CHOICE OF TECHNOLOGY IN IRON & STEELMAKING IN INDIA

A THESIS SUBMITTED TO THE UNIVERSITY OF POONA FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ECONOMICS

BY

S. V. CHAR.

OCTOBER, 1977

.....

ACKNOWLEDGEMENTS

It is immensely difficult to deal single-handedly with the subject matter of the thesis without the inspiration and willing succor of many people. Providentially such advice and sustenance have come in ample measure from several academicians, colleagues and friends. I would not be able to record here all such persons, who have improved my perception of the issues and have generously given of their time and knowledge. But some at least would have to be mentioned.

I am deeply indebted to Prof. V. M. Dandekar, but for whose contributive guidance, constructive criticism, direction and sagacity, I would not have been able to complete this work. He has sharpened my analytical tools and extended the frontiers of my knowledge.

I will always remember Prof. K. T. Merchant, who in the first place emboldened me to undertake the venture on this subject by his persuasive talk.

Mr. Harish Mahindra, Chairman, Mahindra Ugine Steel Co. Ltd., has been not only very understanding and patient as I pursued the theme of this thesis, but has also on several occasions arranged for help. I am grateful to him. Seven years ago, Mr. Ashish Mitra, General Manager, Mahindra Ugine Steel Co. Ltd. and former Chairman, Steel Furnace Association of India (SFAI), New Delhi, introduced to me the intricacies of the subject, which would otherwise remain unintelligible to me. He aroused my interest in the several hypotheses dealt with in this work and at every stage I had occasion to discuss the ticklish issues with him. What is equally important, he provided me many opportunities to undertake this research work. I am beholden to him. Mr. D. Srinivasan, Executive Secretary, SFAI, evinced interest from the very beginning and served as a source of hard-to-find data. My sincerest gratitude to him.

Dr. N.C.B. Nath, Director (Commercial), Steel Authority of India Ltd., Mr. S. K. Kashyap also of SAIL and Mr. R. Sampath of the Ministry of Industrial Development, New Delhi, readily offered help in the form of making available literature regarding steel plants in India. Dr. S. Mani and Dr. (Mrs.) Vatsala Mani, Jawaharlal Nehru University, New Delhi, have not only been helpful with literature but have also been a source of encouragement. Mr. R. Anantha, Chief Design Engineer, Mahindra Ugine Steel Co. Ltd., Khopoli, offered useful comments. He and his assistant, Mr. Subramanya Bhatt, have helped me with the drawing up of scale curves and other figures employed in this work. I wish to record my sense of

ii

2

gratitude to all of them.

In any research work of this nature it is imperative that one obtains information regarding certain techno-economic aspects, costs of production and the costs of equipment. As such, several organisations and persons were approached for this purpose. Those who responded to my enquiries positively and favourably are:

West Germany	:	Demag
Japan	:	Kawasaki Steel
Britain	:	British Steel Corporation
USA	:	Institute of Iron & Steel Engineers, Kaiser Engineers, Spencer Schilling and Midrex Corporation
India	-	Hindustan Brown Boveri (L&T), Bombay; Tata Iron & Steel Co. Ltd., Bombay; M. N. Dastur & Co., Calcutta & Bombay; Maharashtra Electrosmelt, Bombay; Otto India Ltd., Calcutta; Binny Ltd., Madras; Lurgi India Ltd., New Delhi; and several others.

The discussions with Dastur & Co., MEL and Binny were fruitful. I have also made good use of the libraries at the University of Bombay (Dr. B. Anderson has been extremely helpful), Reserve Bank of India (Mr. M. S. Parthasarathy took a paternal interest in the completion of the thesis), Gokhale Institute of Economics

iii

& Politics, Poona; The Industrial Credit & Investment Corporation of India Ltd., Bombay; Indian Institute of Technology (Powai); British Council Library, Bombay; and so forth. Dr. Homiar Vaccha, ICICI, came forward with useful comments, apart from sparing valuable books. Mr. S. D. Kshirsagar (Tata Iron & Steel Company Ltd.) arranged for my borrowing of books from the TISCO Library and from the Library of Tata's Economics Department. I will always remember with gratitude their generous help. I would be failing in my duty if I do not acknowledge the dextrous work of Mr. K. Govind and Mr. Sunder Raj in transcribing the earlier drafts of this illegibly written work. Miss Usha Magar took over this task sometime ago and with consummate skill has got up the last draft and this final manuscript. Mr. Govind has helped me in several other ways also such as in the tabulation of data. I am most thankful to them all.

POONA, October, 1977.

S. V. CHAR.

iv

CHOICE OF TECHNOLOGY IN IRON & STEELMAKING IN INDIA

CHAPTER SCHEME

ACKNOWLEDGEMENTS 1 CONTENTS 5 LIST OF TABLES 11 LIST OF FIGURES 16

CHAPTER I : INTRODUCTION

17-71

- A. Statement of the problem : The context Explanation of 'process', 'route' and 'technology' - BFs, DR, ESFs and OHs, EFs, LD and Q-BOP - The question of technological choice - BF+LD route or DR+EF route or both? -The hypotheses to be tested - Related considerations governing technological choice such as size of operations under each route (tonnage plants or mini plants?) - Unit capital cost, unit production cost, etc. - Three assumptions underlying the study -References to previous studies - Real need for a comprehensive assessment of the economies of routes and an appropriate mix of such routes for India.
- B. Introduction to iron & steelmaking : What is steel? -A diagramatic view of integrated operations - Four major stages of making iron and steel - Classification of iron-ores and historical survey of iron and steelmaking in India and abroad - Modern methods of iron & steelmaking and the evolution of the two-stage production of ferrous metals for reduction of the ore and for purifying it - An account of the working of production facilities : (a) BF : Measures of BF productivity, merits and demerits of BFs, recent trends (b) DR : Plus and minus aspects.

Evolution of steelmaking processes : Landmarks in steelmaking, OH (Seimens-Martin), Thomas (Basic Bessemer) - Working of OH, recent trends - EFs and UHP EFs, their working - LD (BOF) process, its evolution, its variations, working of LDs - Recent developments in iron & steelmaking, relevance for India : Appendix I.1: Classification of direct reduction processes.

CHAPTER II : PROCESSWISE IRON AND STEEL PRODUCTION -A GLOBAL REVIEW (TECHNOLOGICAL CHOICES ABROAD) 72-147

Mix of routes for iron and steelmaking, a world view - Predominant share of BF - Recent trends : OH, BOF, EFs, Q-BOP, etc. - Estimates of requirements of steel and implications for additional capacity creation -Tentative projections of technological choice -Influence of the considerations governing choice of technology - Countrywise survey : USA, USSR, Japan, EEC and its neighbours, Britain, Italy, Spain, Latin America, Brazil, Arab Countries, Iran and ESCAP, Appendix II-A.

CHAPTER III : DEVELOPMENT OF INDIAN INDUSTRY: TECHNOLOGICAL CHOICES IN THE PAST 148-183

Historical growth - Landmarks in the modern iron and steel industry in India covering the period 1830 and 1977 - Major developments since independence - Survey of literature - Industrial policy resolution 1948 -First five year plan - Second five year plan - Third five year plan and during 1964 to 1974 - Projections of iron and steelmaking capacity, to some extent implying choice of technology in the context of 6

projected requirements of steel - The phenomenon of EF (mini steel) units - Industrial licensing policy vis-a-vis EFs and their present status -Projected apparent consumption of steel and proposals for future choice of technology - SFAI projections -Plantwise break-up of processwise capacity data for iron and steelmaking on the basis of tentative plans : 1974 to 1985, Appendices III-A & III-B.

CHAPTER IV : RESOURCE SUPPORT IN INDIA AND MATERIAL BALANCES 184-233

Raw materials for iron and steelmaking under alternative routes and their adequacy - Material balances for : (A) BF+LD (1) Iron-ore needs, reserves available and life periods of deposits (2) Metallurgical (coking) coal : consumption norms and overall needs - Gross in-situ reserves - R&D and formed coke and blending possibilities - Reduction in coke norms - Life periods - Estimates of the Chari Committee; (B) DR+EF : Estimates of the arisings of capital, internal and process scrap - Tentative estimates of requirements and availability of scrap - Estimates of electric power needs and availability - Situation in respect of gas - Appendix 'A' : coke.

<u>CHAPTER V</u>: COSTS OF PRODUCTION AND ECONOMIES OF SCALE ABROAD : SOME EMPIRICAL EVIDENCE 234-332

Earlier treatment of economies of scale - The shape of scale curves - Austin Robinson's findings regarding factors determining economies of scale - Internal and external economies such as indivisibilities, the 0.6 rule and the law of large numbers - Methodological 7

approach to quantifying economies of scale, both intra and inter-route - Inadequacy of statistical cost techniques and survivor technique, the desirability of adopting engineering analysis -Ground rules for engineering analysis such as taking into account locational factors, eliminating extras and over-dimension and comparing likes with likes, temporal comparability of data, levels of performance, etc. - The measures adopted such as unit production cost (UPC), unit capital cost (UCC), minimum efficient size (MES) or minimum optimum size (MOS), reasonably efficient scale (RES), etc. - Budgetary prices -Determining technical optimum in an integrated unit with several production departments - The N - 1 formula in respect of BFs - The simultaneity factor for LDs.

Trends and sizes of production facilities : Economies of s cale abroad : A critique on ten studies, viz., Pratten and Dean, Cockerill, Carlos Faria, Subramanian & Lalkaka, ECLA (Baer), UNIDO, Kawasaki Data on US Costs, Huettner, Cartwright and Suzukie & Saito.

Engineering Estimates :

Anatomy of cost scale relationships : UCC for gas cleaning equipment, coke ovens, BFs, LD converters, DR & ESF, EFs - Tentative conclusions, Practical relevance of MES and RES, larger economies for BF+LD route - UPC and UCC : Scale sensitivity of BFs, DR, ESF, LDs and EFs. CHAPTER VI : COSTS AND ECONOMIES OF SCALE IN INDIA 333-389

q

Survey of previous exercises - The Bokaro case, Dastur's plea, the Ghei Committee Suggestions - The Vijaynagar-Vizag case : The sarin delegation suggestions for scaling-up plants - Budgetary prices of iron and steel equipment in India : Coke ovens, DR and EF - scale quide values and sizes of installed facilities : BF, ESF, DR, Bessemer, OH, LDs, EFs - Diseconomies due to size in Indian plants - Impact of size on UCC - Need for establishing MES/RES for India - Assumptions underlying Table VI-10 for estimating MES/RES - practical problems in establishing MES-sized plants in India - Sources for Data regarding costs estimated in Table VI-10 : (A) Capital costs : BFs, LD, DR, EFs (B) Sources for UPC: BFs : Iron-ore and sinter, coal and coke, other raw materials - LD converters - DR - EF.

Observations and Conclusions : MES for India under BF+LD route and under the DR+EF route - Choice of technology, economies of scale and the objectives in steel to be achieved.

CHAPTER VII : UCC AND UPC UNDER DIFFERENT ROUTES AND THEIR INPUT-PRICE SENSITIVITY 390-419

Analysis of the exercises to build-up UCC and UPC under each route, viz., BF+LD, ESF+LD, Scrap EF, DR+EF (Solid reductant) and DR+EF (Gas based) An analysis of the results of exercises presented in Tables VII-1 to VII-10 - UCC merits of DR+EF : a case study of capital costs for Vijaynagar Project under alternative routes - Capital Cost Reduction CHAPTER VIII : DIFFERENTIALS IN INDIAN AND FOREIGN UCC AND UPC 420-465

Ingot costs in India and UK - Difficulties in obtaining cost data - Comparisons of prices of steel products -Reasons for price differentials - Comparative cost advantage in India - Prices of inputs for BF+LD and DR+EF - Causal factors for higher costs in India -(1) Raw materials and consumption rates (2) Operational performance or x-inefficiency (3) Inventory levels (4) Personnel costs (5) Industrial relations (6) Additional capital expenditure (7) price preference for indigenous equipment (8) Tied aid (9) Long gestation period (10) Over-dimensioning - UCC and creation of capacity through expansion/conversion : Types of expansion -Conversion to Q-BOP - Expansion costs under the two routes - Synergic benefits - The Russian strategy - Lessons for India.

CHAPTER IX : PROSPECTIVE TECHNOLOGICAL CHOICE 466-498

Emerging trends abroad - A. Ironmaking : BF and DR -B. Steelmaking : LD, EF and Q-BOP - Indian scene : Sponge/ ironmaking - Steelmaking : Probable technological choice : LDs, EFs and Q-BOP - Emerging processwise pattern - Three alternative mixes (Japanese, Spanish and Italian) and their implications : Quanta of Investments and UCC - The preferred route mix - Criteria for relevant choice of technology : Material Balances - Energy - Input price sensitivity -Scale considerations - Future Structure of Indian industry -R&D and technology choice - Commitment to a route or to a route-mix.

BIBLIOGRAPHY

499-510

х

xi

TABLE NUMBER

I -1	Landmarks in Steelmaking.
II -1	Countrywise Pig Iron Production : 1971-75.
II-1A	Worldwide Direct Reduction Capacity.
II-2	Processwise & Countrywise Crude Steel Production.
II-3	Processwise World Crude Steel Production.
II-4	Global Processwise Crude Steel Production & Projections : 1960-1985.
II-4A	World Electric Arc Furnace Production.
II-5	Increase in Capacity Needed to Meet Demand.
II_6	Processwise Steelmaking in the USA.
II-7 .	Growth in production During 1950-72 in USSR.
II-8	Sizes of production Units in USSR.
II-9	processwise steel production in USSR.
II - 1 0	Processwise Pig Iron Production in Japan.
II -11	Processwise Production of Crude Steel in Japan During 1971-74.
II -12	Processwise Production of Crude Steel in Britain.
II -1 3	Trends in the process pattern of Crude Steel production in Selected Countries.
II -1 4	Specific consumption of raw materials for pig ironmaking : 1960, 1965, 1970.
II -1 5	Sizes of Italian Steel Units and their
	production in 1971.
II -1 6	Spanish Steel Production : Processwise.
II -17	Spanish Imports of Scrap (Tonnes).
II - 18	Latin America : Production of Pig Iron, Sponge Iron, Steel in ingots & hot-rolled products.
II - 19	Processwise production of Pig Iron in Latin America.
II -2 0	Steel Production by Processes in Latin America.
II-21	Degree of Integration, Processwise & sizewise distribution of Brazilian iron & steel units.
II-22	Processwise pattern of steelmaking in ESCAP Region.

xii

TABLE NUMBER

	The second se
III-1	Development of steelmaking capacity in India
	during the second Five Year plan.
III-2	plantwise break-up of steelmaking (ingot)
	capacity. Targets of capacity & production achievements.
III-3	projected steel consumption in India :
III-4	1955-2000 AD.
	Projections of processwise capacity 1970-81.
III-5	Main facilities of integrated steel plants.
III-6	Plantwise & processwise break-up of existing
III -7	capacity for iron & steelmaking.
III-8	plantwise capacity likely to fructify by
111-0	1985-90 · verv optimistic estimates.
III-9	Estimated processwise & plantwise capacity
111-2	1985.
III -1 0	Estimated processwise & plantwise capacity
	1990.
III-11	Summary of Tables III-9 for 1975, III-10 for
	1980 & III-11 for 1985.
IV-1	Locationwise & categorywise break-up of
11-1	proved and possible Indian iron-ore deposits.
IV-2	Reserves of coal for coking (m.t.).
IV-3	Lifetimes of extractable coking, medium &
21 0	blendable coal reserves for different levels
	of hot metal production.
IV-4	Requirements and availability of coking coal
	for steel plants.
IV-5	Matching resources of minerals.
IV-6	Estimates of scrap originating from
	obsolescence.
IV-7	Estimates of internal scrap arisings
	(Metallurgical).
IV-8	Estimates of process scrap generation.
IV-9	Estimates of requirements of scrap
	(Processwise).
IV-10	Estimates of scrap availability, requirement
	& deficits for different terminal years.
IV-11	Comparative estimates of EF input requirements
	for attaining different shares in total steel
	demand $(1975-76 \& 1980-81)$.
IV-12	Estimates of yearwise requirements of inputs
	for EF industry (including TAS steels &
	castings) for a 25% share in 1975-76 & 30%
	share in 1980-81 in aggregate steel demand.
IV-13	Energy usage under different routes (GCal
	per tonne).

xiii

V-1 V-2	sizes of iron and steel plants. The world's largest steel organisations (cut-off point six million tonnes).
V-3	Increase in BF sizes in Japan.
V-3 V-4	production cost-size relationships : BFs.
V-4 V-5	UCC-size relationships : OH furnaces.
	UCC-size relationships : OH furnaces.
V-6	UPC-size relationships : OH furnaces.
V - 6A	UPC-size relationships : EFs.
V-7	
V-8	UCC-size relationships : Bessemer Converters.
V-9	UPC-scale relationships : BF+LD route.
v-1 0	The economies of scale under BF+LD in Britain.
V-11	UPC-scale relationships : EFs : Break-down into elements of costs.
V-12	Estimates of minimum efficient scale of
	steelworks in terms of annual crude steel
	production.
V-13	Indices of total unit production costs
V= 15	(inclusive of raw materials) in integrated
	(BF+LD) plants of particular scales
	producing hot-rolled strip.
V-14	
V - 14	Economies of scale for BF+LD plants of 1 & 2
	million tonne-capacity (Billets).
V-15	UPC-size relationships : BF+LD plants.
V -1 6	UPC-scale relationships : BF+LD+CC (S.E.
	Asian location).
V-17	UCC & UPC scale relationships for forward integrated BF+LD plants producing non-flats
	: Latin American location.
V - 1 8	UCC & UPC scale relationships for forward
	integrated BF+LD plants producing flats :
	Latin American location.
V - 19	UCC scale relationships : BF+OH (Latin
	American location).
V-20	UPC scale relationships : BF+OH (Latin
	American location).
V-21	Influence of scale on production costs for
	different steelmaking processes.
V-22	UPC-scale relationships for OH, EF, BOF and
	rotary converters : A summary of Table V-19.
V-23	Comparisons of economies of scale for BF+LD
V - 2 4	and DR+EF.
	UCC-scale relationships : Japanese location.
V-2 5	UCC-size relationships : Gas cleaning equipment.

V-26	Breakdown of investment costs for OH steelworks with furnaces of various
*	sizes.
V-27	UCC-scale relationships : BFs.
V-28	Unit capital cost for BOF.
V-29	UCC-scale relationship : ESF.
v-30	Cost-size relationships : Krupp solid
V=30	reductant sponge iron plant (Rotary
	Kiln).
V-31	UCC-scale relationships : DR plants.
V-32	UCC-scale sensitivity : EFs (Germany).
V= 52	
VI-1	Comparison of USSR (Gipromez) and Dasturco
	estimates for Bokaro Steel Plant (4 m.t.
	ingot stage).
VI-2	UCC-scale relationships : Vijaynagar and
	Vishakhapatnam plants.
VI-2A	UPC-scale relationships : Vijaynagar and
	Vishakhapatnam plants.
VI-3	UCC and size relationships : EFs.
VI-4	size distribution of BFs.
VI-5	Size distribution of OH facilities.
VI-6	Size distribution of LD converters.
VI-7	Size distribution of EFs (Licensed).
VI-8	UCC-size (As-installed) relationships :
VIO	Hypothetical EF units.
VI-9	Capital charge as percentage of works cost
V1-9	of ingots.
VI-10	Input price and scale sensitivity of UPC.
VI-10A	Scale sensitivity of BF+LD UPC (including
12 1011	UCC for sinter and coke oven plants).
	the for prince and coke oven princes,
VII-1	UPC estimates for alternative process routes
	(ingot/liquid metal capacity 250,000 tpy).
VII-2	Input price sensitivity of UPC under BF+LD
	route.
VII-3	Input price sensitivity of UPC under ESF+LD
	route.
VII-4	Price sensitivity of UPC under DR+EF route.
Annexure to	Work-sheet for estimating approximate costs
Table VII-4	of reductants for DR.
VII-5	UCC for different routes for a 250,000 t.
	ingot/hot metal plant.
VII-6	Input price sensitivity of UPC for steel
111-0	ingots/hot metal.
VII-7	
	Input price sensitivity of UPC for pig iron/hot metal/sponge iron.
VII-8	Influence of price of iron-ore and energy
	on sponge UPC.
VII-9	Influence of UPC of sponge iron and prices
and states a the state of the s	of scrap on UPC of ingot/liquid metal.
	or scrap on ore or ingot/liquid metal.

TABLE NUMBER	TITLE
VII-10	Influence of scrap price and power tariff on cost of steel ingot/liquid metal.
VII-11	Break-up of capital costs of production departments.
VIII-1	Ingot costs in India and U.K. (1973).
VIII-2	Published home trade iron & steel prices in India and a few foreign countries.
VIII-3	Specific consumption rates for inputs in 1972.
VIII-4	International and domestic prices of major inputs of EFs.
VIII-5	Examples of capital cost items not normally entering UCC of integrated plants abroad.
VIII-6	Capital cost comparisons LD vs Q-BOP (relative percent comparison) : (US location).
VIII-7	Method of increasing Soviet production in 7-year plan.
IX-1	Investment costs for an RES plant.
IX-2 .	Investment costs under three alternative route combinations.
IX-3	Size pattern for a 75-m. tpy capacity.

xv

xvi

FIGURES

FIGURE NUMBER	TITLE
1.1	Immediate Forward & Backward Linkages for Iron & Steelmaking.
VI.1	Hypothetical Japanese (A) and Indian (B) Cost Curves for Bars & Rods.
VI.2	Input Price and Scale Sensitivity of UPC.
VII.1	Influence of Prices of Iron-ore and Energy on Sponge UPC.
VII.2	Influence of UPC of Sponge Iron and Prices of Scrap on UPC of Ingot/Liquid Metal.
VII.3	Influence of Scrap Price and Power Tariff on Cost of Steel Ingot/Liquid Metal.