tables 6.2, 6.4, and 6.6 and Equation (6.3), the complexity level of, a piece of equipment, i, with respect to 'operating conditions', PC_i, can be calculated. In addition, complexity levels of equipment with respect to geometry, EG_i, can be read from Tables 6.7 to 6.22. As data on equipment sizes are not available this aspect has been ignored in this rough illustration.

Application of equation 6.1 to EG_i and PC_i then gives the complexity level of equipment unit i with respect to equipment engineering,

Fig.6.1. CHEMICO FLOWSHEET FOR NH_3 PRODUCTION FROM NAPTHA



SOURCE: Fig. 1, page 342, ref.(139), & Fig. 3, page 303, ref.(140).

Table 6.25 Operating Conditions for Ammonia Process of Figure 6.1

Unit No.	Abbreviation	Temperature (^{o} C)	Pressure (psi)	T_i	P_i
1	FH 1	450-650	150-400	4	2
2	Re 1	300-450	150-400	3	2
3	Ex 1	300-450	"	3	2
4	Ex 2	150-300	"	2	2
5	Dr 1	"	"	2	2
6	Ex 3	"	"	2	2
7	PC 1	"	"	2	2
8	Ex 4	300-450	"	3	2
9	Ex 5	150-300	"	2	2
10	Dr 2	"	"	2	2
11	FH 2	450-650	"	4	2
12	Re 2	300-450	"	3	2
13	PC 2	"	"	3	2
14	Cx 1	<140	400-600	1	3
15	FH 3	>650	1500	5	4
16	Re 3	"	300-450	5	3
17	Re 4	"	"	5	3
18	Ex 6	"	1500	5	4
19	Re 5	300-450	380-460	3	3
20	Ex 7	"	"	3	3
21	Re 6	140-300	150-400	2	2
22	Ex 8	"	"	2	2
23	PC 3	<140	"	1	2
24	Dr 3	"	"	1	2
25	Ex 9	"	"	1	2
26	Ex 10	140-300	500	2	3
27	Ex 11	"	200-400	2	2
28	Cx 2	90-130	"	1	2
29	Dr 4	"	"	1	2

contd.

Table 6.25 (continued)

Unit No.	Abbreviation	Temperature (^{o} c)	Pressure (psi)	T_i	P_i
30	PC_4	90-130	200-400	1	2
31	Ex 12	300-420	200-400	3	2
32	Re 7	"	"	3	2
33	Ex 13	140-300	"	2	2
34	Dr 5	"	"	2	2
35	Cx 3	"	>2000	2	5
36	Ex 14	"	"	2	5
37	Ex 15	"	"	3	5
38	Dr 6	"	"	3	5
39	Re 8	450-600	"	4	5
40	Ex 16	"	"	4	5
41	Ex 17	"	"	4	5
42	Ex 18	140-300	"	3	5
43	Ex 19	<140	"	1	5
44	Dr 7	0-(-30)	"	3	5
45	Ex 20	"	"	3	5
46	Dr 8	"	"	3	5
47	Dr 9	"	"	3	5
48	Ex 21	"	"	3	5
49	Dr 10	"	"	3	5
50	Dr 11	"	"	3	5
51	Dr 12	"	"	3	5
52	Dr 13	"	"	3	5
53	Cx 4	"	"	3	5
54	Ex 22	0 - 30	"	1	5
55	Dr 14	0-(-30)	"	3	5

Source: References (138), (139) and (140)

fabrication, and maintenance aspects i.e. EF_i. In this case:

$$EF_i = \sqrt{0{\cdot}5\left[PC_i^2 + EG_i^2\right]} \qquad (6.20)$$

Table 6.26 below is a tabulation of the consequent values of T_i, P_i, C_i, PC_i, EG_i and EF_i for the units shown in Figure 6.1.

In order to assess the overall system's complexity it is useful to put the units into three categories viz. (a) process equipment units not included in (b) and (c); (b) heat exchange equipment excluding furnace heaters and (c) process vessels such as flash drums, storage drums etc. The mean, minimum, and maximum values of complexity levels for each of these categories can then be calculated. For the ammonia system these values are given in Table 6.27 as follows.

Table 6.27 Overall ammonia system's complexity level w.r.t. equipment engineering

Category of equipment	No. of units	Complexity Level			
		Min.	Max.	Mean for all units	Mean for 80% of units
Process equipment	19	3.2	4.6	3.6	3.5
Heat transfer equipment	22	2.7	3.6	3.1	3.0
Process vessels	14	1.7	3.0	2.6	2.5

"Mean for 80% of units" refers to the average complexity level of the units under each category, including only those with the lowest complexity levels until 80% of the units have been considered.

For the ammonia system then the overall complexity level with respect to equipment engineering, fabrication and maintenance aspects

Table 6.26 Ammonia Process' Equipment Engineering Complexity Levels

Unit No.	ABBREVIATION	T_i	P_i	C_i	PC_i	EG_i	EF_i
1	FH 1	4	2	4	3.5	3	3.2
2	Re 1	3	2	4	3.1	4	3.6
3	Ex 1	3	2	4	3.1	3	3.1
4	Ex 2	2	2	4	2.8	3	2.9
5	Dr 1	2	2	4	2.8	1	2.1
6	Ex 3	2	2	4	2.8	3	2.9
7	PC 1	2	2	4	2.8	4	3.46
8	Ex 4	3	2	4	3.1	3	3.1
9	Ex 5	2	2	4	2.8	3	2.9
10	Dr 2	2	2	4	2.8	1	2.1
11	FH 2	4	2	4	3.5	3	3.2
12	Re 2	3	2	4	3.1	4	3.6
13	PC 2	3	2	4	3.1	4	3.6
14	Cx 1	1	3	2	2.2	5	3.9
15	FH 3	5	4	2	3.9	3	3.46
16	Re 3	5	3	3	3.8	4	3.9
17	Re 4	5	3	3	3.8	4	3.9
18	Ex 6	5	4	3	4.1	3	3.6
19	Re 5	3	3	3	3.0	4	3.5
20	Ex 7	3	3	3	3.0	3	3.0
21	Re 6	2	2	3	2.4	4	3.3
22	Ex 8	2	2	3	2.4	3	2.7
23	PC 3	1	2	3	2.2	4	3.2
24	Dr 3	1	2	3	2.2	1	1.7
25	Ex 9	1	2	3	2.2	3	2.6
26	Ex 10	2	3	3	2.7	3	2.9
27	Ex 11	2	2	3	2.4	3	2.7
28	Cx 2	1	2	3	2.2	5	3.9
29	Dr 4	1	2	3	2.2	1	1.7
30	PC 4	1	2	3	2.2	4	3.2
31	Ex 12	3	2	3	2.7	3	2.9

contd.

Table 6.26 (continued)

Unit No.	ABBREVIATION	T_i	P_i	C_i	PC_i	EG_i	EF_i
32	Re 7	2	2	3	2.4	4	3.3
33	Ex 13	2	2	3	2.4	3	2.7
34	Dr 5	2	2	3	2.4	1	1.8
35	Cx 3	2	5	3	3.6	5	4.3
36	Ex 14	2	5	2	3.6	3	3.3
37	Ex 15	3	5	3	3.8	3	3.4
38	Dr 6	3	5	3	3.8	1	2.8
39	Re 8	4	5	3	4.1	4	4.0
40	Ex 16	4	5	3	4.1	3	3.6
41	Ex 17	4	5	3	4.1	3	3.6
42	Ex 18	3	5	3	4.1	3	3.6
43	Ex 19	1	5	3	3.4	3	3.2
44	Dr 7	3	5	3	4.1	1	3.0
45	Ex 20	3	5	3	4.1	3	3.6
46	Dr 8	3	5	3	4.1	1	3.0
47	Dr 9	3	5	1	4.1	1	3.0
48	Ex 21	3	5	1	4.1	3	3.6
49	Dr 10	3	5	1	4.1	1	3.0
50	Dr 11	3	5	1	4.1	1	3.0
51	Dr 12	3	5	1	4.1	1	3.0
52	Dr 13	3	5	1	4.1	1	3.0
53	Cx 4	3	5	1	4.1	5	4.6
54	Ex 22	1	5	2	3.2	3	3.1
55	Dr 14	3	5	1	4.1	1	3.0

lies between level 3 and level 4 for most of the units. The proportion of the process vessels with complexity level of 1-2 is also small. For a country planning to develop local capital industry and whose technological capacity allows handling of equipment of level 1-2 the ammonia process system considered here would be inappropriate. Similarly for a country whose technological capacity can allow handling of equipment of complexity levels of 4-5, the above system would not be expected to add significantly to the available technological capacity with regard to fabrication, engineering, and maintenance aspects.

(ii) Equipment unit design and system design complexity levels

Procedure for evaluation of process design complexity level for a piece of equipment is given in Section 6.II. In this case equation 6.5 defines the complexity level of a unit i with respect to unit process design ED_i, as a function of complexity levels of the unit with respect to data availability, DT_i, and design procedure DP_i. Section 6.II.B gives the procedure for enumeration of DP_i and in Appendix A.6.II can be found generalized values of DP_i which are used in this example.

Table 6.28 below summarizes the values of the above variables for the ammonia system shown in Figure 6.1. The overall complexity of the system with regard to individual units design can be easily done as for units engineering, fabrication and maintenance aspects above.

In order to evaluate the overall processing system's design complexity it is necessary to isolate design loops which give rise to the system's interactions of a recycling nature. Using the unit design complexity levels, ED_i, given in Table 6.28 below and denoting a design recycle loop by

$$\left[\text{unit } i, j, 1\right]$$

the 'complexity reflecting number' for the loop, C_{xyrk}, is given as before by

$$C_{xyrk} = C_{xyrk}\left[i, j, 1 \ldots\right] = \prod ED_{ik} \qquad (6.19)$$

For the ammonia system of Fig. 6.1 these are calculated as follows:-

Table 6.28 Equipment Unit Design Complexity Levels for the Ammonia System

Unit Number	Abbrev-iation	p_1	p_2	p_3	p_4	$DP_i = \frac{5}{12} \cdot \sum p_k$	DT_i	$ED_i = \sqrt{(DP_i^2 + DT_i^2)}$
1	FH 1	1	2	1	2	2.5	3	2.8
2	Re 1	3	2	2	2	3.8	4	3.9
3	Ex 1	1	1	1	1	1.7	2	1.9
4	Ex 2	1	2	1	1	2.1	2	2.1
5	Dr 1	0	2	1	0	1.3	1	1.2
6	Ex 3	1	2	1	1	2.1	2	2.1
7	PC 1	3	2	1	1	2.9	3	3.0
8	Ex 4	1	2	1	1	2.1	3	2.6
9	Ex 5	1	2	1	1	2.1	2	2.1
10	Dr 2	0	2	1	0	1.3	1	1.2
11	FH 2	1	2	1	2	2.5	3	2.8
12	Re 2	3	2	2	2	3.8	3	3.4
13	PC 2	3	2	1	2	3.3	3	3.2
14	Cx 1	2	1	1	1	2.1	1	1.6
15	FH 3	2	2	1	1	2.5	3	2.8
16	Re 3	3	2	3	2	4.2	4	4.1
17	Re 4	3	2	3	2	4.2	4	4.1
18	Ex 6	2	2	1	1	2.5	2	2.3
19	Re 5	3	2	2	2	3.8	4	3.9
20	Ex 7	2	2	1	1	2.5	2	2.3
21	Re 6	3	2	2	2	3.8	4	3.9
22	Ex 8	1	2	1	1	2.1	2	2.1
23	PC 3	3	2	1	2	3.3	3	3.2
24	Dr 3	0	2	1	0	1.3	1	1.2
25	Ex 9	1	2	1	1	2.1	2	2.1
26	Ex 10	1	2	1	1	2.1	3	2.6
27	Ex 11	1	2	1	1	2.1	2	2.1
28	Cx 2	1	1	1	1	1.7	2	1.9
29	Dr 4	0	2	1	0	1.3	1	1.2
30	PC 4	3	2	1	2	3.3	3	3.2
31	Ex 12	2	1	1	1	2.1	2	2.1
32	Re 7	3	2	2	2	3.8	4	3.9
33	Ex 13	1	2	1	1	2.1	2	2.1

contd.

Table 6.28 (contd.) Equipment Unit Design Complexity Levels for the Ammonia System

Unit Number	Abbrev-iation	p_1	p_2	p_3	p_4	$DP_i = \frac{5}{12} \cdot \sum p_k$	DT_i	$ED_i = \sqrt{(DP_i^2 + DT_i^2)}^{\frac{1}{2}}$
34	Dr 5	0	2	1	0	1.3	1	1.2
35	Cx 3	2	1	1	1	2.1	1	1.6
36	Ex 14	2	1	1	1	2.1	2	2.1
37	Ex 15	1	2	1	1	2.1	2	2.1
38	Dr 6	0	2	1	0	1.3	1	1.2
39	Re 8	3	2	2	2	3.8	4	3.9
40	Ex 16	2	1	1	1	2.1	2	2.1
41	Ex 17	1	2	1	1	2.1	2	2.1
42	Ex 18	2	1	1	1	2.1	2	2.1
43	Ex 19	1	2	1	1	2.1	2	2.1
44	Dr 7	0	2	1	0	1.3	1	1.2
45	Ex 20	2	2	1	1	2.5	2	2.3
46	Dr 8	0	2	1	0	1.3	1	1.2
47	Dr 9	0	2	1	0	1.3	1	1.2
48	Ex 21	2	2	1	1	2.5	2	2.3
49	Dr 10	0	2	1	0	1.3	1	1.2
50	Dr 11	0	2	1	0	1.3	1	1.2
51	Dr 12	0	2	1	0	1.3	1	1.2
52	Dr 13	0	2	1	0	1.3	1	1.2
53	Cx 4	2	1	1	1	2.1	1	1.6
54	Ex 22	1	2	1	1	2.1	2	2.1
55	Dr 14	0	2	1	0	1.3	1	1.2

1. $C_{xyr1}\ [1,2,3] = (3.9)(2.8)(1.9) = 21$

2. $C_{xyr2}\ [6,7,8,9] = (2.1)(3.0)(2.6)(2.1) = 34$

3. $C_{xyr3}\ [11,12] = (2.8)(3.4) = 10$

4. $C_{xyr4}\ [14,15,16,17] = (1.6)(2.8)(4.1)(4.1) = 75$

5. $C_{xyr5}\ [21,22,23,24,25,28] = (3.9)(2.1)(3.2)(1.2)(2.1)(1.9) = 125$

6. $C_{xyr6}\ [30,31,32] = (3.2)(2.1)(3.9) = 26$

7. $C_{xyr7}\ [35,36,37,38,39,40,41,42,43,44]$
$= (1.6)(2.1)(2.1)(1.2)(3.9)(2.1)(2.1)(2.1)(2.1)(1.2) = 306$

8. $C_{xyr8}\ [50,51,52,53,54,55] = (1.2)(1.2)(1.2)(1.6)(2.1)(1.2) = 15$

For units outside design recycle loops

9. $C_{xya}\ [4,5,10,13,18,19,20,26,27,29,33,34,43,44,45,46,47,48,49]$
$= 2.1+1.2+1.2+3.2+2.3+3.9+2.3+2.6+2.1+1.2+2.1+1.2+2.3$
$+1.2+1.2+2.3+1.2+2.1+1.2 = 38$

Thus the overall complexity of the system in terms of C_{xym} is:

$C_{xym}\ [\text{Ammonia}] = 21+34+10+75+125+26+306+15+38 = 650$

From Table 6.24 it can be seen that the complexity level of the ammonia system with respect to system's design is equal to 3.

If the ammonia plant forms part of a 'complex' of processing plants for fertilizer production, it can be seen that the complexity level of the whole 'complex' can only lie between 3 and 5. Returning to the ammonia system of Figure 6.1 the results of the above calculations would indicate whether or not the system's technological complexity lies within the appropriate levels with regard to development of local technological capacity in process systems design and to growth of a local capital goods industry.

6.V.B. TECHNOLOGY OF A SYSTEM FOR PRODUCTION OF METHANE AND FERTILIZER FROM BIOMASS, CROP RESIDUE, ETC.

As with the case of the ammonia system only a rough treatment of this system is given. A simplified flowsheet for a possible "community scale" plant for production of methane, fertiliser and carbon dioxide from biomass, crop residue, and, or animal waste is shown on Fig. 6.2 below. The scheme for the fermentation section of the flowsheet is taken from Pyle (141 and 142) and the gas purification section is adapted from a carbon dioxide removal process given in Kohl and Riesenfeld (143). Data on operating conditions are based on the data reported in the above cited literature. These are summarised in Table 6.29 as follows:-

Table 6.29 "Biogas" plant operating conditions.

Unit Number (fig. 6.2)	Temperature ^{o}C	Pressure psi
1	10 - 30	15 - 30
2	30 - 70	15 - 30
3	30 - 70	15 - 30
4	30 - 70	15 - 30
5	30 - 70	15 - 30

Unit No.	Temperature ^{o}C	Pressure psi
6	30 - 70	200-400
7	30 - 70	200-400
8	30 - 70	200-400
9	30 - 70	15

Complexity levels of individual pieces of equipment with respect to equipment engineering, etc., and their complexity levels with respect to unit process design aspects can be assessed in the same way as in the case of the ammonia system above. The results for complexity levels with respect to engineering etc., are given in table 6.30 and those for complexity levels with respect to unit process design are given in table 6.31 as follows.

FIG. 6. 2. A PROCESS SCHEME FOR BIODEGRADATION OF BIOMASS, CROP RESIDUE AND ANIMAL WASTE.

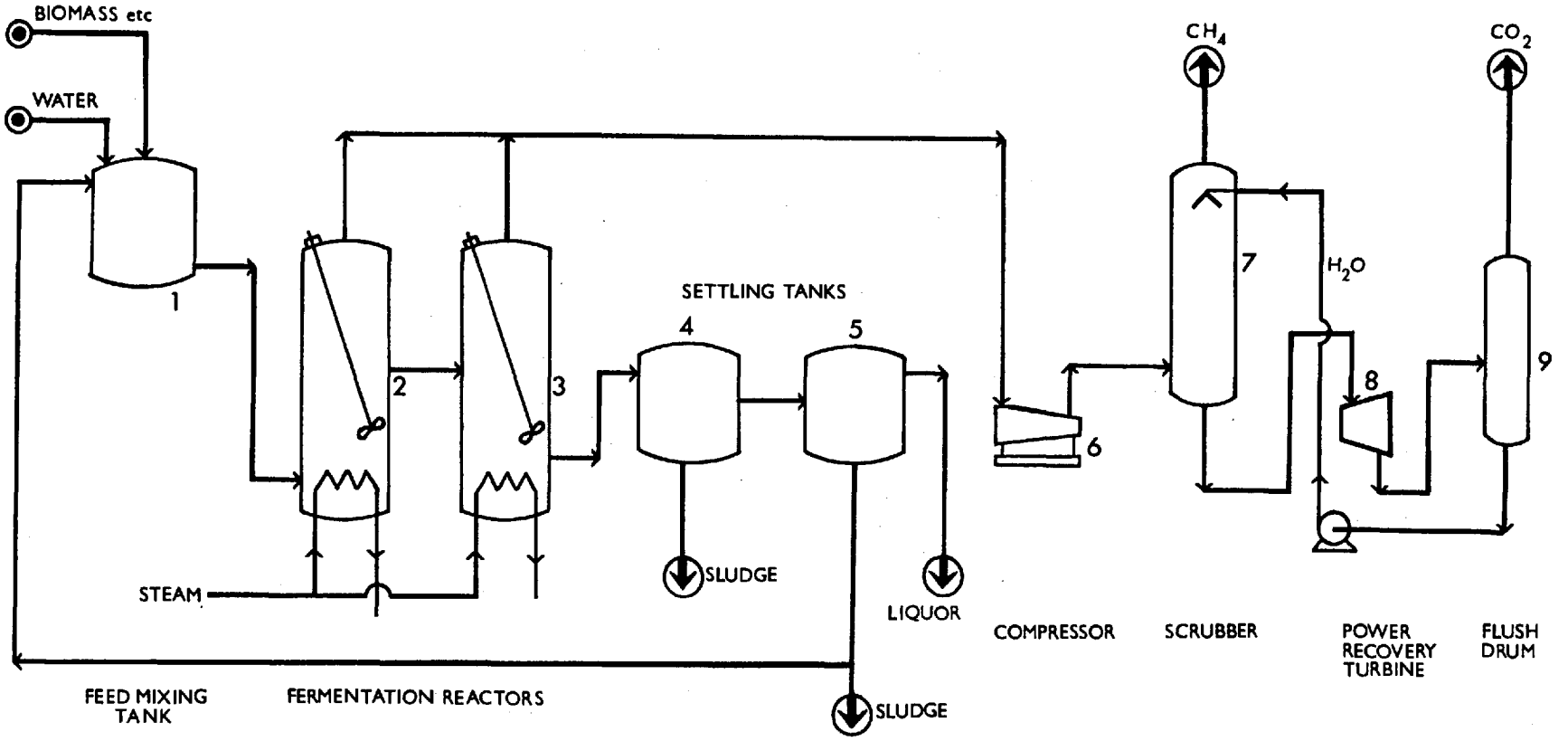


Table 6.30 Unit's Complexity Level with respect to Engineering, etc.

Unit No.	T_i	P_i	C_i	$PC_i=\sqrt{\frac{1}{3}(T_i^2+P_i^2+C_i^2)}$	EG_i	$EF_i=\sqrt{\frac{1}{2}(PC_i^2+EG_i^2)}$
1	1	1	2	1.4	1	1.2
2	1	1	3	1.9	2	2.0
3	1	1	3	1.9	2	2.0
4	1	1	2	1.4	1	1.2
5	1	1	2	1.4	1	1.2
6	1	2	3	2.2	5	3.9
7	1	2	3	2.2	3	2.6
8	1	2	3	2.2	4	3.2
9	1	1	-	1	1	1

Table 6.31 Unit's Complexity Level with respect to Unit Process Design.

Unit No.	p_1	p_2	p_3	p_4	$DP_i=5/12\sum p_k$	DT_i	$ED_i=\sqrt{\frac{1}{2}(DP_i^2+DT_i^2)}$
1	0	2	1	0	1	1	1
2	1	2	2	2	2.9	2	2.5
3	1	2	2	2	2.9	2	2.5
4	0	1	1	0	1	1	1
5	0	1	1	0	1	1	1
6	1	1	1	1	1.7	1	1.4
7	2	2	1	1	2.5	1	1.9
8	1	1	1	1	1.7	1	1.4
9	0	2	1	0	1	1	1

From table 6.30 the overall characteristics of the system with regard to the systems equipment engineering, fabrication and maintenance aspects can be seen to be as shown in table 6.32.

Table 6.32

Equipment Category	No. of Units	Complexity Level			
		For Category			For 80% of Category
		Max.	Min.	Mean	Mean
Process Equipment	5	3.9	2.0	2.7	2.5
Process Vessels	4	1.2	1	1.2	1.1

Using tables 6.31 and 6.24 and the procedures used for the ammonia plant the overall complexity of the "biogas" plant with respect to system design is given by:

$$C_{xyr1}\left[1,2,3,4,5\right] = 1^3 \times 2.5^2 = 7.3$$

$$C_{xyr2}\left[6,7,8,9\right] = 1.4 \times 1.9 \times 1.4 \times 1 = 3.7$$

Thus

$$C_{xym} = 11$$

and so the overall system's design complexity is of level 1.

Comparing the two processing systems it is seen that in terms of complexity levels with respect to overall system design the ammonia plant is shown to be at a much higher degree of sophistication than that of the biogas plant. The proposed method of assessment thus yields results which are meaningful - based on these two examples.

The above calculations also depict the higher degree of sophistication of the ammonia plant relative to the biogas plant with regard to equipment engineering, fabrication, and maintenance needs for the individual units and the system as a whole. In case of the overall system equipment engineering etc., the procedure for setting a

system's complexity level needs to be in some way related to the number of units in the system. The reason for this becomes obvious when one considers two systems: one with, say, 50 units whose average complexity level is, say, 3 but containing 10 units each of complexity level 5 and another with only 10 units whose average complexity level is 3. Most process equipment units are unique - except for standby and parallel units - and as a first step, it can be considered that a system with a given number of units, is more complex than another with fewer number of units but same average complexity level with respect to equipment engineering, fabrication and maintenance requirements. In cases of choice between specified alternatives this information could be adequate provided that the systems are within the band of complexity levels appropriate to that environment.

These illustrations indicate that the proposed method could be practical even when applied without detailed information. There is need, however, to test it with several other processing systems in order to fix the boundaries more confidently and for purpose of refinement.

7.I Reorientation of Choice of Investment Projects and Technology in Developing Economies

The results of this work suggest that growth of a process industry using sophisticated technology and under conditions such as those existing in Kenya in 1976 would not significantly contribute to the welfare of the nation as a whole in terms of generation of immediate national income; creation of immediate adequate direct employment relative to the capital employed; stimulation of growth of a capital goods industry or an intermediate goods industry; or in terms of an effective transfer of production technology and of stimulation of growth of a local comprehensive process technology capacity. It is also suggested that growth of such an industry at a desirable rate would not be feasible from financial considerations.

In general, therefore, continued investment in production technology on the basis of:-

(a) considerations of small domestic markets in the modern sector of a developing economy, which constrains the technology that must be used to meet its product specifications and thereby creating the need for dependency on foreign firms for technology expertise, management, and marketing functions;

(b) considerations of export markets which again constrain the technology to be used and again enhances dependency as in (a);

(c) foreign firms or expatriate control of production facilities' function in management, technology, and marketing;

(d) import of technology at the investment stage followed by continued imports of maintenance equipment and services;

would perpetuate a state of 'underdevelopment', especially of the rural sector, of the whole economy. This is not a criticism of the technology per se, or even of some elements of imports of technology. The evidence of the role of technology in creating wealth in the highly industrialised countries is much too obvious to be overlooked. What the observations clearly indicate is the need for developing economies to choose industrial investments on a broader basis than is evident in some cases. The over-riding consideration would then be choice of technology whose use

would:-

1. create real income for the nation but not at the expense of one sector of the economy, and,

2. facilitate genuine development of a local technological capacity - for the technology chosen - instead of enhancing technological dependency on foreign sources.

Such a reorientation of the basis for choice of technological projects would generally entail the following aspects of industrial projects.

1. A greater proportion of ownership of production facilities could be almost entirely local.

2. Project market considerations could be based on production of goods that either the majority of the country's population needs and at prices that it can afford or the local industry needs as inputs, such as equipment or intermediate chemical products.

3. The technology employed in material processing or manufacture could be at a level of complexity - or sophistication - which allows feasible creation of linkages with a latent or active process equipment industry.

4. The technology employed in material processing or manufacture could largely be designed and engineered locally, or at least have a major portion of the implementation phases of projects as local inputs other than finance and unskilled labour.

5. The manufacturing facilities could be immediately or soon after investment be controlled or largely controlled by nationals with respect to functions in management, technological expertise, and marketing.

The conditions (1) and (2) imply that the cost of production facilities must be low relative to the costs of facilities currently in use in the industrialised countries for production of similar products. This might require that the processes used for local plants be both

smaller in scale and sparing in use of sophisticated equipment or their interconnections. Conditions (3) - (5) also imply that due to shortage of experienced highly skilled manpower and in order to minimise risk of failure, technology for the processes would be of low levels of complexity so that it could be within the level of competence of, say, university graduates with little industrial experience, and that it could be operated and maintained by such other skilled manpower as fitters, technicians, etc. after a relatively short period of technical training. In connection with skilled manpower bottleneck, the local university school of engineering and other relevant faculties could be incorporated in the industrial planning scheme so that the courses taught there would involve a great deal of industrial training at the relevant technology complexity level (and types).

The suggested approach to choice of technology in the process industry raises an immediate and important problem of definition of a process or plant's technology complexity. It is clear that without a consistent and definite measure of technology 'content' of a process or of a plant in an industrial project, incorporation of a technology criterion in project appraisal could be subject to many interpretations. Such a criterion would then not be of much practical use. The first task, therefore, is to evolve a methodology for measuring technology content or complexity of processes and plants, followed by a definition of the 'content' or measure of technology that is acknowledged to be correct by decision makers for a particular developing economy. In this work a method for measuring the complexity of processing systems has been proposed.

7.II. Further Work

The work done here suggests several areas that could be worth further investigation including the following work:-

1. Development of methods of choice of industrial projects that take proper account of important externalities. Work on this is in progress at Imperial College.

2. Testing of the method proposed for assessment of complexity of industrial systems to production systems that can be used for manufacture of broadly defined products like fertilizers, sugar, cement, etc.

3. Refinement, including sensitivity analysis of some variables, of method proposed for technology assessment and its incorporation in a method for project appraisal such as that proposed by Pyle (127).

REFERENCES

1. INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT (IBDR)
"Kenya : Into the Second Decade".
World Bank (1975), p. 17.

2. COOPER, C. M. and HOFFMAN, H. K.
"Developing Countries and International Markets in Industrial Technology".
Science Policy Research Unit and the Institute of Development Studies, Sussex (November, 1977).

3. UNCTAD
"Guidelines for the Study of the Transfer of Technology to Developing Countries".
TD/B/AC.11/9, UNCTAD (1972).

4. STEWART, F.
"Technology and Underdevelopment".
MacMillan (1977).

5. UNCTD
"Major Issues in Transfer of Technology to Developing Countries : A Case Study of the Pharmaceutical Industry".
TD/B/C.6/4, (October, 1975).

6. LAL, D.
"Appraising Foreign Investments in Developing Countries".
Heinemann (1975).

7. TEECE, D. J.
"Technology Transfer by Multinational Firms : The Resource Cost of Transferring Technology Know-How".
The Economic Journal, 87, (June, 1977), pp. 242 - 261.

8. SCHUMACHER, E. F.
"Small is Beautiful".
ABACUS (1974), p. 27.

9. UNIDO
"Guidelines for Project Evaluation".
UN (1972), Publ. No. LD/SER H/(2).

10. LITTLE, I. M. D. and MIRRLEES, J. A.
"Project Appraisal and Planning for the Developing Countries".
Heinemann (1974).

11. SQUIRE, L. and VAN DER TAK, H. G.
"Economic Analysis of Projects".
John Hopkins (1975).

12. IRVIN, G.
"Modern Cost Benefit Methods : Financial, Economic and Social Appraisal".
Institute of Social Studies, The Hague (1976).

13. GUTIERREZ-DURAN, H.
"Studies on the Effects of Social Profitability Criteria on Optimum Process Design".
Ph. D. Thesis, University of London (1977).

14. PETERS, M. S. and TIMMERHAUS, K. D.
"Plant Design and Economics for Chemical Engineers".
2nd Edition (1968), pp. 17 - 18.

15. THE INSTITUTION OF CHEMICAL ENGINEERS
"A Guide to Capital Cost Estimation and Notes on Project Evaluation".
I. Chem. Engr., London (1969).

16. FRUMERMAN, R.
"Profitable Plants: Construction and Operation".
Chem. Eng. 69, (April 16, 1962), p. 133.

17. UNCTAD
Op. Cit., p. 20.

18. STEWART, F.
Op. Cit., p. 119.

19. STEWART, F.
Quoted by: Pyle, D. L., Imperial College, London (1979).

20. GRIFFIN, K. B. and ENOS, J. L.
"Planning Development".
Edidison-Wesley (1970).

21. STEWART, F.
Op. Cit., pp. 52 - 53.

22. See, for example, JONES, H.
"Modern Theories of Economic Growth".
Thomas Nelson & Sons (1975).

23. HIRSCHMAN, A. O.
"How to Divest in Latin America".
Essays in International Finance, No. 76, (November, 1969),
(Quoted by Lal, D. Ref. (6), p. 60).

24. I.L.O.
"Manpower Aspects of Establishing Chemical Industries in Developing Countries".
ILO, Geneva, (1976), p. 30.

25. I.L.O.
Op. Cit., p. 81.

26. CENTRAL BUREAU OF STATISTICS
"Statistical Abstract: 1975"; Table 44 (b).
Ministry of Finance & Planning (Kenya).

27. CENTRAL BUREAU OF STATISTICS
"Kenya Statistical Digest"; Quarterly Review.
Ministry of Finance & Planning (Kenya), Vol. XIII, No. 3, (September, 1975), p. 12.

28. CENTRAL BUREAU OF STATISTICS
Op. Cit., "Statistical Abstract - 1975"

29. CENTRAL BUREAU OF STATISTICS
"Statistical Abstract - 1975", Table 44 (a).

30. THE PYRETHRUM BOARD OF KENYA AND THE PYRETHRUM MARKETING BOARD
"Annual Report and Accounts".
October, 1973 to September, 1974.

31. THE PYRETHRUM BOARD OF KENYA AND THE PYRETHRUM MARKETING BOARD
"Annual Report and Accounts".
October, 1974 to September, 1975.

32. THE PYRETHRUM BOARD OF KENYA AND THE PYRETHRUM MARKETING BOARD
"Annual Report and Accounts".
October, 1975 to September, 1976.

33. THE PYRETHRUM BOARD OF KENYA AND THE PYRETHRUM MARKETING BOARD
"Annual Report and Accounts".
October, 1971 - September, 1972.

34. EAST AFRICAN CUSTOMS AND EXCISE DEPARTMENT
"Annual Trade Report - 1974".

35. CENTRAL BUREAU OF STATISTICS
"Statistics Digest - Kenya".
Vol. XIV, No. 3, (September, 1976).

36. CENTRAL BUREAU OF STATISTICS
"Statistics Digest - Kenya".
Vol. XV, No. 2, (June, 1977).

37. SHREVE, R. N. and BRINK, J. A.
"Chemical Process Industries".
McGraw Hill, 4th. Edition, (1977), p. 162.

38. EAST AFRICAN CUSTOMS AND EXCISE DEPARTMENT
"Annual Trade Report - 1975".

39. EAST AFRICAN CUSTOMS AND EXCISE DEPARTMENT
"Annual Trade Report - 1976".

40. CENTRAL BUREAU OF STATISTICS, KENYA
"Statistical Abstract - 1977", Table 147.

41. EAST AFRICAN PORTLAND CEMENT CO. LTD.
Private Communication, (1977).

42. KAPLINSKY, R. and HOFFMAN, K.
"Technical Change and British Multinationals in Kenya: Some Global Considerations".
Institute of Development Studies, University of Nairobi, mimeo. (November, 1975).

43. KENYA NATIONAL TRADING CO.
Private communication, (1977).

44. CENTRAL BUREAU OF STATISTICS, KENYA
"Statistical Abstract - 1977".

45. SHREVE, R. N. and BRINK, J. A.
Op. Cit., p. 510.

46. ROBSON, R.
"Recent Developments in the World Sugar Industry".
Paper presented at a joint UNEP/UNIDO seminar on the implication of technology choice in the African sugar industry.
Nairobi, April 18 - 22 (1977).

47. CHEMELIL SUGAR COMPANY
Private communications, (1977).

48. CENTRAL BUREAU OF STATISTICS, MINISTRY OF FINANCE AND ECONOMIC PLANNING (KENYA)
"Statistical Abstract 1977", Table 77.

49. CENTRAL BUREAU OF STATISTICS
Statistical Digest Quarterly, Vol. XV, No. 2, (June, 1977), Table 23.

50. CENTRAL BUREAU OF STATISTICS, MINISTRY OF FINANCE AND ECONOMIC PLANNING
"Economic Survey - 1978", (Kenya)

51. CENTRAL BANK OF KENYA
Economic & Financial Review Quarterlies (1973).

52. SHREVE, R. N. and BRINK, I. A.
"Chemical Process Industries".
McGraw Hill, 4th Ed., (1977), p. 469.

53. SHREVE, R. N. and BRINK, I. A.
Op. Cit., p. 169.

54. DUGUID, F. and ALPINE, R.
"Energy Consumption in the Sugar Industry".
Paper presented at the UNEP/UNIDO Seminar on implications of technology choice in the African sugar industry, Nairobi, April 18 - 22, (1977).

55. HYDROCARBON PROCESSING JNL., September, 1974, p. 106.

56. INDUSTRIAL SURVEY AND PROMOTION CENTRE, KENYA
Private communication, (1976).

57. EAST AFRICAN POWER AND LIGHTING COMPANY
Private communications, (1977).

58. EAST AFRICAN POWER AND LIGHTING COMPANY
"Notes on New Tariff Structure Approved by the Ministry of Power and Communications and Introduced by EAPL in January, 1979".

59. THE PYRETHRUM BOARD OF KENYA AND THE PYRETHRUM MARKETING BOARD
"Annual Report and Account", for relevant year.

60. TURNER, T.
"Two Refineries : A Comparative Study of Technology Transfer to the Nigerian Refinery Industry".
World Dev., Vol. 5, No. 3, (1977), pp. 235 - 256.

61. BAMBURI PORTLAND CEMENT COMPANY LIMITED
"Annual Report and Accounts"
Reports for 1974 and for 1975.

62. EAST AFRICAN PORTLAND CEMENT COMPANY LIMITED
"Annual Report and Account".
Reports for 1974 and for 1975.

63. CENTRAL BUREAU OF STATISTICS
"Statistical Abstract".
Ministry of Finance & Planning, Kenya, (1975), Table 62.

64. MINISTRY OF AGRICULTURE, KENYA
"Economic Review of Agriculture".
Vol. 6, No. 4, (1974), pp. 30 - 32.

65. U.N. (1971)
"Survey of Economic Conditions in Africa".
(Quoted by Stewart (4), p. 54).

66. CENTRAL BUREAU OF STATISTICS
Statistical Abstract (1975), Table 220.

67. CENTRAL BUREAU OF STATISTICS
Statistical Abstract (1975), Table 17.

68. CENTRAL BUREAU OF STATISTICS
Statistical Abstract (1975), p. 38.

69. CENTRAL BUREAU OF STATISTICS, KENYA
"Economic Survey".
Ministry of Finance & Planning, (1977), Table 5.10.

70. IBRD
"Kenya : Into Second Decade".
World Bank, (1975), p. 12.

71. PERRY, R. H. and CHILTON, C. H.
"Chemical Engineering Handbook".
McGraw Hill, 5th Ed., (1973), Table 5.10.

72. PERRY and CHILTON
Op. Cit., pp. 25 - 30.

73. UNIDO
"Profiles of Manufacturing Establishments".
Vol. 1, UNIDO, (1967), (ID/SERE/4).

74. GITHINJI, P. M.
"Kenya's Energy Needs, Possible Supplies and Impact on the Environment".
Department of Mech. Eng., University of Nairobi, Kenya.

75. NELSON, W. L.
"How Complexity of Refinery Affects Cost of Construction".
Oil & Gas Jnl., 58, 39, (September 26, 1960), p. 216.

76. NELSON, W. L.
"What is Refinery Complexity".
Oil & Gas Jnl., 64, 10, (March, 1966), p. 93.

77. BOZOVSKY, I.
"Reliability Theory and Practice".
Prentice Hall, (1961), p. 91.

78. BRITISH STANDARDS INSTITUTE (BSI)
"British Standard : Fusion Welded Pressure Vessels for General Purposes : Carbon and Alloy Steel".
BS 1500, Part 1, (1958).

79. PERRY, R. H. (Ed.)
"Chemical Engineering Handbook".
4th Ed., McGraw Hill, (1963), pp. 23 - 27.

80. PERRY, R. H. (Ed.)
"Chemical Engineering Handbook".
4th Ed., McGraw Hill, (1963).

81. PERRY, R. H. and CHILTON, C. H.
"Chemical Engineering Handbook".
5th Ed., McGraw Hill, (1973).

82. Ref. (81), pp. 6 - 102.

83. Ref. (81), pp. 6 - 101.

84. Ref. (81), pp. 23 - 71.

85. BLACKHURST, J. R. and HARKER, J. H.
"Process Plant Design".
Heinemann Educational, (1973), p. 215.

86. AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
"Boiler and Pressure Vessel Code - 1962".
Section VIII under "Unfired Pressure Vessels".

87. KIRK and OTHMER (Ed.)
"Encyclopedia of Chemical Technology".
Vol. 16, 2nd Ed., Wiley & Sons, (1968), p. 482.

88. Ref. (80), pp. 23 - 34.

89. JOHNSTONE, R. E. and THRING, M. W.
"Pilot Plants, Models and Scale-Up Methods in Chemical Engineering".
McGraw Hill, pp. 9 - 11.

90. RUDD, D. F. and WATSON, C. C.
"Strategy of Process Engineering".
Wiley & Sons, (1968), p. 179.

91. CENTRAL BUREAU OF STATISTICS
Statistical Abstract, (1970), Table 93,

92. CENTRAL BUREAU OF STATISTICS
Statistical Abstract, (1975), Table 105(a).

93. CENTRAL BUREAU OF STATISTICS
Statistical Abstract, (1976), Table 133(a).

94. CENTRAL BUREAU OF STATISTICS
Statistical Abstract, (1977).

95. CENTRAL BUREAU OF STATISTICS
Statistical Abstract, (1970).

96. DIMOPLON, W.
"What Process Engineers Need to Know About Compressors".
Hydro. Proc. Jnl., (May, 1978), pp. 221 - 227.
97. PERRY (81), pp. 8 - 32.
98. PERRY (81), pp. 11 - 11.
99. BERMAN, H. L.
Chem. Eng. Jnl., (June 19, 1978), pp. 99 - 104.
100. PERRY (81). pp. 20 - 29.
101. PERRY (81), pp. 20 - 36.
102. BLACKHURST and HARKER
Op. Cit.
103. BLACKHURST and HARKER
Op. Cit., p. 216.
104. PERRY (81), pp. 8 - 16 to 8 - 17.
105. PERRY (81), pp. 8 - 33.
106. PETERS and TIMMERHAUS
Op. Cit., p. 542.
107. PERRY (81), pp. 10 - 25.
108. PERRY (81), pp. 10 - 19.
109. PERRY (81), pp. 10 - 31.
110. PERRY (81), p. 10.
111. PERRY (81), pp. 13 - 7.
112. PERRY (81), pp. 18 - 8.
113. PERRY (81), pp. 18 - 7.
114. PERRY (81), pp. 18 - 14.
115. TREYBAL, R. E.
"Mass Transfer Operations".
McGraw Hill, 2nd Ed., (1968), p. 369.
116. PERRY, pp. 20 - 21.
117. PERRY, pp. 4 - 34.
118. PERRY, pp. 4 - 37.
119. SMITH, J. M.
"Chemical Engineering Kinetics".
McGraw Hill, (1956), p. 288.
120. PERRY, pp. 4 - 35 to 4 - 36.
121. PERRY, pp. 4 - 16.
122. ROSEN, E. M.
"A Machine Computation Method for Performing Material Balances".
Chem. Eng. Prog., 58, 10, (1962), pp. 69 - 73.

123. RUDD and WATSON
Op. Cit., p. 45.

124. ROSEN, E. M.
Op. Cit., p. 70.

125. RUDD and WATSON
Op. Cit.

126. PYLE, D. L.
"Intermediate Technology in the Chemical Industry".
Chemistry & Industry, (April 3, 1976), pp. 286 - 291.

127. PYLE, D. L.
"Choice of Technology in Chemical and Process Industry".
Imperial College of Science & Technology, London, (1979), mimeo.

128. PETERS and TIMMERHAUS
Op. Cit., p. 96.

129. LAL, D.
Op. Cit., p. 206.

130. CENTRAL BUREAU OF STATS. (CENT. BUR. STATS.)
"Statistical Abstract" (Stats. Abst.): 1969

131. CENT. BUR. STATS.
Stats. Abst. 1974.

132. CENT. BUR. STATS.
Stats. Abst. 1971

133. CENT. BUR. STATS
Stats. Abst. 1972

134. STONE, R. and G.
"National Income and Expenditure"
10th ed., Bowes and Bowes (1977)

135. GREGG, J.V. et al
"Mathematical Trend curves: an aid to forecasting"
Monograph No. 1 : ICI (1964)

136. CENT. BUR. STATS.
"Economic Survey, 1978"

137. KENYA HIGH COMMISSION (LONDON)
"Pyrethrum board of Kenya plans to build a 1.5 million K£ factory at Nakuru".
Kenya Digest, Sept. 1972.

138. SLACK, A.V. and RUSSELL JAMES, G.
"Ammonia" Volume I.
Marcel Dekker (1973).

139. SLACK, A.V. and RUSSELL JAMES, G.
"Ammonia" Volume II
Marcel Dekker (1974).

140. SLACK, A.V. and RUSSELL JAMES, G.
"Ammonia" Volume III.
Marcel Dekker (1977).

141. PYLE, D.L.
"Energy and Fuel from Biomass" p.E6.
Paper presented at the National Energy Symposium,
Kenya, Nov. 22 - 24, 1978.

142. PYLE, D.L. et al
"Biogas Technology in the Third World" p.37
International Development Research Centre Canada (1978).

143. KOHL, A.L. and RIESENFELD
"Gas purification" p.155
McGraw-Hill (1960).

APPENDIX A.4.I.

TABLE A.4.I.1

ACTUAL DATA ON EXPORTS OF OIL PRODUCTS BY KENYA TO EAST AFRICAN COUNTRIES AND OTHERS

Oil product/ year	Kenya's Exports to Tanzania and Uganda			Kenya's Exports to other countries		
	Quantity	Value (f.o.b.) (K£)	Price	Quantity	Value (f.o.b.) (K£)	Price
LPG	mt		K£/mt	mt		K£/mt
1974	2,662.8	62,613	23.51	1,457.8	35,620	24.43
1975	2,571.5	107,685	41.88	2,290.4	160,860	70.23
1976	2,376.1	147,958	62.27	2,549.1	170,774	68.17
Motor spirit	litre x 10^3		K£/litre x 10^3	litre x 10^3		K£/litre x 10^3
1974	181,730.571	4,959,469	27.29	20,105.901	862,443	42.89
1975	177,657,686	6,638,230	37.36	26,883.666	1,494,691	55.60
1976	153,423.077	7,183,515	46.82	25,375.808	1,574,870	62.06
Jet fuel						
1974	57,087.941	998,757	17.50	147,597.355	5,995,654	40.62
1975	50,666.185	1,683,141	33.22	166,877.278	8,328,790	49.91
1976	31,760.508	1,219,590	38.40	336,515.337	16,611,827	49.36
Kerosene						
1974	66,765.229	1,339,193	20.06	14,024.763	469,169	33.45
1975	78,163.069	2,679,753	34.28	7,851.513	446,715	56.90
1976	80,879.624	4,350,550	53.79	8,660.815	526,005	60.73
Gas oil						
1974	122,703.546	2,858,186	23.29	64,166.869	1,976,602	30.80
1975	121,242.584	3,956,882	32.64	67,234.394	2,706,334	40.25
1976	110,205.606	3,993,687	36.24	67,798.209	3,453,329	50.93
Diesel oil						
1974	20,575.447	298,774	14.52	97,017.467	2,104,476	21.69
1975	14,204.975	405,704	28.56	78,365.263	2,443,910	31.19
1976	8,473.041	298,393	35.22	50,509.816	2,023,626	40.06
Fuel oil						
1974	101,098.293	1,211,547	11.98	333,357.383	5,211,755	15.63
1975	70,703.283	1,637,556	23.16	275,301.236	6,849,609	24.88
1976	56,922.014	1,623,308	28.52	114,348.309	3,794,084	33.18
Bitumen	mt			mt		K£/mt
1974	7,634.6	118,988	15.60	414.3	23,642	57.06
1975	5,936.2	168,309	28.35	3,066.8	205,023	66.85
1976	5,141.7	281,082	54.66	2,187.4	152,978	69.94
Residue				litre x 10^3		K£/litre x 10^3
1974	-	-	-	582,635.406	9,564,814	16.42
1975	-	-	-	393,032.241	9,396,826	23.91
1976	-	-	-	560,503.947	10,950,622	19.54

Source of Data: Annual Trade Report; Reference (34) for 1974
Reference (38) for 1975
Reference (39) for 1976

CALCULATIONS OF INCOME GENERATION BY FIRMS j = 1, 2, ... 5, WITH RESPECT TO PRODUCT OUTPUTS AND RAW MATERIAL INPUTS TO THE PLANTS

PYRETHRUM PROCESSING, FIRM j = 1

TABLE A.4.I.2

EXPORTED OUTPUT PRODUCTS

Product/year	Quantity, EO_{jk} (mt)	Export price, p_{Ek} (K£/mt)	Value, $(EO_{jk} \times p_{Ek})$ (K£)	Value, $EO_{jk} \times p_{Ek} \times (r_{bf} - r_{b\ell})$ (K£)
Pyrethrum Extract	EO_{11} =		$EO_{11} \times p_{E1}$	
1974	474.664		4,559,886	
1975	313.913		3,506,286	
1976	506.304		5,726,774	
Pyrethrum Powder + Flowers	EO_{12} =	p_{E2} =	$EO_{12} \times p_{E2}$	
1974	4,094.0	272	1,112,880	
1975	4,593.4	282	1,296,386	
1976	3,664.9	328	1,201,094	
Pyrethrum Marc	EO_{13} =		$EO_{13} \times p_{E3}$	
1974	6,187.7		175,187	
1975	5,076.0		181,142	
1976	1,626.2		60,645	
All products			$\sum_{k=1}^{3} EO_{1k} \times p_{Ek}$	$(r_{bf} - r_{b\ell}) \sum_{k=1}^{3} (EO_{1k} \times p_{Ek})$
1974			5,847,954	526,316
1975			4,983,814	448,543
1976			6,988,513	628,966

TABLE A.4.I.3

LOCAL RAW MATERIALS

FIRM j = 1

Raw material/year	Quantity, LR_{ji} (mt)	Domestic price, p_i (K£/mt)	'Would-be import' prices		$LR_{ji} \times (p_i' - p_i)$ (K£)
			Uncorrected p_i'' (K£/mt)	Corrected p_i' (K£/mt)	
Dry Pyrethrum Flower	LR_{11} =	p_i =	p_i'' =		
1974	13,722	292.96	330	360	919,374
1975	15,035	286.80	340	371	1,264,620
1976	14,267	310.44	350	382	1,027,224

CEMENT MANUFACTURING FIRM j = 2

TABLE A.4.I.4

DOMESTIC CONSUMPTION OF OUTPUT PRODUCT

Product/year	Quantity, DO_{21} (mt)	p''_{D1} (K£/mt)	p'_{D1} (K£/mt)	p_{D1} (K£/mt)	$(p'_{D1} - p_{D1})$ (K£/mt)	DO_{21} $(p'_{D1} - p_{D1})$ (K£)
CEMENT						
1974	156,350	15	16.35	14	2.35	367,420
1975	171,950	20	21.80	18	3.80	653,410
1976	188,440	19	20.71	16	4.71	887,550

TABLE A.4.I.5

EXPORTED OUTPUT PRODUCT

Product/year	Quantity, EO_{24} (mt)	p_{E4} (K£/mt)	$EO_{jk} \times p_{E4}$ (K£)	$EO_{jk} \times p_{E4} \times (r_{bf} - r_{b\ell})$
CEMENT				
1974	530,120	8.54	4,527,200	409,450
1975	550,410	10.93	6,016,000	541,440
1976	628,440	12.84	8,069,200	726,230

TABLE A.4.I.6

LOCAL RAW MATERIALS

FIRM j = 2

Raw material/ year	Quantity, LR_{ji} mt	$p_i^{''}$ K£/mt	$p_i^{'}$ K£/mt	p_i K£/mt	$(p_i^{'} - p_i)$ K£/mt	$LR_{ji}\ (p_i^{'} - p_i)$ K£
LIMESTONE	LR_{22} =	$p_2^{''}$ =	$p_2^{'}$ =	p_2 =		
1974	909,210	1.0	1.09	1.0	0.09	81,830
1975	956,740	2.0	2.18	2.0	0.18	172,210
1976	1,081,930	2.5	2.73	2.5	0.23	248,840
GYPSUM	LR_{23} =	$p_3^{''}$ =	$p_3^{'}$ =	p_3 =		
1974	29,210	4.2	4.58	4.2	0.38	11,100
1975	30,740	10.2	11.12	10.2	0.92	28,280
1976	34,760	14.9	16.24	14.9	1.34	46,580
All raw materials						$\sum LR_{ji}\ (p_i^{'} - p_i)$
1974						92,930
1975						200,490
1976						295,420

CEMENT MANUFACTURING FIRM j = 3

TABLE A.4.I.7

DOMESTIC CONSUMPTION OF OUTPUT

FIRM j = 3

Product/year	Quantity, DO_{31} mt	p''_{D1} K£/mt	p'_{D1} K£/mt	p_{D1} K£/mt	$(p'_{D1} - p_{D1})$ K£/mt	DO_{31} $(p'_{D1} - p_{D1})$ K£
CEMENT						
1974	170,000	15	16.35	14	2.35	399,500
1975	170,000	20	21.80	18	3.80	646,000
1976	170,000	19	20.71	16	4.71	800,700

TABLE A.4.I.8

LOCAL RAW MATERIALS

FIRM j = 3

Raw material/ year	Quantity, LR_{ji} mt	p_i'' K£/mt	p_i' K£/mt	p_i K£/mt	$(p_i' - p_i)$ K£/mt	$LR_{ji}\ (p_i' - p_i)$ K£
LIMESTONE	LR_{32} =	p_2'' =	p_2' =	p_2 =		
1974	225,160	1.0	1.09	1.0	0.09	20,260
1975	225,160	2.0	2.18	2.0	0.18	40,530
1976	225,160	2.5	2.73	2.5	0.23	51,790
GYPSUM	LR_{33} =	p_3'' =	p_3' =	p_3 =		
1974	7,234	4.2	4.58	4.2	0.38	2,750
1975	7,234	10.2	11.12	10.2	0.92	6,660
1976	7,234	14.9	16.24	14.9	1.34	9,690
All raw materials						$\sum_i LR_{ji}\ (p_i' - p_i)$
1974						23,010
1975						47,190
1976						61,480

SUGAR FACTORY FIRM j = 4

TABLE A.4.I.9

LOCAL RAW MATERIALS

FIRM j = 4

Raw material/year	Quantity, LR_{ji} mt	Domestic price, p_i K£/mt	'Import' prices, $p_i^{''}$ and $p_i^{'}$ K£/mt		$LR_{44} \times (p_4^{'} - p_4)$ K£
SUGAR CANE	LR_{44} =	p_4 =	$p_4^{''}$ =	$p_4^{'}$ =	
1974	392,300	3.09	5	5.45	925,120
1975	399,200	4.47	7	7.63	1,260,840
1976	460,900	5.23	8	8.72	1,608,890

TABLE A.4.I.10

DOMESTIC CONSUMPTION OF OUTPUT

Output product/ year	Quantity, DO_{jk} mt	Domestic price, p_{Dk} K£/mt	'Import' prices, $p_{Dk}^{''}$ and $p_{Dk}^{'}$ K£/mt		$DO_{jk} \times (p_{Dk}^{'} - p_{Dk})$ K£
REFINED SUGAR	DO_{42} =	p_{D2} =	$p_{D2}^{''}$ =	$p_{D2}^{'}$ =	$DO_{42} \times (p_{D2}^{'} - p_{D2})$
1974	39,230	126	126	137	431,530
1975	39,920	155	155	169	558,880
1976	46,090	164	164	179	691,350

TABLE A.4.I.11

EXPORTED OUTPUT PRODUCTS

FIRM j = 4

Output product/ year	Quantity, EO_{jk} mt	Export price, p_{Ek} K£/mt	$EO_{jk} \times p_{Ek}$ K£	$EO_{jk} \times p_{Ek} \times (r_{bf} - r_{b\ell})$ K£
MOLASSES	EO_{45} =	p_{E5} =	$EO_{45} \times p_{E5}$	
1974	13,720	7.83	107,430	9,670
1975	13,960	7.26	101,350	9,120
1976	16,135	34.20	551,820	49,660

FIRM j = 5

IR_{ji} = Imported raw materials, IR_{51}

TABLE A.4.I.12

Year	Quantity mt	p_i K£/mt	$IR_{ji} \times p_i$ K£	$IR_{ji} \times p_i \times (r_{bf} - r_{b\ell})$ K£
CRUDE OIL	IR_{51}			
1974	2,807,700		67,027,000	6,032,400
1975	2,825,500		86,822,000	7,814,000
1976	2,490,000		93,470,000	8,412,300

TABLE A.4.1.13

DOMESTIC CONSUMPTION OF OUTPUT PRODUCTS

Output product/ year	Quantity (unit)	p''_{Dk} (K£/unit)	p'_{Dk} (K£/unit)	p_{Dk} (K£/unit)	$p'_{Dk} - p_{Dk}$ (K£/unit)	$DO_{jk}(p'_{Dk} - p_{Dk})$ (K£)
LPG (mt)						
1974	DO_{53} = 12,400	p''_{D3} = 25.0	p'_{D3} = 27.3	p_{D3} = 41.5	−14.2	− 176,080
1975	DO_{53} = 13,400	p''_{D3} = 45.0	p'_{D3} = 49.1	p_{D3} = 66.2	−17.1	− 229,140
1976	DO_{53} = 14,700	p''_{D3} = 60.0	p'_{D3} = 65.4	p_{D3} = 70.0	− 4.6	− 67,600
Motor spirit (litre x 10^3)						
1974	DO_{54} = 311,489	p''_{D4} = 31.6	p'_{D4} = 34.4	p_{D4} = 30.5	3.9	1,214,800
1975	DO_{54} = 324,974	p''_{D4} = 40.0	p'_{D4} = 43.6	p_{D4} = 38.6	5.0	1,624,900
1976	DO_{54} = 333,553	p''_{D4} = 49.3	p'_{D4} = 53.7	p_{D4} = 55.0	−1.3	− 433,600
Jet fuel (litre x 10^3)						
1974	DO_{55} = 318,881	p''_{D5} = 20.4	p'_{D5} = 22.2	p_{D5} = 27.5	−5.3	−1,690,100
1975	DO_{55} = 377,042	p''_{D5} = 34.2	p'_{D5} = 37.3	p_{D5} = 40.8	−3.5	−1,319,600
1976	DO_{55} = 304,164	p''_{D5} = 46.2	p'_{D5} = 50.4	p_{D5} = 42.7	7.7	2,342,000
Kerosene (litre x 10^3)						
1974	DO_{56} = 68,269	p''_{D6} = 23.5	p'_{D6} = 25.6	p_{D6} = 33.0	−7.4	− 505,200
1975	DO_{56} = 70,862	p''_{D6} = 37.1	p'_{D6} = 40.4	p_{D6} = 39.1	1.3	92,100
1976	DO_{56} = 68,052	p''_{D6} = 50.5	p'_{D6} = 55.0	p_{D6} = 55.0	0.0	0
Gas oil (litre x 10^3)						
1974	DO_{57} = 297,899	p''_{D7} = 23.1	p'_{D7} = 25.2	p_{D7} = 29.4	− 4.0	−1,191,600
1975	DO_{57} = 303,718	p''_{D7} = 35.5	p'_{D7} = 38.7	p_{D7} = 33.7	5.0	1,508,600
1976	DO_{57} = 340,806	p''_{D7} = 44.6	p'_{D7} = 48.6	p_{D7} = 42.7	5.9	2,010,800
Diesel oil (litre x 10^3)						
1974	DO_{58} = 47,599	p''_{D8} = 20.0	p'_{D8} = 21.8	p_{D8} = 23.4	−1.6	− 76,200
1975	DO_{58} = 38,640	p''_{D8} = 30.0	p'_{D8} = 32.7	p_{D8} = 32.0	0.7	20,000
1976	DO_{58} = 52,609	p''_{D8} = 40.0	p'_{D8} = 43.6	p_{D8} = 42.0	1.6	84,200
Fuel oil (litre x 10^3)						
1974	DO_{59} = 437,098	p''_{D9} = 16.0	p'_{D9} = 17.4	p_{D9} = 21.4	−4.0	−1,748,400
1975	DO_{59} = 464,295	p''_{D9} = 25.0	p'_{D9} = 27.3	p_{D9} = 26.0	1.3	603,600
1976	DO_{59} = 534,010	p''_{D9} = 30.0	p'_{D9} = 32.7	p_{D9} = 33.0	−0.3	− 160,200
Bitumen (mt)						
1974	DO_{510} = 27,104	p''_{D10} = 40.0	p'_{D10} = 43.6	p_{D10} = 35.4	8.2	222,300
1975	DO_{510} = 30,200	p''_{D10} = 45.0	p'_{D10} = 49.1	p_{D10} = 31.2	17.9	540,600
1976	DO_{510} = 31,204	p''_{D10} = 55.0	p'_{D10} = 60.0	p_{D10} = 50.0	10.0	312,000
All raw materials						$\sum_{k=3}^{10} DO_{jk}(p'_k - p_k)$
1974						−3,950,500
1975						2,841,100
1976						4,087,600

TABLE A.4.I.14

EXPORTED OUTPUT PRODUCTS FOR FIRM j = 5

Output product/ year	Quantity, EO_{jk} (unit)	Export price, p_{Ek} (K£/unit)	Value, $EO_{jk} \times p_{Ek}$ (K£)	Value $EO_{jk} \times p_{Ek} \times (r_{bf} - r_{b\ell})$ (K£)
LPG	mt EO_{56} =	p_{E6} =		
1974	4,120.6	23.84	98,240	8,840
1975	4,861.9	55.23	268,520	24,170
1976	4,925.2	64.71	318,710	28,680
Motor spirit	litre x 10^3 EO_{57} =	p_{E7} =		
1974	186,958	28.84	5,391,870	485,270
1975	166,834	39.76	6,633,320	597,000
1976	157,837	48.98	7,730,860	695,780
Jet fuel	EO_{58} =	p_{E8} =		
1974	25,719	34.17	878,820	79,090
1975	35,777	46.02	1,646,460	148,180
1976	6,614	48.42	320,250	28,820
Kerosene	EO_{59} =	p_{E9} =		
1974	66,765	22.38	1,494,200	134,480
1975	81,853	36.35	2,975,360	267,780
1976	82,926	54.46	4,516,150	406,450
Gas oil	EO_{510} =	p_{E10} =		
1974	168,752	25.87	4,365,610	392,910
1975	186,165	35.35	6,580,930	592,280
1976	148,494	41.84	6,212,990	559,170
Diesel oil	EO_{511} =	p_{E11} =		
1974	117,592.9	20.44	2,403,600	216,320
1975	95,570.2	30.78	2,941,650	264,750
1976	58,982.9	39.37	2,322,160	208,990
Fuel oil	litre x 10^3 EO_{512} =	p_{E12} =		
1974	434,455.7	14.78	6,421,260	577,910
1975	346,004.5	24.53	8,487,490	763,870
1976	171,270.3	31.63	5,417,280	487,560
Bitumen	mt EO_{513} =	p_{E13} =		
1974	8,048.9	17.72	142,630	12,840
1975	8,703.0	42.90	373,360	33,600
1976	7,329.1	59.22	434,030	39,060
Export residue	litre x 10^3 EO_{514} =	p_{E14} =		
1974	582,635.4	16.42	9,566,870	861,020
1975	393,032.2	23.91	9,397,400	845,770
1976	560,503.9	19.54	10,952,250	985,700
All exports			$\sum_{k=6}^{14} EO_{5k} \times p_{Ek}$	$\sum_{k=6}^{14} EO_{5k} \times p_{Ek} \times (r_{bf} - r_{b\ell})$
1974			30,763,100	2,768,700
1975			39,304,490	3,537,400
1976			38,224,680	3,440,200

INCOME BENEFITS FROM PURCHASE OF UTILITIES - WATER

TABLE A.4.I.15

INCOME BENEFITS FROM PURCHASE OF PROCESS WATER BY FIRM j

Firm/year	Process water consumpt. m^3/annum	Rates (industrial) 0.05 x K£/m^3	Rates (public) 0.05 x K£/m^3	WUB_j K£/annum
Firm 1	U_{11} =			
1974 - 76	-	-	-	-
Firm 2	U_{21} =	u_{m1} =	u_{p1} =	
1974		1.9	3.5	−48,800
1975	6.1 x 10^5	2.1	3.9	−54,900
1976		2.4	4.4	−61,000
Firm 3	U_{31} =	u_{m1} =	u_{p1} =	
1974		0.9	2.0	−5,500
1975	1.0 x 10^5	1.2	2.5	−6,500
1976		1.5	2.9	−8,500
Firm 4	U_{41} =	u_{m1} =	u_{p1} =	
1974		0.3	1.0	−10,500
1975	3.0 x 10^5	0.4	1.2	−12,000
1976		0.5	1.4	−13,500
Firm 5	U_{51} =			
1974 - 76	-	-	-	-

INCOME BENEFITS FROM PURCHASE OF UTILITIES - ELECTRICITY

TABLE A.4.I.16

BENEFITS FROM PURCHASE OF ELECTRIC POWER BY FIRM j (K£/annum)

Firm/year	Power consumption Kwh/annum	Rate of charge (industrial) 0.05 x K£/Kwh	Rate of charge (small consumers) 0.05 x K£/Kwh	PUB_j K£/annum
Firm j = 1	U_{12} =	u_{m2} =	u_{p2} =	
1974		0.14	0.35	— 5,250
1975	5.0×10^5	0.18	0.39	— 5,250
1976		0.21	0.43	— 5,500
Firm j = 2	U_{22} =	u_{m2} =	u_{p2} =	
1974		0.12	0.35	—1,495,000
1975	1.3×10^8	0.15	0.39	—1,560,000
1976		0.18	0.43	—1,625,000
Firm j = 3	U_{32} =	u_{m2} =	u_{p2} =	
1974		0.12	0.35	—195,500
1975	2.7×10^7	0.15	0.39	—324,000
1976		0.18	0.43	—337,500
Firm j = 4	U_{42} =	u_{m2} =	u_{p2} =	
1974		0.14	0.35	— 11,550
1975	1.1×10^6	0.18	0.39	— 11,550
1976		0.21	0.43	— 12,100
Firm j = 5	U_{52} =	u_{m2} =	u_{p2} =	
1974		0.14	0.35	— 87,150
1975	8.3×10^6	0.18	0.39	— 87,150
1976		0.21	0.43	— 91,300

SALARIES PAID TO LOCAL EMPLOYEES

The number of persons engaged by firms in the sample from the processing industry is given below. Estimates of salaries paid to local employees are based on the average salaries for the manufacturing sector as a whole published in the official statistics records (44). In the case of firm j = 5 these salaries have been increased by 0.5 times because the firm requires a smaller number of relatively unskilled employees than is the case with most of the other firms in the sample and in the manufacturing sector.

TABLE A.4.I.17

LSB_j

Firm/year	Number engaged	Average salary/ employee (K£/annum)	Estimated earnings by local employees (K£)
Firm 1	Ref.[1]		(LSB_j)
1974	481	427.2	205,480
1975	521	489.8	255,190
1976	566	530.2	300,090
Firm 2	Ref.[1]		
1974		427.2	304,590
1975	713	489.8	349,230
1976		530.2	378,030
Firm 3	Ref.[1]		
1974		427.2	64,080
1975	150	489.8	73,470
1976		530.2	79,530
Firm 4	Ref.[1]		
1974	750	427.2	320,400
1975	752	489.8	368,330
1976	625	530.2	331,380
Firm 5	Ref.[1]		
1974	282	600.0	169,200
1975	293	700.0	205,100
1976	289	800.0	231,200

Ref.[1] = Private Communications

TABLE A.4.I.18

DIRECT DISTRIBUTION OF DIRECT INCOME FROM FIRM j = 1 TO RURAL ECONOMY

Income item/year	Value A	Distribution coefficient B	Rural income benefit (A.B)
	K£		K£
Exports	$\sum_{k=1}^{3} EOT_{1k}$	ξ_R	
1974	526,316	0.5	263,160
1975	448,543	0.5	224,270
1976	628,966	0.5	314,480
Imports	$-MET_1$	ξ'_R	
1974	— 36,000	0.5	— 18,000
1975	— 13,700	0.5	— 6,850
1976	— 6,700	0.5	— 3,350
Local materials	$-LRM_{11}$	γ_{11}	
1974	— 919,374	0.9	— 827,440
1975	— 1,264,620	0.9	— 1,138,160
1976	— 1,027,224	0.9	— 924,500
Total			W_{1R}
1974			— 582,280
1975			— 920,740
1976			— 613,370

Column

Data source — Tables (A.4.I.2), (A.4.I.3) and (A.I.22); Text 4.I.B.1

TABLE A.4.I.19

DIRECT DISTRIBUTION OF DIRECT INCOME GENERATED BY FIRM j = 2 TO RURAL ECONOMY

Income item/year	Value A	Distribution coefficient B	Rural economy benefit (A.B)
	(K£)		(K£)
Cement	DOT_{21}	β_{21}	
1974	367,420	0.2	73,480
1975	653,410	0.2	130,680
1976	887,550	0.2	177,510
Exports	EOT_{21}	ξ_R	
1974	409,450	0.5	204,730
1975	541,440	0.5	270,720
1976	726,230	0.5	363,120
Imports	$-MET_2$	ξ'_R	
1974	− 135,000	0.5	− 67,500
1975	− 176,500	0.5	− 88,250
1976	− 238,400	0.5	−119,200
Local Materials	$-\sum_{i=2}^{3} LRM_{2i}$	γ_{2i}	
1974	− 92,930	0.8	− 74,340
1975	− 200,490	0.8	−160,390
1976	− 295,420	0.8	− 236,340
Total			W_{2R}
1974			136,370
1975			152,760
1976			185,090

Column		
Data source	Tables (A.4.I.4), (A.4.I.5), (A.4.I.6) and (4.I.22)	Text 4.I.B.1

TABLE A.4.I.20

DIRECT DISTRIBUTION OF DIRECT INCOME FROM FIRM j = 3 TO RURAL ECONOMY

Income item/year	Value A	Distribution coefficient B	Rural Income Benefit (A.B)
	K£		K£
Cement	DOT_{31}	β_{31}	
1974	399,500	0.3	119,850
1975	646,000	0.3	193,800
1976	800,700	0.3	240,210
Imports	$-MET_3$	ξ_R	
1974	— 40,500	0.5	— 20,250
1975	— 70,800	0.5	— 35,400
1976	— 41,500	0.5	— 20,750
Local materials	$-\sum_{i=2}^{3} LRM_{3i}$	γ_{3i}	
1974	— 23,010	0.8	— 18,410
1975	— 47,190	0.8	— 37,750
1976	— 61,480	0.8	— 49,180
Total			W_{3R}
1974			81,190
1975			120,650
1976			170,280
Column			
Data source	Tables (A.4.I.7), (A.4.I.8), and (A.I.22)	Text 4.I.B.1	

TABLE A.4.I.21

DIRECT DISTRIBUTION OF INCOME FROM FIRM j = 4 TO RURAL ECONOMY

Income item/year	Value A	Distribution coefficient B	Rural Income Benefit (A.B)
	K£		K£
Refined sugar	DOT_{42}	β_{42}	
1974	431,530	0.6	258,920
1975	558,880	0.6	335,330
1976	691,350	0.6	414,810
Exports	EOT_{45}	ξ_R	
1974	9,670	0.5	4,840
1975	9,120	0.5	4,560
1976	49,660	0.5	24,830
Local materials	$-LRM_{44}$	γ_{44}	
1974	— 925,120	0.3	— 277,540
1975	— 1,260,840	0.3	— 378,250
1976	— 1,608,890	0.3	— 482,670
Imports	$-MET_4$	ξ'_R	
1974	— 45,000	0.5	— 22,500
1975	— 59,200	0.5	— 29,600
1976	— 29,800	0.5	— 14,900
Total			W_{4R}
1974			— 36,280
1975			— 57,960
1976			— 57,930

Column

Data source — Tables (A.4.I.9), (A.4.I.10), (A.4.I.11) and (4.I.22); Text 4.I.B.1

TABLE A.4.I.22

DIRECT DISTRIBUTION OF DIRECT INCOME FROM FIRM j = 5 TO RURAL ECONOMY

Income item/year	Value, A	Distribution coefficient, B	Rural Income Benefit (A.B)
	K£		K£
Kerosene	DOT_{56}	β_{56}	
1974	−505,200	0.3	−151,560
1975	92,100	0.3	27,630
1976		0.3	
Gas oil	DOT_{57}	β_{57}	
1974	−1,191,600	0.2	−238,320
1975	1,508,600	0.2	301,720
1976	2,010,800	0.2	402,160
Diesel oil	DOT_{58}	β_{58}	
1974	−76,200	0.2	−15,240
1975	20,000	0.2	4,000
1976	84,200	0.2	16,800
Raw material imports	$-IRM_{51}$	γ'_{51}	
1974	−6,032,400	0.5	−3,016,200
1975	−7,814,000	0.5	−3,907,000
1976	−8,412,300	0.5	−4,206,150
Other imports	$-MET_5$	ξ'_R	
1974	−90,000	0.5	−45,000
1975	−106,900	0.5	−53,450
1976	−105,500	0.5	−52,750
Exports	$\sum_{k=6}^{14} EOT_{5k}$	ξ_R	
1974	2,768,700	0.5	1,384,350
1975	3,537,400	0.5	1,768,700
1976	3,440,200	0.5	1,720,100
Total			W_{5R}
1974			−2,081,970
1975			−1,858,400
1976			−2,119,840

Column

Data source — Tables (A.4.I.12), (A.4.I.13), (A.4.I.14) and (4.I.22); Text 4.I.B.1

APPENDIX A.4.II & III.

APPENDIX A.4.II

TABLE A.4.II.1
EMPLOYMENT IN THE WHOLE OF THE MODERN SECTOR

Year	Column A	Column B	Column C	y
1965	582,100	-	-	-
1966	585,400	3,300	0.6	0.4
1967	597,500	12,100	2.1	1.4
1968	606,400	8,900	1.5	2.2
1969	627,200	20,800	3.4	3.0
1970	644,500	17,300	2.8	3.7
1971	691,200	46,700	7.2	4.6
1972	719,800	28,600	4.1	5.6
1973	761,400	41,600	5.8	6.5
1974	826,300	64,900	8.5	7.3
$C_{AVG} = 4.0$				$y = 0.86x + 0.4$

Notation

C_{AVG} = Arithmetic average annual growth rate (per cent)
Column A = Number of persons engaged in modern sector employment
Column B = Annual growth in number engaged
Column C = Annual per cent rate of growth of employment in the modern sector
y = Annual rate of growth of employment (moving average)
x = Number of years from year 1966

Source of Data: Reference (66) for Column A

TABLE A.4.II.2

EMPLOYMENT GROWTH IN THE CHEMICAL INDUSTRY

Number Engaged

Year	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Total
1964	NA	589	271	513	427	717	695	3,212
1965	NA	710	278	601	206	524	710	3,029
1966	NA	623	158	654	187	759	895	3,276
1967	NA	610	159	665	204	710	945	3,293
1968	3,309	732	853		216	787	980	6,877
1969	3,892	718	929		205	1,028	1,064	7,836
1970	3,704	818	1,090		200	1,112	1,100	8,024
1971	3,978	824	1,261		366	1,199	1,181	8,809
1972	2,978	1,576	1,811		456	1,493	1,589	9,903
1973	2,922	1,368	1,852		482	1,233	1,603	9,460
1974	2,618	1,835	2,117		499	1,644	1,679	10,392
1975	3,587	1,796	2,326		534	1,475	1,814	11,532

(1968 total excluding group 1 figures = 3,568)

"Group" refers to manufacturing firms group as follows:-

Group 1 = Sugar factories and refineries (small and large scale)

Group 2 = Basic industrial chemicals and petroleum

Group 3 = Paint

Group 4 = Soap and vegetable oil

Group 5 = Pyrethrum extract

Group 6 = Miscellaneous chemicals

Group 7 = Cement

Data source: 1964 - 1968, Ref.(91); 1969 - 1973, Ref. (92); 1974 - 1975, Ref. (93)

TABLE A.4.II.3

MANUFACTURING SECTOR'S CAPITAL FORMATION AND EMPLOYMENT

Year	Number engaged	Annual increase of number	Capital formation (current prices) K£ x 10^6				
			Buildings	Other construction works	Transport equipment	Machinery and equipment	Total
1967	51,360	-	-	-	-	-	-
1968	54,971	3,611	3.41	1.64	0.98	8.09	14.13
1969	59,398	4,427	1.24	0.46	1.05	8.76	11.50
1970	69,277	9,879	0.47	1.66	1.70	10.11	13.94
1971	76,336	7,059	0.85	0.87	1.92	14.18	17.81
1972	84,804	8,468	2.87	2.78	2.46	20.59	28.70
1973	94,453	9,649	0.83	4.61	2.63	22.38	30.45
1974	101,332	6,879	7.92	2.12	4.02	15.79	29.86
1975	100,731	— 601	2.69	1.99	3.16	23.39	31.23
1976	108,776	8,045	4.89	1.01	4.30	33.45	43.65

Data Source: (a) Number Engaged – Table 90 of Ref.(130) for 1967
Table 109 of Ref.(131) for 1968–1971
Table 221 of Ref.(28) for 1972–1974
Table 261 of Ref.(44) for 1973–1976

(b) Capital Formation-Table 46 of Ref.(130) for 1969
Table 48 of Ref.(95) for 1969
Table 49 of Ref.(132) for 1970
Table 54 of Ref.(133) for 1971
Table 53 of Ref.(131) for 1972–1973
Table 53 of Ref.(44) for 1974–1976

APPENDIX A.4.III

CAPITAL INVESTMENT PROJECTS (1964 - 1976) AND FORM OF FINANCING FOR A SAMPLE OF 7 LARGE FIRMS IN THE KENYAN PROCESS INDUSTRY

Firm k = 1

Processing plant operated by this firm came on stream in 1968. In 1966 its equity capital was K£ 0.1 x 10^6 and had a loan of K£ 2.45 x 10^6. A 1967 - 1968 part of the project cost K£ 3.6 x 10^6 which was fully financed by a foreign loan of DM 24.2 x 10^6 (K£ 3.6 x 10^6). For this firm the situation is estimated as follows:-

Total capital investment costs	= K£ 6.2 x 10^6
Equity financed capital	= K£ 0.1 x 10^6
Borrowed finance	= K£ 6.1 x 10^6

Fixed capital costs are estimated at K£ 5.5 million (balance is assumed to cover financing costs).

Firm k = 2

One of the older firms in the industry, firm k = 2, built a processing plant in the late 1940s. In 1953 equity capital was K£ 0.75 x 10^6. In 1964 a processing unit was added and 1966/67 more additions to the plant units were made with the aid of a foreign loan of K£ 0.13 x 10^6. Costs of the 1964 expansions are not available. By 1973 some retained profits had been capitalised so that equity capital in 1973 stood at K£ 1.35 x 10^6. During 1973 - 1975 another production unit was added at a cost of K£ 0.5 million and at this time the value of locally borrowed loan was K£ 0.22 million and foreign loans worth K£ 0.2 million. In 1973 the book value of fixed assets was K£ 1.7 x 10^6, capital reserves of K£ 0.07 x 10^6, and profit after tax of K£ 1.8 x 10^6.

New capital investments over the period 1964 - 1976 are estimated at K£ 1.2 million of which loans account for about 85% judging by the 1973 case. Thus:-

Estimated total fixed capital investment in 1976	= K£ 2.0 million
Estimated fixed capital investments costs 1964/1976	= K£ 1.5 million
Estimated value of loans	= K£ 1.3 million

Firm k = 3

Operations here started in 1964 with capital investment of K£ 6 million. In 1966 the firm had issued shares valued at K£ 2 million so this can be taken as the value of equity capital at the time. The facilities were expanded in 1972 - 1974 and an additional owner acquired 50% of the shares values at K£ 2 million. This expansion cost about K£ 13 million. Foreign loans worth £ sterling 6.5 million were available and it is reasonable to assume some local borrowing was also possible due to the importance of the firm in the local industry. For this firm estimates are as follows:-

Total capital investment costs (1976) (includes cost of finance) = K£ 13 x 10^6 + K£ 6 x 10^6
= K£ 19 million

Value of borrowed capital (1964 - 1976) (assuming that K£ 2 x 10^6 for expansion project 1972 - 1974 came from retained profits) = K£ 4 x 10^6 + K£ 9 x 10^6
= K£ 13 x 10^6

Value of fixed capital investment = K£ 4.5 + K£ 11.3 million
= K£ 15.8 million

Firm k = 4

Manufacturing facilities for this firm were set up on a very small scale for the first time in 1959 followed by trebling of plant capacities in 1960 - 1961 although still remaining a relatively small concern. Expansion work took place over the period 1971 - 1974 at a cost of K£ 1.7 million and then 1975 - 1977 contractual work alone cost K£ 0.64 x 10^6. Total cost for this expansion could be estimated at K£ 1.0 million. Proportion of borrowed finance is high as is shown by liabilities of the company: bank overdraft in 1974 was of K£ 1.12 million, in 1975 it was of K£ 0.98 million, while loans ('creditors and provisions liabilities') stood at K£ 0.86 million in 1974 and K£ 0.61 million in 1975. For this firm, therefore:-

Estimated fixed capital investments as of 1977 = K£ 3.0 x 10^6
(value of 0.3 million K£ nominally given to retained old plant equipment)

Estimated capital investment 1964 - 1976 = K£ 1.7 x 10^6 +
K£ 1.00 x 10^6
= K£ 2.7 x 10^6

Estimated borrowed capital 1964 - 1976 = K£ 2.0 million

Firm k = 5

Production started in 1954 for this firm and the plant was of a modest capacity. Several expansion projects have been implemented since including expansions completed in 1963, 1967 and 1976. The last expansion project changed the capacity by 70% of the capacity over the 1967 - 1975 value. This 1976 expansion cost K£ 9.0 million. Using this cost per tonne of capacity increase the 1963 and 1967 expansions are estimated to have cost equivalents of K£ 2.3 million and K£ 5.4 million respectively in 1976 plant expansion cost values. Also using 80% value of the 1976 expansion cost/tonne capacity the estimated total fixed capital investment in 1976 is K£ 17.2 million (rounded to K£ 17.0 million).

The 1958 equity capital value for this firm was K£ 0.15 million and the plant is estimated to have cost about K£ 1.0 million. This would suggest borrowing 'practice' of about 80% of capital expenditure. Payments to credit institutions and banks abroad amounted to K£ 0.031 x 10^6 and K£ 0.045 million in 1975 and 1976 respectively, suggesting some foreign borrowing. On the strength of the 1958 pattern it is estimated that 70 - 90% of the expansion costs were financed by borrowing. This conclusion is also strengthened by pattern of financing of firm k = 7 which is a "subsidiary" of this firm. Thus:-

Estimated fixed capital investment as of 1976 = K£ 17 million
Estimated total cost of expansions 1964 - 1976 = K£ 15.4 million
Estimated borrowed capital 1964 - 1976 = K£ 12 million
(for expansions)

Firm k = 6

Firm k = 6 is a recent and new project. The processing plants were still under construction in 1976 and the on-stream date was scheduled for 1977. Equity capital for this project amounted to K£ 5.6 million and project contracts including civil works, site preparation, etc. amounted to K£ 24 million. The amount of capital financing from overseas loans amounted to K£ 15 million and loan

servicing charges are estimated at around K£ 6 million. Thus:-

Fixed capital investment = K£ 24 million
Total capital investment = K£ 30 million
Borrowed capital finance = K£ 24 million

Firm k = 7

This firm is owned by the same shareholders of firm k = 5 although at different proportions of equity ownership between the partners, i.e. a major shareholder here can be a minor shareholder in firm k = 5. The degree of consultation and corroboration between the firms is admitted to be high. Since 1964 there was a major expansion project completed in 1973 and another one started in 1975 which was scheduled for completion by 1977/78. The respective capital costs were K£ 1.5 million and estimated K£ 2.0 million. For these projects local borrowing amounted to K£ 1.7 million and a foreign loan of K£ 0.6 million was also obtained. Bank overdraft facilities for the firm amounted to up to K£ 0.9 million in between 1974 and 1975. In spite of these financial commitments the amount of dividend paid to the shareholders was K£ 0.24 million (1972), K£ 0.255 million (1973), and K£ 0.255 million (1974) out of after-tax profits of K£ 0.245 million (1972), K£ 0.26 million (1973), and K£ 0.314 million (1975).

Based on the cost of expansions total fixed capital investment of the firm is estimated at a value of K£ 4.0 million. Thus:-

Estimated total fixed capital investment (1976) = K£ 4.0 million
Expenditure over the 1964 - 1976 period = K£ 3.5 million
(Estimated) Amount of borrowed capital = K£ 2.9 million

TABLE A.4.III.1

SUMMARY OF CAPITAL INVESTMENT COSTS, FIXED CAPITAL INVESTMENT COSTS, AND PROJECT FINANCING FOR A SAMPLE OF 7 FIRMS IN THE PROCESS INDUSTRY

ITEM	FIRM/VALUE, K£ x 10^6						
	k1	k2	k3	k4	k5	k6	k7
1. Estimate of fixed capital investments in 1976 - 1977	5.5	2.0	16	3.0	17	24	4.0
2. Total capital investments (excluding land) and including financing costs for 1963 - 1976 period	6.2	1.5	19	2.7	15	30	3.5
3. Borrowed finance to cover capital investment costs for 1963 - 1976	6.1	1.3	13	2.0	12	24	2.9

Source: Summary of outline given at the beginning of Appendix A.4.III. The outlines are a summary of field data.

TABLE A.4.III.2

CAPITAL FORMATION AND GROSS PRODUCT IN THE WHOLE ECONOMY AND IN THE MANUFACTURING SECTOR ONLY

K£ x 10^6

Year	WHOLE ECONOMY			MANUFACTURING SECTOR ONLY		
	Δk	GDP	ΔGDP	Δk	GP	ΔGP
1963	-	304.67	-	-	28.42	-
1964	45.14	325.53	20.86	6.95	33.17	4.75
1965	46.54	333.27	7.74	7.55	36.74	3.57
1966	61.24	384.67	51.40	9.51	41.90	5.16
1967	81.30	406.57	21.90	14.90	45.19	3.29
1968	90.06	442.02	35.45	12.70	49.99	4.80
1969	93.73	476.33	34.31	9.46	56.84	6.85
1970	112.71	518.94	42.61	12.95	62.16	5.32
1971	144.20	570.06	51.12	18.47	71.68	9.52
1972	160.37	648.52	78.46	28.02	84.35	12.67
1973	181.46	740.12	91.60	31.84	94.60	10.25
1974	203.76	896.30	156.18	29.86	119.07	24.47
1975	242.54	1,029.57	133.27	31.23	127.13	8.06
1976	298.04	1,253.36	223.79	43.65	151.33	24.20

Sources of Data:

(a) (i) Table 46 of Ref. (95) for capital formation in 1964 - 1968
(ii) Table 47 (a) of Ref. (28) for capital formation in 1969 - 1972
(iii) Table 51 (a) of Ref. (94) for capital formation in 1973 - 1976

(b) (i) Table 43 (a) of Ref. (95) for gross domestic product and GP in 1964 - 1968
(ii) Table 44 (a) of Ref. (28) for gross domestic product and GP in 1969 - 1972
(iii) Table 45 (a) of Ref. (94) for gross domestic product and GP in 1973 - 1976

where:

Δk = Annual capital formation value
GDP = Gross domestic product for whole economy per annum : Δ denotes increase
GP = Gross product per annum for the manufacturing sector : Δ denotes increase

CENTRAL BUREAU OF STATISTICS
MINISTRY OF FINANCE AND PLANNING
P.O. Box 30266
Nairobi
Kenya
Telephone: Nairobi 333970
Telegraphic Address: HERUFI

Reference No: CBS 39/31/01

19th February, 1979

Imperial College,
Department of Chemical
Engineering & Chemical Technology,
Prince Consort Road,
LONDON - SW7 2BY
(Att: Mr. Kamau)

Dear Mr. Kamau,

Re: Data Request: No. of large scale establishment/Firms, Capital Expenditure and value of gross Product

Please find enclosed herewith the above as requested by you for your research work. We apologise for the delay.

Unfortunately, it has not been possible for us to give you information pertaining to the years 1959 to 1962, it is very difficult to trace the information.

I would like to inform you further, that some of the data given are estimates because of the problems of classification system which has been changing overtime and also our adherence to confidentiality.

As you may be aware we are precluded by the Statistics Act not to divulge information in a format which would make it possible for a specific information pertaining to a particular responding firm to be identified. As such we have always regrouped firms to avoid identification when we are publishing data. It has been difficult to trace information from our firm file for some two or three firms, the result is that we have to make estimate from the published data which have been grouped already.

On the whole I think the data will be of much use to you.

Yours faithfully,

(F. A. Kene)
for: DIRECTOR OF STATISTICS

APPENDIX A.6.I, II & III.

APPENDIX A.6.I

EXAMPLES OF EQUIPMENT COMPLEXITY LEVELS WITH RESPECT TO GEOMETRIC AND SIZE FACTORS

A. Reciprocating, Centrifugal and Axial Compressors

Equipment's Static Elements Complexity Factors

Reciprocating compressors consist essentially of sealed chambers equipped with pistons. This is equivalent to simple vessels of complexity level 2.

Axial and centrifugal compressors are equivalent to stirred vessels and also of complexity level 2 because impeller design is very important.

Sealing and Valve Factors

Sealing between moving parts and between low and high pressure regions is a critical factor in all compressor's engineering and fabrication. Complexity level is taken equal to 2 for reciprocating machines and equal to 1 for axial and centrifugal machines.

Transmission Requirements

The reciprocating machines operate intermittently in service and contain more moving parts in the drive and gear arrangements than centrifugal compressors. Complexity level with respect to transmission requirements can thus be considered equal to 1 for axial or centrifugal compressors and equal to 2 for reciprocating compressors.

1. Overall Geometric Complexity Level

Thus, the overall complexity level with respect to geometric factors in engineering and fabrication of

Axial and Centrifugal Compressors = 2 + 1 + 1 = 4 ;

and of Reciprocating Compressors = 2 + 2 + 2 = 6 : reduced to 5 in order to constrain it within the range of 1 - 5.

2. Compressor Size Factor

Operating ranges for single stage compressors have been published. Thus, Table 6.35 of Perry (81) allows the following generalisation:-

	Capacity range ft^3/min	Maximum pressure
Reciprocating (single stage)	1 - 350	$\leq$ 125 lb in^{-2}
	350 - 1,000	$\leq$ 40 lb in^{-2}
Centrifugal compressors (single stage)	500 - 100,000	1.25×10^4 ft of fluid

For multistage compressors appropriate ranges based on reference (96) are

	Capacity range (ft^3 min^{-1})	Maximum pressure lb in^{-2}	
		Small Machines	Large Machines
Reciprocating compressors	$\leq$ 3,000	60,000	3,000
Centrifugal compressors	500 - 200,000	10,000	<<< 10,000
Axial compressors	75,000 - 600,000	-	$\leq$ 130 -

The above information is used to assign duty classification, viz. light = level 1, medium = level 2, etc. The equipment size is based on throughput ft^3 min^{-1} as in the text.

B. Solid Particles Air Classifiers

1. Static Elements Complexity Factors and Dynamic Elements Complexity Factors

Classifiers are simple chambers equipped with blades. Complexity level is thus considered to be equal to 2 with respect to the static elements of the equipment. The degree of sealing and valves engineering demands is low compared to compressors and the transmission elements are correspondingly less severe. These can be considered to

have a combined dynamic elements' complexity level of 1. Thus overall geometric complexity level with respect to engineering and fabrication = 3.

2. Size Factors

Sizes of mechanical air classifiers range from 3 to 24 ft in diameter with power requirements from 3 to 600 hp. (97).

C. Heat Exchanger Equipment

(Including coolers, evaporators, heaters, condensers, especially of the floating type shell and tube exchangers).

1. For multitubular shell and tube exchangers, the geometric complexity level treated as in the text and consisting only of the static equipment elements is equal to 3.

2. Size Factors in Heat Exchangers

Some common shell size ranges over which different minimum plate thicknesses are required and based on British Standards Code (BS 1600), have been reported by Blackhurst and Harker (85). These ranges are as follows:-

Shell internal diameter ranges:
(inches) : 8 - 12; 13 - 24; 25 - 29; 30 - 39; 40 - 60

Shells with diameters of less than 24 in are treated as pipes for design purposes. Standard tube lengths in chemical plants and petroleum refineries are:

(feet): 8, 10, 12, 16 and 20 with the 16 ft as the most common (98)

It is these figures which have been of use in assigning the complexity level of heat exchanger (shell and tube) with respect to size factors in the text.

D. Tubular Furnaces (Indirect Fired Heaters)

1. Equipment Geometric Factor

Following the procedure outlined in the text puts tubular furnaces at a complexity level of 3 with respect to geometric factors.

2. Size Factors

A convenient size indicator for furnaces is the furnace thermal duty. Thermal duties range from about 0.5×10^6 BTU.hr^{-1} to over 1.0×10^9 BTU.hr^{-1} but most fired heater installations fall within 10 - 350 million BTU.hr^{-1} (99).

E. Continuous Through Circulation Conveyor Dryers

1. Geometric Complexity Factors for Equipment

Typically, a continuous through circulation conveyor dryer consists of a sheet-metal enclosure housing the conveyor screen, inlet gas distributor (often air), and a feed collector as well as the blower and the heater. Ignoring the blower and the heater, the static elements of equipment are simple and the complexity level is considered equal to 2. The dynamic elements of the equipment unit are also simple including, as it were, a chain power transmitting component. These are considered to be of complexity level 1. Thus combined geometric complexity level = 3.

2. Size Factor for Through Circulation Dryers

Conveying screens are fabricated with conveyor widths from 1 to 12 ft in sections 5 to 8 ft long (100). Cost data given on Table 20-11 of Perry (81) cover conveyor widths of 8 ft and 10 ft wide and length ranges of 20 - 30 ft, 30 - 40 ft, 40 - 50 ft and 50 - 60 ft. These can be considered as the industrially important size ranges for the equipment and can be used to assign the complexity levels for the equipment with respect to size.

F. Direct Heat Rotary Kiln

1. Geometric Complexity Factors

This is usually a metal cylinder lined on the interior with

insulating block and/or refractory brick for high temperature operations. It requires a combustion chamber and is in effect a high temperature process furnace without exchanger tubes. Static elements' complexity level is thus considered equal to 2.

The dynamic elements of the unit include facilities for rotary motion with the length of the kiln as the axis. Gearing is simple helical or spur and for up to 200 hp, single drives are used. Air seal can be a T-section ring mounted on a wearing pad around the feed end of the kiln. The combined dynamic elements' complexity level can be considered equal to 2. Thus the overall geometric complexity level = 4.

2. Size Factors

The first rotary kilns used in the United States are reported to have been 6 ft in diameter by 60 ft in length, and the sizes then increased to a maximum of 12 ft in diameter by 450 ft in length, with a few larger units being installed recently (101). In terms of drives requirements, single drives can be used for up to 200 hp. Table 20-16 in Perry (81) gives sizes, range of motor horsepower, and some capacities for typical rotary kiln installations. Based on this table and the above discussion, the important size ranges for duty classification can be obtained.

G. Plate or Packed Physical Separation Columns

1. Geometric Factors

As in the text, this is equal to level 4.

2. Size Factors

A rule of thumb for tower shell specification procedure recommended by Blackhurst and Harker (102), gives shell thicknesses from 0.25 inches for tower diameters of 3 ft to 0.5 inches for tower diameters of 5 ft. They also recommend allowances for additional stresses for tower heights greater than 50 ft. Suggested shell thicknesses thus calculated should have additional shell thickness allowances of 0.0625 inches for each 20 ft of tower height over 50 ft (103). Common shell diameters range from 2 ft to 16 ft. These figures can be used in assignment of complexity levels for different column size ranges.

H. Chemical Reactors

1. Geometric Factors

Single Continuous Stirred Tank Reactors and Batch Reactors

Overall geometric complexity level is equal to 2.

Continuous, Staged, Stirred Tank Reactor and Multitubular Reactors

Overall geometric complexity level is equal to 3 following the procedure outlined in the text.

Solid Bed and Fluidised Bed Reactors

Overall equipment complexity level for these reactors is equal to 4 since they are really packed columns.

2. Size Factors

Assignment of complexity levels for different reactor sizes can be based on shell and tube size figures.

I. Jaw Crushers

1. Geometric Factors

The static elements of a jaw crusher such as the Blake type, consist of a chamber equipped with a crushing plate fixed in a vertical position at the front of a hollow rectangular frame. A similar plate is attached to a swinging lever suspended from a shaft resting in the sides of the frame (104). The equipment is thus considered to have static elements of geometric complexity level of 2.

The dynamic elements include facilities for creating reciprocating motion of the jaws and are considered to have a complexity level of 1.

The overall geometric complexity level for jaw crushers is, therefore, equal to 3.

2. Size Factors

On Table 8-8 of Perry (81) Blake swing jaw crusher sizes, required horsepower for motor, capacities, etc. are shown. Thus for crusher capacities of 7 - 10 tons hr^{-1}, 25 - 30 tons hr^{-1}, 70 - 90 tons hr^{-1}, 150 - 175 tons hr^{-1}, 190 - 230 tons hr^{-1}, 230 - 270 tons hr^{-1}, the

horsepower requirements are 7, 15, 40, 75, 100, 125 - 150 hp respectively.

J. Gyratory Crushers and Impact Breakers

Both the geometric and size factors can be considered in much the same way as for jaw crushers using information and data contained in Chapter 8 of Perry (81).

K. Tumbling Mills (e.g. Ball and Tube Mills)

1. Geometric Factors

The static element here is a shell charged with a grinding medium such as balls of steel, flint, or porcelain. This gives a geometric level of 2.

The dynamic elements include provisions for assembly enabling the shell to rotate on a horizontal axis. Complexity level for this is considered equal to 1.

Overall geometric complexity level is thus equal to 3.

2. Size Factors

Data used for assigning complexity levels against mill sizes are those given on Table 8-18 in Perry (81) for the performance of Marcy ball mills.

L. Ring Roller Mills

1. Geometric Factors

Static elements in ring roller mills consist essentially of a chamber housing rollers that operate in conjunction with grinding rings. The assembly is more complicated than in stirred vessels or their equivalent and its geometric complexity level is considered equal to 3.

The dynamic elements are not simple and are taken as equal to a level of 2.

Overall geometric complexity level is thus equal to 5.

2. Size Factors

Raymond ring roll mills have a capacity range from 0.5 to 50 ton hr^{-1} and the power requirements ranges from 40 - 700 horsepower (105). The "B & W" pulverizer commonly used for pulverization of coal is built with capacities up to 14 tons hr^{-1} (105).

APPENDIX A.6.II
EXAMPLES OF EQUIPMENT UNITS DESIGN WITH RESPECT TO DATA AVAILABILITY

A. Gas Compression Processes

General Nature of Process and Main Design Relation

Physical behaviour of fluid under compression can be expressed by:

$$PV = nZRT \tag{A.6.1}$$

where (in appropriate units):

n = number of moles of gas or vapour.
Z = the gas compressibility factor.
R = gas constant.
T = absolute temperature of gas.
P = absolute pressure of gas.
V = volume of gas.

The basic design relation for compressors is:

$$HP = f(P, V, T, Z, K) \tag{A.6.2}$$

where:

f denotes 'function of'.
K = ratio of specific heats (at constant pressure and at constant volume).
HP = theoretical horsepower, i.e. work done in the cylinder on the gas during compression.

The mechanical process depends on such factors as cylinder and piston dimensions for reciprocating compressors or impeller characteristics for axial and centrifugal compressors, rate of piston strokes or of impeller rotation, etc. Specification of such items constitute compressor sizing work.

Data Availability Level

For single gas components thermodynamic data normally required are widely available in the open literature. For multicomponent gas mixtures, properties are largely estimated from pure component properties with reasonable accuracy. Thus data levels are 0 for single components and 1 for multicomponent gas mixtures.

Equipment sizing for the reciprocating compressors requires data on compressor's adiabatic and mechanical efficiencies, piston displacement, volumetric clearances, etc. Other types of compressors have similar requirements. Preliminary design can be done using literature data but detailed design requires equipment manufacturer's actual specifications. However, manufacturers are normally ready to give required data and the data level can be taken equal to zero.

Thus overall complexity level of compressors with respect to design data availability, f_1 (= DT_i), is as follows:-

(a) for single component gases and vapours:

$$f_1 = (4/3) \cdot (0/6) + 1 = 1$$

(b) for multicomponent fluids:

$$f^*_1 = (4/3) \cdot (1/6) + 1 = 1$$

B. Heat Exchange Operations

Nature of General Process

Heat transfer processes are governed by the physical laws of conduction, convection and radiation of heat in materials and between bodies.

The basic design relation is the integral equation for heat transfer given in terms of the transfer area:

$$A = Q/u \, \Delta T_{MTD} \qquad (A.6.3)$$

---

* Values of f_1 in all the equipment considered in this Appendix are rounded to the nearest unit (number).

where:

A = the heat transfer area (in appropriate units),
Q = rate of heat transfer (in appropriate units),
u = overall coefficient of heat transfer (in appropriate units),
ΔT_{MTD} = mean temperature difference across the transfer path.

Design Data Requirements

Apart from basic physical properties data, equipment design requires data on heat transfer coefficients for convective and conductive films and the radiation zone transfer constants. Equipment geometry necessitates extra data in order to allow consideration of heat losses, fluid by-pass, and different temperature profiles. Pressure drop of flowing fluids is an important design consideration. Availability of data varies according to the degree and nature of the heat transfer process and the heat transfer equipment used.

B.1 For Heaters and Coolers - where heat transfer occurs without substantial change of phase in shell and tube heat exchangers

Abundant film coefficients correlations are available in the open literature and are considered to yield values for film heat transfer coefficients accurate to within ± 20% of experimental values (106). Thus data level here is zero.

The best correlation for calculation of pressure drop on the shell side - excluding nozzles - gives values up to 50% lower and up to 200% higher than experimental values (107). Data level = 2.

Baffles effects on heat transfer coefficients and on pressure drop although not accurately correlated are widely available. Data level = 1.

Thus for shell and tube heater or cooler:

(a) without baffles:

$$f_1 = (4/3) \cdot (1/6) \cdot 2 + 1 = 1$$

(b) with baffles:

$$f_1 = (4/3) \cdot (1/6) \cdot (2 + 1) + 1 = 2$$

B.2 Single Component Shell and Tube Condensers

Heat transfer coefficients for condensing vapours are estimated from correlations based on Nusselt theory, and give low values of the coefficients (108). Data level here = 1.

Pressure drop correlations and effects of baffles are as for coolers and heaters above. Therefore;

$$f_1 = (4/3) \cdot (1/6) \cdot (1 + 2 + 1) + 1 = 2$$

B.3 Multicomponent Shell and Tube Condensers

The condensate film heat transfer coefficients are estimated from pure vapour condensation coefficients using mean liquid properties. The sensible heat transfer coefficients for the vapour gas-stream decreases as condensation proceeds (109). The level of accuracy of estimated values is therefore generally lower than that for single component condensers. Data level = 2.

Although pressure drop correlations for two phase flow are not as accurate as for single phase flow correlations are widely available. Data level = 2.

Geometric factors effects are as for heaters and coolers. Data level = 1.

Thus for multicomponent condensers:

$$f_1 = (4/3) \cdot (1/6) \cdot (2 + 2 + 1) + 1 = 2$$

B.4 Reboilers

Heat transfer coefficients correlations are only very approximate (109), and worse than for single phase condensers. Data level = 3.

Other factors as for multicomponent condensers:

$$f_1 = (4/3) \cdot (1/6) \cdot (3 + 2 + 1) + 1 = 2$$

C. Physical Separation Processes in Plate Columns

For design purposes relationships that require data include thermodynamic equilibrium relations for components involved in inter-phase contacting, and steady state material and energy balances. Equipment specification requires knowledge of phase contacting efficiency and fluid flow characteristics in the equipment units.

C.1 Binary and Tertiary Component Separation in Plate Columns

Accurate vapour-liquid equilibrium data are not generally available for most mixtures (111). Data level = 2.

Pressure drop data available in open literature is mainly only for bubble cap plates (112). Data level = 3.

Flooding and entrainment data is also restricted to specific plate types and sizes, weirs, and plate spacings (113). Data level = 2.

Plate efficiency data have been correlated and are accurate to within ± 30% of actual values (114). Data level = 1.

Calorimetric data for binary and tertiary mixtures are also not highly accurate (111). Data level = 1.

Thus the overall data availability level here is:

$$f_1 = (4/3) \cdot (1/6) \cdot (2 + 2 + 2 + 1 + 1) + 1 = 3$$

C.2 Multicomponent Separation in Plate Columns

The amount of vapour-liquid equilibrium data required increases as the number of components increases. Data available in open literature covers few mixtures and prediction methods based on pure substance data are often inaccurate. Data level = 3.

Adequate methods for dealing with tray efficiencies for multicomponents are not generally available (115). Data level = 3.

Calorimetric data estimations are correspondingly more difficult to estimate for multicomponent mixtures. Data level = 3.

Pressure drop and other column hydraulics data are of some availability levels as with binary mixtures. Thus:

$$f_1 = (4/3) \cdot (1/6) \cdot (3 + 3 + 3 + 3 + 2) + 1 = 4$$

C.3 Packed Columns Separation Equipment

As in binary and tertially separation processes in plate columns.

D. Solids Drying

In solid-liquid-gas systems the process involved is of simultaneous mass and heat transfers when hot gas is brought in contact with the liquid on the solid surface and in which the gas is insoluble. The equipment unit consists of a blower, a heater, and the solids container.

D.1 Cross Circulation Tray Dryers - Batch

Data requirements include mass and heat transfer coefficient for prediction of the drying rates and the drying time. These coefficients have been correlated where air is the drying gas, and the liquid is water. The correlations apply only for the constant drying rate region and the accompanying empirical constants vary with equipment geometry (116). Data levels for heat transfer coefficients = 2, and for mass transfer coefficients = 2.

Effects of bed thickness and properties of the solid on the drying rate and critical moisture contents can only be roughly estimated. Data level = 2.

For batch through circulation tray dryers:

$$f_1 = (4/3) \cdot (1/6) \cdot (2 + 2 + 2) + 1 = 2$$

D.2 Continuous Through Circulation Dryers

Design of continuous through circulation dryers requires pilot-plant tests. Data levels as above are therefore, 3 + 3 + 3 and:

$$f_1 = (4/3) \cdot (1/6) \cdot (3 + 3 + 3) + 1 = 3$$

E. Chemical Reactors

E.1 Homogeneous Isothermal and Adiabatic Reactors

Chemical kinetics and reaction equilibrium data cannot be generalised but data for most common industrial reactions are available (117). Data level for isothermal reactions is about 2 and due to effects of temperature 3 for adiabatic reactions.

Mixing effects on the reactor design are not easily amenable to empirical or analytical treatment for design of specific equipment. Other flow considerations are based on pipe flow and flow through particle beds. Data level is about 1. Thus:

(a) for isothermal reactions:

$$f_1 = (4/3) \cdot (1/6) \cdot (2 + 1) + 1 = 2$$

(b) for adiabatic reactions:

$$f_1 = (4/3) \cdot (1/6) \cdot (3 + 1) + 1 = 2$$

E.2 Pseudo-Isothermal Reactors (with addition/removal of heat)

Chemical reaction rate, equilibrium constant, and effect of temperature data are same as for adiabatic reactions, i.e. data level of 3.

Heat transfer coefficients are well correlated for kettle side of cooler/heater but jacket side or coil side coefficients are not generally well correlated (118). Data level is about 2.

Flow considerations data level = 2. Thus:

$$f_1 = (4/3) \cdot (1/6) \cdot (3 + 2 + 2) + 1 = 3$$

E.3 Heterogeneous Chemical Reactors

In heterogeneous reactors heat and mass transfer within the reactor must frequently be taken into account. If the reactor is jacketed for cooling or heating, there may be significant temperature variations in the radial direction across the reactor vessel or tube; and in some reactors there may be significant differences in temperature and concentration between fluid and solid particles (119).

Mass transfer generalised correlations for both gas - and liquid - solid systems covering both fixed and fluidized beds have been derived which give the mass transfer coefficient in terms of modified Reynolds number (120).

Heat transfer coefficients have also been correlated by several workers (120).

The report of so many correlations reflects the difficulty of accurate prediction of the necessary rate coefficients. The chemical reaction rate is also affected by reactor type and scale in a manner that is usually unpredictable on a quantitative basis, and design of commercial scale reactors requires at least laboratory and/or pilot-plant data on reactions followed by a satisfactory scale up procedure (121). This is particularly true of heterogeneous chemical reactor design. Consequently, data levels are assigned as follows:-

Chemical reaction rate data = Level 3
Heat transfer data = Level 2
Mass transfer data = Level 2
Pressure drop data = Level 1
Catalyst effects data = Level 2
Geometric factors = Level 2

Thus for:

E.3 Non-catalytic heterogeneous reactors:

$f_1 = (4/3) \cdot (1/6) \cdot (3 + 2 + 2 + 1 + 2) + 1 = 3$

E.4 Catalytic heterogeneous reactors:

$f_1 = (4/3) \cdot (1/6) \cdot (3 + 2 + 2 + 1 + 2 + 2) + 1 = 4$

APPENDIX A.6.III
COMPLEXITY OF SYSTEM'S DESIGN

A. Effect of Type of Inter-Unit Interactions on System's Design Complexity

Effect of type of connections between units, i.e. whether the units are connected in series or in series with recycling, is demonstrated by considering the computation procedure for a system's material balance flowsheeting. This can be done using any of the common techniques such as those based on the work of Nagiev (122).

A system whose units are serially connected and with arbitrary number of units and no recycles, i.e. an acyclic system with arbitrary number of units, is shown in Fig. A.6.1. The computation procedure, for a component's mass balance flowsheeting in this system is compared with the component's material balance flowsheeting procedure for a recycling system with the same number of units, and same number of components. This system is shown on Fig. A.6.2 below.

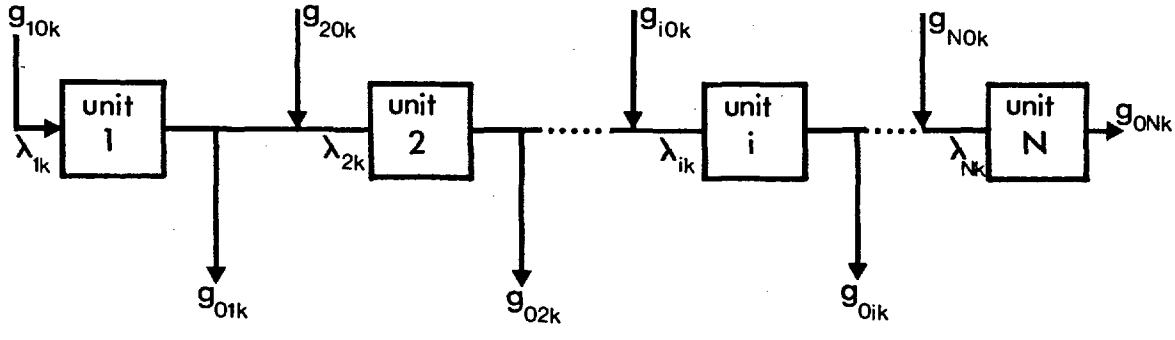


Fig. A.6.1 An acyclic processing system with N units

In the acyclic system, λ_{ik} denotes total flow of a component k into equipment unit i; q_{i0k} and q_{0ik} denote flows of component k into and from unit i that comes from and goes out into, respectively, the outside of the system's boundaries. The component mass balances are then given by:

$$\lambda_{1k} = g_{10k} \tag{A.6.4}$$

$$\lambda_{2k} = (g_{20k} + g_{10k}) - g_{01k} \tag{A.6.5}$$

$$\lambda_{3k} = (g_{30k} + g_{20k} + g_{10k}) - (g_{01k} + g_{02k}) \qquad (A.6.6)$$

....

$$\lambda_{ik} = (g_{i0k} + g_{(i-1)0k} + ... + g_{10k}) - (g_{01k} + g_{02k} + ... + g_{0(i-1)k}) \qquad (A.6.7)$$

....

$$\lambda_{Nk} = (g_{N0k} + g_{(N-1)0k} + ... + g_{10k}) - (g_{01k} + g_{02k} + ... + g_{0(N-1)k}) \qquad (A.6.8)$$

Thus if the fresh feeds g_{i0k} and the product withdrawals from each unit g_{0ik} are known, the flowsheet material balance for a component is solved in one sweep through the set of N equations. With no fresh feed or withdrawal of products between the first and last units, $\lambda_{ik} = \lambda_{1k} = g_{10k} = g_{0Nk}$.

Considering now the recycling system shown in Fig. A.6.2, α_{ijk} denotes the recycle fraction of flows from unit j going into unit i for a component k and:

$$g_{01k} = \alpha_{01k}\,\lambda_{1k} \quad , \quad g_{02k} = \alpha_{02k}\,\lambda_{2k} \quad , \quad \text{etc.} \qquad (A.6.9)$$

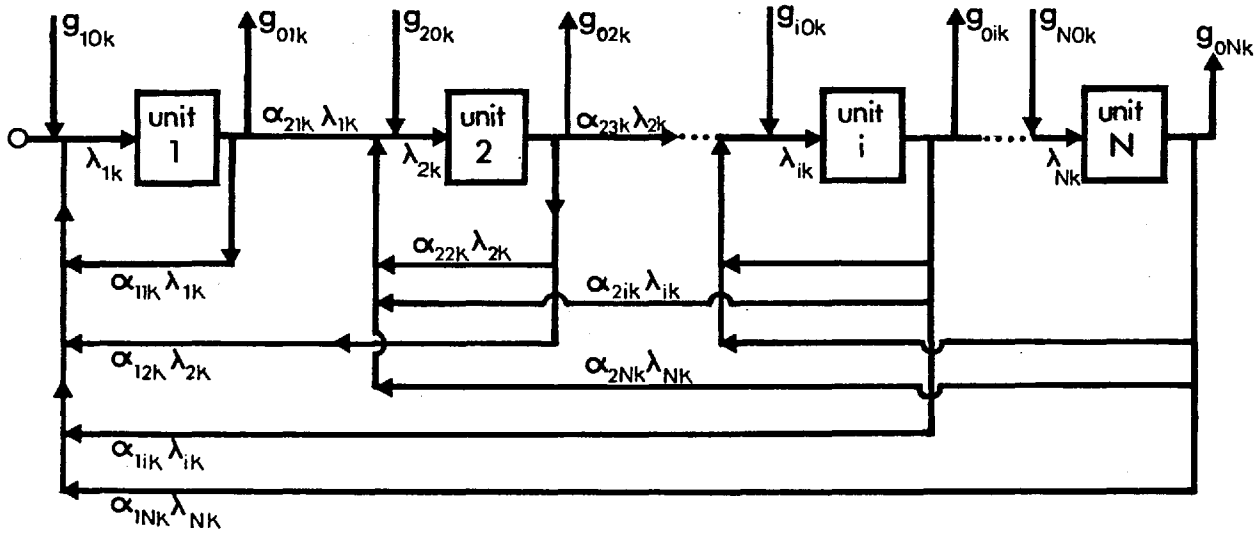


Fig. A.6.2 A recycling system of N units

In this case the material balance for component k in the system is given by the following set of equations:-

$$(1-\alpha_{11k})\,\lambda_{1k} - \alpha_{12k}\,\lambda_{2k} - \alpha_{13k}\,\lambda_{3k} \quad \ldots\ldots - \alpha_{1Nk}\,\lambda_{Nk} = g_{10k} \qquad (A.6.10)$$

$$-\alpha_{21}\,\lambda_{1k} + (1-\alpha_{22k})\,\lambda_{2k} - \alpha_{23k}\,\lambda_{3k} \quad \ldots\ldots - \alpha_{2Nk}\,\lambda_{Nk} = g_{20k} \qquad (A.6.11)$$

$$-\alpha_{i(i-1)k}\,\lambda_{(i-1)k} + (1-\alpha_{iik})\,\lambda_{ik} - \ldots\ldots - \alpha_{iNk}\,\lambda_{Nk} = g_{i0k} \qquad (A.6.12)$$

$$-\alpha_{N(N-1)k}\,\lambda_{(N-1)k} + (1-\alpha_{NN})\,\lambda_{Nk} = g_{0Nk} \qquad (A.6.13)$$

Thus when the fresh feed flows to the units (g_{i0k}) and the recycle fractions α_{ijk} are known, and given values of products withdrawn from each unit (g_{0ik}), the mass balances of a component in the system is given by solution of the above set of N equations in λ_{ik} simultaneously.

By considering the number of computations necessary to solve a set of 2 simultaneous equations, a set of 3 simultaneous equations, and a set of 4 simultaneous equations, all having sufficient number of constrained variables, the observation by Rudd and Watson can be accepted. This is that frequently the difficulty of solving a set of equations increases as the cube of the number of equations that must be solved simultaneously (123).

In all recycle loops solution to design or operating problems of a unit involves simultaneous consideration of the affected variables throughout a loop, much like in the example of the recycling system given above. In this example, the difficulty of solving the material balances for component k can be expected to be roughly equal to N^2 times the relative difficulty in solving the material balances for the component in a cyclic system with the same number of units. For different numbers of units relative 'solution' difficulty for each system type is as shown on Table A.6.1.

From these figures it can be seen that even relatively simple (3 - 6 units) recycle loops can have a dramatic effect in increasing the computational demands of a system. For multicomponent systems the calculations are increased by a factor equal to the number of components. However, in this case the recycle ratios α_{ijk} can be complex functions of process conditions and the amount and nature of the other components in the system (124). This makes the computations much more complicated.

TABLE A.6.1

No. of Units	Number reflecting difficulty of solving material balance equations	
	Acyclic System	Recycling System
1	1	1
4	4	64
10	10	1,000
20	20	8,000
30	30	27,000

B. Effect of the Number of Interactions

In practice processing systems have 'information flow' interactions between units whose number depends on number of 'state variables' common to adjacent units. These state variables are part of the variables present in every equipment unit in a process and are included in design relationships governing process operation in the unit. Design variables constitute the other variables of the unit and these are so called because their values are fixed by the designer or process operator (125). Optimisation problems of the whole system during the design and operation stages are greatly influenced by the number of information flows between units due to state variables and design variables present in the unit.

Optimisation problems can often be solved through use of direct search methods treating the whole system as a unit or, as in dynamic programming, through suboptimisation of individual units in sequence. Since these methods use trial and error procedures the computation load depends heavily on the number of variables considered as well as the number of units in the system. Thus for an acyclic system such as shown on Fig. A.6.3 below, the systems optimisation using dynamic programming can be shown to involve a number of computations, C_{ompt}, given by:

$$C_{ompt} = \sum_{1}^{N-1} (t_s^{s_{i+1}} t_d^{D_i}) + t_d^{D_N} \qquad (A.6.14)$$

where,

s_i = number of state variables with information flows between units i and (i+1),

t_s, t_d = number of trial points that adequately span the range of each of the state variables and design variables respectively,

D_i = number of design variables for unit i.

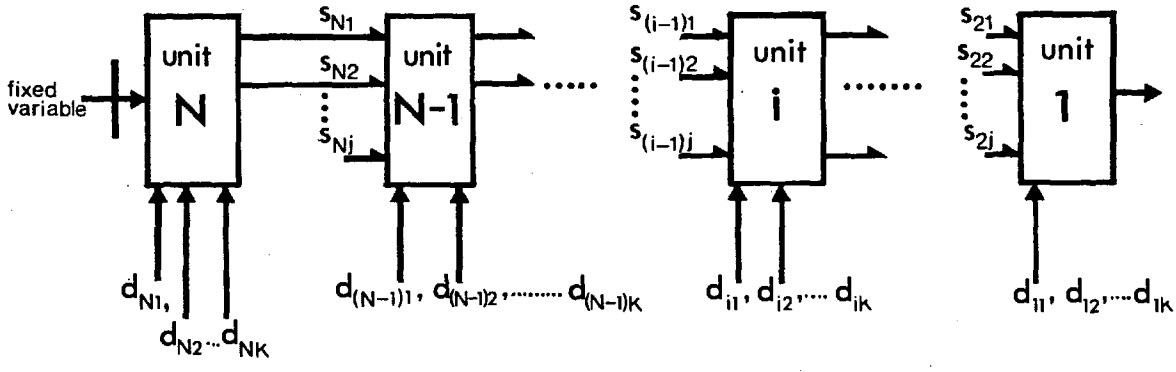


Fig. A.6.3

where,

s_{ij} denotes jth state variable connecting unit (i-1) to unit i,

d_{ik} denotes a kth design variable for unit i which is free to be manipulated by the designer.