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Expert Group on Metalworking Industries as
Potential Export Industries in Developing Countries

THE PLANNING OF PRODUCTION AND EXPORTS IN THE METALWORKING INDUSTRIES[1]

by

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[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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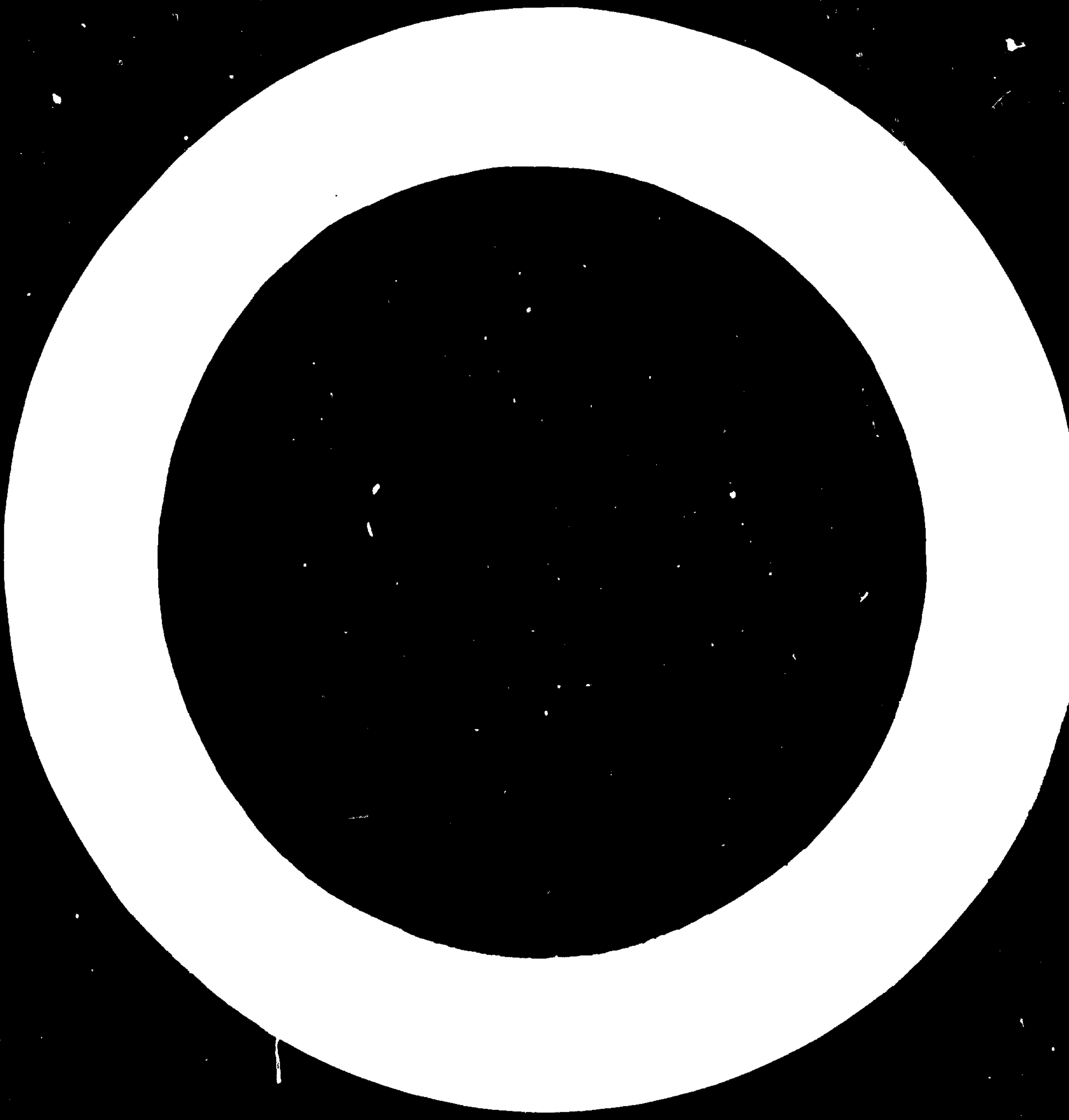

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Foreword

This is the report of a study aimed at developing a workable approach to the effective planning of production and exports in the metalworking sector of developing countries. The study was made within the Center for Economic Planning of the New School for Social Research, New York, N.Y., over a period of approximately nine months. The report covers problems of planning methodology, the experience gained in the collection of empirical materials on a pilot basis and the suggested application of selected concepts and empirical materials to over-all sectoral planning decisions in individual countries.

Given the general lack of orientation with regard to an effective planning approach to the metalworking sector, the study represents a significant advance. The conceptual orientation that has been achieved and the experience that has been gained with the collection of programming data now make it possible to recommend, as a next phase, an approximate but comprehensive technical-economic description of the key features of the sector as a whole, aimed at an overview of developmental possibilities and the identification of the main lines of advantageous growth in individual countries. At the same time, several major problems remain without an adequate solution. One of these is the development of fully worked-out practical programming approach under decreasing costs. Another is a practical shortcut to the problem of costing; that is, the provision of a system of success indicators for potential projects and product categories without full immersion in quantified technological detail. Future progress on this front will depend on establishing an adequate interconnexion between programming data at different levels of detail.

A separate Bibliography and Keyword Index has been submitted to the United Nations Industrial Development Organization together with the present report.

Other materials not included in this report that have either been produced as a part of the same project or that have been prepared in co-operation with the project while separately commissioned by the United Nations, are the following:

1. A report by Professor Abraham Ber on empirical technical-economic description work in the agricultural and dairy equipment branches; this was produced as a contribution of the present project to the initiation of the country study in Israel and is to be submitted directly to the United Nations.

2. A report by Professor Van Court Hare on technical-economic description in the agricultural equipment branch including a discussion of input-output and information processing problems by Stedman Noble. Although commissioned separately, the latter report was prepared in co-operation with the present project. However, it is to be submitted directly to the United Nations.

3. Report by Mrs. János Deák on the metalworking-industries sub-models within the Two-Level Programming Model of the Hungarian Academy of Sciences. This study was commissioned separately but prepared in co-operation with the present project. It is to be submitted directly to the United Nations.

The empirical materials of Chapter IV (Section E: Empirical testing of methodology: electrical machinery and equipment industries) have been compiled, organized and drafted by a staff working group headed by Mr. Nathan Ginsburg, with the co-operation of Mr. Peter Bearse and Mr. Richard Lissak, and the assistance of Mr. Robert Baker. This phase of the project was greatly strengthened by the fact that Ginsburg acted not only as a research economist but also as a consultant in electrical engineering relying on seventeen years of practical engineering experience in the electrical products industries. Mr. Bano Fahrenstock of New York City acted as a consultant to the working group on problems concerning transformers.

The basic approach of semiquantitative programming data has been introduced by Professor Van Court Hare of Columbia University, a consultant to the present project. Professor Hare also organized the data-collection effort at this level of detail and drafted the text of Chapter V, Semiquantitative programming data: concepts and pilot empirical work.

The classification of the sector by industrial branches, given in the Appendix to Chapter IV, was prepared in co-operation with the project by Mr. Jaroslav Schejbal of the Export Industries Section of the United Nations Industrial Development Organization.

The rest of the report was written by Professor Thomas Vietorisz, Center for Planning of the New School for Social Research, New York, N.Y., who was the Project Director.

The integration of the various parts of the project has greatly benefited from the work of Mr. Richard Lissak, Assistant Project Director, who at one time or another participated in every aspect of the project. He wrote the initial version of the separately submitted Bibliography, participated in the working group on electrical-equipment industries and worked on problems of methodological synthesis.

The contributions of Mr. Martin Kenner and Miss Rachel Strauber, acknowledged in the separately submitted Bibliography, have been indispensable in gaining a well-rounded background for the project and have resulted in what is hoped will be an important source of general reference for planning problems within the sector. Mr. Peter Bearse, in addition to his above-mentioned contributions, has been responsible for co-ordinating all computer programming work involved in the updating, indexing and selective output generation of this Bibliography. He also contributed to the over-all integration of the project methodology.

In the stage-by-stage development and refinement of the over-all methodological approach of the project, periodic staff discussions proved to be invaluable. The participation of Professor Van Court Hare and of Mr. Stedman Noble, a consultant on input-output and information-processing methodology who is contributing to a separately commissioned report under the broader United Nations project, in these staff discussions, and their fundamental contributions, are gratefully acknowledged.

For the clarification of problems relating to the method of approach and the practical execution of the country studies, grateful acknowledgement is also extended to the following persons: Professor Abraham Ber, Technion, Haifa, Mr. Y. Merzel of the Ministry of Commerce and Industry, and Mr. N. Pardo of the Israel Investment Authority, who participated on behalf of the Government of Israel in a preparatory meeting held in July 1966; to Mrs. János Deák of the Ministry of Finance, Mr. Ferenc Nemes of the Ministry of Metallurgy and Machine Building, and Mr. József Drecin of the National Planning Board of Hungary, who have engaged in a number of clarifying discussions connected with the preparation of the country study in Hungary and have consented to participation in its initial stages; to Dr. Gyorgy Cukor, Dr. János Kornai, Dr. Lészló Csapó, Dr. András Bródy, and Mr. Gyorgy Kondor of the Economic Research Institute of the Hungarian Academy of Sciences who have generously contributed their time to a series of discussions of methodological issues in planning for the metalworking sector; and to Dr. Béla Martos of the Economic Research Institute of the Hungarian Academy of Sciences who, on a scholarly exchange visit to the United States, spent two weeks at the Center for Economic Planning of the New School for Social Research and contributed his experience to the evaluation of the project methodology in its final stages.

A number of ideas and other contributions received from staff members of the United Nations Industrial Development Organization in discussions concerning both theoretical and practical problems of planning for the sector are gratefully acknowledged. Foremost among these was a clarification of basic problems in working out a practical approach to technical-economic description of the sector, by Mr. Vladimir N. Vasiliev. Other helpful discussions were held with Mr. Igor Radovic and Dr. János Fáth.

The consistently generous help and co-operation of Mr. Sidney Cashton, Director of the United Nations Computing Centre, as well as the help extended by the centre's staff, were indispensable in the preparation of the Bibliography.

The project also benefited from additional resources made available by the United Nations in the form of computer time, key-punching, thermocopying, typing, and other secretarial services. In addition, generous assistance and co-operation were made available at all times by the Reference and Documentation Unit of the United Nations Industrial Development Organization, by the United Nations Headquarters Library, and by the Regional Commissions Section of the United Nations Department of Economic and Social Affairs.

Miss Isabel Ackerman rendered valued secretarial services throughout the course of the project.

I. INTRODUCTION

1. The planning problems arising within the metalworking and engineering products sector are both the most interesting and the most exasperating of the sectoral planning problems. These problems are of great practical significance because the metalworking sector is the key producer of capital goods and thus a strategic agent for growth; it is also a center of innovation and a focus of the cultural change signalled by the upgrading of skills and organizational abilities at all levels that characterize economic development. At the same time, it is the most exasperating of the economic sectors since the problems that arise in it call into question many of the comfortably entrenched notions of the economist about matters such as the aggregative description of the phenomena connected with production, the role of the price system in decentralized resource allocations and the constancy of technical input coefficients. For this very reason, it is also the most challenging sector; progress toward solution of the problems it presents offers a hope of obtaining a new and clearer picture of the key characteristics of the economic process.

2. It has long been evident that the planning problems of this sector must be attacked at a fundamental level if progress is to be achieved toward the compilation of programming data and the definition of proper methods of planning procedure. Several attempts to come to grips with these problems have been made recently.[1-4] However, none of these seems entirely satisfactory. The present study attempts to synthesize these earlier approaches and extent the best features.

3. Much of the study is dedicated to the clarification of conceptual problems. Empirical work was originally to have been undertaken entirely in separately commissioned country studies but, due to major delays on the latter, some data have been gathered on a pilot basis in the United States of America, primarily as a test of the methodological concepts developed in the course of the present study.

A. Purpose

4. The present project is part of a broader effort undertaken by the United Nations Industrial Development Organization (UNIDO) to promote the growth of new and dynamic export industries in the developing countries. Its specific

aim is to improve the techniques of production and export planning in the metalworking and engineering products sector. For the purposes of the project, the sector is defined as including classes 35 through 39 of the International Standard Industrial Classification.[5]

5. In particular, the efforts of the project are focused on the objective of providing policy-makers with factual tools that will help them to answer such vital questions as:

(1) What kind of investments would be economically justified in new or expanded productive resources?

(2) What branches of production and, within these branches, what kinds of product assortments should receive the principal emphasis?

(3) Taking into account the potentialities of the world market, what exports deserve serious promotion?

(4) What should be the guiding principles of foreign trade negotiations in regard to the sector considered here, so that desirable kinds of trade agreements can be reached?

B. Linkage between domestic production and exports

6. The metalworking and engineering products sector presents both great opportunities and particular difficulties in the development of new, high-grade exports linked with systematic import substitution in a developing country. The opportunities have to do with the key role of this sector in economic development, as pointed out above. By giving simultaneous consideration to exports as well as to the domestic market, economies of scale can be attained that would otherwise be impossible to achieve, and a source of foreign exchange earnings can be provided that is far less subject to price instabilities in the international market than the typical primary exports of the developing countries.

7. The close relationship between domestic production and exports in this sector is further underlined by the following institutional considerations:[6]

8. (1) Exports in any sector, but particularly in the metalworking sector, which shows marked dependence on technological advance and on a high degree of efficiency in regard to production methods and inspection techniques, will generally be very difficult to promote effectively unless they are based on a broad experience of sales on the domestic market. Foreign

purchasers are understandably reluctant to commit themselves to a source of supply that has not passed the practical test of acceptance within its home market.

9. (2) At the same time, potential domestic purchasers of newly introduced import-substituted metalworking products will show a similar distrust in regard to such considerations as the expected quality, performance, reliability of continuing service and spare-parts supply of domestic production. This hesitancy can be most readily overcome by a simultaneous promotion of the products for export. The esteem in which these products is likely to be held in the home market will rise in proportion to the acceptance they achieve in foreign markets.

10. (3) This psychological acceptance of domestically produced metalworking products to the extent that they are accepted abroad is of course further shared up by the well-recognized requirements for quality and performance that are inevitably imposed on export products, as against the possible carelessness and even shoddiness to which import-substituted products may fall victim within their protected, isolated and non-competitive small home markets. Temptations in the latter direction on the part of producers may be difficult to resist, even with the best of intentions, since small crises that appear to seemingly justify an erosion of quality, one small step at a time, are everpresent in the daily operation of such industries. When a firm must produce for export in order to survive, it simply cannot permit the quality of its products deteriorate.

11. The principal difficulties in regard to the metalworking sector are organizational rather than strictly technical. While much of the requisite technical know-how can in principle be readily obtained by any country intent on having it, it is also indispensable in the development of proper individual and collective attitudes toward the organizational requirements of the modern production processes and the adoption of adequate planning procedures. These attitudes and procedures are required for a suitable articulation of the many activities that make up the metalworking and engineering sector in a manner that will allow either competitive entry into the world markets or planned international specialization.

C. Difficulties of planning for the sector

12. There are three chief sources of these difficulties, namely: (1) the diversity of production facilities and of products, (2) the multipurpose nature of productive resources and (3) decreasing costs in production.

The diversity of production facilities and products

13. The great diversity of metalworking machinery is well known; the number of sizes and types of just metalcutting machine tools has been recently estimated at over fifteen hundred.[7] Such machines can be organized into shops or production departments in the most diverse ways. The number of different kinds of metalworking-engineering products that are being manufactured is of the order of a quarter of a million for a medium-sized country defined as one with a population of ten million and an annual per capita income of US$ 400 with a fairly well developed metalworking sector for which information can be obtained.[8] The United States federal government procurement agencies reportedly work with over four million items, a major fraction of which is produced within the metalworking sector (this includes military items).[9] As against the diversity found in this sector, it is of interest to compare the relatively simple nature of planning for the basic chemical industries, where a recent United Nations study covering the entire Latin American region was able to encompass a significant fraction of the production value of this sector by means of an investigation of about seventy products and ninety production processes.[10]

The multipurpose nature of the productive resources

14. While in the basic chemical industries a given plant generally produces only one kind of output (for example, an ammonia plant normally produces only ammonia), in the metalworking sector, on the contrary, a given piece of equipment characteristically produces a wide variety of products. In principle, a lathe can turn out components for an unlimited range of end-products, and even in practice its yearly capacity will be divided among a great many individual items. Forges or foundries are capable of an equal diversity of output. As a result important economic connexions are established between the jointly produced products that make it impossible to "cost out" a given product independently of all other products. Thus, since there exists a great diversity of both productive resources and

products, the consequences would appear to be that the metalworking sector cannot be adequately dealt with except by the simultaneous consideration of hundreds of thousands of interconnected details. This conclusion evidently reflects no more than an inappropriate approach. It will be the task of this study to point the way toward a drastic simplification.

Decreasing costs in production

15. Decreasing costs in the metalworking sector appear in two guises. First, the real costs as measured in resource inputs decrease with the seriality (lot size) of production and second, independently of the former phenomenon, costs also fall with the scale of total yearly output of a productive facility. The result of these two effects is that there frequently exists a sharp lower limit to feasible seriality or total yearly production scale. This kind of technology precludes the proportional subdivision and averaging of inputs for distinct production facilities and creates the greatest mathematical difficulties for any kind of programming effort. Among other things it excludes the possibility of an exact decentralization of production and investment decisions by means of any linear system of prices or other incentives. Thus, in the presence of a decreasing-cost technology, linear and even nonlinear programming fail, and any cost analyses of individual enterprises that operate within the sector can be built only on very shaky foundations. In such a situation the only known way of constructing an efficient plan is to define alternative industrial complexes based on individual combinations of the fixed costs that are implied by the lower limits on serialities and on total production scales and to choose the most favourable of these complexes.[11] Unfortunately, when comparing this requirement with the implications of the previous two sections, it becomes clear that an astronomical number of possible combinations exists. The common virtue of mathematical programming and of a decentralized market mechanism, provided that they are capable of operating in a given situation, is exactly that they cut through the combinational jungle of possible alternatives and lead directly to the optimum. Unfortunately, in the present situation these shortcuts are not applicable; this is the crux of the third difficulty that arises from decreasing production costs.

16. Owing to the three sources of difficulty discussed above, no suitable planning procedure exists that provides guidance in regard to the basic

problems faced by this sector. The planning methods customarily employed are inadequate in one of the two ways. They either investigate each product or small group of products individually and, due to the neglect of the broader connexions between the productive resources, lead to excessively high cost estimates and poor prospects of capacity utilization, thus making too many production activities appear uneconomical, or they renounce the exact exploration of issues connected with efficiency and place the entire emphasis upon the elaboration of a single coherent, balanced feasible plan. In either case it remains doubtful if a given plan has adequately succeeded in exploiting existing potentialities. The application of such methods resorted to in the absence of better alternatives often results in a sense of uncertainty about the appropriateness of basic planning decisions that must be taken in regard to the sector.

D. The requirements of a suitable planning methodology

17. What is most urgently required is a planning approach that will yield an approximate but essentially correct overview of the entire sector, that will permit precisely the type of panoramic orientation that is presently needed. As long as this need is unmet, no amount of conscientious compilation of detail - of which there is no lack in many cases - will resolve the doubt as to whether the sector as a whole is moving in the right direction. In line with the objectives of the present project, as described above, such a direction must strike a mean course between the extremes of insufficient and underutilized capacities, between uneconomical diversification and over-specialization, and between undue risks in producing for the open world market and excessive rigidities in commitments to long-term trade agreements.

18. The definition of a successful planning methodology presupposes both (1) an adequate technical-economic description of the sector that none the less manages to avoid the danger of drowning in detail; (2) a programming technique that is applicable to the case of decreasing costs and can thus cope with the ensuing combinatorial problem of alternative industrial complexes.

19. These two considerations are closely interrelated since it is impossible to cut through the welter of technical data unless there already exists an awareness of the type of detail that wil play a key role in the course of

programming. At the same time, however, the task of programming cannot be formulated unless resources and activities are already suitably grouped and specified so as to suppress all but characteristic detail.

20. In the course of the present project it became evident that the entire question of the level of detail at which the technical-economic description of the sector is attempted plays a key role both in the cost and speed of data collection and in the definition of the fundamental approach to be used for planning. It has been found best to specify three distinct levels of detail, the first two of which have been explored empirically: (1) the "semiquantitative" level, suitable for preliminary orientation and project preselection, (2) the "fully quantified" level, which provides programming data for costing purposes, thus laying the basis for feasibility studies and (3) the level of concrete project engineering and blueprinting preparatory to the final go-ahead decision in plan execution.

21. These three levels are taken to be typical, but the possibility of additional intermediate levels that might become useful at some stages of programming need not be excluded. The threefold classification corresponds closely to the one employed in general for project evaluation and sectoral-level planning within the United Nations and elsewhere.[12]

22. Data have been collected for this study on a pilot basis both at the semiquantitative and fully quantified levels, leaving aside the third level of concrete project engineering as lying wholly outside the adopted terms of reference. Programming strategies have also been explored primarily at the first two levels.

E. Prospect

23. The report is organized as follows. After a survey of the literature (Chapter II) the key features of the approach adopted are spelled out (Chapter III). The rationale of fully quantified programming data is discussed and the results of a pilot data-gathering effort are presented in Chapter IV. Semiquantitative programming data are discussed and a collection of such data is presented in Chapter V. The application of the concepts and empirical data of the study to planning decisions and further studies in individual countries is discussed in Chapter VI.

Notes for Chapter I

[1] See for example: United Nations, "Expert working group on industrial development programming data", Industrialization and Productivity Bulletin No. 5 (1962), pp. 35-36.

[2] Some of these studies are discussed in the literature survey (chapter II) of this report; a more detailed listing is provided in the separate Bibliography of the project. The most important of these studies include: Economic Evaluation of Steel Transforming Processes in Latin America (S. Podgorski), Latin American Meeting of Experts on Steel Making and Transforming Industries, Sao Paulo, 1956, ST/ECLA/CONF.4/L.BIV-1/Rev.1; The Manufacture of Industrial Machinery and Equipment in Latin America-I. Basic Equipment in Brazil, New York, 1963, Sales No. E/CN.12/619/Rev.1; "Some methodological problems in the programming of machine-tool and other equipment industries" (in Spanish), Industrial Programming Seminar, Sao Paulo, 1963, ST/ECLA/CONF.11/L.11, "Criteria and background materials for the programming of the machine tool industry" (in Spanish) Industrial Programming Seminar, Sao Paulo, 1963, ST/ECLA/CONF.11/L.12; "The metal-transforming industry in Venezuela: an import substitution development programme", Latin American Symposium on Industrial Development, Santiago, 1966, ST/ECLA/CONF.23/L.4.

[3] University of North Carolina, Chapel Hill, N.C., Institute for Research in Social Science, Production Coefficients and Technological Trends in Soviet Industry: Soviet Planning Study No. 7, An Input-Output Analysis of Machinery Construction (1959). See also: No. 6, Input-Output Analysis of Soviet Heavy Machinery (1958), No. 6 Supplement (1958); No. 5, Analysis of Production Process in the Soviet Heavy Machine Building Industry (1956); No. 5 Supplement (1956).

[4] Markowitz, H.M., and Rowe, A.J., "The Metalworking Industries", "Metalworking Requirements Analysis", " A Machine Tool Substitution Analysis", "Future Metalworking Analysis" and "Statistical Appendix on Metalworking", in Manne, A.S., and Markowitz, H.M., eds., Studies in Process Analysis: Economy-Wide Production Capabilities, Cowles Foundation Monograph No. 18, New York, Wiley, 1963, Chap. 10-14. Earlier versions published as Rand Corp. Research Memoranda No. 685 and No. 1512.

[5] A classification of the activities of the sector into twelve major groups and ninety-two branches is given in Chapter IV, Appendix Table IV-1. This classification has been prepared by the Export Industries Section of the United Nations Industrial Development Organization in co-operation with the the present project.

[6] These ideas have been set forth in personal communications by Dr. Meir Merhav of the United Nations Industrial Development Organization.

[7] United Nations, Review of the activities of the Centre for Industrial Development and considerations relating to its future programme of work, A Preliminary Study of the Current Situation of the Machine Tool Industry, Committee for Industrial Development, Fifth Session, E/C.5/85, April 1965. p.9.

[8] Private communication concerning the number of total products listed for planning purposes in Hungary, together with the approximate fraction in metalworking-engineering products (1966).

[9] Estimate based on items listed in United States Government procurement catalogues. Private communication.

[10] United Nations, The Chemical Industry in Latin America (in Spanish), Mexico, 1964, Sales No. 64.II.G.7.

[11] Fixed costs represent a simple approximation to more general types of decreasing-cost functions. The programming problems posed by decreasing costs are discussed in more detail in Sec. III-B-4-c.

[12] For a discussion, see T. Victorisz, "Sector Studies in Economic Development Planning", in A.S. Manne and H.M. Markowitz, eds., Studies in Process Analysis: Economy-Wide Production Capabilities, Cowles Foundation Monograph No. 18, New York, Wiley, 1963, Chap. 17.

II. PREVIOUS WORK ON PLANNING AND PROGRAMMING OF THE SECTOR

24. While there is a great deal of accumulated know-how in relation to the planning and programming of the sector, no satisfactory integrated approach exists for a fundamental attack on the difficulties described in the introductory chapter.

25. Prior approaches to the problem of planning for the metalworking sector in developing countries have largely concentrated in two areas. The first is the aggregate estimation of the desired growth of the sector, loosely coupled with product-by-product or at best branch-by-branch feasibility studies or project analyses. The latter are intended to provide estimates of local costs of production that can be compared with world market prices as a guide to the decision whether a given project has a chance of success in the country under study. The other approach is the construction of material balances characteristic of centrally planned economies in which most decisions concerning domestic production and foreign trade are prejudged on the basis of prior experience and project-by-project cost studies enter only as afterthoughts, primarily to fill in the details of the plan that has already been pre-set in its major dimensions. These two approaches share an inability to relate the resource allocation side of the planning process organically to the side of precise cost evaluation of individual activities within the framework of the plan as a whole. With the first approach, the neglect of technological interconnexions between commodities and branches of production leads to an overestimation of costs and an underevaluation of development possibilities; insofar as a process appears feasible at all, it tends to be oriented toward import substitution, and there is only a minimal spill-over into the consideration of the export market. With the second case there is insufficient attention to valuation problems, with a resultant tendency to become excessively autarchic or at least not properly related to foreign trade potentials.

A. Centrally planned economies

26. The metalworking and engineering products sector of the economy, like all other sectors, is necessarily subject to continuous practical decision making in all countries with centrally planned economies. Until very recently[1] the focus of these planning efforts has been mainly upon the preparation of a consistent plan. Questions concerning the efficient allocation of resources have been handled by the assignment of overall priorities and the application of a variety of evaluation criteria to individual projects.[2] As a result a large amount of technical detail concerning the sector has been embodied in planning norms, engineers' and designers' manuals and technical articles, while the procedures of plan preparation, as well as the formulation of policies designed for increasing productivity and technical progress have been developed into a complex art.[3] This material is exceedingly useful as a source of reference, primarily in regard to practical problems of development policy and the kind of costing information that is subject to commercial secrecy in private-enterprise economies. It does not, however, readily lend itself to the drawing up of summary but accurate technical descriptions of the sector that would be reasonably transferable from one country to another, nor does it directly permit a quantitative analysis of the problems posed by the process indivisibilities, product interrelations and economies of scale that must underlie the formulation of policies under the widely diverging conditions of different economies.

27. A good idea of the scope and content of the technical-economic materials from sources of the Union of Soviet Socialist Republics can be gained from a series of studies by the University of North Carolina[4] which contain very detailed literature citations up to approximately 1961. These studies are discussed in detail below. Another convenient guide to sources from the Soviet Union and other Eastern European countries is available in English through the translations of the Joint Publications Research Service of the United States Department of Commerce.[5] Even though some of these sources address themselves directly to the problem of planning within the sector,[6] they do not add up to an integrated quantitative approach suitable for coping both with the resource-allocation and the cost-evaluation aspects of sectoral planning.

28. In the course of the present project there have been a few limited opportunities for gathering spot information on planning practice in the metalworking sector in countries with centrally planned economies through conversations with United Nations staff members who have had direct personal contact with the respective planning organizations in the countries concerned. These conversations confirmed the impression gained from the literature that planning for the metalworking sector in these countries is at present done largely in a pragmatic fashion, relying on detailed engineering information and the preparation of material balances but with little formal attention to problems of efficient resource allocation and cost evaluation.[7] In addition, the project provided one opportunity for more direct and intensive contact with the range of problems faced by centrally planned economies in the development decisions concerning this sector. This opportunity was offered by a visit to Hungary in preparation for a study of the sector as an independent part of the current broader United Nations effort concerning the problems of planning for the sector. In the course of this visit contacts were established with persons working in the Central Planning Office, the Ministry of Metallurgical and Machine Building Industries, and the Economic Research Institute and the Center for Computing Techniques of the Hungarian Academy of Sciences. These contacts permitted the formation of what may be regarded as a reasonably accurate general overview of the current status of planning techniques for the sector in at least one country with a centrally planned economy. The brief characterization offered in the introductory remarks to Chapter II is based on this overview. The eight key quantitative features of the techniques used are: (a) principal reliance on material balances, (b) the prejudgment, based on experience, of proportions between domestic production, imports, and exports, and the distribution of these among branches of the sector, (c) the use of technical norms for drawing up the material balances, (d) the necessarily broad aggregation in the balances characterizing this sector, even though the material-balances approach generally aims at homogeneous resource and product categories insofar as possible, (e) the existence of detailed project studies, (f) the lack of coherence between the material balances and the project studies, due to the fact that the latter are drawn up in terms of far more detailed product classes than the resource and product classes for which balances are prepared, (g) the use of project studies to fill in the pre-existing plan

framework provided by the material balances, which is done in the course of detailed programming for the sector as the plan is carried into execution; and (h) the consequent almost complete lack of feedback from project studies to the broad production, import substitution and export decisions embodied in the plan.

29. The above characterization does not, of course, approach the inclusion of all features of the planning approach used within the sector; rather, it concentrates on those features that are of particular interest to the present project and bypasses a great deal of additional significant information. A description that did full justice to current practice would have to include, for example, the organized flow of communications between the central, ministerial and enterprise-level planning organs, detailed production scheduling at the plant level and its relation to the planning process, institutional features having to do with policy concerning innovations, productivity and incentive systems, details of supply, financing, control of enterprises, and a host of others.

30. It has been found that the quantitative features of the current overall planning practice for the sector, enumerated above, do not reflect a general satisfaction with the state of the art; on the contrary, the shortcomings of the existing largely pragmatic approach are well recognized and deplored. There has, however, been agreement among all persons contacted who were engaged in practical planning decisions that no alternative was available at present; in particular, the current types of mathematical programming models were specifically rejected as direct decision-making tools due to the wide range of unacceptable oversimplifications that were known to be invariably involved in their construction. None the less, such models were acclaimed to be useful sources of background information, provided that their results were viewed with proper critical reservations and within a broader perspective.

31. A very large economy-wide planning model of the linear programming type is under construction within the Economic Research Institute and the Computing Techniques Center of the Hungarian Academy of Sciences.[8] This model has two levels, corresponding respectively, to central and sectoral planning decisions, and is organized along lines that make it suitable for computer solution by means of the well-known Dantzig-Wolfe "decomposition" technique.[9]

There are fifty sub-models at the sectoral level,[10] eleven of which fall within the broadly defined metalworking sector of the present project, with 133 individual products covered.[11] Details are presented in the next section of this chapter. In gathering data for the metalworking portions, originally about as much enthusiasm was said to be encountered on the part of the respective Ministry as could be expected from any operating organization that was being inconvenienced for data for economic research purposes. However, as initial results accumulated, a distinct arousal of interest was reported, due to the recognition of the value of the results as guides to practical decision-making. This augurs well for the future utility of the programming approach as a whole as a means of dealing with the planning problems of this sector.

B. Process-analysis studies

32. The above model is an outstanding example of process analysis applied to the economy as a whole and to the individual sectors within it. The present section will be devoted to a more detailed survey of the metalworking sector by the techniques of process analysis.

33. The two major academic studies that have been seen[12] are by Markowitz and Rowe[13] (hereafter MR), the University of North Carolina Center for Social Studies[14] (hereafter UNC). The term "process analysis" refers to the

> "... analysis of industrial capability through models reflecting the structure of industrial processes."[15]
>
> "The models are generally based upon relationships well known to the industrial engineer ... The aim is to cast these relationships into a form usable for the analysis of economy-wide capabilities. In most cases the models are of the activity-analysis type ..."[16]

A summary description and evaluation of the two studies mentioned above as well as an analytical comparison with suggestions for generalization is available.[17]

34. The two principal parts of the MR study are a "requirements analysis" and a "substitution analysis". Both are aimed at the definition of the capabilities of an existing set of productive facilities in the United States of America rather than at the construction of a set of investment policies for optimizing economic growth. In the requirements analysis, the

input coefficients of about fifty types of metalworking and auxiliary machinery into 1000 dollars' worth of the output of the major branches of the metalworking sector constitute the basic information.[18]

35. The knowledge of such input-requirement coefficients, together with an estimate of the existing machine-park of the sector permits the prediction of maximum productive capability in a particular line of output, given the levels of production of other outputs. In turn, this prediction can be refined by means of the second part of the study; that is, by substitution analysis. In the latter, the rigid one-to-one correspondence between outputs and input classes is relaxed by permitting alternative input combinations to occur (substitution between machines, as between a lathe and a milling machine) in producing given outputs.[19]

36. The UNC study covers heavy machine building in the Soviet Union and is quite similar to the MR requirements analysis in its rigid association of inputs with outputs. The inputs are, however, not individual machines but co-ordinated groups of machines called "resource elements" that roughly correspond to a production shop, such as a forge, casting shop or machine shop, while the outputs are typical but highly specific individual end-products such as a given highly specific individual tractor or a railroad freight car. Several classes of such products are chosen as representative of each industrial branch, and the capital and flow inputs of each of these "representative products" are derived by a process of weighted averaging of the inputs of the "typical sample products". The coefficients thus constructed can be used for capability analysis much in the same way as the MR coefficients.[20]

37. The principal contribution of these studies to the present project has been in helping to define the proper method and the proper level of detail for the description of technology within the sector. The concepts of resource element and typical product have been taken over from the UNC study (see Chapter IV for exact definitions of these terms), while the analysis of substitution possibilities has been adapted from the MR study, even though at a level of technical detail below the one found there. In general, the availability of the UNC study has been important in defining the core of the proposed fully quantified description of technology and in making a confident estimate that the required research task for completing a description of the sector, while onerous, is manageable.

38. In addition to these two studies, the Hungarian two-level planning model, referred to earlier, also contains a detailed process-analysis type description of the metalworking sector. In this description, inputs are specified in terms of monetary costs rather than in physical units or in terms of resource elements. As in the other two studies, economies of scale due to aggregate output or lot size are left implicit; all the activities included in the model are permitted to vary in a proportional fashion. The detailed coefficients of this model have not been disclosed; information concerning it has been obtained from a published summary description and personal communications.[21]

39. Apart from a model for Mexico[22] (see below) in which the metalworking sector was schematically sketched in, using American data borrowed from the MR study, the above model is the only instance of a technical-economic description of the metalworking sector placed in the context of an economy as a whole. This gives it an extraordinary importance from the point of view of the programming tasks that are the subject of the present project. While the description of the sector is not sufficiently detailed, and the use of costs rather than physical units reduces the operating significance of the input data, and while, further more, economies of scale are not quantified, these defects of the model can be readily remedied by building a third, more detailed level below the existing two levels. This has reportedly already been done in one other sector of the model, namely in mining. The existence of a comprehensive process-analysis type model for the economy as a whole permits experimentation with a variety of programming approaches to the metalworking sector and evaluation of the repercussions of either sectoral decisions on the rest of the economy or changes in the rest of the economy upon the desirable structure and development of the sector.

C. Other materials of the process-analysis type

40. In defining the suggested approach of the present project, the MR and UNC studies mentioned above have been complemented by some technical-economic materials that do not by themselves constitute complete process-analysis studies but which, owing to their similarities of approach, have been found valuable in giving guidance on particular details of technical description and programming methodology.

41. An interesting set of technical-economic studies pertaining to the sector was developed for the Latin American Meeting of Experts on Steel Making and Transforming Industries held at São Paulo, Brazil, in 1956. Unfortunately, these studies have not been included in the published proceedings, which concentrated primarily on steelmaking.[23] They cover technical and economic aspects of casting, forging, and machining, and include an outstanding paper in which Podgorski attempts to integrate these aspects into a comprehensive method for dealing with the sector.[24] Two papers on economies of scale in steel tube-making and boiler shops,[25] prepared for the São Paulo Industrial Programming Seminar in 1963, reflect a similar approach. All of these materials are considered particularly valuable for secondary corrections for capacity and flow input coefficients based on resource elements when developing fully quantified programming data.

42. The UNC study itself was originally designed to be more comprehensive than the portions that have been actually completed. At the sudden termination of the project for external reasons in 1961, many valuable materials were left in a semi-finished condition, particularly those pertaining to additional branches of the sector and to supporting materials on individual resource elements. A modest amount of financing was made available by the United Nations to get the results of this semi-finished research work on paper for economic development purposes,[26] and a separate consulting study was commissioned to test the transferability of a small sample group of the UNC technical coefficients from one country to another.[27] Both of these efforts were contributions to the meeting of the Expert Working Group on Industrial Development Programming Data convened at United Nations Headquarters in 1961.[28] The first effort resulted in what is essentially an appendix to the UNC study, while the second called attention to some of the sources of intercountry variation in technical coeffients.

D. Programming of the sector by aggregate projections

43. Aggregate projections of the sector differ from approaches of the process-analysis type in that no attempt is made in them to cope directly with the description of technological relationships; instead, various aggregative measures characterizing the sector are developed and are projected in simple ways after correlation with explicatory variables.[29]

Of particular interest are the projections of the United Nations Economic Commission for Latin America (UNECLA) that employ a number of variations of this technique.

44. The scale of output of the sector and of its branches is quantified in terms of total value or total tonnage. Demand for the sector as a whole can be projected by input-output methods, as in the UNECLA study in Peru in which the sector is treated as one grouping in a 20 x 20 table.[30] The branches of the sector are subsequently projected by correlation with the scales of using industries; for example, tin cans with canned fish products and mining machinery with mining. A similar procedure for projecting demand is followed in an UNECLA study in Brazil,[31] where the demand for chemical, petroleum refining, cement producing, power generating and other equipment is projected on the basis of the estimated growth of these same industries, complemented by the precise equipment inputs of known projects targeted for future realization. The recent study, the metal-transforming industry in Venezuela[32] follows an analogous procedure.

45. In each of these cases, however, the key economic decision concerns the division of total demand between domestic production and imports, and this cannot be taken on the basis of projections alone. The Economic Commission for Latin America has been following a pragmatic but none the less useful technique in arriving at these decisions. All available information is first marshalled and organized branch by branch, beginning with production and import trends and complemented by indicators such as capital intensity, level of skills and share of domestic raw material inputs. While these data do not lend themselves to a direct computation of future import substitution percentages, once they are assembled it is possible to get together small groups of experts (including, in addition to the personnel of the study, people such as local businessmen, engineers, economists and government officials) whose collective judgment and experience can be brought to bear on the available objective data. The required future percentages are thus turned out in an intuitive but potentially quite reliable manner. In the case of machine tool production,[33] the demand estimate is somewhat different, but the appraisal of domestic production possibilities follows in the same spirit. In no case is there a comprehensive quantification of product interrelations, resource indivisibilities, and the influences of

lot size on required inputs that would be required for a critical appraisal of the present structure and optimal growth characteristics of the sector;[34] what is offered instead is an ingenious and effective method of extrapolating the trend of development, assuming an increasingly efficient utilization of opportunities within the framework of given structural and institutional characteristics.

46. In addition to the work of the Economic Commission for Latin America, aggregate projections of the sector appear in a number of economy-wide programming models in which domestic production and imports are explicitly considered as competing alternatives, even though still at a highly aggregated level. One of the earliest of these models, Chenery's model based on an input-output table for Italy and South Italian data[35] contains the mechanical sector as one of fourteen industry groupings. A particularly interesting methodological feature of this model is the consideration given to the effects of increasing product diversity and other sources of increased costs as the degree of import substitution increases while total demand is constant. This feature allows the quantification of the diminishing returns that accrue to import substitution in various sectors and ensures that an efficient programme will push such efforts up to a common economic limit.[36] The device of quantifying increasing costs as a function of the scale of the sector at an aggregate level is an important element of the methodology of using fully quantified programming data explored in the course of the present project.

47. Among a number of similar models, two are singled out for mention. A model for India by Eckaus and Lefeber[37] treats the equipment sector as one of eleven industry groupings in a multi-period formulation that permits the introduction of the time lags and the exploration of efficient growth possibilities over a span of years. Versions of this model with a more detailed sectoral breakdown are known to exist. A model for the key sectors of the Mexican economy by Manne[38] merits special attention, since it considers the metalworking-machinery sector in a breakdown of twenty-eight branches, each represented by a commodity row and by a corresponding production activity. The technical coefficients for this breakdown have been adapted provisionally, for lack of other sources, from the coefficients of the MR study covering conditions in the United States of America. Subject

to obvious reservations concerning the reliability of such data, it is interesting to note that the model projects domestic production rather than imports for each of these branches of the sector.[39]

E. Other previous work

48. Some selected results of a literature and source survey are given below by major groupings. The separately published bibliography of the project gives more detailed findings.

Other work by United Nations agencies and consultants

49. An analysis of the sector based on the statistics of a large number of countries has been prepared by the Centre for Industrial Development.[40] A series of important papers have also been published in the Industrialization and Productivity Bulletin. Outstanding among these for its wealth of ideas and novel approaches is a paper by Melman.[41] Descriptive studies are available for several areas, the most comprehensive of which are by the Economic Commissic for Europe and the Economic Commission for Asia and the Far East.[42] Considerabl work on the machine tool industry was undertaken by the Centre for Industrial Development,[43] and a large number of papers has been prepared for the Interregional Symposium on the Development of Metalworking Industries in Developing Countries held in Moscow in 1966.[44] The 2000-odd papers prepared for the 1963 Geneva Conference on the Application of Science and Technology for the Benefit of the Less Developed Countries,[45] include about three dozen that have a bearin on the problems of the sector, but even these mostly offer only qualitative insights rather than bases for quantification.

Work by United States foreign-aid agencies and consultants

50. Hundreds of technical-economic papers and reports have been published under a series of acronyms (MSA, FOA, ICA, and currently AID). Of these, about four dozen refer to branches of the metalworking sector. In addition, a collection of Fact Sheets for Industry, organized according to United States Census classes and that contains extensive data compilations for branches of the sector is also available. While these sources contain valuable reference material, their general focus on establishment-by-establishment presentation of data, with no consideration given to broader product interrelations, resource indivisibilities and other factors crucial for a proper planning and programming of the sector, reduces their direct usefulness for planning

purposes. There is also a tendency to stress consideration of the smaller-sized establishments, with consequently little information on economies of scale. None the less, they offer significant help in undertaking the technical-economic description of the sector.[46]

The industrial economics literature

51. Some monographs, such as those that cover the automotive industry,[47] and numerous chapters in industrial economics texts focus primarily on institutional and market characteristics. These sources often contain attempts at measuring economies of scale in some reasonable aggregative fashion for purposes of analyzing conditions of entry; for example, minimum economic scales for stampings, motor manufacture, assembly etc. are given in the monographs on the automotive industry referred to above. Two shorter papers on capital-labour substitution in machinery, by Kurz and Manne[48] and by Boon[49] deserve special mention.

Technical literature

52. Most valuable for this project are various industrial texts containing process descriptions and estimating procedures.[50] These are essential aids for undertaking the technical-economic description of the sector. There is also a vast periodical literature whose comprehensive survey has been excluded for the present; the main titles have been listed as reference material for branch-by-branch technical description.[51]

Direct technical-economic information from industry sources

53. Among the principal categories are: published standards, manufacturers' specifications made available to users of their products, confidential production and cost data of private firms which can sometimes be obtained or can be drawn upon indirectly by engaging the services of consulting engineers familiar with this material (such consultants can base conclusions on the data without revealing individual items), manufacturers' and retailers' catalogues, trade association statistics and other information.[52]

54. Examples of the use of information drawn from the miscellaneous sources enumerated will be given below in sections reporting on the collection of semi-quantitative and fully quantified programming data for the sector on a pilot basis.[53]

Notes for Chapter II

1 See the official descriptions of the planning process submitted by the Governments of Czechoslovakia, Hungary, and the Union of Soviet Socialist Republics in connexion with meetings in 1962/1963 of a group of experts appointed by the Secretary-General of the United Nations to study the experience gained and the techniques in use in the planning of economic development by different countries (published in Planning for Economic Development, Volume II, Studies of National Planning Experience, Part 2, Centrally Planned Economies, New York, 1965). While these descriptions present established practice, a survey of the Economic Commission for Europe (Economic Survey of Europe in 1962, Part 2, Economic Planning in Europe, Geneva, 1965) also includes recent methodological innovations (see especially chap. 4) whose details have been obtained in large part from the professional economic literature. A comparison of these sources reveals a tendency toward a great increase in emphasis upon formal analysis of efficiency problems in resource allocation.

2 See "Evaluation of Projects in Centrally Planned Economies", United Nations, Industrialization and Productivity Bulletin, No. 8, New York, 1964, pp. 7-40.

3 For a comprehensive survey of planning problems within the sector, primarily at the level of enterprises, see P.A. Zhukov, *ed.*, "The Economics of machine-building, the organization and planning of enterprises" (in Russian) Moscow, State Scientific Technical Publishing House for Machine-Building Literature, 1963, 504 pp.; transl. United States Department of Commerce, Office of Technical Services. Joint Publications Research Service; No. JPRS: 26,277, pp. 64-41, 536, Washington, D.C., 8 Sept. 1964 (No. TT 64-41, 536).

4 *Op. cit.*, see note (3), Chapter I.

5 See separate Bibliography of the project for a survey of this source material.

6 See Zhukov, *op. cit.*, note (3) above.

7 See, however, the reference to recent methodological innovations contained in note (1) above. A valuable source survey is provided by the proceedings of a recent conference on Mathematical Techniques and Soviet Planning University of Rochester, New York, 1965, in publication; preliminary version reproduced by Research Analysis Corp., McLean, Va. This survey discusses process analysis type models applied to a number of industries in the Union of Soviet Socialist Republics; however, no model dealing with any metalworking industry is mentioned.

8 For a summary description see János Kornai, "Mathematical programming as a tool in drawing up the Five-Year Economic Plan", Economics of Planning, Oslo, Vol. 5, No. 3, 1965, pp. 3-18.

9 Dantzig, G.B., and Wolfe, P., "The decomposition algorithms for linear programs", Econometrica, Vol. 29, No. 4, October 1961, pp. 767-778.

[10] Kornai, <u>op. cit.</u>, p. 5, note (8) above.

[11] A detailed report on the metalworking portions of this model has been commissioned by the United Nations as part of the broader effort concerning planning for the metalworking sector, following the preparatory work undertaken as part of the present project. This report has not been received at the time of submission of the present study.

[12] Undoubtedly some relevant studies, particularly in Eastern Europe, have escaped the attention of the literature survey so far completed. Programming studies of rail transport, cement and ceramic pipe industries are known to have been undertaken (up to the end of 1963) in the USSR; and of the cotton textile, synthetic fibre, and aluminium industries in Hungary, apart from the two-level planning model referred to earlier.

[13] <u>Op. cit.</u>; see note (4), Chapter I.

[14] <u>Op. cit.</u>; see note (3), Chapter I.

[15] Manne, A.S., and Markowitz, H.M., Studies in Process Analysis: Economy-Wide Production Capabilities, Cowles Foundation Monograph No. 18, New York, Wiley, 1963, p. 3.

[16] <u>Ibid.</u>

[17] A summary and critical evaluation of the UNC study is given in D. Gallik, "Exploration in the development of pre-investment data for the mechanical transformation sector", Expert Working Group on Industrial Development Programming Data, New York 17-19 May 1961, Doc. No. IDP/EWG6, 12 May 1961, dittoed, 15 pp. (Abbreviated version of original consulting paper). Both the UNC and MR studies are described and critically evaluated from the point of view of applying them to a study of the machine-tool industry in Brazil in United Nations, "Some methodological problems in the programming of the machine-tool industry and other equipment industries" (in Spanish), Industrial Programming Seminar, Sao Paulo, 1963, ST/ECLA/CONF.11/L.11. The UNC and MR studies and other materials are analytically compared with an attempt at generalization, in T. Vietorisz, "Alternative approaches to metalworking process analysis", in A.S. Manne and H.M. Markowitz, <u>eds.</u>, Studies in Process Analysis, Cowles Foundation Monograph 18, New York, Wiley, 1963, Chapter 15. An expanded version of this paper is available in Metalworking Process Analysis and Industrial Development Planning, Industrial Business Machines Corp. Research Report No. RC-715, Yorktown Heights, N.Y., July 29, 1962.

[18] In the original version (Rand Corporation, Santa Monica, California, Research Memorandum No. 1085, 12 May 1953) there had been 25 major and 14 additional sub-machine classes, for a total of 39, while in the later version (see note 4, Chap. I) 46 are given. The numbers of industrial branches covered in these two versions are 51 and 45, respectively.

[19] The substitution analysis in the MR study is just sketched out. Coefficients have been derived only for metalcutting machine tools, and not by industrial branch, but at a level of much greater technical detail. This would have to be complemented by an analysis of demand, branch by branch at the same level of detail. Such a demand estimate has never been actually carried out.

[20] Key characteristics of this study are discussed in much greater detail in Chapter IV, section A-I.

[21] See notes (10) and (11) above.

[22] Manne, A.S., "Key sectors of the Mexican economy", in Manne and Markowitz, *op. cit.*, Chapter 16.

[23] A complete listing of the papers is given in United Nations, Problems of the Steel Making and Transforming Industries in Latin America, Vol. 1, New York, 1958, Sales No. 1957.II.G.6 Vol. I, pp. 50-51. For a discussion, see the separate Bibliography of this project.

[24] *Op. cit.*, see note (2), Chapter I.

[25] United Nations Economic Commission for Latin America, Industrial Programming Seminar, Sao Paulo, 1963, Economies of Scale in the Fabrication of Welded Steel Tubes (in Spanish), ST/ECLA/CONF.11/L.14; and Economies of Scale in Boiler Shops (in Spanish), ST/ECLA/CONF.11/L.13.

[26] United Nations, Contributions to the Development of Pre-Investment Data for the Mechanical Transformation and Machinery Industries, prepared for the Industrial Development Programming Project, jointly sponsored by the Division of Industrial Development of the Department for Economic and Social Affairs, the Economic Commission for Latin America, and the Bureau of Technical Assistance Operations, Santiago, Chile, October 1961, 208 pp., mimeographed, no United Nations document number assigned.

[27] Arthur D. Little, Inc., An Examination of the ZIL 120 Engine Description Contained in "Input-Output Analysis of Soviet Machinery Construction to Determine its Probable Accuracy and the Similarity of the Engine to a Comparable U.S. Model", a report to the Division of Industrial Development, United Nations, C-63333, Cambridge, Massachusetts, February 1961, 37 pp.

[28] For a report on this meeting, see reference cited in note (1), Chapter I.

[29] For statistical correlations involving a number of industries, see H.B. Chenery, "Patterns of Industrial Growth", American Economic Review, September 1960, 624-654; United Nations Centre for Industrial Development, A Study of Industrial Growth, 1963, Sales No. 63.II.B.2; United Nations Statistical Office, Patterns of Industrial Growth 1938-58, 1960; United Nations Statistical Office, The Growth of World Industry, 1965. For the sector in particular, see P.C. Mayer, Machinery Production and the Size of the Domestic Market, Research Center in Economic Growth, Stanford University, Stanford, California, Research Memorandum No. 50, April 1966.

[30] United Nations Economic Commission for Latin America, The Industrial Development of Peru, Analyses and Projections of Economic Development Series, No. 6, 1959.

[31] *Op. cit.*, see note (2), Chapter I.

[32] *Op. cit.*, see note (2), Chapter I.

[33] United Nations Economic Commission for Latin America, "Criteria and background materials for the programming of the machine tool industry" (in Spanish), ST/ECLA/CONF.11/L.12, 19 December 1962; "The machine tool industry in Brazil - Background material for the programming of its development" (in Spanish), ST/ECLA/CONF.11/L.32, January 1963.

____ "The manufacture of industrial machinery and equipment in Latin America: IV, Machine Tools in Argentina (in Spanish), ST/ECLA/CONF.23/L.18, 14 February 1966.

[34] For the case of the machine-tool industry two methodological papers have been prepared by the Economic Commission for Latin America: United Nations Economic Commission for Latin America. "Some methodological problems in the programming of machine tools and other equipment" (in Spanish), ST/ECLA/CONF.11/L.11, 19 December 1962; and United Nations Economic Commission for Latin America, "Criteria and background materials ......", *op. cit.*, note (33) above. In the first, the approaches of the MR and UNO studies are considered and rejected for application to a study of the machine-tool industry in Brazil and other Latin American countries on the grounds that the available coefficients are nontransferable because they are incompatible with existing practice (efficient or not), and that the development of suitable coefficients is impossible or excessively burdensome. In the second, a number of technical-economic norms are distilled from the detailed study of five model machine-tool plants of progressively increasing size. The first three, corresponding to the smaller plants are based on existing practice in Brazil, again without consideration of whether this practice - involving the enormous dispersion of production characteristic of an unplanned proliferation of small enterprises - is inherently efficient or not. These three model plants are complemented by two sizes not yet encountered in Latin America, based on Western European practice.

[35] See H.B. Chenery, "The role of industrialization in development programs", American Economic Review, May 1955, pp. 40-57; H.B. Chenery and K.S. Kretschmer, "Resource allocation for economic development", Econometrica, Vol. 24, No. 4, October 1956, pp. 365-399.

[36] The analogous device of a step function to quantify increasing costs has been used in a linear programming model of the Greek economy by J.B. Nugent, "Programming the optimal development of the Greek economy, 1954-1961", Center of Planning and Economic Research, Athens, 1966. In this model the metalworking-engineering products sector is divided into two parts; transport equipment appears as one of the fifteen industrial groupings, while the rest of the sector is included in "manufacturing".

[37] R.S. Eckaus and Louis Lefeber, Planning in India, Universities-National Bureau of Economic Research Conference on Economic Planning, Princeton, New Jersey, November 27-28, 1964, Proceedings (in press).

[38] A.S. Manne, "Key sectors of the Mexican economy, 1960-1970", in A.S. Manne and H.M. Markowitz, eds., Studies in Process Analysis, Cowles Foundation Monograph No. 18, New York, Wiley, 1963, Chapter 16.

[39] The model contains no provision for increasing costs in each branch and thus exhibits the all-or-nothing behaviour typical of linear models. An independent estimate by A.S. Manne, On the Role of Machinery Production in the Economic Development of Mexico. Organization of American States, Committee of Nine, Washington, February 1963, based on an ingenious adaptation of United States census data on establishment size distribution, to an extrapolation from the United States to the much smaller Mexican market (0.5 per cent of the United States market) give the rough indication that some two thirds of imports within the sector could be reasonably considered for substitution.

[40] United Nations Committee for Industrial Development, "Manufacture of industrial machinery and equipment in developing countries", Inter-Regional Symposium on the Development of the Metalworking Industries in Developing Countries, Moscow, 7 Sept. - 6 Oct. 1966, CID/SYMPD/A-3.

[41] Seymour Melman, "Aspects of the design of machinery production during economic development", Industrialization and Productivity Bulletin, No. 8, United Nations, New York, 1964, 62-70.

[42] United Nations Economic Commission for Europe, Production and Export of Mechanical and Electrical Engineering Goods, Geneva, 1963, ST/ECE/ENG/1; United Nations Economic Commission for Asia and the Far East, "Engineering Industries in the ECAFE region", Industrialization and Development News, No. 1, New York, 1965, Sales No. 65.II.F.16, pp. 48-88.

[43] United Nations Committee for Industrial Development, "A preliminary study of the current situation of the machine-tool industry", Committee for Industrial Development, Fifth Session, E/C.5/85, 5 April 1965.

[44] A series of summaries of these papers is available at the United Nations Industrial Development Organization.

[45] The materials of the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas are surveyed in the separate Bibliography of the project, Sec. II-B.

[46] For example, in the technical-economic description of selected branches of the electrical machinery and equipment industries, Sec. IV-E, this material was used as a source of reference.

[47] G. Maxcy and A. Silberston, The Motor Industry, Cambridge Studies in Industries, New York, Macmillan, 1959; A.C. Neisser, The Impact of the Canada-United States Automotive Agreement on Canada's Motor Vehicle Industry: A Study in Economies of Scale, Doctoral Dissertation, New School for Social Research, New York, N.Y., June 1966.

[48] M. Kurz and A.S. Manne, "Capital-labour substitution in metal machinery", American Economic Review, September 1963, pp. 662-681; G.K. Boon, "Optimal Capital Intensity in Metal Chipping Processes", Progress Report No. 1, Institute of Engineering-Economic Systems Engineering, Stanford University, Stanford, California, 1965.

[49] G.K. Boon, Economic Choice of Human and Physical Factors of Production, North Holland Publishing Co., Amsterdam, 1964.

[50] See for example: Duncan Burn, ed., The Structure of British Industry, Cambridge, University Press, 1958, with chapters on the machine-tool industry, the motor industry, the aircraft industry, the shipbuilding industry, the electronics industry, and the cutlery trade; Walter Adams, ed., The Structure of American Industry, New York, Macmillan, 1954, with chapters on the automobile industry and the tin can industry; and G.C. Allen, British Industries and their Organization, London, Longmans, Green, 1945, with chapters on the engineering, motor vehicles, and shipbuilding and marine engineering industries.

[51] See the separate Bibliography of the project. The periodical literature is briefly surveyed in Section II-G and the most important periodicals are listed in Section (2) of the Select Bibliography.

[52] Technical-economic data of a similar nature available in the planning norms of centrally planned economies have already been mentioned in Section II-A. Among published sources, see for example: János Fekete, Laszlo Mezey, Istvan Rady and Tibor Rigler, Material Input Norms in Machine Building (in Hungarian), Economic and Legal Publishing House, Budapest, 1956.

[53] See the presentation of fully quantified and semi-quantitative empirical materials in Chapter IV, Section E, and in Chapter V.

III. KEY FEATURES OF THE PROJECT

55. The present study represents an attempt to break new ground in attacking, at a fundamental level, the difficulties and complexities characterising the sector and evolving an integrated approach to the planning of both domestic production and foreign trade.

A. Strategic considerations

56. This section surveys five strategic considerations in planning for the sector that underlie the choice of approaches selected for the study. These are: (a) multipurpose production facilities and capacity utilization, (b) lot size and standardization, (c) exports, specialization and trade agreements, (d) a two-level planning framework and programming models and (e) the description of technology and the information-system approach.

Multipurpose production facilities and capacity utilization

57. While the metalworking sector is characterized by the overwhelming use of multipurpose production facilities, there are, of course, branches of it that use special-purpose equipment, among them can lines for making tin cans, machines for making wire products and/or machinery for making components of electrical appliances such as television sets. None the less, the essential core of the sector can be well represented by a common set of resource element inputs.

58. Loosely speaking, a multipurpose resource element can be identified with a shop, that is, a casting shop, a forge, a machine shop or the like. The advantage of this concept is that it avoids the excessively burdensome need to keep track of individual machines in the metalworking operations. Thus lathes, drill presses, planing and boring machines of a certain size and accuracy class are handled as a single machine shop, and input requirements for making a certain product, such as bicycles, can be expressed in terms of tons or shop-hours. Resource elements such as casting and forging can be handled similarly. An industrial branch can then be analysed in a quantitative fashion by defining a limited number of typical products and investigating the input requirements of resource-element (shop) units into these products. The total shop-hour or tonnage capacities of different shops that are required can then be derived for an industrial branch by a weighted averaging of the various typical products.

59. One of the difficult problems of planning for the metalworking industries is to decide what capacity to maintain (or invest in) with regard to each of these resource elements. Certain ones, such as heavy forges, have enormous yearly capacities, and it is not feasible, except perhaps in the larger industrialized countries, to achieve full utilization of such a resource element on the basis of the input requirements of a single branch, such as agricultural equipment or electrical machinery. On the contrary, it is desirable that all the various branches of the economy of a developing country should participate in raising the utilization of the capacity of such a forge, since there is an inherent indivisibility. The forge is either established at the given yearly capacity or it is not; one cannot invest in one-fourth of a forge. The same problem exists with regard to other resource elements, especially those adapted to handling outsize or heavy workpieces, and those designed for specialized jobs. In sum, since the proper utilization of productive capacity requires the sharing of this capacity between various branches of the economy, the planning process for this sector must necessarily cut across these branches.

Lot size and standardization

60. One of the key determinants of cost in metalworking is seriality, that is, the length of a production run of identical workpieces. Both the total number of shop-hours required for putting out a single workpiece and factors such as kinds of skilled labour, tooling material, floor space, and inputs into the shop itself charge with the degree of seriality. For example, in drilling holes into the flanges of electrical motors, if a thousand units are produced in a single run, it will be worthwhile to construct an elaborate jig that will hold the workpiece in place and perhaps drill several holes simultaneously, thereby greatly reducing shop-hours per workpiece at the same time the latter procedure will require a greater input of tool-and-diemaking skills than the hand production of single units. From the point of view of planning methodology, this phenomenon not only forces the subclassification of resource elements by seriality but also places a heavy premium on the widest possible use of standard end-products as well as standard components and subassemblies within the sector. The latter may range from nuts and bolts to more complex elements such as motors, clutches and transmissions. Such standardization has inherent disadvantages as well

as advantages beyond a certain point, since it sacrifices the full adaptation of design to the peculiarities of the individual product. Only a sector-wide planning approach can balance all the advantages of increased seriality against the disadvantages of greater rigidity in the design, since the gains of standardization depend on total seriality that often may not be achieved except in the sector as a whole.

Exports, specialization, and trade agreements

61. Non-traditional exports from developing countries are, to paraphrase Mark Twain, like the weather: everybody complains about them but nobody does anything about them. The highly industrialized countries have so far moved with glacial slowness in this area, and the developing countries lack the proper instruments with which to attack the problem effectively.[1] Why should a developing country purchase the potential surplus of, say, bicycles or sewing machines from another developing country when such items are likely to be more expensive, of lower quality, with poor or no service facilities, no financing aids, and similar disadvantages, as compared with imports from a developed country? There is clearly but one over-riding potential incentive; namely that of mutuality.

62. In other sectors the requisite joint planning of industrial growth encounters the very severe problem of the acceptable apportionment benefits. In the Central American common market, for example, there has been continuous discord over the location of the handful of very large plants (chemicals, petroleum refining, rayon, glass) intended to serve the market as a whole. In the metalworking sector, fortunately, the large diversity of products helps the kind of specialization that will maintain a continuously balanced allotment of benefits to all participants from the very beginning. This need not mean that trade must be balanced exclusively within the sector. Since production facilities are bulky and indivisible, the more advanced (larger, heavier, more specialized) resource elements may well exist only in one member of the group at any given stage of growth, and a balancing of benefits may then, at least in part, involve extra-sectoral offsets.

63. There is an evident advantage in arranging suc trade agreements on a multilateral basis, possibly within the framework of a common market, since this increases the market and reduced rigidities and excessive dependence on individual partners. There is also, however, a corresponding increase in

difficulties, not the least of which is the inability of policy-makers to predict confidently the benefits and costs that will flow from any given political-economic agreement. A better grasp of the economic realities within the sector that this project will hopefully contribute will thus make it easier to negotiate trade agreements.

64. No less essential is the contribution that such a grasp can make to sectoral trading possibilities with the industrially more advanced countries, either under special agreements or on the open world market The experience of these countries in their trade in metalworking and engineering products with each other has been that technical and economic progress has contributed to specialization and an increase in trade. Thus the more economic growth the developing countries can achieve via multilateral trade agreements with each other, the greater the stimulus for expanded trade between these countries as a group and the industrially more advanced countries as a group. Trade agreements based on joint supra-national planning of the sector in the developing countries are thus not competitive with more trade with the industrially advanced countries on the contrary, they are complementary to it.

65. As a foundation for the evaluation of these various trading possibilities, it is thus essential to define the range of appropriate resource combinations and product assortments within the sector for a number of stages of economic development.

A two-level planning framework and programming models

66. The placement of an economic sector in the context of an economy-wide planning and programming approach to which the planning problems of individual sectors are subordinate is regarded as indispensable for rational planning decisions. Two-level (or multi-level) programming models are well-known conceptual tools[2] that permit experimentation with the key aspects of such an interrelation between economy-wide and sectoral decisions. They establish channels of interaction between the upper and lower levels that may consist of steering prices or resource allocations communicated from the upper to the lower level, and corresponding resource claims (in response to steering prices) or shadow resource valuations (in response to specific resource allocations) communicated from the lower to the upper level. These models, however, cannot cope with economies of scale and indivisibilities that are particularly pronounced in the metalworking sector in general, no price-type or other linear

decentralizing system can be expected to give reliable results when these economies are present.

67. An exact programming solution under these conditions would require models of the integer[3] type that pose exceedingly onerous computing problems whenever they are of a scale sufficient to make them of practical use in planning. As far as presently known, in a two-level planning model an exact integer programming solution would require giving up the advantages of decomposition into economy-wide and sectoral sub-parts and would thus represent a backward step from the sequential solution of several smaller models to the simultaneous solution of a single very large model.

68. If the claim to an exact solution is given up and approximations are accepted, some variant of full-cost pricing can achieve a partial decomposition of the programming problem.[4] Since such a programming decomposition is the counterpart of decentralized decision-making in planning organizations, any part of the problem that can be decomposed within a tolerable limit of error can also be made subject to administrative decentralization or merely indicative (rather than positive) planning.

69. Decisions concerning a partial decentralization in a two-level planning system are thus based on considerations of decomposability of a programming model; these in turn are based on a previous decision as to the importance of fixed costs and indivisibilities relative to the resources used within the sector as a whole. Some activities or resource inputs may thus indeed be sufficiently continuous to allow an allocation of their fixed costs on the basis of capacity or near-capacity production. Such a partial decentralization is inherently more complex than decentralizing schemes based simply on the use of shadow prices or other linear decentralizing instruments and depends upon an overview of the sector in an economy-wide context. Consequently, no simple technique can be made to work satisfactorily for a branch-by-branch planning of the metalworking sector, and the conclusion is reinforced that the proper planning technique treats the sector as an integrated whole within the framework of multi-level planning.

70. It is thus essential that the investigation be oriented as much to an over-all view of the problems of economic planning as to the application of detailed engineering or managerial judgement. While an adequate technological description requires a very broad coverage of engineering information, the

proper articulation of all this detail into an optimal decision for the sector as a whole requires economic insights of a high order. It should be added that, despite the emphasis on the use of advanced analytical tools, it is deemed that the results of a purely formal analysis can never be accepted uncritically, particularly if they have been produced by mathematical programming models whose internal workings are not fully transparent. Thus the judgement of the economist-planner becomes crucial in translating the results of formal analysis into practical planning decisions.

Description of technology and the information-system approach

71. The description of technology for the metalworking sector raises problems that call into question some of the currently used methods of technological description that have been found to be useful for other sectors.

72. Aggregation problems. Statistical techniques of the input-output type and, generally, any methods based upon aggregation have great shortcomings; this is even more true in metalworking than in other industries. The problem is that no classification scheme that is used for describing the sector *ex ante* can be adequate for information requirements that typically arise at a later stage of planning. If, for example, an export project that requires an unusual and expensive input, such as a rare metal used in a new kind of special steel, should appear advantageous, it is impossible to estimate the requirements of this new input on the basis of the old classification scheme of an inter-industry table. The same may be true for certain intermediate products such as ball-bearings of a specialized kind. In other words, it can never be foreseen which individual detailed input will become critical at a future time from the point of view of the sector or even of the economy as a whole. Thus any scheme of technological description based on a fixed classification and aggregation will be inadequate to the needs of planning. This limitation also applies to material balances which cannot avoid the use of aggregate categories in the metalworking-engineering products sector.

73. The shortcomings of a fixed aggregated technological description as currently used in input-output models are particularly striking in connexion with the decision-making technique known as management by exception, the underlying concept of which can be readily generalized from individual enterprises to entire sectors or economies. Management by exception works on the principle that the highest decision-making level must avoid dealing with routine manage-

ment problems and concentrate on exceptions to the regular working of the organization. Thus it is always the unusual or the crisis situation that is passed up to the higher decision-making level. Since a crisis can arise from bottle-neck conditions in any one of an infinity of detailed technical commodity categories, it is evident that an exhaustive <u>ex ante</u> technological description of any given industry or sector is out of the question.

74. While these problems are encountered to some extent in all sectors of the economy, they are less troublesome in those characterised by a large measure of homogeneity in their products; the basic chemical sector is a good example. It is evident, however, that these considerations become the crux of successful planning for the metalworking sector.

75. It is thus inevitable that an effective planning approach to the metalworking sector must be based on a more flexible concept of technological description than the mere compilation of rigidity defined input-output coefficients or technical norms.

76. <u>Technological adaptation.</u> It might be thought that a change-over from inputs expressed in cost aggregates to ones specified in terms of resource-element units ("standard shops"[5]) would overcome the aggregation problem and thus the limitations imposed by fixed classifications. Unfortunately, this is not the case. If an attempt is made to construct a representation of technology in the sector from a manageable number of resource elements used as "building blocks", then these modular elements, for the very reason that they are typical of a wide range of practice, (for example, a standardized heavy forge with given total output and seriality) will never be completely adapted to the production of any given assortment of output pieces. In other words, a technical-economic description of the sector based on standardized resource elements will never be able to cope with the problem of specific technological adaptations and will necessarily overstate the required resource inputs. If the resource-element input coefficients were to be regarded as rigidl given once and for all, serious distortions in any planning decisions based upon them would be created. Accordingly, the programming process must make roo not only for successive revisions that modify the combinations of activities that are included in a trial programme (as characteristically undertaken in the course of obtaining an optimal solution to an activity-analysis model), but also for revisions of the activity coefficients themselves upon which these

combinations are based. At this point the usual clear-cut divisions between data collection, model building, programming and practical decision-making in the course of planning vanish, giving way to the concept of an integrated information and decision system in which data-collection and decision-making become inextricably linked by mutual interactions.

77. Learning effects and labour productivity. Variations in labour productivity that are attributable to different degrees of cultural adaptation to the production process at all levels from the individual shop to the economy as a whole pose more of a problem for the planning of the metalworking sector than for many others. In the production of basic heavy chemicals, for example, productivity is paced to a much greater extent by the machine than by the operator, and problems of work scheduling and organization are of minor importance except for maintenance - which is of course a metalworking operation. In the metalworking sector, productivity varies with learned skills at a number of levels: at that of the technical skill of the machine operator, at that of the organizational and work-scheduling skill of the foreman or the manager in a job-shop, at that of the higher-order managerial skills involved in coping with the inevitable interruptions of a continuous mass-production operation.[6] at that of the interaction of firms through delivery, subcontracting, and other institutional arrangements and at that of the stability and continuity of government policies and/or plans affecting the individual enterprises. All of these productivity variations are superimposed, even on an unchanging technological basis, without taking into account the continuous qualitative transformations of the production process through innovations. Given such variability, the use of rigid technical coefficients in planning becomes entirely illusory no matter how cleverly they may be defined, and it becomes indispensable to shift to the point of view represented by an integrated information and decision system such as has been mentioned in the previous section.

78. Programming data within an information-and-decision system. To be sure, coefficients and norms are indispensable for attacking and solving any given planning problem including the preparation of projections and perspective plans for the entire sector. These coefficients and norms must, however, be maintained in files organized so as to lend themselves readily to revision or complementation by technical experts prior to use. What is required is a data system handled if possible by modern information-processing methods and kept up to date by small groups of technical specialists who cover particular branches or activities

within the sector. The success of any planning method for the sector hinges on the improved flexibility of technological description by the application of the information-system concept.

B. Characteristics of the approach used in the present study

79. In the study that is the subject of the present report it has not been possible to follow through on all lines of approach to the planning of the sector that have been suggested by the strategic considerations discussed in the previous major section. In what follows the key feature of the approach actuall used in the course of the work thus far completed will be surveyed.

Integrated approach

80. The sector as a whole has at all times been at the focus of attention. An attempt was made to work toward a programming method capable of encompassing resource allocation problems for the entire sector while simultaneously providing guides for the evaluation of individual projects. Such a method is designed to overcome the present characteristic lack of linkage between aggregat branch-by-branch (or resource-by-resource) projections and detailed feasibility studies. For the sake of an integrated approach it has been judged worthwhile to accept a rather wide margin of error on technical detail, as for example in the use of semiquantitative programming data.[7]

Explicit attention to the characteristic planning difficulties of the sector

81. An attempt was made to confront directly the problems created by product diversity, product interrelation via multi-purpose production facilities, indivisibilities in productive resources and economies of scale attributable to lot size. This was considered to be preferable to devising a method of approach that would bypass these difficulties. While not yet fully satisfactory, the results of this attempt have clarified many conceptual problems and have established the basis for further work on the broader project.

Two levels of detail in the description of technology

82. The study began with an attempt to describe the technology of the sector immediately in a fully quantified manner, using the concept of resource elements for creating modular units for such a description. Because of numerous difficulties and slow progress, a parallel effort was soon initiated to devise a semiquantitative method of description in order to obtain a rapid if sketchy

overview of the sector as a whole. In time it was found that these two efforts were mutually supportive in data collection and, at the level of programming, represent two initial stages of a sequential decision-making process the final stage of which leads to project engineering.

83. Semiquantitative programming data. These aim primarily at defining lists of products and productive processes and at establishing incidences between these two, that is, specifying whether or not a given productive process is used in the manufacture of an individual product. Information of this kind can be assembled rapidly and at low cost and, despite its elementary nature, it has a surprising range of planning applications. The effectiveness of this information can, moreover, be greatly increased by a few simple and low-cost extensions, including: (a) the identification of productive processes that are in some sense critical to the manufacture of a given product, (b) the provision of footnotes containing incidental information in regard to critical processes or other features of production, (c) the specification of product weights and their approximate percentage distribution between such major processes as casting or forging and (d) the provision of rough quantitative indications with regard to processes that cannot be characterized by weight, such as machining or heat treatment.[7]

84. Fully quantified programming data. These data aim at specifying the pattern of physical inputs and outputs associated with the production of an individual product or an assortment of related products, in sufficient detail to permit the undertaking of approximate estimates of production costs on a comparable basis for products that are candidates for import substitution or for export. This effort requires, first of all, the decomposition of products into sub-assemblies and components, subsequently these must be related to basic production processes such as machining or assembly. The endless variety of product designs is represented by a restricted number of typical products, the limitless range of alternative production facilities is, in turn, reduced to combination of standardized modules referred to as resource elements. Together, these concepts permit a quantification of the technical-economic description of the sector.[8]

85. Interrelations between the two levels. From the point of view of data collection, the two levels of detail described above do not represent closed universes. On the contrary, the experience of the study indicates that great

economies of effort can be achieved by a close co-ordination of the two data-gathering tasks. Thus the construction of suitable resource elements needed for deriving fully quantified data is greatly facilitated by undertaking semi-quantitative work prior to this attempt or concurrently with it. At the same time, since semiquantitative data are not suitable for attacking in depth the problems posed by economies of scale due to either aggregate output or lot size they need the support of a parallel search for fully quantified programming data in order to gain the assurance of being focused on the decisive features of technical-economic structure within the sector.

86. With regard to the task of programming as distinct from data gathering, the two levels of detail are also interrelated; in fact, they are also related to the third level, that is, to the level of project engineering. There are great advantages to a sequential decision-making process that progressively narrows the range of open alternatives through the use of more and more detaile information, from semiquantitative data all the way to engineering blueprints. The crucial issue is whether the sequantial process trends toward the best of all possible alternatives or simply leads to a local optimum. This question is discussed in some detail in section III-B-4-c below.

A programming framework

87. Despite of some reservations about the ultimate direct applicability of a programming approach to the planning problems of the sector, it has been found useful to utilize activity analysis[9] as a conceptual framework for thinking through the problems of technical-economic description, resource allocation and project evaluation. The chief characteristics of this conceptual framework are presented here. The details of a practical programming approach based on the available technical-economic description of the sector have not yet been worked out, however.

88. Programming and the technical-economic description of the sector. The activity format has proven highly effective for the collection and organizatio of process-analysis type data in other sectors [10] it can be provisionally retained for metalworking even if the objective of actual optimization were eventually to be given up. This format, moreover, lends itself readily to the type of extension discussed in the previous section, that is, the relaxation of the rigidity of technical coefficients that are given once and for all. Particular activities describing a set of industrial processes at a given level

of detail can be readily replaced by other activities that incorporate a more detailed description of the same processes; thus, if a sequential decision-making process narrows down to a particular sub-area of the sector, more information can be channelled into the description of that sub-area. With analysis and information-retrieval alternating in this manner, the planning process can be conceptualized as a series of programming models that become ever more detailed within a continually narrowing zone.

89. Semiquantitative programming data fit readily into this conceptual framework; they represent the initial and most approximate way of describing the technology of the sector. While such data are not sufficiently quantified to permit optimization in the formal sense, the orientation process which they make possible nevertheless involves an appraisal of alternatives and a selection of a range of preferred choices. This procedure is entirely in the spirit of optimization and in the next stage, through the channelling of additional quantitative information into the description of the preferred alternatives, in fact leads directly into formal optimization.

90. <u>Programming and the integration of balances and priorities</u>. Programming models furnish an immediate integration of the resource-allocation side of planning (that is, the preparation of consistent resource balances) with the project evaluation side (that is, the determination of priorities among competing projects). In the simplest case, namely, linear programming, two mathematical solution algorisms (the "primal" and the "dual" simplex methods[9]) can be regarded as paradigms, (respectively, of either working toward a perfect priority ordering of activities while resources are always balanced, or conversely, working toward the elimination of resource bottle-necks while a highly efficient priority ordering of activities is maintained at all times. The two methods intersect at the optimal solution which satisfies simultaneously the criteria of optimal resource balance and optimal priority ordering of activities. The last property of the optimal solution of linear programming models also extends to the general nonlinear case, even though the solution methods themselves do not. This property furnishes one of the key attractions of programming as a conceptual framework for planning.

91. The priority ordering of activities in programming models is achieved by means of "shadow prices" calculated for all resources, activities are then costed out at these prices. The designation "shadow price" serves to distinguish

these calculated priority indicators from actually prevailing institutional prices in the economy. In linear programming models, shadow prices have the property of assuring that all activities included in the optimal solution at positive levels will exactly break even, that is, that the costs of these activities calculated at shadow prices will exactly offset their revenues, which are also calculated at shadow prices. Activities showing losses will be shut down, while profitable activities may never occur in an optimal solution; in fact, the very presence of profitable activity signals that the optimal solution has not yet been attained, since the expansion of profitable activities can achieve further benefits. The elimination of all profits in the optimal solution of linear programming models is analogous to the elimination of profits in the theory of perfectly competitive markets.

92. <u>Indivisibilities and economies of scale</u>. The presence of these phenomena in programming models introduces major mathematical impediments to the finding of an optimal solution, since the usual strategies based on the gradual improvement of trial programmes can no longer guarantee the eventual attainment of the optimum. The score of these difficulties is the possibility of the occurrence of several local optima which are separated from each other by zones of programmes that are less attractive, in a manner analogous to the separation of distinct peaks in a mountain range by valleys or saddles. It is relatively easy to find a programming method that will arrive at some local high point, but very difficult to find one that will identify the highest of all peaks.

93. To the extent that programming models can be taken as a conceptual paradigm of the broader planning-decision making process, indivisibilities and economies of scale destroy the assurance that a sequential decision-making process such as, for example, the one outlined above in sub-section (a) will converge to an optimal plan. Such a process may, instead, zero in on a local optimum, with the result that there will not even exist a way of checking if the plan arrived at is tolerably efficient that is, if the local optimum is reasonably close to the over-all optimum or if, on the contrary, it is drastically inferior to it. The same shortcoming characterizes market systems and potentially also the type of decentralized planning systems that are now being introduced in some countries with centrally planned economies. When it was earlier mentioned in this report that present planning methods

often leave a residue of major doubt as to whether the sector as a whole is moving in the right direction, it was precisely this possibility of convergence of either the planning process or the market toward a drastically inferior outcome that was implicitly postulated. The problem is thus far from having merely academic interest, in fact it is crucial for the assurance of a proper over-all orientation with regard to central decision-making and decentralized processes in general. The need for such an over-all orientation is held to be of such importance that even rough approximations become acceptable in the technical-economic description of the sector if they furnish a complete overview within a large but known margin of error.[11] Since the case of economies of scale can be reduced to the case of indivisibilities represented by the occurence of fixed costs, the discussion will be conducted in terms of the latter and, for the sake of simplicity, in the context of otherwise linear models.

94. The key step is to classify the fixed costs[12] which occur in such problems - in the case of the metalworking sector, the ones originating in minimal production series and minimal shop scales - into small and large fixed costs. What is to be regarded as small and what as large depends on the tolerable margin of errors in finding an optional solution, given the status of planning for this sector, it is preferable at the outset to allow a relatively high margin of error rather than renounce the possibility of an over-all orientation, even though the latter may be rather gross in many ways. Initially, therefore, many or perhaps most fixed costs can be classified as small ones these can be dealt with by dividing the fixed costs between the number of units produced, on the basis of an estimated degree of capacity utilization. If full-capacity utilization is taken as the basis of distributing fixed costs, a lower limit on actual total costs is obtained: in other words, if it is assumed that the indivisibilities represented by fixed costs are for the purposes of programming none the less divisible, then the optimal programme so defined will always appear more favourable than reality can actually ever be.

95. After having been distributed in this manner, fixed costs behave like the proportional costs of ordinary activities if all fixed costs can be thus distributed, a normal programming problem is obtained that can be solved readily and that produces normal shadow prices. In a linear model these prices are, in principle, identical with the prices established by

a perfectly competitive market mechanism, provided that the individual enterprises base their cost calculations not on their marginal costs, but on their average (full) ones.

96. What procedure shall be adopted for the large fixed costs? If these were similarly distributed over output either by linear programming or by some market mechanism based on full-cost pricing, the consequence would be an overstepping of the tolerable limit of error. Consequently, central decisions about fixed costs become unavoidable; decentralizing mechanisms must be renounced. The higher the tolerable margin of error, the smaller the number of "large" indivisibilities that require centralized decision-making; at the same time, the chance diminishes that some unusually favourable combination of such large indivisibilities will remain hidden from specialists who have an intimate knowledge of the sector. Thus by describing and comparing programmes based on selected, *a priori* attractive combinations of indivisibilities one can usually obtain a reasonable approximation to the optimal solution. Any error committed will be subject to quantitative appraisal in the following manner. Since the fixed-cost-distribution method based on the assumption of full utilization of capacity always overshoots the actual optimum, while the combinatorial method based on a partial sample of fixed-cost combinations generally falls short of the optimum or at most equals it, the estimates obtained by the two methods box in the optimum, and their difference establishes an upper limit to the error of optimization.

97. Even though this result can be rendered sharper and more elegant by the use of advanced mathematical methods such as integer programming, what has been said captures the essence of the problem and is quite enough for an overview such as that required for practical planning applications. Where fixed costs are encountered they are distributed over output to the largest tolerable extent, while the remaining fixed costs are tested in diverse, *a priori* favourable-appearing combinations. With each of these combinations there is associated a normal programming problem the total costs of which are calculated as the sum of the following three items: fixed costs that are explicitly treated as fixed, fixed costs that are distributed over output, and proportional (variable) costs. Selecting the best of these alternative combinations amounts to a central decision with regard to the large fixed costs; all other decisions concerning fixed and

variable costs can be decentralized to any desired degree by means of a market or other linear incentive system.

98. In planning for the metalworking sector the indivisible decisions concern the questions of whether or not a given commodity should be produced or whether or not investment should be made in the establishment or enlargement of some productive capacity. The majority of these indivisible decisions can be handled by full-cost pricing and can therefore be decentralized within a tolerable margin of error. The programming framework, however, also allows the identification of large indivisibilities and offers a way of making rational decisions about them. A key virtue of this approach is that it bases the cost calculations required for decentralized decisions in enterprises or lower-level planning organs on a set of prices that can in principle be determined only <u>after</u> the central decisions pertaining to the large fixed costs have already been undertaken, regardless of whether the determination of prices is based on formal programming or on the automatic outcome of some market mechanism. Thus the approach creates a rational basis for the establishment of a price system even in the presence of major indivisibilities and separates the fields of decision that can be effectively decentralized from those that cannot.

99. The establishment of a rational price structure has primary significance for the international division of labour, since in the absence of such a price structure it is almost impossible to judge the direction and extent of the desirable international specialization of a country. Reliance of these prices permits the determination of that limit of production costs up to which it is worth while for any branch of the sector to engage in exports, and also the estimation of that somewhat higher cost limit beyond which imports are preferable to domestic production. Apart from transport and other costs incident to foreign trade, these two limits determine the real value of foreign exchange. If commercial relations should be undertaken with two or more trade areas that are isolated from each other, a separate exchange rate must be determined for each area within the above system of prices.

100. The costs associated with the large fixed ones that are subject to central decision-making are not to be counted as part of the production

costs of individual commodities as long as a significant part of the indivisible capacity remains unutilized. If, however, as a result of general economic growth or physical depreciation such capacities become subject to periodic renewal, then just before such renewal, no slack remains. An exact mathematical solution would demand that in such no-slack periods the respective commodities be charged not only with current costs but also with accumulated costs of the capacity in question that have not been charged in the preceding slack periods. This of course would lead to unacceptable cost and price fluctuations which must necessarily be moderated with a view to practical long-term price stability. A certain measure of fluctuation is none the less entirely rational, since it is desirable that in periods in which there is a slack, secondary uses of the respective capacity be encouraged. In periods when the capacity limit is approached, on the other hand, all uses that are to some extent flexible should be deterred from using the capacity in question. This situation is similar to the price fluctuations that occur between peak and off-peak hours in the electrical power industry, with the simple difference that the fluctuations in the user price of productive capacity are typically on a multi-year cycle rather than on a daily cycle. World market prices are established by the bridging over of these indivisibilities that are of course small as compared with total world production. Individual countries can take advantage of the potentialities offered by their own price cycle in drawing up long-term plans for production, trade and investment.

Orientation to country studies

101. While insisting on a fundamental approach to the planning problems of the sector, the present study was focused from the start on the objective of early applicability of its concepts and empirical results to practical planning decisions in individual countries.

102. When the study was initiated it was contemplated that most of the empirical material would be gathered in two country studies; in Israel and Hungary. These country studies were also intended to test the assumptions and working methods developed in the course of the project. The selection of these two countries was determined by the following consideration:

(a) Both of these countries are beyond the stage of underdevelopment and thus dispose of a substantial range of metalworking activities as well as trained personnel for the execution of the studies.

(b) In both of these countries there is a substantial measure of co-ordinated planning or decision-making.

(c) At the same time, the current development problems faced by these countries are more similar to the problems of the underdeveloped countries than to those encountered in the most highly industrialized areas of the world.

(d) The size of both countries is of an order of magnitude that permits encompassing the entire metalworking sector with a limited effort.

(c) The metalworking sector plays an important role, actually or potentially, in the export earnings of both of these countries and thus the studies were expected to throw a light not only upon the problems of planning for domestic production but also upon the problems of export planning.

(f) In the case of Hungary an additional consideration of key importance for the project was the availability of a two-level linear programming model covering the economy as a whole, with detailed sub-models extending over fifty sectors, including eleven which fall within the metalworking and engineering products sector as defined in the present study.[13] This provides a conceptual framework for the planning problems of the sector, much relevant empirical information, and established institutional channels for further data collection.

103. It has been contemplated that, at a later stage of the broader project, similar country studies would be undertaken in some of the less-developed countries that face more serious organizational and technical problems.

104. While these country studies were to be initiated separately by direct arrangements between the United Nations and the host countries, they were planned and prepared in close co-ordination with the present project. Early stages of the work are now actually under way in both of these countries, but there have been delays and problems of limited resources which made it impossible to obtain results in time for evaluation and inclusion in the present report.

105. Because of these delays, a substantial part of the data-gathering effort had to be initiated in the United States of America. As a result of the broad technological gap between that country and developing nations, this procedure is far from ideal. To remedy the shortcomings of the

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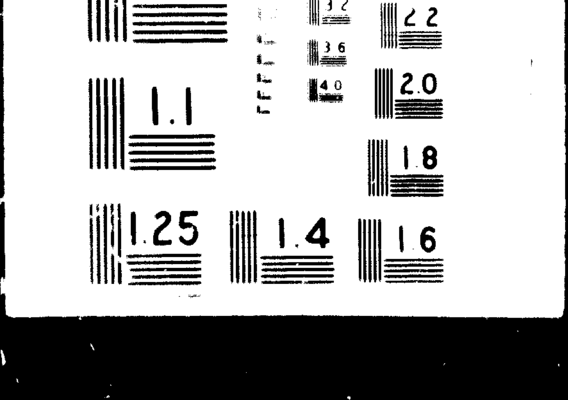

empirical material, it is hoped that the progress represented by the launching of the main effort of the two country studies, in the case of Israel hopefully coupled with a technical assistance mission, will be sufficiently rapid to allow an early checking of the existing technical-economic description method in the context of actual planning decisions concerning the sector.

C. Emphasis of the project

106. It would be unreasonable for a project of this kind to attempt to cover all problems that nominally fall within its range of reference. To gain a sharp outline of the key features, those that are considered secondary must be put aside. This is being done without apology; indeed, the suggested approach may be open to the criticism that it tries to cover too much ground.

107. In order to avoid arbitrariness it is, however, essential to attempt to show how the given emphasis, the particular inclusions and exclusions were determined.

A fundamental dichotomy

108. The fundamental assumption underlying the suggested approach is that every economy has a technological core that is potentially invariant between countries with different social systems and different *per capita* incomes. This invariance is called potential rather than actual, since many technical activities will be found uneconomical under given local conditions, and the actual selection will be highly (and systematically) differentiated. The invariance is thus postulated for the universe of technical activities from which the selection is made. The empirical backing for this postulate is provided by the present ready diffusion of technical know-how and by the experience that under proper conditions any group of people can be trained and educated in the use of modern technology and modern concepts of technical and economic organization.

109. If the invariance of the technological core is accepted, the analytical task of devising rational planning and programming procedures for economic development can be broken into two main parts, as follows.

110. The first task is to define the basic range of economic alternatives that are compatible with this invariant technological core, given the

particular endowments of population and resources and the empirically verifiable consumption requirements and/or preferences of the broad masses of the population.

111. Second, once such a basic range has been defined it must be narrowed down, and a development target must be selected by reference to the constraints that are imposed by cultural and institutional conditions. Alternatively, the kind of cultural or institutional changes that would be required for attaining stated targets within the basic range must be analysed.

112. The present study has been directed almost exclusively at the first of these two tasks, and its emphasis has been determined accordingly. It is of course recognized that no conceptual dichotomy of such heroic proportions can ever be completely clean cut: as much can be said of supply and demand. While this has resulted in some lack of definition at the periphery, it is none the less felt that the former dichotomy is the key to a successful approach in depth to the planning and programming problems of this difficult sector.

Institutional aspects

113. Among others, in focusing on the basic range of possibilities, the following institutional aspects have been largely disregarded: supply of skills, labour training, entrepreneurship; credit and financing problems; cultural and institutional conditions that determine an orientation to growth as against an essentially static outlook on economic reality; organizational problems in planning; problems of incentives; problems of resistances and inefficiencies in plan implementation; problems of relations between enterprises and market organization; and problems of the setting up of economic development targets and the definition of policies.

114. One institutional aspect that enters the analysis, at least at the conceptual level, is the consideration of international trading possibilities either via trade agreements or on the open world market. The emphasis here, however, is again on the careful difinition of alternatives rather than on the exploration of institutional arrangements conducive to successful negotiations or successful entry into particular export markets.

115. The abstraction from training and education is a distinct limitation of the analysis, since the social costs and time delays of these activities

are sufficiently significant to affect the main conclusions; it has, none the less, been decided to put them to one side for the moment as a matter of expediency. The omission is of no long-term consequnce, since at a later stage the analysis can be expanded to include this aspect without significantly altering the key features of the approach as here presented.

Technical-economic aspects

116. In defining the basic range of possibilities, emphasis has been placed on those features of technical-economic reality that are most characteristic of the sector, and others consequently were given less stress. Thus the utilization of multiple-purpose productive equipment is at the center of analysis even though it is recognized that there are some branches of the sector in which highly specialized, single-purpose equipment is predominant.

117. An important limitation of the analysis is the exclusive reliance on the deterministic (as against probabilistic) description of alternatives. This has been dictated by simple expediency, even though it is recognized that reserve stocks and their fluctuations, queuing phenomena connected with capacity utilization and related questions are entirely glossed over by this mode of approach. Considering that nonconvexity is explicitly taken into account, the former simplification will probably be found excusable. It is of course an empirical question which of the two analytical difficulties, nonconvexity or the role of uncertainties is the more crucial in practice. In attempting to formulate an answer (pending an alternative approach whose outcome alone can finally decide the issue) it should be noted that some of the phenomena mentioned, such as queuing, occur at a level of aggregation below the one chosen for this study, while others, such as the determination of optimal reserves, will hopefully not be unduly sensitive to the structure chosen for the sector by the suggested approach.

Notes for Chapter III

[1] The question of non-traditional exports from developing countries has been thoroughly reviewed by the United Nations Conference on Trade and Development, Geneva, 1964. See Proceedings of the Conference, particularly Vol. IV, Trade in Manufactures, United Nations, New York, 1964, Sales No. 64.II.B.14.

On linear programming decomposition methods, see: G.B. Dantzig and Paul Wolfe, "The decomposition algorithm for linear programs", Econometrica, Vol. 29, No. 4, Oct. 1961, pp. 767-778; J. Kornai and T. Liptak, "Two-level planning", Econometrica, Vol. 33, No. 1., Jan. 1965, pp. 141-169. Further on two-level planning, see United Nations Economic Commission for Asia and the Far East, Formulating Industrial Development Programs, Development Programming Series No. 2, Bangkok, 1961, Chap. 2.

Recent surveys of integer programming will be found in G.B. Dantzig, Linear Programming and Extensions, Princeton University Press, Princeton, New Jersey, 1963, Chap. 26; E.M.L. Beale, "A Survey of Integer Programming", Operations Research Quarterly (London), Vol. 16, No. 2, 1965, pp. 219-228. For an excellent summary of fundamentals, see R.E. Gomory, "Large and non-convex problems in linear programming", Proceedings of the Symposium on Interactions between Mathematical Research and High-Speed Computing, American Mathematical Society, Vol. XV, 1963. For an appraisal of rounded continuous solutions, and a new algorithm, see R.E. Gomory, "On the relation between integer and non-integer solutions to linear programs", Proceedings, National Academy of Sciences, February, 1965.

[4] T. Vietorisz, "Project evaluation in the presence of economies of scale and indivisibilities", Inter-Regional Symposium on Industrial Project Evaluation, Prague, October 1965, CID/IPE/B.28. Forthcoming in Proceedings of Symposium.

[5] The concept of standard shops was briefly introduced in section III-A-1. For a more detailed discussion see section IV-C-1.

[6] For a discussion of the logic of productive organization in a job-shop versus organization in a continuous operation, see Adam Abruzzi, "The production process: operating characteristics", Management Science, Vol. 11, No. 6, April 1965, B-98 through B-118.

[7] Semiquantitative programming data are discussed in detail in Chapter V.

[8] For a detailed discussion of this procedure, see Chapter IV.

[9] The terms "activity analysis" and "mathematical programming" are used interchangeably. A simple type of mathematical programming is linear programming. Standard references on these topics are: Dantzig (1963), op. cit. (note 4); S.I. Gass, Linear Programming: Methods and Applications, New York, McGraw-Hill (1958); G. Hadley, Linear Programming, Reading, Massachusetts, Addison-Wesley, 1961; R.L. Graves and P. Wolfe, eds., Recent Advances in Mathematical Programming, New York, McGraw-Hill, 1963. For applications to economic and planning problems, see T.J. Koopmans, ed., Activity Analysis in Production and Allocation, New York, Wiley, 1951;

R. Dorfman, P.A. Samuelson, and R. Solow, Linear Programming and Economic Analysis, New York, McGraw-Hill, 1958; H.B. Chenery and P.G. Clark, Interindustry Economics, New York, Wiley, 1959; and Manne and Markowitz, eds. op. cit. in Chapter I, note (12).

[10] The activity format is useful for data presentation and analysis in a variety of other sectors. See for example: Manne and Markowitz, op. cit. (petroleum refining, chemicals, food and agriculture, iron and steel), T. Vietorisz, "Programming Data Summary for the Chemical Industry", Industrialization and Productivity Bulletin No. 10, United Nations, New York, 1967, pp. 7-56.

[11] See Vietorisz (1963), op. cit., note (4).

[12] "Fixed costs" are here used in the sense of fixed resource inputs, given preferably in physical units.

[13] See the discussion of the Hungarian two-level planning model in section II-A. A classification of the branches of the sector, as used in this project, is given in Appendix to Chapter IV, part 1.

IV. FULLY QUANTIFIED PROGRAMMING DATA: CONCEPTS AND PILOT DATA-COLLECTION EFFORT

118. The description of the technical and economic features of the metalworking and engineering products sector is the foundation of the present project on which all other aspects must be built. It is therefore of crucial importance to develop adequate methods for performing this task.

119. The present chapter reports on work concerning fully quantified programming data. Such data have been briefly introduced in Section III-B-3-a and have been contrasted with semiquantitative programming data.

120 The entire conceptual framework of the study was initially built around the collection, organization and programming application of fully quantified programming data. While semiquantitative data have been defined and introduced at a later stage, and even though they are most highly productive in terms of immediately applicable empirical results, the conceptual framework built for and around the fully quantified programming data continues to be of fundamental importance to the project. This is so for at least two reasons: (a) the effectiveness of semiquantitative programming data in coping with key difficulties in planning for the sector would be impossible to judge except with reference to the conceptual framework provided by fully quantified programming data; and (b) the rapid over-all orientation provided by semiquantitative programming data is but a jumping-off point for a more exact quantitative definition of planning problems within the sector. For this, reliance must be placed on fully quantified programming data.

121. The term "fully quantified" is used to define the contrast between these data and semiquantitative data; it must not be taken to mean that the respective data are the ultimate in precision and reliability. Far from being so, they could equally well have been referred to as "rough quantitative" data. As will become apparent from the discussion that follows, they are based on a modular description of productive facilities by means of the key concept of resource elements, which were briefly introduced in Chapter III, Section B-3-b. While fully quantified, they are thus no more than initial approximations. Feasibility studies based on them will be subject to large errors in costing, and all conclusions arrived at through their use will have to be re-worked for final decision-making by reference to data representing a third level of detail and precision, such as concrete project engineering data or their equivalent.

122. The question may be posed; Why was the conceptual framework of the study worked out in terms of the second level of detail (fully quantified programming data) rather than in terms of the third, practically most significant level? The answer to this hinges precisely on the intermediate position of fully quantified programming data between the two extremes represented by semiquantitative data and project engineering data. The first level yields over-all orientation with a total sacrifice of precision of detail, while the third level yields full precision of detail with a total sacrifice of an over-all orientation. Fully quantified programming data are designed to mediate between these two extremes. Given a future effort at a sufficiently comprehensive scale, they can cover the sector as a whole at a tolerable cost in resources expended; nevertheless they maintain a sufficient degree of precision to yield a starting point for fully refined cost estimates and other project engineering work preparatory to final decision-making and plan execution.

123. The chapter will report on the nature of the concepts used in defining fully quantified programming data and will present the results of a small pilot data-gathering effort. The details of programming the sector through the use of fully quantified programming data have not yet been worked out within the study covered by the present report. The method of programming will only be sketched out in sufficient detail to serve as a background for the discussion of technical-economic description.

A. The University of North Carolina study of the machine-building industries

Survey

124. In approaching the technical-economic description of the metalworking sector at the fully quantified level defined above, the project has drawn on the ample experience and empirical materials of the study of the metalworking and machine-building industries of the Union of Soviet Socialist Republics undertaken over a number of years by the University of North Carolina that produced several substantial reports prior to its abrupt termination in 1960.[1] The UNC study used a process-analysis type of approach, based almost entirely on source material published in the Union of Soviet Socialist Republics,[2] particularly of the engineering and industrial type. Indeed, the approach was developed in part as an experiment in the use of technical-economic data in lieu of scarce statistical information for analyzing economic capabilities. The method evolved progressively over the course of years and in its latest version incorporated the fruits of a great deal of experimentation that has saved the present project much time and effort.

125. The chief reason for revising the UNC methodology is that it was oriented toward a kind of economic task different from that pursued by the present project. Whereas the UNC study aimed at the definition of the capabilities of existing productive facilities and an estimate of the resources needed for capacity expansion based on the existing structure, the present project poses the much more difficult question of identifying the most suitable structure for promoting economic growth.

126. In brief, the investigation of basic production processes (technologies) constitutes the core of the UNC analysis, implying a two-step or two-phased route to the derivation of final input coefficients.[3]

127. In the first phase the input requirements of machinery, labour, material et cetera of fourteen basic production processes, including forging, foundry, machining, heat treatment, assembly, among others were determined. Each of these is studied in a number of variants called "resource elements." In all, fifty-three resource elements have been covered. The input requirements are expressed in physical units (tons, man-hours, numbers of specified machines) per unit of output. The output itself is either a semifabricate, such as a rough forging, or a processing service, such as the heat treatment of a component part. In either case the output is again measured in physical units, in metric tons wherever possible. As customary in activity analysis, the output can be regarded as defining the level of utilization of each process.

128. In the second phase the outputs of phase 1 take on the role of inputs. The objective of this phase is to generate numerical estimates of these inputs into a sample of typical but highly specific individual end-products, namely, machines of different kinds.

129. Thus, when using this two-phase approach, capital, labour, material and other coefficients of input into machines are derived indirectly rather than directly via the levels of basic processes that are utilized in their manufacture. The advantages and disadvantages of this indirect method of estimation are discussed below; in sum, it achieves an aggregation of the innumerable individual items of capital found in the sector at a level that is both meaningful and computationally manageable and is the key to a comprehensive yet fully quantified description of technology.

130. For the purposes of capability analysis, the next step in the UNC study is to choose a small number (six or so) classes of end-products to represent each branch of the machine-building industry. The inputs of these aggregate "represen-

tative products" are then constructed by averaging the inputs of selected individual products that are derived in detail from largely engineering sources. These individual products will be referred to as "typical products" in the present study. The averaging procedure is based on statistical estimates of the total tonnage of each kind of product that is similar to a given typical product. In all, thirty-three branches of the sector have been covered by the UNC study, among them machine tools, boilers, diesel engines, gasoline engines, tractors, cranes, excavators, automobiles, trucks and railroad cars.

131. If this methodology were to be applied directly to the present project it might be used for estimating the kinds of productive facilities that could be established and reasonably fully utilized in a developing country. Thus, if the requirements for the capacity of a medium forge capable of producing such things as parts for agricultural implements, hand tools, builders' hardware and simple machines which had been previously imported or for which an export market could be found, were totalled, it might be discovered that such a forge could be fully utilized. In this way, when starting with a list of imports and potential exports and adding up the implied input requirements for several kinds of foundry, forge, metalworking shop, et cetera, some of these resource elements would be found to be required at a scale equal to several times their basic yearly output; others (typically the heavy and specialized ones) would be found to be required a scale so small as to keep them busy for perhaps only a few days out of the year and would be completely out of the question for a reasonable investment programme Finally, there would be intermediate cases that would have to be analyzed in greater detail prior to investment decisions.

132. The principal difficulty inherent in this approach, apart from the question of whether some components of a complete product could be domestically produced while others were being imported, is that of lot sizes. While the question of part-domestic production can be handled by reasonable institutional assumptions and has in fact been frequently encountered, for example, in connexion with automobile production in the developing countries, where a decision is required concerning the domestic manufacture or import of components for assembly, the proble of lot sizes forces important extensions of the method.

133. Lot size or seriality refers to the number of identical workpieces produced in a single production run. In the UNC study, variants of a basic process (resource element) are distinguished by major categories of seriality, namely "unit" "small series", "medium series", "large series", and "mass production". When

required in differing yearly amounts, a given product is handled by this method, in effect as though it were an entirely distinct product. This procedure is acceptable so long as seriality is not one of the key variables in making decisions about an industrial branch. If the branch can be adequately subdivided into two or three typical seriality classes, each of which is associated with one or two kinds of products, then the half-dozen or so representative products will indeed be able to reflect the assortment produced within the branch with a reasonable degree of approximation. In developing countries with restricted markets, however, the key decision in each branch is how far import substitution and new exports should be pushed, since there is a progressive reduction in lot size in the first case as a greater and greater variety of products has to be produced for achieving successive amounts of foreign exchange savings, while there is an increase in lot size in the second case. Unless these phenomena can be quantified there will be inherent uncertainty in regard to the effectiveness of resource utilization, that is, in regard to the costs of additional production in diverse industries. A method based on describing a branch of the sector by means of a handful of aggregate representative products will not be adequate to the task of handling seriality explicitly as is required here.

Extensions

These extensions of the UNC method are required for the present project. First, while the preliminary subdivision of processes into major seriality classes is accepted, secondary corrections are essential for describing more exactly the changes in capacity utilization that result from differing lot sizes. Thus, in estimating how much of the yearly capacity of a medium-sized, medium-seriality shop is utilized for producing a specific part for a given agricultural implement, allowance must be made for the fact that in somewhat larger lot sizes each unit of output requires a somewhat smaller number of shop-hours. While no serious technical difficulties are foreseen in estimating approximate corrections of this kind, this procedure has not yet been tested in practice during the pilot data-gathering effort so far completed.

. Second, the description of a branch by a few typical products for which detailed inputs are estimated, is complemented by a "long list" consisting of "related products" for each of which only a much more limited amount of information is to be collected. The long list is designed to contain from one hundred to two hundred products per branch, for each of which only two kinds of information are essential: (a) a statement specifying which of the handful of typical products the given product is similar to, and (b) the yearly demand for it. (If desired, this information may be slightly expanded, as discussed below.) Using the information on typical products and making the secondary corrections for exact seriality, this permits the estimation of inputs for the entire long list.

136. Third, the rest of the branch is to be represented in an aggregative fashion by extrapolating the trend of resource utilization implicit in the long list. As the scale of production within a branch (measured in tonnage or value terms) increases, the increasing diversity of products will generally raise resource input (or cost) coefficients, except when serialities can be raised by means of exports. The conception underlying this method is taken from the papers by Chenery and by Chenery and Kretschmer.[4] Some conceptual problems remain that are attributable to the fact that the order in which different products on the long list are considered for domestic production must be known before the cost trend can be plotted for extrapolation; no major difficulties are anticipated, however, in resolving those once the problems concerning indivisibilities (fixed costs) are given adequate consideration.[5]

137. With the three extensions noted, the resource inputs required for progressive import substitution and export development in each branch can be closely estimated. The additional burden imposed on the process of data collection by these extensions is considerably smaller than the original task of defining resource elements and estimating inputs for typical products; thus the extended method should be manageable with the same scale of research effort as that of the original UNC study.

138. In addition to import substitution and export promotion the method will allow estimating the effects of the lengthening of series through standardization and through modular design.

B. Technical-economic description by means of fully quantified programming data: a summary

139. The emphasis of the preceding section has been on relating the approach of the present project to the materials contained in the UNC study; in subsequent chapters the key concepts used in the technical-economic description of the sector will be discussed in greater detail. The purpose of the present section is to interpose between these two presentations a brief but complete self-contained summary of the approach used, even though this will result in some duplication of material found in the preceding sections and in the one that follows.

140. The technical-economic description of the sector is undertaken with the aid of the following concepts:

(a) For the description of resources, standard tasks, and resource elements (standard shops) are defined.

(b) For the description of products and groups of products distinguished by branches of production, typical products, and extrapolated products are defined.

Resource elements

141. The main purpose of the definition of resource elements (standard shops) is to cut across the diversity of productive resources. For example, instead of keeping track separately of thousands of kinds of metalcutting machine tools, machining tasks are grouped into ten to twenty standardized classes in accordance with the weight of the workpiece, the average seriality, and possibly the degree of precision required. One such standard task might be the machining of a workpiece that weighs 10 - 100 kilograms, with a seriality of 250-1000, but without regard to whether the kind of machining required involved turning, milling, planing, drilling, other metalworking operations, or combinations of them. The fundamental issue is the standardization of the tasks; once this has been accomplished, the products that are produced by the many kinds of machines and equipment are no longer directly broken down (decomposed) into inputs of these individual machine or equipment classes, but into inputs of standard tasks.[6]

142. A standard task is performed by a suitably defined standard shop (resource element), with a machine supply that is just capable of accomplishing the kinds of machining jobs that occur on the average in the flow of standard task units that are channelled to this resource element. For example, a standard shop (resource element) for the accomplishment of the standard task described above is defined in such a way that the lathes, milling machines, planes, drills, et cetera that are included in the machine equipment of this resource element are present in such types and proportions as to permit the performance of all machining jobs that fall within the definition of the given standard task. The capacity of such a resource element can be given in total yearly available machine hours, and the inputs required for the production of a given product are then also expressed in terms of net standard-shop hours. (At times, it may be more convenient to measure both the capacities and the input requirements of some resource element in tons of product, square feet of assembly area, or other suitable physical unit). In this way the labour, equipment and indirect material inputs (tools, lubricants, form sand) of a product are registered not directly but via the concept of resource elements in two distinct phases. The first is the determination of the equipment and flow inputs going into the standard shops (resource elements) on

the basis of full capacity utilization, while the second is the decomposition of individual products into net standard-shop-hour inputs of different kinds.

143. Inter-country comparisons can be readily accomplished by means of a uniform definition of standard tasks; at the same time, the adaptation of plans to local conditions is facilitated by the flexible handling of the machine parks of the standard shops associated with given standard tasks. Thus, the proportions of capital and labour inputs vary between countries as a more or less highly automated technology is chosen for the performance of standard tasks. This has no effect whatever on the input coefficients of the second phase; it merely modifies the input coefficients of the first phase systematically in the one or the other direction. In a similar manner, the total yearly capacity of the standard shop is also adaptable to local conditions within technological limits. If desired it is even permissible to associate within a single country more than one kind of standard shop with a given standard task. In this case it becomes easier to describe the variety of existing productive resources, and at the same time the decision concerning future investments can also be undertaken with consideration given to a broader range of possibilities. For example, the degree of desirable mechanization and automation can be decided endogenously within the programming model rather than being prejudged by the one-to-one association of standard tasks and resource elements (standard shops).

144. The most important groups of resource elements are: foundries, sub-classifie into cast iron, steel, and nonferrous; forges, comprising both free and die forging; stamping shops, covering diverse cold-forming operations; upsetting shops, covering screw machining and related processes; machine shops; welding and boiler shops; heat-treating units; and assembly shops. Following this kind of subdivision, considerable material covering fifty-three resource elements and thirty-three product-group decompositions is available in the UNC study.[7]

145. This material contains the results of many man-years of labour by an engineering-economics research team and offers a useful point of departure for the application of the approach indicated above, even though the objective of the UNC study was not planning for the sector but the estimation of the effects of capacity losses and major restructurings of production.

146. The groups of resource elements outlined above will be complemented below by a group of so-called "organizational" resource elements, discussion of which is, for the sake of convenience, postponed until Section 3 of this summary.

147. In the course of programming the sector, the concept of resource elements is applied to investment decisions based on given total demands, that is, to the allocation of scarce investment resources to the establishment or expansion of given standard shops. Thus, in a developing country, the procedure begins with an estimate of total demand; this is translated into net-standard-shop-hour inputs by means of a breakdown of the respective products. The total of these shop-hours is compared with the lower limits of economical operation for each resource element, and the orders of magnitude of potential reasonable investments are immediately clarified. There will be some resource elements whose total input requirements implied by the structure of product demand do not come up to more than perhaps two or three per cent of minimal yearly capacity; thus economical investment in such resource elements - usually the heavier and more specialized ones - is out of the question. Contrariwise, there will also exist certain other resource elements for which the sum of input requirements is a multiple of their usual yearly capacity; the total scale of operation of these resource elements can therefore, within a tolerable margin of error, be regarded as a continuous variable. This permits the application of normal (convex) programming and the determination of conventional shadow prices to this part of the over-all task. Finally, there will exist some resource elements whose total input requirements fall between the above two extremes; the really difficult combinatorial problem will therefore be restricted to the latter ones.

148. In countries where pre-existing capacities are significant the concept of resource elements lends itself better to the analysis of new investments than to the satisfactory description of existing production potentials. In such cases, instead of increasing the number of variants of resource elements for the sake of improving the description, it is also possible to take a direct census of existing capacities and to establish a correlation between the costs of production in real resource inputs (singly or in groups, statistically or by engineering estimates) and the scale of operation of the respective production units.

149. Proceeding in this manner, when total demand within the country is translated from products into resource-element inputs expressed in net shop-hours, the latter total is subtracted from the net hours corresponding to available capacities; thus the programming of investments is based only on those resource-element requirements that exceed the precisely determined pre-existing capacities. It should be noted that the correct measurement of capacities does not require that the nature of existing shops coincide with the definitions of standard tasks and shops; thus it is entirely permissible that the capacity of an existing shop

be subdivided between the available net hours of two or more standard tasks. In this way the description of existing capacities gains greatly in flexibility without thereby contributing in the least to the difficulty of analysing new investments in the manner indicated before.

150. So far the application of resource elements to the task of programming has been discussed on the assumption of fixed total demand. This simplification is not only a convenience of presentation but may also play an important role in the actual planning process, because the determination of the production, investment or foreign-trade implications of given total demand assumptions is far simpler than allowing total demand to vary in response to export potentialities or other factors that tend to increase the seriality of production. Thus the prospects for the early practical application of this approach are far better in its simplified form, which involves selecting for study a few a priori interesting combinations of product demands, and subsequently putting into execution the combination that turns out to be most favourable. Here choice is based on a modest number of alternatives, notwithstanding the theoretical possibility of finding an even more favourable alternative by means of a systematic programming approach.

Description of products

151. While the concept of resource elements (standard shops) cuts across the diversity of the means of production, it is still necessary to apply a similar simplification to the diversity of products before the latter will lend themselves to a programming approach. The basis of description here is the concept of a typical product which must be decomposed into resource-element inputs as well as direct material (metal), subassembly and component inputs on the basis of detailed engineering information. Since it has been deemed advisable to distinguish about one hundred branches within the sector[8], an average of six to ten products per branch will already impose a task of nearly one thousand decompositions. Although by no means a light task, this is two to three orders of magnitude below the number of individual products likely to be of importance to countries in the range of development that is of primary interest to the project. In addition to these products it is necessary to distinguish within each branch a variable number, of the order of one to two hundred listed products, that jointly form what is termed the long list for each branch. The description of these listed products is undertaken parametrically on the basis of limited information, leaning mostly on the seriality of production.

152. This is done as follows. For the description of a listed product, data are sought only for specifying qualitative similarity to a given typical product, for total yearly demand and possibly for one additional parameter quantifying weight or size. The decisive datum is the exact seriality, since the net standard-shop-hour inputs required for producing such a product can be parametrically corrected within the seriality range of a given resource element, (for example, a range of 250-1000 for a "medium series"). In this way the precise component and resource-element inputs of a relatively small number of typical products can be generalized to a group of products whose number is ten to twenty times greater, and this can be accomplished in a simple and convenient manner that is throughly familiar to engineers. It is particularly noteworthy that the resource inputs of individual products on the long list are not based on some arbitrary averaging process but are estimated individually within a reasonable margin of error.

153. One interesting feature of this procedure is that the use of a limited number of typical products for parametric cost estimates, in the analogous form of parametric pricing formulas, is a well known procedure in the planning of administratively determined prices within large enterprises as well as within national planning organizations.[9] Cost estimating for commercial bidding purposes is likewise well known to be based on analogy, with the degree of sophistication varying from crude rules of thumb to large bodies of statistically organized and correlated information being brought to bear on a given problem in an almost scientific fashion.

154. The third concept required for product description is that of extrapolated products and is based on the hypothesis that the listed products within a branch can be ordered in accordance with their rising costs of production per unit of selling or transfer price, provided that the prices of all flow and stock type resources, intermediate products, components and subassemblies, as well as the prices of all finished products are given. Considering that the most important products within the total demand of each branch are treated as listed products, their resource inputs are estimated and thus, given a set of prices, their production costs per unit of output value can be established within a reasonable margin of error. Since in each branch the listed products can be expected to cover the overwhelming fraction of the value of total demand, it is anticipated that their cost trend can be generalized to the numerous remaining products of the branch by means of a modest extrapolation. The margin of error of such a procedure can be checked easily by reference to a few pilot branches. The extrapolated products are thus those contained in the extrapolated portion of the cost distribution

that is drawn up by reference to the listed products alone. In other words, the total volume of demand of the branch, calculated at disposal prices, is taken as the abscissa of a graph, while the cost per unit output value of the listed products is taken as the ordinate. The graph is drawn up by ordering the listed products in the sequence of ascending costs per unit output value and plotting for each listed product its production cost per unit output value against the cumulative volume of output for the branch. For example, if the listed products should cover 85 per cent of the total volume of demand in the branch, then the graph can be extrapolated from 85 per cent to 100 per cent, by a visual continuation of the trend. More sophisticated methods of extrapolation would hardly be justified in view of the considerable error of the data.

155. The above procedure presupposes a number of concepts that have to do with the task of programming. The appropriate prices assignable to resources depend on the projected combinations of the larger fixed costs, while the disposal prices of products are tied either to the export and import prices of the world market, to the barter ratios of trade agreements or to the production and utilization potentialities in other sectors. The sequence of product ordering within a branch depends on what standard-shop capacities will be available in the plan period as a result of investment decisions and also on the technique chosen for the production of a commodity if there exists more than one alternative in this regard; moreover, this sequence is strongly dependent on total demand, commodity by commodity, since the raising of the seriality of a given commodity by standardization or increased exports leads to a reduction in production costs and consequently to a shift within the sequence of product ordering. In practice the task of technological description cannot avoid taking its departure from some existing or anticipated system of prices that permits proceeding with the branch-by-branch extrapolation indicated above; subsequently, in the course of the programming effort that is based on this technological description, it becomes evident if these prices that have been provisionally accepted ex ante are approximately correct or strongly distorted. In the latter case the procedure must be repeated with revised prices.

Organizational standard tasks

156. It is convenient at this point to complement standard tasks associated with the resource elements discussed under the heading resource elements above, which refer to mechanical transformation processes, by the following organizational standard tasks: (a) product design, (b) production engineering and cost control, (c) the planning and programming of production, (d) marketing, (e) technological research and development and (f) general administration.

157. The concept of resource elements can be generalized to this group of standard tasks, except that the emphasis of resource requirements is not on plant and equipment but on technical specialists. For example, the standard shop associated with product design comprises a balanced group of engineers representing different specialties, draftsmen, computing technicians and office staff that can deal with all tasks of product design within a group of products or a branch of production; these personnel are complemented by the requisite number of typewriters, desk computers, drafting equipment, and current resource inputs such as heat and light. Organizational standard tasks show two differences as compared with standard shops associated with mechanical transformation processes, even though these are a matter of degree rather than of kind: (a) the inputs required for production, measured in net hours of resource element use, are largely independent of the seriality of the process of physical production; and (b) the required inputs are characteristic not so much of a single product but of a whole group of products. The first observation can be restated by saying that the respective inputs are approximately fixed. Nonetheless, a formal correspondence with resource elements of the mechanical transformation type can be readily established, that is, the average input can be given as an inverse function of seriality. The second observation can be modified to state that the inputs of organizational standard tasks do not depend exclusively on the production of a single commodity but jointly on the production of several of them. A mathematically simple case of such point dependence is a fixed input (embodied for example in research and development work) that creates the possibility of beginning the production of an entire group of commodities.

158. The significance of organizational standard tasks is very great from the point of view of the planning methodology of the sector, because (in keeping with the two observations of the previous paragraph) they markedly decrease production costs. For example, in the agricultural machinery industry the tasks of product design, research and development and maintenance of contact with the market in order to serve its quantitative and qualitative requirements effectively, all require the establishment of a large group of specialists. The reduction of the size of such a group when serving a smaller total volume of demand is either impossible or can be undertaken only by seriously lowering the quality of the output. However, in the farm equipment industry as in many other branches of the sector, low quality not only represents a direct economic loss, but since it goes hand in hand with a technological lag behind leading world standards, it critically undermines the possibilities of export. The only apparent way to circumvent this

problem is to rely upon imported techniques; this, however, results not only in a loss of foreign exchange and in dependence on foreign technology but also deprives the country of the favourable external effects that result from the activities of a continuously operating group of specialists.

159. These considerations are counterbalanced by the fact that the creation of adequate groups of specialists for the individual branches of production requires such large amounts of productive skills that are in limited supply that the possibility of economical production in many or most branches of the sector is vitiated except in the most highly industrialized and largest countries. Smaller countries must either specialize and thereby significantly increase the length of their production series over which the fixed costs of a group of specialists can be distributed or be prepared to suffer the harmful consequences of high costs and/or low qualities.

160. An important part of the planning methodology outlined herein is, on the one hand, the description of the requirements of organizational standard tasks for the production processes of given commodities and branches of production and, on the other hand, the solution, within a tolerable margin of error, of the difficulties connected with programming under increasing returns, so that the most favourable direction and extent of the required specialization within the sector may be specified with a reasonable assurance.

C. The resource-element concept

161. The present major section of this chapter is devoted to a detailed exploration of the analytical problems raised by the concept of resource elements. It largely follows and expands the summary exposition of resource elements given in Section B above.

Definition

162. The resource element concept was developed in the course of the UNC study after years of experimentation with the estimation of capital, labour and other input requirements directly into end-products. It was found that the aggregation of the great variety of capital equipment into self-contained resource groupings was the essential conceptual tool that permitted an adequate representation of technology within the sector. The resulting resource elements are defined so as to comprise the primary and auxiliary machines needed for a basic process, together with an amount of building construction that is expressed in terms of floor area.

> "The complexes of capital so formed are intended to serve a threefold function within the general framework of input-out analysis:
>
> (a) to contribute toward the estimation of capital input coefficients for a wide range of machinery items;
>
> (b) to provide a basis for measuring the inputs incident to their own expansion (viz., capital expansion coefficients); and
>
> (c) to facilitate the estimation of flow inputs incurred in the production of selected "representative" end-products.[10]
>
> A unit of capital is understood here to embrace the "bundle" of individual equipment items associated on the average with certain well-defined production activities or sets of operations. For practical purposes this aggregation of individual pieces of capital is accomplished at actual levels of operation corresponding for the most part to the production shop or in some cases to the plant specializing in a particular process output."[10]

163. The data required for the definition of resource elements were taken in the UNC study entirely from published Soviet source material, particularly of the engineering and industrial type. In fact the studies were in large part in the nature of experiments in the use of scattered "technico-economic" data appearing in comparative abundance in these sources, in lieu of scarce statistical information.[11] It will of course be a great deal easier to define resource elements when any published material can be complemented with on-the-spot investigation of productive facilities; the fact that it has been feasible in the UNC study on the basis of published material alone gives reason to hope that the definition of resource elements will be a readily manageable research task in connexion with the country studies to be undertaken as the sequel to the present project.

164. In its last and still incomplete stage, the UNC study distinguished fifty-three resource elements, as shown in Table IV-I.[12]

Table IV-1

Resource elements distinguished by the UNC study

Production process	Number of resource elements formulated[13]
Free-forging process	8
Die-forging process	2
Mixed free-forging and die-forging process	1
Cast-iron casting process	6
Malleable-iron casting process	1
Steel casting process	3
Non-ferrous casting process	3
Precision casting process	1
Stamping	5
Upsetting	3
Machining	6
Tool-making	1
Assembly (including crating and painting)	7
Heat treatment	4
Steel fabrication (welding)	2
	53

165. Among the resource elements still missing at the termination of the UNC study, spring-making has in the meantime been covered in a report written for the United Nations by one of the original authors.[14] The following processes are among those that have not been covered: electrical equipment (wiring, insulation, armature), auxiliary processes (storage, repair, intra-plant transport, utilities, laboratory), minor production shops (electroplating, woodworking) and organizational functions (design, engineering, production planning, marketing, research and development, general administration).

166. Each resource element is characterized,[15] as far as possible, by a minimum number of crucial attributes. These generally include the six following:

(a) the scale of operations; that is, the average annual capacity of the resource element with a normal work regimen (generally two shifts daily except for unusually heavy facilities operating on a three-shift basis);[16] (b) the prevailing seriality of output (or repetitiveness of production lots); (c) the products and in some cases kinds of machine parts typically associated with particular resource elements (these are specified, though not exhaustively.); (d) part size (this is introduced in the resource element definition via the maximum weight of part handled. The model, that is the most frequent range of weights is however considerably less than the maximum. For foundries, the model range is practically between 1 per cent and 10 per cent of the maximum weight[17]);

floor-space, as a guide to the estimation of construction requirements; and

f) the equipment profile of each resource element developed in considerable but varying detail.

167. Variants of basic processes that are defined as separate resource elements in the UNC study are based on these crucial attributes. The needed number of variants is, however, lessened by the fact that in practice some of the attributes are found to be correlated.[18]

168. In the course of the UNC study the number of variants has been sharply reduced. In earlier versions, for example, more than seventy-five foundry processes were distinguished in unit and small-series production alone[19]. This has ultimately been reduced to only two foundry resource elements in these seriality classes.[20] It is not implied that the estimation of these aggregate foundry shops or resource elements was easier than the detailed proliferation of casting processes which we undertook for heavy machinery; actually the reverse is true, that is, the task of definition (averaging) proved to be more difficult in the global approach though probably in itself less accurate. Where the tremendous economies of research time occur are in the "Phase II" aspect of the problem. With the shop formulation we can treat the weight of castings in a given commodity virtually as a unit and at most distinguish between a limited number of metal types, for example cast iron, cast steel non-ferrous. By contrast, the "old" process definitions required the breakdown of product weights into as many as seventy-five different kinds of castings.

> Corresponding simplifications have been achieved with respect to the forging and machining processes as well as in... stamping and upsetting. In all likelihood the altered framework for machining has yielded the greatest research efficiencies and without, it appears, significant changes in the accuracy of the results. What we have done in this area has been to abandon the "chips-removed" technique for deriving machining inputs. Instead of estimating these requirements for a highly differentiated set of machine tool types and sizes we have placed reliance on direct (though adjusted) Soviet data relating to the total machine-hour needs of various commodities. These aggregate machine-time inputs, in turn, we have associated with complexes of machine tools of given capacities.... These (resource) elements, as in the case of casting referred to above, are designed to handle a broad range of structurally similar commodities, homogeneous as to size class and seriality. Hence the whole machining requirement can be disposed of, so-to-speak, in one application.[21]

169. In sum, the resource element concept is a compromise between two opposing requirements:

> Ideally, the study aims at the formulation of internally homogeneous resource elements, but at the same time practically it requires that they be comparatively few in number .... As a rough rule of thumb, we have sought to encompass the total of machine-building activities in something under seventy-five elements.[22]

170. As defined in the UNC study, the resource-element concept is subject to three limitations which will be relaxed in the present project:

(a) By assumption no inter-element substitution is allowed....[22] This is a necessary limitation of input-output analysis that can be realxed when more powerful programming techniques, for example linear or integer programming, are adopted. In practice the relaxation of this limitation means that alternative patterns of resource element inputs into an end-product become admissible. Thus a crankshaft may be produced by either forging or precision casting, each followed by machining. These two modes lead to two alternative input breakdowns for the crankshaft.

(b) Continuing from the preceding quotation, ...except as a commodity undergoes changes in the seriality of production (in which case, as we view it, it becomes a different commodity).[22]

If substitution between resource elements is excluded by definiton, then the unavoidable substitution between resource elements of different seriality in respons to changes in demand must be redefined as a change in the nature of the product. As discussed above, the method of the UNC study will be extended in regard to seriality by introducing secondary corrections.

(c) Within each element... product substitution is considered to be complete. That is, a particular element is deemed to be capable of producing any of its "own" products with equal efficiency (the meaning of "homogeneity" as we use the term above).[22]

It is not necessary to maintain this assumption in its rigid form as used in the UNC study, even though for its purposes it yields a good first approximation. The authors generally presume individual estimating error margins of up to 20 per cent for the study as a whole. This would be entirely satisfactory for the present project.[23] Exactly because the first approximation is good, however, secondary corrections can be introduced at the cost of only slight effort by means of simple multiplicative factors that take the entire structure of a resource element as changed and merely adjust the estimated fraction of their capacity that is utilized in producing a particular output. The seriality correction referred to in the preceding paragraph is of this type; analogous corrections can be introduced for <u>complexity</u> in forging, for <u>precision</u> in machining and, in general, for use of a resource element for a product mix that is slightly different from the one for which the resource element is taken to have been designed.

<u>Advantages</u>

71. The advantages of the resource element concept, some of which have already been implicit in the previous discussion, include the eight discussed below.

(a) The resource element concept offers a means of representing the almost endless set of equipment combinations which produce the great variety of products of the sector by means of a limited number of "average" or "typical" combinations.[24]

(b) The fact that inputs and outputs are expressed in physical terms separates technological information from pricing information and makes it possible to transfer information on potential production processes directly from one country to another. Two qualifications to this second point are, however, necessary.

> (i) Note the emphasis on "potential" production processes. A technology adopted to one country may be feasible in another from the engineering point of view but be highly inefficient economically.
>
> (ii) The averaging process implicit in resource element definition may, in a hidden way, incorporate characteristics peculiar to one country and that are non-transferable. This risk must be specifically guarded against.

(c) Seriality is handled explicitly by means of the classification of resource elements, even though not in sufficient detail for the purposes of the present project. The description in this regard can, however, be improved.

(d) The <u>convertibility of metalworking capital</u> from one use to another is highlighted... This may be particularly useful for underdeveloped regions where the likelihood of low rates of output makes it important to disclose practical possibilities for combining the production of products usually produced in separate facilities in highly industrialized countries. For example, it may be feasible to integrate (on the basis of similarity in many of the constituent processes, and consequently in capital equipment) the production of a variety of piston-type machines and mechanisms, such as internal-combustion engines (diesel, gasoline), pumps, compressors, steam engines, etc. An alternative approach such as for example the (definition of) capital requirements ideally designed to produce one end-product would not in itself suggest such possibilities for integration. Such integration may well make feasible a project which size of the market and capacity costs would otherwise preclude.[25]

(e) A considerable amount of institutional rigidity is avoided by the separation of major processes into separate resource elements.... This permits considerable flexibility in recombining to suit various needs and alternative systems of industrial organization.[25]

In particular, this leaves open the question of horizontal and/or vertical integration either according to patterns observed in the industrialized countries or according to other patterns that might be more appropriate to developing ones.

(f) The resource-element concept simplifies the collection of information and the reconciliation of fragmentary data. Intermediate concepts such as this may appear superfluous from a purely analytical point of view because they are eliminated from the analysis at a subsequent stage. In the present instance, for example, they disappear in the course of a matrix multiplication that carries their levels into capital and flow inputs. Nevertheless, they can be indispensabl in practice, since they often correspond to the categories by which the original information is easiest to collect. In addition, they permit the focusing of attention on a limited number of variables at a time, thus facilitating the recognition of basic connexions among the data. Finally, they create broad classes of phenomena within which statistical regularities can reveal themselves, whereas in working with unaggregated information such as coefficients of material or labour inputs directly into a particular product, the data are often so few that any potential relationships among them are masked by the accompanying random variations. Thus in the UNC study, earlier attempts to evaluate directly the flow inputs into classes of individual end-products have met with serious difficulties, whereas the achievement of the same objective in an indirect manner, through the intermediary of the resource element concept, has been successful and has permitted the compilation and organization of a large body of empirical information.

(g) The resource element concept is a convenient means of bringing together statistical and engineering information. In the UNC study, for example, the determination of resource element inputs into typical individual products within an industrial branch is undertaken principally by engineering techniques, among them the study of product blueprints, of shop layouts, equipment lists and personnel classifications. This analysis is then complemented by estimation of a weighted average of individual products for the purpose of representing the industrial branch as a whole, with the weights derived from statistical sources.

An alternative approach, used by Markowitz and Rowe[26] for deriving material, labour and equipment input coefficients for the sector is based largely on data of the census type, and engineering estimates are suggested by the authors only for the purposes of secondary corrections. This method is useful and accurate in the case of structurally stable and well-studied economies such as that of the United States of America. Its applicability, however, becomes severely limited when either considerable structural change is taking place which renders statistical coefficients rapidly obsolete, or when statistical data sources are few and unreliable, as is the case with all but a few countries and in most regions within individual countries. When working with developing economies, one must cope with both structural instability and a lack of reliable data. In such situations, the combined engineering-statistical approach to requirements estimation, used in connexion with resource elements, appears to be considerably superior to an attempt at transferring statistical information from one country for which it is available, such as the United States of America, to another country for which it is not available. Thus, for planning and programming of the metalworking and engineering products sector in situations of economic development where structural changes are of central interest, the combined engineering-statistical approach made possible by the resource element concept is decisively superior to an approach based largely on statistical data.

(h) The resource-element concept, even while maintaining a unique pattern of process inputs into end-products (as in the UNC study) nevertheless introduces a considerable degree of flexibility into the investigation of economic capabilities by allowing substitution between the kinds of output that can be obtained from a given resource element. Thus the yearly capacity of a foundry or a forge, expressed in tons of output, is reasonably constant for pieces of generally equivalent complexity and unit weight, produced under conditions of comparable average lot size. This concept thus permits dealing with the overwhelming majority of trivial substitutions between standard metalworking machinery operations by the elementary method of creating an aggregated concept. When alternative input patterns are subsequently introduced (substitution between resource elements) attention can be centred on a relatively small number of critical substitutions without overwhelming the model with a flood of detail.

Problems and ambiguities

172. The problems inherent in the use of an aggregative concept have been pointed out previously. Actual production shops in a country vary considerably, and the

use of an average for representing a particular type of shop abstracts from the factors which are responsible for this variation. Thus even if the aggregate is reasonably representative of the conditions of the country from which the data were derived, this variability makes it necessary to proceed with caution in the transfer of data from one country to another. In the UNC study, in particular, the resource elements were defined to represent average conditions in the Union of Soviet Socialist Republics for the purposes of capability analysis. There can be no presumption that these data will directly fit the conditions of the developing countries, particularly in attempting to use them for purposes of costing and programming.

173. Before going on to a detailed discussion of the analytical problems raised by the resource-element concept it will be instructive to quote at length from a technical opinion written for the present project.[27] This paper reflects the point of view of engineers and managers geared to United States practice and gives a most graphic illustration of what any attempt at a manageable technical-economic description of the sector must contend with. In this particular view the second and third levels of detail (fully quantified programming data as compared with detailed project engineering) have not been separated; this fact accounts in some measure for the picture of apparently overwhelming complexity. In studying this opinion the reader should keep in mind that, in the present project, resource elements are suggested for a description at the second (not the third) level of detail, and it is thus accepted that their modular character necessarily involves an approximation. It is anticipated that any cost estimates based on such a modular description will be too high because of a lack of proper adaptation of technology to the particular individual productive conditions that are being considered. Conclusions drawn from such a description are to be taken as merely indicative and must be reworked in the course of a sequential decision-making process through the introduction of a large amount of technological refinement corresponding to the third level of detail. Haro[28] should be consulted on this point.

> The resource elements provided by the University of North Carolina (UNC) study consist of typical Soviet shops engaged in the manufacture of heavy equipment and some consumer items. It is desired in this study to make use of information from the prior UNC study so that subsidiary inputs, as estimated in the UNC study for labour, utilities, etc. on a per pound of output basis, can be used again in this United Nations Study.
>
> Two facts are apparent from a general survey of the UNC resource elements. They are basically concerned with the manufacture of heavy items, such as machine tools, industrial equipment, compressors, etc., with lesser

emphasis on consumer items, such as bicycles, typewriters and the like. Moreover, even when long runs are indicated for a given shop, it would appear that by United States standards mass seriality is never reached. Design of products, resting often on bulky castings (where United States practice would lean to lighter stampings produced with more exotic tooling) is consistent with the UNC resource elements but not with competitive world technology as of 1967, a factor to be considered when planning for export. Similar comments may be made about the substitution of materials, e.g. aluminium for iron and copper, plastics for steel and aluminium, the use of transfer machines and automated machine tools, etc. Thus the typical shops suggested in the UNC study are in a sense irrelevant to current design, manufacture, and seriality in the world consumer market, although they might well be suitable for the limited manufacture of heavy equipment locally or for limited export.

Second and more distressing than the UNC emphasis on heavy items made in short runs is the concomitant lack of emphasis on assembly technique and assembly resources. To make the distinction in practice, note that the Soviet shops were set up to make in one place all of the parts required for a given item, whereas, on the contrary, in more advanced operations of a mass character there is always a major make-or-buy decision in design and manufacture. In short, the number of resource elements and types considered by a United States designer and manufacturer is much larger and more varied than the list of resource elements proposed in the UNC study. In practice, each part of a product design is scrutinized for manufacturing method, cost, and alternate source of supply. United States corporations are often ruthless internally in insisting on the least expensive source whether it be their own shops, departments, and subsidiaries, or those of others. Indeed, many United States firms manufacture only a few critical parts, and purchase all others - a practice which is highly sensible in a well articulated economy. Such an approach to the production of a final product prevails over a wide spectrum of both consumer and industrial goods, and, in terms of the present project, means that the number of resource elements available to the United States industrial planner ranges to the thousands and tens of thousands, rather than to the restricted number of resource elements proposed for the UNC work.

Before continuing, it is worthwhile to note how the United States planner can handle so wide a range of diversity - which seems an insuperable obstacle for the present work. The secret is emphasis upon a particular product design, or group of designs, so that detailed specialization of the planning function is possible. Thus, within a given product grouping, United States practice calls for not only product specialists, but product part specialists, and often further specialization in the detail of part. Thus, an electrical manufacturer may have a specialist in relays, a further specialist in industrial relays for power control, and yet another specialist in electrical contacts for such relays. At the final stage, the specialist will have at his disposal a complete picture of the detailed resource elements available to him, not only in the U.S. but in the world. And he will be entirely capable of handling the range of resources available at his level of specialization - which is so great that relatively few alternative sources remain in his list of possibilities.

With such a hierarchy of specialists, however, the manufacturing firm as a whole can handle a cornucopia of potential sources, which are co-ordinated by the structure of the planning function. This approach to the problem of production is one of the major secrets of United States productivity, because it permits great flexibility in the introduction of new technology, in the reduction of costs, and in truly mass manufacture.

Returning to the problem of assembly, it follows that with a wide range of sources for component parts, whether internal or external, the final culmination of efficient production resides in efficient assembly. We take it for granted that the components for a given design can be made to specification. The remaining planning is for the combination of the variety of parts made or procured, for the test of the finished unit, for its packing, and finally for its distribution. These latter resource needs are virtually omitted from the UNC resource list, yet they remain as major ingredients in the completed product, and by United States standards are often the most critical.

For example, in mass production the balanced flow of assembly, finishing, testing, packing, and material handling to finished inventory is one of the higher-level planning steps in the United States manufacture. Often major bottlenecks can be expected in each of these steps, any one of which could halt the production process. Thus, extraordinary sums are spent by United States firms on, say, high-speed spray painting and baking production lines, automated testing facilities and test planning, packaging innovation and material handling, and the co-ordination of semi-finished and finished inventories.

This form of planning and co-ordination is often totally lacking in foreign productive facilities; the assembly operation proceeds on a hand-fit basis, in short runs, often without adequate inventory commitments, cost and quality controls, or material-handling facilities. And, it would appear that the distinction between hit-or-miss specialization in the utilization of available resource elements and the lack of well-planned and controlled assembly operations - versus the contrary counterparts in an advanced technology - is a major resource element in manufacture which must be taken into account before calculations of export potential can be made with confidence.

It is not difficult to admit that in the world market the picture of single-shop versus integrated manufactur-procurement-assembly operations, with its associated hierarchy of planning and control, is of major if not critical importance.

However, it is not so easy to foresee how developing economies can exploit the relatively ephemeral resource elements implied by the highly complex technological alternatives of planning and control upon which advanced manufacture is based. Indeed, to encompass in one scan all of the possible resource elements which could be considered in planning for the manufacture of a list of products, as yet undefined specifically, is a combinatorial impossibility - even for products made of metal. These combinatorial difficulties are, of course, compounded when the range of specificity is widened not only from a specific group of products but to international rather than regional constraints. In short, the question raised by a shift from regional, one-shop production to the exploitation of world-wide resource elements and markets is one not only of hardware capability and allocation, but one of allocating technical specialization in organization and control. And, as a limiting factor, or as a potential asset, this "software" capability is at least as important - if not more so - than the "hardware" capability available to a developing economy. Unfortunately, the range of possibilities for differential diagnosis and specification for a given economy in the software area - the range of possibilities for organizational development in relation to present status - is far greater than a study of hardware alone

> would indicate. Yet, it is difficult to see how hardware problems can be divorced from software problems when development is in progress.
>
> The dilemma in selecting resource elements, then, is compounded not only by the much wider range of hardware specialization to be found in competing world technologies, but also by the competing organizational capabilities encountered by the developing economy. Together these two forms of capability combine to produce not only a completely unmanageable list of resource element forms (equipment combinations, technical skill combinations, and realizable organizational combinations), but also resource elements for which data are essentially unavailable for programming purposes.[28]

174. Following Hare's critique above from the point of view of the technician or manager, it will now be attempted to explore the analytical roots of the difficulties.

[illegible] Limitations of the resource-element concept under the objectives of the [illegible] study. It is convenient to begin with the empirical case study that has been actually carried out, even though its purposes differ from those of the present report.

(a) The flexibility of resource elements in representing a whole class of production activities by implied internal substitution is obtained at the expense of product-mix problems. Many actual shops are significantly specialized to the range of products they produce and in defining general-purpose resource-elements there is both a tendency to overestimate the average amount of machinery that will be required and, conversely, to overstate seriously the degree of substitutability that exists within each resource element. For machining resource elements, for example, it has been written that the degree of overstatement rises sharply as the seriality characteristic moves from unit to mass production. Shops of the latter type are characterized by a large proportion of specialized equipment which can be employed for a range of products much narrower than that attributed to the resource element. Even shops made up exclusively of general-purpose machine tools of the same size can differ widely in terms of the mix of tools by functional type. The machine hour capacity of an element is therefore strictly applicable only to the end-product for which it was designed.[29]

The same is true, possibly to a lesser extent, of other resource elements. The suggestion is made in the UNC study that this problem might be handled by the use of correction factors that take into account the reduction of substitutability. Numerical factors that vary from 40 per cent to 90 per cent are offered as educated guesses concerning the actual range of reduction.[29]

One way of handling the product-mix problem is to increase the number of resource elements and to narrow the definition of each; this, however, leads back to the same difficulties that have been experienced already at an earlier stage of the UNC study. A possible compromise might be to handle specialized, outsize and otherwise scarce machinery items and their auxiliaries as separate resource elements. Only the actual research experience to be gained in the country studies can decide at which point the optimal compromise should be drawn between product-mix problems on the one hand and an undue number of resource elements on the other. It might be advisable to raise the target figure for total resource elements from seventy-five to perhaps two hundred.[30]

(b) A second source of error in the UNC study is the use of the same coefficients for average capital requirements versus expansion (representing most modern practice). This problem is not expected to create serious difficulties in the developing countries.

(c) A shortcoming of the UNC study in its terminal but unfinished state was the existence of gaps in the coverage of resource elements. This of course should not be charged against the concept of resource elements, but will none the less require attention in the country studies. Of special interest are the organizational functions[31] which have been found to absorb as much as 15 to 25 per cent of total money costs in the UNC study.[32]

176. Limitations of the resource elements concept as used in the UNC study when transferred to other countries. Under this heading we consider features of the resource element concept as used in the UNC study that were appropriate to the purposes of that study but which create problems of transfer of technology from one country to another.

177. The sizes, or output capacities of resource elements were set at approximately the average of such shops in the Soviet Union. This datum was not considered critical in the UNC study since it was felt that proportionality could be assumed for a considerable range of capacities, and also that very small additions of new capital were unlikely in so large an economy.[33] In application to smaller economies and particularly to those of developing countries, however, scale effects become critical. The data of Gallik show that even in the Union of Soviet Socialist Republics there is a considerable increase of efficiency (measured in terms of labour productivity) not only with lot size, but also with the scale of the production shop or the entire machine-building plant.[34] In these relationships shop or plant scale is a separate and independent variable in addition to lot size. In general, there is a systematic shift in the assortment and cost of capital equipment with the scale of the shop or the plant. For the

purposes of this project it is of crucial importance to quantify this relationship in the country studies or at least to determine an approximate minimum economic scale for various resource elements.

178. The process content of some of the resource elements is not as "pure" as might be desired, in that more than one distinct process was incorporated in the same resource element. Examples of this are die-casting and permanent mould-casting of non-ferrous metals, free and die-forging. This... is due to several causes: the desire to reflect Soviet practice; data availability; and the need to restrict the number of resource elements.[35]

179. Certain <u>institutional conditions</u> are incorporated into the definition of the UNC resource elements. Soviet metalworking plants have historically tended to be highly integrated as compared, for example, with plants in the United States, and until very recently little reliance was placed on the purchase of components or services from specialized plants. This tendency brought about "captive" facilities for nearly all components including fasteners and other standard parts as well as for such services as machinery repair, tool-, pattern- and die-making and utilities. To the extent that this is explicitly visible in the UNC study, no difficulty is encountered. However, in many cases this integration is implicit in the definition of the resource elements.[36] A comparable degree of integration may or may not be appropriate to the developing countries to which process technologies are to be transferred; however, while only one set of coefficients is available, no critical approach to this matter is possible.

180. It is instructive in this regard to cite the results of a single spot comparison of the UNC data with equivalent production practice in the United States. A consulting report commissioned by the United Nations[37] compares the process inputs required for two technically highly similar gasoline engines, as shown in the UNC study, as against one obtained from engineers familiar with the technology of the United States. To begin with, the metal content of the finished engine, as reported in the UNC study, is approximately 20 per cent greater despite comparable performance specifications. This reflects a difference in design practice (and possibly durability) that does not in itself affect the definition of resource elements. In addition, however, the metal losses reported in the UNC study are also 10 per cent higher. The other principal inputs are very close to each other on a per-engine basis, with the exception of three classes of labour (machining, auxiliary, junior service personnel) that are significantly higher

as shown in the UNC study; while conversely, electricity consumption is very much higher (almost double) in the case of the United States.[37,38] This reflects a higher degree of mechanization of auxiliary functions in that country as well as a closer approximation of mill shapes and of the output of preparatory processes to the final shape, resulting in less machining there.[39]

181. In general, according to Gallik, Soviet metalworking facilities tend to large-scale operations; on the other hand, seriality is probably low in compariso with the United States, with a concomitantly lower degree of specialization.[40]

182. The resource-element concept in relation to cost and efficiency studies. The first problem in this connexion concerns coverage. Under the capability objectives of the UNC study, steel and non-ferrous rolling processes were not covered since they were considered as falling outside the sector. In cost and efficiency studies, however, there are significant trade-offs with these processes that require attention. For example, the amount of machining to be done on a piece of round bar stock depends upon the number of standard sizes of this stock that are available; if there are many, a size close to the final dimension can be selected. There is thus a trade-off between the number of different kinds of stock produced by rolling in the primary metal sector where variety increases cost and the amount of machining to be done in the metalworking sector.

183. The second problem concerns aggregation. The degree of aggregation employed in the UNC study is inadequate to cope with problems of cost and efficiency unless the method is revised and extended. Aggregation problems that force such a revision enter at three different levels described below.

(a) The level of end-products. The suggested extension of the UNC method to cope with this level of aggregation involves complementing the narrow set of typical products covered in the UNC study by a long list and an extrapolated portion of the product assortment in each productive branch.

(b) The level of resource elements. Summarizing and extending several points made in preceding sections, the problems that occur here have to do with:

(i) inadequate adaptation of highly aggregated resource elements to specialized product assortments;

(ii) inadequate adaptation of such resource elements to specific serialities, complexity levels and precision requirements of particular products;

(iii) loss of description of technical process detail by having mixtures of different processes represented in a single resource element;

(iv) loss of description of potential variability in capital and flow inputs of resource elements that differ in scale but are represented by a single aggregated element; and

(v) loss of representation of the possible adaptations in the productive facilities to local conditions, via capital/labour substitution and other means, due to the definition of a single resource element for a given combination of technological characteristics rather than the definition of alternatives taking into account such adaptations.

134. Points (i) and (ii) can be handled by secondary corrections that adjust the exact claims of particular outputs upon the capacity of an aggregated resource element, the internal structure of which is assumed to be constant. The reliability of the results will depend upon how close the initial (uncorrected) approximation would have been. Only the country studies and their applications to concrete development programming tasks will reveal whether or not the margin of error implicit in the suggested level of resource-element aggregation (maintaining the UNE objective of approximately seventy-five resource elements) is adequate for the requirements of practice.

135. Point (iii) has not been of great importance in the UNC study. Adjustments of the resource-element concept given there would be required primarily in the definition of separate resource elements for tool-, pattern- and die-making and for internal repair services, since most of these auxiliary processes are included in the UNC resource-element definitions.

136. Point (iv) requires an important extension of the effort in defining resource elements. Scale effects must either be accounted for explicitly (functionally relating resource inputs to the scale of the resource element, that is, by distinguishing fixed and variable parts of inputs) or at least be taken into account by specifying reasonable lower economic limits on scale.

137. Point (v) raises an issue of sufficient importance to merit the separate discussion that follows.

138. <u>The level of capital and flow inputs.</u> Aggregation problems at this level are inherent in the classification adopted for different classes of machinery that make up the resource elements and for the different labour, material and other flow inputs that their operation entails. Lack of detail at this level interferes with the proper costing of these inputs. In particular, the expansion of the resource elements themselves may, to some extent, involve the appraisal of domestic production possibilities for the kinds of machinery they employ; the flow inputs involve problems of resource allocation within the economy that must be related adequately to economy-wide programming approaches.

Capital-labour substitution and local adaptation

189. Capital-labour substitution within resource elements. Capital-labour substitution in the sector takes place primarily through the degree of mechanization and automation of the productive facilities and the organization of the typical queuing process of production shops. Both of these are reflected in the definition of resource elements: their machine park and their labour inputs.

190. The mutual substitution of machines of different degrees of automation and/or different working methods has been studied for the process of machining. Since the investment costs of metalcutting machine tools differ among each other, the respective capital-labour ratios can be derived on the assumption that one worker per shift will be assigned to each machine. Such a study has been performed by Kurz and Manne (1963),[41] using original data of Markowitz and Rowe obtained from engineering estimates.[42] Kurz and Manne found that the capital-labour substitution process could be adequately represented by a Cobb-Douglas production function of the form

$$Q = a. K^{0.5} .L^{0.5},$$

where Q is output, K is capital, L is labour, and a is a proportionality factor.[43] The unit elasticity of substitution characteristic of such a function means that a 10 per cent rise in the price of capital relative to labour will result in a 10 per cent drop in the use of capital, provided that the total output remains constant. The numerical value of the labour and capital exponents of the function indicate the share of these factors in the total product under ideal competitive conditions, estimated as exactly equal (50-50) for the present case. Since these data were derived from the engineering characteristics of various types of machine tools suitable for making specific cuts (for example, an outside circular cut) the results are transferable from the United States to other countries provided that they fall within the range of the original data.[44]

191. Another study of capital-labour substitution, also in machining, is that of Boon (1965),[45] whose study was aimed at determining which machine tool was optimal (in terms of minimum capital plus labour cost) for performing a number of machining tasks. He undertook his calculations for a wide range of relative prices, adequate for characterizing conditions in unindustrialized, semi-industrialized and highly industrialized countries, and also took into account lot-size variations. He concluded that the higher the precision requirements in production and the larger the sizes of the work piece, the greater the restriction

in choice of technology.[46] Thus if it can be assumed that countries in early stages of economic development will start or expand metalworking production for the simpler smaller tasks rather than for the complicated or very large tasks, this implies that their choices for capital-labour substitution will be wider than the choices facing the more industrialized countries.[47] This observation must be qualified by the fact that, for one quarter of all tasks, flexibility was found to exist only at small lot sizes, while for another quarter, it was found only at large lot sizes.[48]

142. Boon, like Kurz and Manne, makes the simplifying assumptions of one-shift operation, a one-to-one ratio between workers and machines and full machine utilization. On the first count his results overestimate the degree to which optimal capital intensity differs between developed and underdeveloped countries; on the second count, they underestimate it, while the effects of the third assumption may go either way.

(a) If we allow for continuous rather than one-shift operation in the underdeveloped countries in order to improve capital utilization, unit capital costs drop to less than one third, representing an element of great additional flexibility in capital-labour substitution.

(b) In the United States and other highly industrialized countries, available machine time is reduced by the fact that there is less than one worker assigned to each machine; thus in the queuing process characterizing machine shop operations, idle machines will typically be waiting for workers (whose time is fully utilized) to become available to operate them. Conversely, in developing countries more than one worker can be assigned to each machine in order to make sure that machine capacity is more fully utilized. Thus in actual operating practice the amount of capital per worker is greater in the United States and less in the underdeveloped countries than estimated by Boon, thereby tending to widen the gap between the optimal technologies.

(c) Whether indivisibilities are more important in the United States or in the underdeveloped countries in reducing full utilization of machines depends on how efficiently the sector can be planned in an integrated fashion in the latter countries. In the United States the dispersal of capacity between separate enterprises tends to reduce average machine utilization, while in the underdeveloped countries limited markets create an inherent limit in many lines, in addition to which there may also exist a capacity-dispersal problem for the same reason as in the United States and as observed, for example, in the metalworking sector in Brazil.[49]

193. Other mechanisms. Capital-labour substitution can, to a lesser degree, also take place via three other mechanisms:

(a) Given alternative production methods (alternative resource-element inputs) for producing the same product, there is an opportunity for choosing more or less labour- (or capital)- intensive technologies;

(b) Given alternative possible product designs for realizing given technical specifications, the design can be adjusted to use more or less labour- (capital)- intensive technologies in its production;

(c) There is a possibility of product substitution in final or intermedia uses in response to price (or allocation) signals reflecting greater or lesser labour- (capital)- intensity.

194. Capital-labour substitution is a way in which resource elements can be adapted to prevailing local conditions. Depending on the relative scarcities of these factors, generally reflected in their prices, the productive process is organized in such a way that it economizes on one relative to the other to a deg that can be readily determined either by means of market (or market-like) proces or by programming studies.

195. Local adaptations by other than capital-labour substitution. In addition t capital-labour substitution there are other ways in which the productive process is adapted to local conditions. These are reflected either in the definition of the resource elements or in their mutual relationships within larger structures:

(a) Scale. The scale of individual resource elements and of entire factor composed of these can vary in response to the size of the market served. While larger scale entails significant economies, in small markets it may be preferable to forego some of these economies rather than to have no domestic production at a

(b) Specialization - integration with regard to output (horizontal integration). This is again a phenomenon related to the size of the market. In large ones, individual resource elements and entire factories can be adjusted in their basic design to a relatively narrow range of product outputs; in small markets, on the contrary, resource elements and factories must be designed for a wider product assortment. This means foregoing some of the economies of specialization, but this may again be preferable to having no domestic production at all

Note that scale and specialization are inversely related. Specialization may be increased by building smaller plants turning out more homogeneous products, while scale increases integrated facilities at the expense of a wider product assortmen

There is every indication that, at the sizes of the markets found in the developing countries, scale effects are strongly dominant over specialization,[50] since scale effects become overwhelming at small scales, giving rise to the approximate definition of "minimum economic scales".

(c) *Overlap between resource elements*. This is an aspect of the problem of resource element specialization. The less specialized each resource element is, the more a given semi-fabricating operation will be capable of being carried out by different resource elements. In the UNC study, for example, there is a large overlap of size classes. For example, the larger forges can handle most of the output of the smaller ones, and the smaller ones likewise can handle a good part of the output of the larger ones, since the average weight of parts handled is very much below the maximum. This leads to substitution between resource elements in the production of the same nominal output. This is not the same as substitution such as between forging and casting in the production of crankshafts.

The problem of overlap becomes troublesome when the scale of each resource element within an overlapping class is too small to be considered economical for a small developing country. For example, total demand may not admit forges distinguished by several size and seriality characteristics. Due to the overlap of the production capabilities of these resource elements, however, it might be possible to establish one or two forges that could handle a far broader range of sizes and serialities than the typical range of the product assortment on which the resource element had originally been defined. If secondary corrections are systematically applied to a large part of the individual products which make up the product assortment of the integrated forge in the developing country, the resulting estimates can be reasonably accurate.

In general, if the machine park of productive facilities is regarded as flexible, the problem is to select the optimal number and optimal composition of such facilities. If too few are built there will be a loss of efficiency, since these facilities will not be well adapted to any particular range of sizes or serialities. If too many are chosen, their adaptability will be much better but they will suffer from diseconomies of small scale. The optimal structure depends on the solution of a non-convex programming problem. There is thus a clear analogy between this aspect of the overlap problem and specialized versus broad product assortments characterizing a productive facility; except that in the present case the criterion of specialization is not the nature of the product, but its size and seriality characteristics.

Some overlap between resource elements in regard to size, seriality, and product-assortment classes is desirable at all times, since it results in an increased flexibility in the productive process. If there were no overlap at all, the probability of running into bottlenecks would be greatly increased as a consequenc of unforeseen fluctuations in demand and production. This flexibility, however, is achieved at the expense of reduced specialization and adaptability of a resource element to a specific class of outputs.

(d) Specialization-integration with regard to resource elements. This refers to the degree of vertical integration of the productive process. Does a factory have shops for producing minor parts such as nuts and bolts at a relativel small scale or does it purchase them? Does it perform its own repair and maintenance operations with special machine tools that have a low rate of utilization? Does it have shops with large minimal capacities, such as a heavy forge, that is only partly utilized? Does it make its own tool dies and patterns? These questions have to do with the scale and utilization of individual resource elements. Self-sufficiency is inversely related to the scales of resource elements as well as to the typical lot sizes for intermediate products: the more self-sufficiency, the smaller will be the scales and lot sizes implied.

(e) Over-all organization of the productive process: bipolarity. In the industrialized countries production within the sector is typically organized around specific product lines such as automobiles, agricultural machinery and ship Even though there are many enterprises that specialize in the production of semi-fabricates by a given process (commercial foundries, upsetting shops) and there is an extensive network of subcontracting, the core of the productive process is undertaken in vertical integration between product-oriented activities (design, assembly, marketing, product research and development) and the major semifabricati processes (foundries, forges, machining, et cetera). In the automotive industry, for example, the manufacture of motors or of large stampings is typically undertaken with captive capacity, while the manufacture of such items as lights, batteries, sparking-plugs, carburettors, mufflers or trim is subcontracted in whole or in part. In the developing countries, on the other hand, the scale of demand may not justify the maintenance of heavy captive capacity in any given industry defined by a specific class of products such as automobiles, but may suggest instead the organization of the sector around facilities such as foundries, forges or machine shops so as to serve a wide variety of end-products. The contrasting pull toward organization by end-products versus organization by major fabricating processes will be referred to as the bipolarity of the sector. While the logic of organization around fabricating processes under the conditions of the developing countries is very clear, the contrary pull is far from negligible and centers on *organizational* functions (design, engineering).[51] Product design for increasingly economical and efficient service of customers, for example, in agricultural machinery or machine tools, is closely involved with marketing experience and thus tends to pull in the direction of organization of the sector by products. At the same time, effective design (e.g. modular design of a product line) must be based on intimate day-to-day familiarity with the production process, thus exercising a pull toward the integration of fabricating processes with design.

196. *Suggested method for handling the problem of capital-labour substitution and adaptation in defining resource elements.* How shall resource elements be defined for the purposes of planning and programming of the sector in developing countries, in the face of the wide range of variability and the adaptation problems inherent in the concept?

197. It is suggested, first, that the concept of a resource element be differentiated from the concept of a standardized *function* or *task* which can be physically embodied in a number of standard shops (resource elements) differing somewhat among each other.

198. Secondly, it is suggested that in the initial planning and programming approach for a country only one single resource element should be defined for each standard task.

199. Thus in the first instance the problems of capital-labour substitution and local adaptation are to be decided *ex ante*, by means of informal judgement. This judgement is to be based on the results of the country studies. Each of these studies will result in the description of a set of resource elements adapted to the countries in question, and will in addition give qualitative or possibly quantitative indications of the range of variation that is to be found in these countries. If resource elements in the different *pilot* country studies are defined to correspond to the same standard task, there will result a number of different locally adapted variants of the same resource element from which a unique set can be chosen to approximate the local adaptation to the conditions of a particular developing country.

200. Four problems are raised by this approach. They are: standardization of tasks; efficiency of model resource elements; adequate range of variability; and needless prejudgement of the results of a broader planning approach. They are considered below.

201. Standardization of tasks. Tasks are combinations of technological function and characteristics that underlie the individual resource elements. The proposed approach depends on such a standardization of tasks even while it permits the loc adaptation of resource elements.

202. In particular, the technical characteristics to be standardized in order to define a task include: (a) principal technical characteristic (free- or die-forging, iron, steel, or non-ferrous casting, et cetera), (b) size class, and (c) seriality class. Features subject to local adaptation and thus excluded fro the definition of a task comprise: (a) capital-labour substitution, (b) scale, (c) product assortment, and (d) overlap with related resource elements.

203. In the country studies the effects of scale are to be functionally describe if possible;[52] a typical product assortment is to be selected, or alternately several typical product assortments may be given. The flexibility achieved by the given degree of overlap between resource elements is to be evaluated qualitatively.

204. It is of course evident that this very process of standardization of the number and kind of tasks will somewhat reduce the sharpness with which the resour element concept reflects local conditions in the countries in which the pilot studies are to be carried out. In some pilot country studies it might otherwise perhaps be better to define a larger number of resource elements, in others a smaller number. It also might be desirable that the exact combinations of technological characteristics defining a task be adjustable.

205. There is no reason why a country should refrain from defining an alternate set of tasks in addition to the standardized ones. If it did so, the standardized set would then serve for international comparisons, while the more sharply defined one might be used for additional experiments in programming. Since it is in any case an essential part of the present approach to insist that all technical descriptions be based on a data-system concept permitting frequent revision and redefinition due to reasons inherent in their subsequent programming use (completely independently of the issue of international comparisons), there is no loss of effort in working with a double set of resource elements. On the contrary, it is a useful exercise in testing the flexibility of the technical information system.

206. In defining the standardized set of tasks for country studies, it will be useful to keep in mind the already available UNC set, since the initial two studie would in that case complement the UNC resource elements representing quite different local conditions.

207. Efficiency of the model resource elements. How can one know that the resource elements derived from the UNC study or the ones that will result from the country studies will not suffer from serious built-in inefficiencies? Is it not gratuitous to assume without further tests that the existing productive facilities in any given country are locally adapted with a perfect degree of efficiency? Conceivably the practice in any given country might suffer from varying rigidities that prevent the full exploitation of known technological alternatives. If model resource elements were to be based on such rigid practices they would be burdened with the inefficiencies of their sources.

208. There is no doubt that this factor will lead to some errors in the suggested approach. The error can be reduced in some cases where the source of inefficiencies is obvious and the description of a resource element can be based on an engineering estimate of improved practice rather than on the prevailing unsatisfactory practice. It would however be dangerous to go too far in this direction since it is often hard to judge beforehand whether the suggested improvement is really feasible or whether it is merely based on wishful thinking.

209. Inherently more difficult are the cases of inefficiency that are not even recognized as such, for the very reason that there is no standard with which to compare existing practice adequately. One of the major dividends of the suggested method of approach is precisely that its systematic long-range application will result in setting up alternatives based on standardized international comparisons with which existing practice in individual countries can be compared notwithstanding the admitted shortcomings of standardized description.

210. Adequate range of variability. Will the UNC study and the country studies between them cover a sufficient range of local adaptations to permit choosing a set of resource elements to represent conditions in any developing country? Would it not be useful to include a developing country among the countries in which the first pilot studies are to be conducted?

211. In answering these questions the considerations of efficiency discussed under the previous heading are of decisive importance. It would be very dangerous to base model resource elements on practices known to be burdened with the major irrationalities that are characteristic of the metalworking sector in many developing countries. For this reason the countries for pilot studies were selected from among countries with a higher degree of economic development but which were subject to the market limitations within the sector that are also found in the developing countries.

212. It may be objected that the institutional conditions under which economic developmwnt takes place are part and parcel of the problem and either cannot or should not be subtracted from it. To this wholly legitimate objection the only possible answer is that the philosophy underlying the entire method of approach suggested in this study, as clearly indicated before,[53] is based on carrying as far as possible the separation of the "basic range of economic alternatives" built on the assumption of an invariant, internationally transferable core of <u>potential</u> technology, from secondary cultural-institutional limitations. It is not argued that the latter be disregarded, but rather that they be treated as constraints to be imposed on the basic range of economic alternatives. This is the reason for the insistance on removing them from the description of technology.

213. It still remains a valid criticism, however, that the range of local adaptations will be too narrow. An inescapable dilemma appears to exist in this regar one either applies not fully appropriate resource element variants chosen from a limited but more reliable range or one widens the range at the expense of contaminating the model resource elements with serious irrationalities. The suggested approach opts for the first alternative. Once a complete programming technique is established on the basis of this technological description it will be possible to study the sensitivity of the results to any reasonable changes in resource-element coefficients that might be expected as a result of the (unrepresented) local adaptations to the conditions of the developing countries, and thus the error inherent in the approach will be readily measurable. Opting for the other alternative would result in an uncertain and undefinable degree of misrepresentation.

214. <u>Needless prejudgement of the results of a broader programming approach</u>. Would it not be possible to avoid the exercise of subjective judgement in the selection of a unique set of resource elements for representing the adaptation to the conditions of a country by including multiple variants of a given resource element among the activities of a programming model? If a model formulated for developing country <u>X</u> were to include technically feasible alternatives from the UNC study as well as from the pilot country studies, then the optimizing procedure applied to such a model would automatically discard all alternatives found to be inappropriate in the light of the entire programme for the sector and the country, thereby eliminating the need for subjective prejudgement of the issue.

215. This criticism is valid in offering a more powerful procedure as a standard by which the suggested approach is to be judged, but the improvement at least in the initial stages of the project is not felt to be worth the additional complexity.

In border-line cases it is always possible to repeat the entire programming procedure with a revised set of resource elements.

Provisional classification of standard tasks

216. It was pointed out in the previous section that tasks underlying individual resource elements need to be standardized between pilot studies even while local adaptations of resource elements within these standard classes of tasks are to be explicitly permitted. In the following, a provisional classification of tasks is given that is based on the UNC study and is submitted exclusively as a basis for an initial approach to the country studies.[54]

217. At the same time and for the same reasons it appears desirable to standardize the description of the capital-equipment content of these resource elements. Here the UNC classification is the only available starting point, since no further work could be undertaken within the present study.

218. Resource element classification[55]

(a) Forging. Follow UNC classification. Where this is inadequate, it has been suggested[56] that additional resource elements be provided to give more flexibility to die-forging as well as to separate free- and die-forging in some of the UNC resource elements. "As developed, the resource elements reflect the high reliance on free forging, and the relatively low use of presses with open and impression dies in the Soviet Union".[56]

(b) Casting. Follow UNC classification. Gallik suggests adding a resource element for "simple, virtually unmachined castings such as manhole covers and sewage pipe fixtures", as well as the separation of die casting and permanent-mould casting.

(c) Machining. Follow UNC classification. However, should a precision dimension be added for subclassification? To do so would change the machine park considerably. The exact precision requirement for a product can be handled by a correction factor based on comparison with average precision of the typical product mix; however, having more than one precision class would permit assigning a product first to such a class in a rough way, as is done in the case of seriality.

Since the termination of the UNC study a major technical innovation has taken place in machining, namely the rapid spread of numerical control. This does not affect the classification of standard tasks but may make it desirable to introduce alternative resource elements for this particular process.[57]

(d) Stamping. Follow UNC classification.

(e) Upsetting. Follow UNC classification.

(f) Heat treatment. Follow UNC classification. It should be understood that the coefficients for resource elements iv, v and vi in the UNC study are known to be of very poor quality.[58]

(g) Steel fabrication (welding). Follow UNC classification.

(h) Assembly. Follow UNC classification.

(i) Auxiliary processes. The following are not included in UNC classification but their inputs may at times be included in UNC coefficients: Pattern-making; tool- and die-making; repair services; storage; intra-plant transpor plant laboratory services and quality-control services.

(j) Resource elements for certain industries not covered by UNC study: electrical industries (wiring, insulation, armature); shipbuilding (ways); and others. The questions of how to identify missing resource elements remains open

(k) Organizational resource elements (for overhead-type activities): design; engineering, costing, estimation; production planning; marketing; research and development and general administration.

219. Resource elements for related extra-sectoral activities. Certain major processes in the primary metals sector are interrelated with sectoral processes by way of mutual trade-offs.[59] These are the following: (a) ingot casting: steel; (b) ingot casting: non-ferrous: copper and copper alloys;(c) ingot cas non-ferrous: aluminium and aluminium alloys; (d) rolling steel; (e) rolling non-ferrous: copper and copper alloys; (f) rolling: non-ferrous: aluminium a aluminium alloys.

220. An open question is whether an attempt should be made to cover each of the processes with resource elements in detail comparable to that of intrasectoral processes? The classification is after all arbitrary, and problems of standardization encountered with ingots and rolled shapes are exactly analogous to standardization problems with semifabricates falling within the sector as conventiona defined for the present project.[60] Source material on the above casting and roll processes is more abundant than for metalworking processes in general. A process analysis type study covering the former is available whose methodology could be readily adapted to the needs of the present project.[61]

D. Description of products

221. The present major section of this report covers the detailed exploration of the analytical problems of product description and decomposition into inputs. It generally follows and expands the summary exposition contained in Section IV-B.

Definitions

222. Given a set of resource elements, the next task of programming for the sector is the decomposition of a group of typical products for each branch into subassembly, component and resource element inputs. The level of use of each resource element must be given in physical terms (tons, shop-hours) per unit of a specific individual end-product; for example, in a detailed breakdown of inputs into a specific gasoline engine, the number of tons of castings, forgings, stampings, welded fabrication and upsettings (fasteners), as well as the total number of tons of parts requiring heat treatment, must be specified, and these tonnage estimates must be complemented by figures for total machine-shop hours (machining) and square-meter-years (assembly floor-space). These levels of resource-element use can be compactly summarized by a column of coefficients that act in many ways like a conventional activity vector except that for purposes of cost and efficiency studies it cannot be assumed that the levels of inputs vary linearly with the scale of production, since economies of scale must be taken into account, both in regard to lot size and to the scale of the resource elements utilized.[62]

223. The product to which the decomposition into subassembly, components and resource-element inputs is applied is not an average but a single highly specific individual product, identifiable as to year and design, technical specifications et cetera.

In the UNC study, for example, such an end-product is the ZIL-120 gasoline engine whose process level (resource element) inputs are given in Table IV-2. The inputs, as usual in the UNC study, have been normalized to 1000 metric tons of engine output. Given these process level (resource element) inputs, the primary capital and flow inputs can be derived using the input coefficients of the set of resource elements previously defined. These primary inputs are listed in Table IV-3.[63]

224. A specific individual product such as the ZIL-120 gasoline engine is referred to as a typical product. In the UNC study the typical products are utilized to construct "representative products" for each branch by a process of weighted averaging of their resource-element input levels. A representative product is thus a statistical aggregate and is used to characterize statistically defined classes of products within each productive branch. In diesel engine manufacture,

Table IV-2

Process levels per thousand tons of ZIL-120 gasoline engine

Process	Resource element code	Unit of measurement	Process code	Process level
Die forging	F9	10^3 metric ton	A_9	.1603
Stamping	S5	10^3 metric ton	A_{25}	.0361
Upsetting	U3	10^3 metric ton	A_{33}	.0176
Foundry: cast iron	C3	10^3 metric ton	A_{38}	.8345
Foundry: aluminium, manganese zinc and alloys	C13	10^3 metric ton	A_{48}	.0575
Machining	M5	10^5 effective machine hours[a]	A_{60}	.4375
Heat-treatment	H1	10^3 metric ton	A_{71}	.5051
Heat-treatment	H2	10^3 metric ton	A_{72}	.3104
Heat-treatment	H3	10^3 metric ton	A_{73}	.0388
Rolled steel[b]	RS3	10^3 metric ton	A_{126}	.3500
Assembly	A5	10^3 square meters per year	A_{90}	.106

Source: UMC Study, op. cit., pp.III-92-95, IV-3-5, 13. Assembly not listed in source table, p.IV-13; input level derived from IV-24.

[a] The unit of measurement for machining has been normalized by multiplication by a factor of 100. In this way coefficients of equal order of magnitude will reflect the same order of magnitude in costs.

[b] Duplicates flow inputs into forging, stamping and upsetting, plus 30% (latter possibly an error).

Table IV-3

Flow and capital input per thousand tons of ZIL-120 gasoline engine

Type of flow or capital input	Process from which input originates	Code	Unit of measurement	Input
1. Labour				
Forging production labour	F	b_1	man-hour	1 539
Stamping production labour	S	b_2	man-hour	2 419
Upsetting production labour	U	b_3	man-hour	1 072
Casting production labour	C	b_4	man-hour	31 816
Heat treatment production labour	H	b_5	man-hour	44 780
Machining production labour	M	b_6	man-hour	38 474
Assembly production labour	A	b_7	man-hour	11 542
Auxiliary labour	All processes	b_{29}	man-hour	78 159
Engineering and technical personnel	All processes	b_{30}	man-hour	26 040
Clerical and office personnel	All processes	b_{31}	man-hour	12 270
Junior service personnel	All processes	b_{32}	man-hour	6 426
Total labour	All processes	b_{38}	man-hour	254 587
2. Power and fuel				
Electricity	All processes	b_{39}	kilowatt hour	1 315 012
Conventional fuel	FSUCHMW	b_{40}	kilogram	769 502
Steam	FSU HMW	b_{41}	kilogram	628 478
Compressed air	FSU HM	b_{42}	cubic meter	2 296 319
3. Metal				
Rolled forging steel	F	b_{54}	metric ton	208
Rolled steel (bars, shapes etc.)	SUW	b_{55}	metric ton	62
Pig-iron	C	b_{56}	metric ton	587
Alloying ingots	C	b_{58}	metric ton	63
Ferrous scrap	C	b_{63}	metric ton	318
Non-ferrous scrap	C	b_{64}	metric ton	2
Alloying additives	C	b_{65}	metric ton	23
4. Other materials				
Water	FSU HM	b_{96}	cubic meter	20 596
Chemicals	FM	b_{97}	kilogram	113 865
Lubricants	FSU	b_{98}	kilogram	2 073
Coolant (concentrate)		b_{99}	kilogram	1 098
Dies	FSU	b_{100}	kilogram	2 455
Cutting tools	SHM	b_{101}	kilogram	3 031
Measuring tools	M	b_{102}	kilogram	264
Jigs and fixtures	M	b_{103}	kilogram	1 893
Heat-treating fixtures	H	b_{104}	kilogram	7 378
New sand and clay	C	b_{105}	kilogram	1 947 000
Sand binders	C	b_{106}	kilogram	46 126
Slag-forming	C	b_{108}	kilogram	108 854
Refractories	CH	b_{109}	kilogram	96 189
Electrodes	CW	b_{110}	kilogram	863
Paint	A	b_{115}	metric ton	10
Paint solvent	A	b_{116}	metric ton	6
Wood (crating)	A	b_{117}	metric ton	28
5. Capital: resource element capacities				
Die forging	F9	c_9	per cent of normal monthly capacity	6.99
Stamping	S5	c_{25}	per cent of normal monthly capacity	.90
Upsetting	U3	c_{33}	per cent of normal monthly capacity	1.53
Foundry: cast iron	C3	c_{38}	per cent of normal monthly capacity	10.01
Foundry: alloys	C13	c_{48}	per cent of normal monthly capacity	34.50
Machining	M5	c_{60}	per cent of normal monthly capacity	83.33
Heat treatment	H1	c_{71}	per cent of normal monthly capacity	14.09
Heat treatment	H2	c_{72}	per cent of normal monthly capacity	44.87
Heat treatment	H3	c_{73}	per cent of normal monthly capacity	108.28
Assembly, painting, crating	A5	c_{90}	per cent of normal monthly capacity	29.17

Source: UNC study, op.cit., IV-22-24, see also IV-6-11.

for example, the categories "light", "medium" and "heavy" were established on th basis of a statistical survey. The task then was to construct a representative product for each category. In the case of light diesels it was first ascertainec that these included automotive, aviation and tractor diesels. Data were availabl only for the latter type, but the coverage was deemed satisfactory since automoti diesel were known from statistical sources to represent only about ten per cent of the total. A tabulation of thirteen different designs was then prepared, givi the year of production and technical specifications for each. These data reveale a trend toward a reduction in the weight-to-horsepower (kg/hp) ratio. Detailed parts data were available only for one of these, the D-36 engine with a relative weight of 20 kg/hp and weights for the most important parts and/or subassemblies also available for the SMD-55 engine, with a relative weight of approximately 10 kg/hp. The resource element inputs were then derived for these two typical products, and coefficients for a representative light diesel engine were constructed on the basis of the assumption that the process levels per ton of the D-36 engine was representative of process levels per ton of tractor diesels with a relative weight of 18-22kg/hp (or broadly those produced in 1958), and that process levels per ton of the engine SMD-55 were similarly representative of the tractor diesels with relative weight of around 10 kg/hp (which were estimated to be coming into production in 1959-60). The statistical weights used in the aggregation (85-15) were estimates of the share of each category in the total tonnage of the branch.[64]

225. Representative products are useful for capability analysis but are unsuitab for efficiency, cost and programming studies such as that which the present projec intends to pursue. For this reason the present analysis follows the UNC method on up to the decomposition of typical products into subassembly, component, and resource element inputs (determination of process levels) but parts ways with it thereafter. The typical sample product shall be used not in defining statisticall aggregated representative products but in constructing, on the basis of demand, a sequence of products lined up approximately in the order of increasing production costs per unit of output value, using for this purpose a "long list" of products in each branch.

Research technique of the UNC study

226. In the UNC study the decomposition of typical sample products

> ....entailed first, the determination of the net distribution of processed metals. The latter were expressed, necessarily, in terms consistent with the outputs of resource elements (process activities).....
> The second step in this typical pattern was to convert the net processed

metal inputs to a gross (pre-machining) basis by means of given or estimated coefficients of metal utilization. The pertinent coefficients of utilization for our study are summarized [in Table IV-4, reproduced from the UNC study]. Having determined the requisite gross processed metal inputs, the calculation of implied flow and capital requirements followed in the usual case by applying the previously estimated inputs per unit of process activity [i.e., the resource element capital and flow inputs] and summing for all processes. This left the residual non-processed items, purchased from other sectors, to be determined according to the individual commodity analysis, i.e., in greater or lesser aggregation according to data availability.[65]

227. The research method utilized to establish process levels had three variants: (a) party-by-part analysis, (b) direct derivation of process levels on the basis of literature sources and (c) analogy.

228. In a few instances the basic process distributions were developed piecemeal through a part-by-part analysis. This procedure itself has several variants all of which proved fairly laborious but in the main, economical of the time of skilled personnel. What was involved, essentially, was the detailed stripping and weighing of the elements of a given machine according to process origin.[66]

At times the required data were found in product catalogues containing weights of parts and metal or process designations; usually, however, because of incomplete data, considerable part-weight information had to be developed from engineering drawings and then grouped by engineering assessment into relevant process categories.

The latter technique was found extremely if not prohibitively slow when applied to whole machines; on the other hand [it was possible] to utilize graduate assistants effectively in limited undertakings of this sort.[66]

229. Process distributions were found at times directly in the literature, either for subassemblies or for complete products or product groups. At times such coefficients were applied from more global sources on classes of products.

Analogy was used in part or whole for "data-scarce" commodities by borrowing and adjusting data referring to comparable Soviet machines and, as a last resort, from United States models.

Such scarce data as were available relating primary inputs directly to specific end-products were used as a check on the two-phase derivation via resource elements, and were occasionally used to supersede the latter.[67]

All of the foregoing referred to resource element levels that depend on gross weight of the part. Machining, assembly, and heat treatment process levels required special estimating techniques.

(a) Machining inputs had originally been related to chips removed, that is, the difference between gross and net weights of the part.[68] Though this technique of estimation was abandoned for machining, the gross-net estimates are still essential for the purpose spelled out in the previous section, that is, for going from part weights as assembled to gross part weights prior to machining that determine casting, forging, et cetera resource element input levels. The final technique for estimating machining input levels was based on "several dozen sources" by different end-product classes, including technical norms, special technical studies, and related references; it involved a direct estimate of effective machine-hours based on these literature sources.[69]

(b) Process levels for assembly "were derived in relation to machining inputs as were corresponding magnitudes (flow and capital) from the pertinent machining resource element....they represent a mixed reliance on norming and empirical evidence.[70]

(c) Heat treatment inputs were estimated partly on the basis of aggregative data supplied in Soviet sources, but mainly by means of specific engineering analyses. The latter involved establishing the percentage of each kind of processed metal in an end-product undergoing heat treatment (allowing for repeated applications) and subsequently a breakdown by major classes of heat-treating techniques (normalization and hardening, gaseous cementation, surface hardening).[71] These estimates are known to be burdened with considerable error.[72]

Modifications and alternatives

233. The principal modification of the UNC research technique is based on the additional degree of freedom afforded by doing such studies in the country whose data underlie the work, and being able to complement or supersede published sources by original observations.

234. The part-by-part approach is thus much more broadly feasible than was the case in the UNC study. At the same time, it is indispensable to devise research methods designed to cope with the burden of detail that this approach imposes.

235. Given the specifications of a machine, the first task is to identify each part as to kind of metal and process of origin. In view of the very large number of parts in a complex machine, this is no mean task. For example, in a detailed analysis of sixteen Soviet metalcutting machine tools the average part count was over 800.[73] A good working procedure for economizing the time of highly trained persons in performing this task is to have them check off the individual parts on the specifications with a coded set of coloured pencils; thereafter the weight of each part can be calculated by research assistants of considerably lesser training.[74] At least initially, the colour-coded check-off must be done by ex-

experienced **mechanical engineers; eventually much of this work** could be taken over by specially trained graduate engineering students whose performance would still have to be supervised by the senior engineers. Another task requiring a high degree of technical competence is the estimation of the gross-to-net weight ratio for different parts as well as effective machine hours for machining requirements and heat-treatment specifications. Purchased parts such as motors can be identified by reference to standard lists.

A suggested shortcut of the *part-by-part approach* is the grouping of parts into different functional shapes such as axles, housings, gears and fasteners; then exact estimates of process origin, machining time, weight et cetera can be restricted to the most important members in each class plus two or three other members of smaller sizes and/or complexities. This permits an approximate estimation of the other members of the group without the time-consuming individual inspection and measurement inherent in the fully detailed procedure. This method can also be relied upon in estimating secondary corrections for resource element inputs in regard to seriality, complexity and precision which are discussed below. The origin of this suggestion is a verbal account[75] of an estimating procedure that is used in the Union of Soviet Socialist Republics for defining the production costs of new machine designs within an accuracy of some 20 per cent. Such estimates are prepared for supporting appropriation requests for subsequent more detailed and accurate production analyses, and their preparation is taught at engineering schools at the equivalent of the Master of Engineering level of instruction.

Among the other approaches used in the UNC study, the utilization of direct costings of process level inputs wherever available from previous technical studies is of course to be recommended insofar as its reliability is comparable to the part-by-part estimate. Estimates by analogy must be restricted insofar as possible, as was also done in the UNC study.

There are at least two additional potential costing shortcuts that could be explored as to their applicability to the project which were not included in the UNC study, namely, shortcut cost estimates in industries where bidding is a common practice and where they are related to subcontracting.

In some branches of the sector *bidding on jobs* is a common practice. This is particularly true of branches connected with construction, as on oil refineries, power plants and chemical plants on which bidding may at times be international. The same applies to major pieces of custom-made equipment such as hydroelectric turbines and generators, or certain categories of railroad rolling stock. In all of these cases the preparation of bids must be undertaken on the basis of major specifications without reliance on detailed part-by-part designs, and shortcuts are used as a matter of normal technical and management practice. Much can be learned from a detailed study of these estimating procedures. Their use is nevertheless limited by the fact that in many cases the coefficients refer to value rather than to physical inputs; in other words they implicitly incorporate assumptions concerning one particular set of price ratios. Whether or not this aggregated information can be divided into price and quantity components will depend on the particular case. As a minimum, such estimating procedures can be used as independent checks on the quality of the technological descriptions arrived at by means of the part-by-part approach.

240. In industries where subcontracting is common the contracting enterprises will generally know the production costs of their subcontractors to the penny. It is said that automobile manufacturers in the United States drive bargains based on this knowledge to within one tenth of a cent per piece on long production runs.[76] The estimating methods habitually employed in these industries would be instructive if they could be obtained, possibly through consulting engineers familiar with these industries.

241. A special case of importance to the developing countries is the large distribution enterprise that contracts the manufacture of its merchandise with many different producers. The big mail-order houses in the United States have such a policy and are said to be able to estimate the production costs of the merchandise offered in their catalogues with great precision. Since their operations cover not only the United States but a number of developing countries, particularly in Latin America, access to and international comparison of their estimating procedures for the large number of items falling within the metalworking and engineering products sector would be most valuable. The relevant products include not only consumer durables and semi-durables (kitchen equipment, hardware), but also hand tools, farm equipment, builders' hardware and the like.[77]

Advantages versus problems and ambiguities

242. The basic advantage of product decomposition is that it permits the piecing together of joint requirements for resource element capacities that originate in many different individual products and their parts. This is the all-important justification of the technique; all of the problems and ambiguities to which it gives rise must be weighed against this overriding virtue.

43. Unique decomposition versus alternatives. The productive techniques that can be used for manufacturing a product need not be unique. As mentioned before as a case in point, an automobile crankshaft can either be forged or precision cast prior to machining. Depending upon these two alternatives, the same product may have two different breakdowns into process levels. This does not create particular difficulties once the framework of analysis is generalized from input-output to a more powerful programming approach.

44. End-products, subassemblies, parts. Only the simplest unassembled products can be represented by a single list of process levels (resource element inputs). If there are subassemblies of different hierarchical orders and parts within each, some of these levels can be treated as an end-product in its own right and must often be so treated in order to reflect possibilities of partial domestic manufacture complemented by imports or standardization and modular design. Thus, for example, the same engine, clutch, brake assembly, battery or whatever can be used in different kinds of automobiles and possibly even lorries, tractors, and industrial engines and the same standard individual fasteners (parts) will typically be used sector-wide in a great many different products. It is thus not easy to decide what should be treated as an individual product for decomposition purposes. A practical (though analytically not completely satisfying) procedure is to define not only a list of typical sample end-products to represent production possibilities within a sector (see next section) but also a list of subassemblies and parts that are to be treated independently.[78]

45. Whichever set of sub-parts of a composite end-product is treated as a unit, its representation by a single set of process levels is possible only if each part within the unit can be uniquely represented; otherwise there is a combinatorial proliferation of alternative process-level input patterns. If there are only a few significant combinations, these can be enumerated as such, but if the number of alternative combinations becomes at all large it is preferable to treat the sub-parts having several input-pattern variants as individual products in their own right.

46. Coefficients of metal utilization. The determination of these coefficients cannot be regarded as a straight technical problem subject solely to engineering judgement. The amount of metal removed by machining from bar or other stock depends on the variety of bar sizes and other shapes produced in the primary metals sector; the amount of machining to be done on forgings and castings depends on the closeness of tolerance achieved in these preparatory processing steps. In each of these cases there is a trade-off between the metal losses and resource

inputs due to machining and the added resource inputs required for producing a wider assortment of primary shapes or closer tolerances in preparatory processing. In practice, none the less, this trade-off will necessarily have to be handled implicitly, at least in the first definition of the problem; later, it can be added as a complementary sensitivity study built around the initially derived results. To take explicit account of the required resource-element and product-input variants appears, at least at this stage, to be intolerably burdensome.

247. Pre-classification of process inputs. Inputs into end-products necessarily must be pre-classified in accordance with the set of pre-defined resource elements. Pre-classification categories in the UNC study include type of product (typical products characterizing a resource element), size class and seriality class. Further pre-classification categories that might be included in future resource element lists are precision and complexity of part produced. In the UNC study the pre-classification works in the following way. Let us suppose that one is analysing the production of a 2.9-ton turret lathe that has 896 separate individual parts.[79] The resource elements chosen to represent forging, casting, machining et cetera inputs of this turret lathe would first of all have to cover parts for machine tools among their listed output assortments. Since in the UNC study there is no distinction between most resource elements of the same size and seriality class by type of product assortment, it is necessary to make sure that the one variant that is given is actually appropriate. Now for selecting the size class, the criterion is the maximum weight of a part; thus it is necessary to estimate the exact weight of the heaviest forging, casting, machined part or whatever. In the case of machine tools this is undertaken not on a part-by-part basis but using the following additional statistically-derived information: "Assume maximum weight of cast part of a machine tool to be between 20 and 40 per cent of the total weight (the heavier the machine tool the smaller the percentage share of its heaviest part), and 1/3 of maximum weight of cast parts to be the maximum weight of forged parts."[80] The given turret lathe has approximately a median weight among the sixteen machine tools listed in the reference,[80] therefore an estimating factor of 30 per cent is appropriate for maximum weight of casting, giving 870 kg; accordingly the maximum weight of forging is 290 kg. Positing further a seriality class of "small series" it is thus possible to select Forging Resource Element No.4 (heaviest forging, 320 kg). Foundry Resource Element No.5 is the best among poor choices, since it is "medium" rather than "small" series, and its part-size is too large (5000 kg, although 1000 kg maximum part size would be more appropriate but is available only in "mass" seriality). For copper castings, the choice is

are poor. Only two resource elements are defined for this alloy group; one too high in seriality, the other in part size. For machining, the fit is considerably better: Machining Resource Element No.3 is the preferred choice with "and medium" series and maximum rough weight of part, 2 tons.

It should be noted that the underlying assumption that all similarly pro-[illegible] parts for a given end-product are handled in the same resource element; forged parts are not subdivided by size class and distributed between larger and smaller forges, and likewise for operations such as casting or machining. This is a consequence of the institutional set-up encountered by the UNC study, namely that production is organized around end-products rather than around the required processes for different end-products. As a result, each resource element tends to have a broad range of capabilities, and the degree of capacity utilization depends on the product assortment. To the extent that production (as in a developing country) can be organized more closely around the processes rather than around the end-products, the typical resource element can be defined with a considerably narrower range of capabilities, and the estimation of process-level inputs can be made more independent of the exact size, seriality, precision, or complexity distributions characterizing a given product assortment. In other words, the UNC material contains resource element definitions that make the closeness of the description of technology highly dependent on working with approximately the same product assortments for which the resource-element definitions were originally derived. In revising the method for application to developing countries, it is therefore convenient to standardize on a somewhat larger number of resource elements, more narrowly defined primarily by size class than the UNC study, and to make capacity and flow input corrections as described below.

Secondary corrections

The principal drawback of the unmodified UNC approach from the point of view of cast, efficiency and programming studies is the fact that once an end-product is associated with an input originating in one of the pre-classified variants of a fabricating process (that is, a resource element), the numerical magnitude of the process level, whenever expressed in tonnage terms, is proportionally tied to the gross weight of the fabricated parts. Thus once the castings of an end-product (as in the case of the illustrative turret lathe of the previous section) are associated with Foundry Resource Element No.5, all capital and flow inputs from that point in the casting process are taken to be proportional to the tonnage of castings produced, regardless of the number, complexity, tolerances and size distribution of the cast parts going into that particular end-product.

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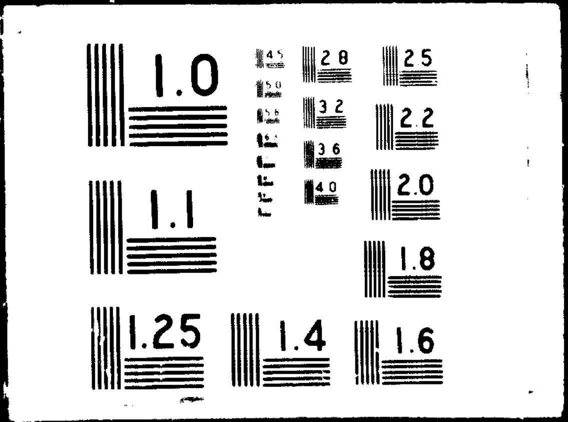


Moreover, given the seriality class of the resource element that determines its exact machine park and flow inputs, variations in the seriality class are likewise suppressed.

250. The purpose of this section is to suggest a way of taking such variations into account without going to the opposite extreme of defining, as at an earlier stage of the UNC study, as cited before, seventy-five variants of unit-and-small-series casting and similarly for other processes. The basic assumption will be that the machine park of a resource element is taken as fixed once the size, seriality and possibly the product-assortment class, if specified. The exact fraction of output capacity that is utilized and the exact flow inputs can, none the less, be freed from the ties of rigid proportionality to tonnage output by introducing simple corrections factors that are interposed between this tonnage and the input requirements.

251. <u>Seriality</u>. From the point of view of developing countries and their limited markets, this is the key correction. Within a given seriality class such as "medium", the capacity of each resource element must be standardized by reference to producing at a stated, known "base" seriality.

252. The simplest way of setting up the information required for this correction is to start by calculating total available yearly "effective hours" of each resource element similarly as is done in the UNC study for the case of machining resource elements.[81] These yearly effective hours are summed for different machines. (a) These are, in part, determined technologically; that is, they cannot exceed the maximum defined by continuous operation, allowing for reasonable down-time for maintenance and inspection purposes. (b) In part, limits are clearly introduced by <u>institutional</u> conditions such as the number of shifts, holidays, or work-relief time allowed to workers. Once the technologically feasible maximum effective hours are known, adjustments can be readily made to take into account country-to-country variations in institutional conditions. (c) Inherently more difficult is the estimation of a third, intermediate category of deductions from the yearly effective hours, owing to various delays that are more or less closely tied to the structure of production. These include worker-fatigue allowance, tool breakage, material shortages, time lost due to scrap or defective parts, waiting time for cranes, absence of tools, unplanned repair, labour absenteeism and failure to observe proper procedures.[82] (d) A final category of deductions is <u>planned underloading</u>, that is, the less-than-complete utilization of productive facilities that is foreseen as a result of indivisibiliti in the productive process. This category must be divided into two main parts.

The first comprises an allowance for the inherent lack of perfect balance between the capacities of the various machines that make up a productive facility, in producing all parts of the product assortment, and the consequent impossibility of keeping all machines operating at all times even apart from the earlier mentioned factors. The second is that planned underloading arises from indivisibility in a productive facility (resource element) as a whole, that is, the fact that it has a minimum economic scale measurable in terms of total output. Unless this minimum economic scale is small in relation to total demand for the capacity of such a resource element, the unevenness of investment will reflect itself in a fluctuating but at times marked underutilization of capacity that can be clearly foreseen in the process of planning. In allowing for a deduction from the yearly time fund it is essential to exclude the latter kind of planned underloading and make a deduction only for the former one, since otherwise a key step in the programming process, namely the appraisal of capacity utilization, becomes submerged in the definition of resource element capacity rather than being handled explicitly.

253. The exact number of effective hours of capacity that is utilized per ton of resource-element output must now be related to the exact seriality (lot size). This relationship can be kept quite simple. It may take the form of an approximate fixed set-up time (in effective hours), regardless of seriality, plus a variable handling-plus-processing time proportional to seriality, or the sum of these two effective-hour requirements then characterizes a whole series of a single output. This can be referred back to a per-ton basis by dividing through by the total tonnage of the series.

254. The most precise way of using this method would involve estimating a separate set-up time (including tear-down time) and marginal (per-unit) handling-plus-processing time for each individual product. This would, however, impose an excessive burden on the research procedure at least initially and is therefore not recommended. Rather, the assumption of approximately valid uniform set-up and marginal effective-hour requirements is suggested as the basis of deriving secondary corrections. The latter can always be adjusted up or down informally on the basis of judgement when some additional qualitative information happens to be available in regard to a particular series; for example, that a given product requires an unusually high or low set-up or marginal time, or that two or more products produced one after the other have similar physical set-ups resulting in a significant shortening of the full set-up time when changing from one to the other.

255. In order to translate the principle of this approach into a correction factor, all that is required is to standardize the seriality of a given resource element, for example, of "medium" seriality, at a fixed numerical level. Let us suppose that the standard seriality is fifty units. In this case one adds the (uniform) set-up time plus fifty times the (uniform) marginal-time to obtain total effective hours for the standard series. Division by tonnage yields per-ton effective-hour requirements for the standard series. The correction factor sought is the ratio of per-ton effective-hour requirements for a non-standard series, divided by the same for the standard series.[83] Such correction factors can be tabulated or graphed for easy reference.

256. Comments on the seriality correction. As noted previously, the assumption underlying the correction procedure is that inputs are first pre-classified into a seriality class, for example, "medium", for which the corresponding resource element has a given fixed machine park adjusted to the range of serialities occurring within the given class. Corrections do not affect this assumed machine park, only the capacity requirement per ton of output.

257. The correction is based on fixed and marginal requirements that are assumed to be, first, independent of other production requirements, and second, uniform between different outputs. The first assumption is weakened by the known variation of set-up and tear-down times according to whether the set-ups in a sequence are physically similar; the second is an approximation suppressing the known variations between products.

258. The seriality correction as considered here tacitly assumes that capacity and input requirements per ton are independent of the weight of the part produced. Since this is patently not correct, the accuracy of the seriality correction suffers unless a weight (size) correction of a similar nature is simultaneously applied.

259. Weight (size) and other similar corrections. The device used for this purpose can be exactly analogous to the seriality correction. Capacity requirements are standardized for a part of given weight (size), and the correction factor is calculated as the ratio between effective hours per ton of actual workpiece and effective hours per ton of standardized workpiece. The numerical estimate of the correction factor has to be based on an empirical correlation between size of the piece and total effective hours. Corrections for complexity of part produced, for tolerance (or closeness to final dimension) and for hardness (workability) of metal can be handled in an analogous manner.

260. Correction for product assortment. This correction cannot be made as exactly (or in as simple a manner) as the foregoing ones. Supposing that the machine park of a resource element is approximately balanced for a given product assortment, the production of pieces that have machine-input requirements widely divergent from that characterizing the average assortment, can unbalance the over-all input needs of various kinds and increase the unavoidable underutilization of capacity. As mentioned earlier, corrections for this factor have been suggested in the UNC study for machining resource elements, with the strongest corrections (greatest unbalance and therefore, greatest increase in claim on nominal capacity) occurring in the case of resource elements designed for high seriality.[84]

E. Empirical testing of the methodology: Electrical machinery and equipment industries

261. This major section reports on the results of an effort to apply the methodology worked out for fully quantified programming data on a pilot basis to the problem of technical-economic description in selected branches of the metal-working and engineering products sector. All data are from United States sources. The products selected for treatment are: (a) electric motors and generators; (b) transformers; (c) electrical distribution and control apparatus.[85]

262. In each case an attempt is made to find the characteristic input requirements, the machine park and the labour and material flows needed for production of a given product. For each product the methodology requires the definition of a table of capital and flow-input coefficients based on resource-element utilization. For the most part, it has not yet been possible to produce this desired table as an end result. A well-defined, pre-existing set of resource elements must be at hand before coefficients of this type can be estimated. At this time, the problem of defining resource elements, particularly the ones characteristic of those branches not covered by the University of North Carolina study (as was the electrical good branch), is still a matter of discussion. In the course of this report, however, it will be indicated where the data are helpful in dealing with the problems posed by the methodology and where they are not.

263. For purposes of general orientation with regard to the position of the electrical goods branch within the sector, the reader is referred to a classification of branches given in the Appendix to this chapter.

Electric motors and generators

264. Product list: motors and generators. Given a set of resource elements, what determines which typical end-products shall be decomposed into resource element inputs? Specific individual products must be chosen to typify a class of products within the branch so that they will be representative of a very broad spectrum of the different products found in the branch. A product list is constructed for this purpose.

265. The product list is meant to represent the entire spectrum of products in a particular sub-branch. The closest approximation to such a spectrum is the listing provided by the 1963 Census of Manufacturers of the United States Department of Commerce. The Statistical Department of the National Electrical Manufacturers Association (NEMA), which is the industry trade association in the United States, also provided some data. The Commerce Department data are better because they provide more coverage and greater refinement. This is because more manufacturers report to the census than belong to the association and also because the census asks for and receives more detailed data than does the association.

266. The number of products was arbitrarily set at two hundred. It was hoped that these 200 products would include 80-90 per cent of the volume and/or value of the spectrum of products. Products were included on the basis of a combination of volume and value by giving equal weight to volume and value. If a product was too low in volume and value it was excluded. This gives a bias in favour of high seriality and high value and, by the same token, a bias against low seriality and low value and is thus a bias in favour of large markets and import substitution. The orientation of the product list therefore leans toward potential export industries. The census lists a range of products broken down by seven-digit Standard Industrial Classification (SIC) classes rather than specific individual products. For the present purposes, however, it is necessary to obtain the specific individual products within the given range. Fortunately, industry standards covering motors and generators are available. The Motor and Generator Standards of NEMA, MG-1-63 were used to obtain the exact sizes (product ratings) within the range. This procedure is sufficient where the products are manufactured to industry standards but will not suffice in any branch where the products are manufactured without industry standards. In the latter case, more time will have to be spent to achieve the same degree of precision in choosing the correct products. The product list for motors is shown in Table IV-4.

Table IV-4

Motor product list

Universal motors [a]

10 mhp
15 mhp
25 mhp
35 mhp
1/20 hp
1/12 hp
1/8 hp
1/6 hp
1/4 hp
1/3 hp
1/2 hp
3/4 hp
1 hp

Direct-current motors and generators

1 mhp
1.5 mhp
3 mhp
5 mhp
10 mhp
15 mhp
25 mhp
35 mhp
1/20 hp
1/12 hp
1/8 hp
1/6 hp
1/4 hp
1/3 hp
1/2 hp
3/4 hp

Alternating-current shaded-pole motors

1 mhp
1.25 mhp
1.5 mhp
2 mhp
2.5 mhp
3 mhp
4 mhp
5 mhp
6 mhp
8 mhp
10 mhp
12.5 mhp
16 mhp
20 mhp
25 mhp
30 mhp
40 mhp

Alternating-current shaded-pole motors (cont.)

1/20 hp
1/15 hp
1/12 hp
1/10 hp
1/6 hp
1/5 hp
1/4 hp

Other alternating current motors

1 mhp
1.5 mhp
2 mhp
3 mhp
5 mhp
7.5 mhp
10 mhp
15 mhp
25 mhp
35 mhp
1/20 hp
1/12 hp
1/8 hp
1/6 hp
1/4 hp
1/3 hp
1/2 hp
3/4 hp

Single-phase integral-horsepower motors, open frame, 1800 rev/min.

1/2 hp
3/4 hp

Polyphase integral-horsepower motors, open frame, 1800 rev/min.

1 hp
1-1/2 hp
2 hp
3 hp
5 hp
7-1/2 hp
10 hp
15 hp
20 hp
25 hp
30 hp
40 hp
50 hp
60 hp

Table IV-4 (continued)

Polyphase integral-horsepower motors, open frame, 1800 rev/min. (cont.)

75 hp
100 hp
125 hp
150 hp
200 hp
250 hp
300 hp
350 hp
400 hp
450 hp
500 hp
600 hp
700 hp
800 hp
900 hp
1000 hp
1250 hp
1500 hp
1750 hp
2000 hp
2250 hp
2500 hp
3000 hp
3500 hp
4000 hp
4500 hp
5000 hp

Direct-current motors and generators

1/2 hp
3/4 hp
1 hp
1-1/2 hp
2 hp
3 hp
5 hp
7-1/2 hp
10 hp
15 hp
20 hp
25 hp
30 hp
40 hp
50 hp
60 hp
75 hp
100 hp
125 hp
150 hp
200 hp
250 hp

Direct-current motors and generators (cont.)

300 hp
400 hp
500 hp
600 hp
700 hp
800 hp

Gasoline engine-driven generator sets:

Direct-currant output

1 kW
3.5 kW
7.5 kW

Alternating-current output

500 W
3/4 kW
1-1/2 kW
2 kW
2-1/2 kW
3-1/2 kW
5 kW
7-1/2 kW
10 kW
12-1/2 kW
15 kW
30 kW
65 kW
115 kW
170 kW

Diesel engine-driven generator sets:

Direct-current output

50 kW
150 kW

Alternating-current output

3 kW
12 kW
30 kW
40 kW
50 kW
60 kW
75 kW
100 kW
150 kW
200 kW
300 kW
400 kW
600 kW

Table IV-4 (continued)

Other motor-generator sets:

Alternating-current

1/12 hp
1/4 hp

Direct current

1/20 hp
1/6 hp
1/2 hp

Integral horsepower:

Alternating-current output

4-1/2 kW
25 kW
100 kW
170 kW

Direct-current output

4-1/2 kW
25 kW
100 kW
320 kW
480 kW
640 kW

---

a/ The symbol mhp represents "millihorsepower".

267. Motor construction.[86] Figure IV-1 shows an exploded view of a typical electric motor. The particular type of motor represented is a polyphase, integral-horsepower, squirrel-cage induction motor with an open frame, drip-proof enclosure. The exploded view is a pictorial decomposition of the components of the motor and should be referred to in reading the following text.

268. The main components of an electric motor are the stator and rotor assemblies. The stator assembly is the stationary portion of the motor and the rotor assembly is the rotating portion. Figure IV-2 is a design tree of an electric motor which shows how a motor is broken down into its functional components.

269. Squirrel-cage motors derive their name from the shape of the rotor assembly. Open-frame construction of the protective enclosure means that the frame and brackets are supporting structures and that the motor is self ventilating, with no restriction to ventilation other than that required by mechanical construction. Drip-proof construction means that covers have been added to prevent falling liquid or objects from entering the motor. These covers may be built integrally with the enclosure.

270. The frame structure supports, surrounds and retains the stator. The stator consists of a sheet-steel core built up of laminations with slots in which insulated coils are placed. The coils are so grouped and connected as to produce a rotating magnetic field when connected to a source of electric power.[87] The frame structure also provides the mounting feet by which the motor is fastened in place, usually by bolting to a stationary or sliding base. The base-plate is not considered as part of the motor but as an accessory.

271. The ends of the stator coils are brought out through an opening in the frame structure where they are connected to the motor leads, which provide the source of power. The connexion of stator and motor leads requires mechanical protection. A motor terminal box is attached to the frame structure for this purpose.

272. End-bells (shields) or bearing brackets are bolted to the ends of the frame structure to support and locate the motor bearings in which the shaft rotates.

273. The bearing brackets have ventilating openings through which air is drawn into the motor by the cooling fans mounted on each end of the rotor. Ventilation prevents overheating of the motors.

274. The rotor, like the stator, is constructed of steel laminations, with the electrical conductors consisting of metal bars placed approximately parallel to the shaft and close to the rotor surface. These bars are short-circuited by

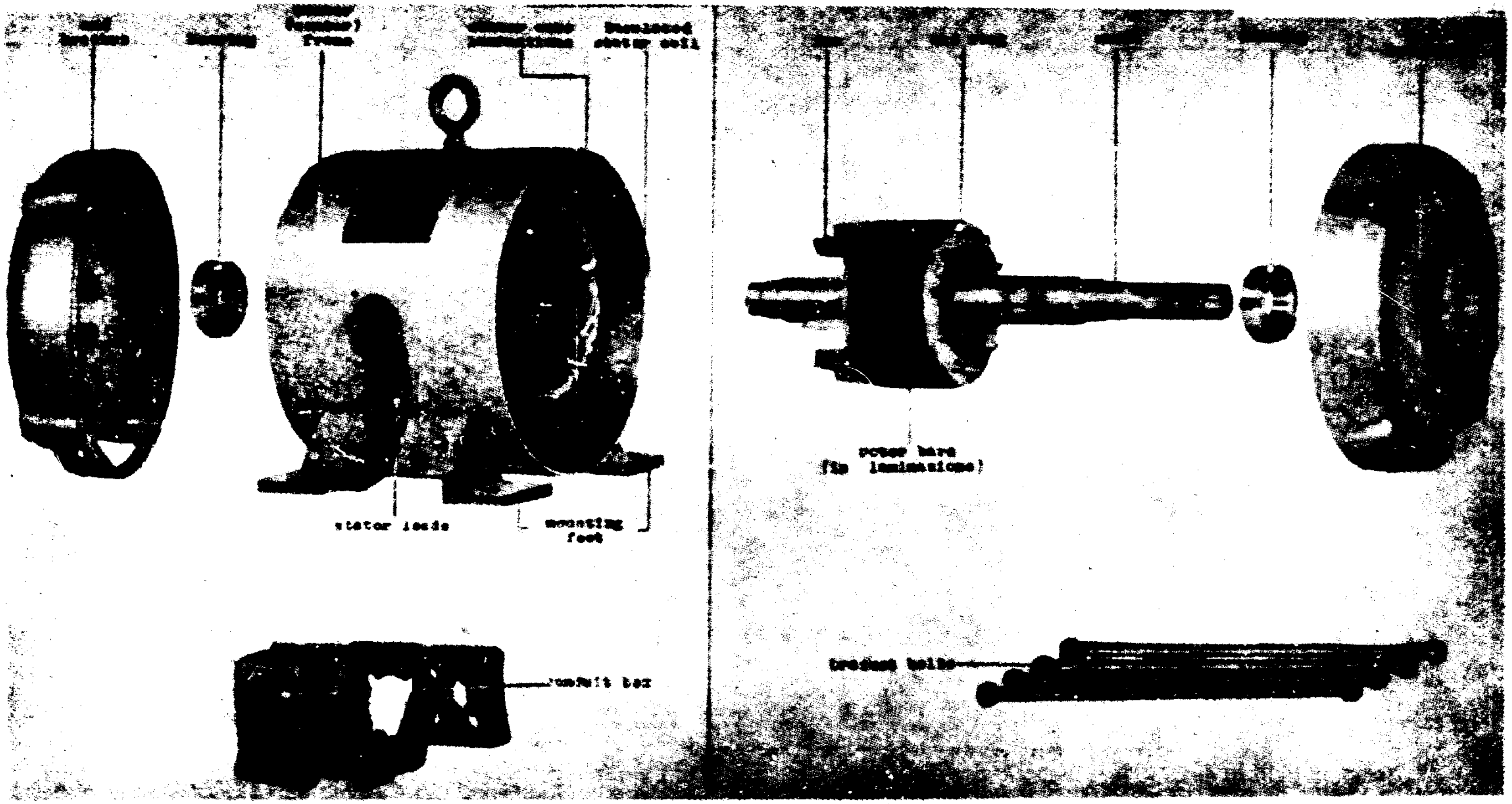
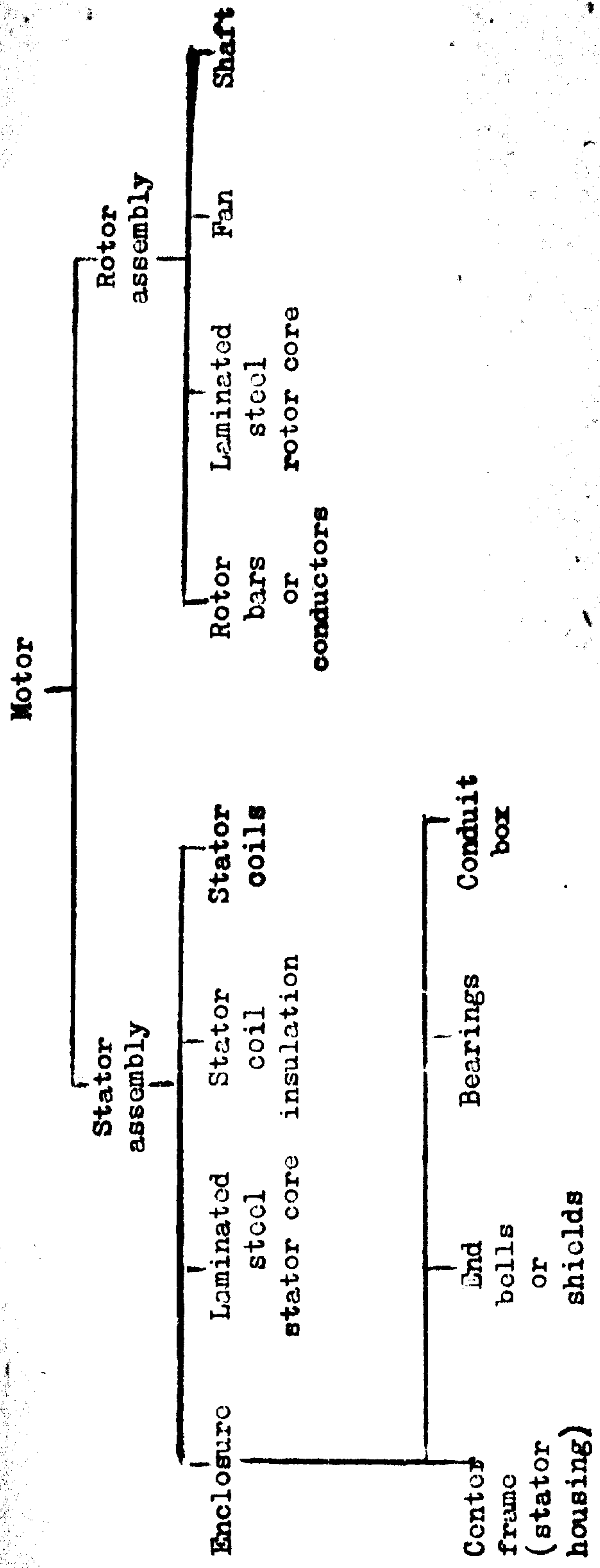


Figure IV-1

Exploded view of a typical electric motor

Figure IV-2

Design Tree for an Electric Motor



being connected at each end of the rotor by a solid ring of copper or brass. The completed rotor assembly is fixed to a rigid shaft with a slot and key, completing the rotating portion of the motor.

275. Parts and processes. Table IV-5 indicates the processes used to produce the main components of an induction motor. In each case, the "most critical" process is indicated by the number "2" in the table.[88] This process is usually the first process in a sequence. The alternative activities (A1, A2, A3) shown in the columns of this table are for increasing ranges of horsepower sizes such as small, medium and large motors. For example, in the first column, the frame of a small motor would be formed of sheet steel or aluminium, that of a medium size motor would be cast of iron or aluminium, while a large motor would have its frame made of welded steel.

(a) Enclosure construction. The frame has usually been made of cast iron in motors of sizes up to 200 horsepower. Cast aluminium is being used more and more due to its better heat dissipation, lighter weight and also because of a decrease in the price of aluminium relative to that of steel. Fabricated steel is often used in motors of larger horsepower and in those of low speed.

The frame or housing of an electric motor can be formed from sheet metal, cut from steel or aluminium (tube-stock), cast in iron or aluminium, or welded and/or bolted from plates and angles. The frame must have holes (for attaching hardware and for mounting on a base) drilled and reamed, or threaded and mating surfaces must be machined and polished. All tolerences must be checked, before finishing by plating or painting.

The ball- or sleeve-bearings are invariably purchased parts. The end-brackets can be cast, formed or welded while the motor terminal box is pressed or cast.

(b) Stator core. The stator core is made up, in part, of laminated steel punchings, usually 0.014 to 0.025 inches thick, stacked together. These laminations may or may not be insulated with a coating of varnish. The laminations are made in a high-speed press by die-stamping silicon steel strip fed into the press from coils. The laminations are notched (by the stamping process) so that the stack of stator-core laminations can be aligned to permit the insertion of the stator windings. Together the stack of stator alminations and inserted stator windings make up a pre-wound stator core. This assembly is then pressed into the centre frame in such a way that an air space remains between the stator and frame for ventilation purposes.

Table IV-5

Resource Activity Table of Components Required to Produce Electric Motors

Activity / Resource (Process)	Frames			Stator core		Stator windings		Rotor core		Rotor bars		Shaft		End Shields			Conduit box		Base		Machines required
	A1	A2	A3	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A3	A1	A2	A1	A2	
Forming	2						1							2			2		2		Power rolls 70-75 ton press
Casting		2								2					2			2		2	Foundry
Cutting											2	1	1								Power hack saw
Shearing			1													1					Metal shear
Die Stamping				2	2			2	2												Punch press
Welding			[illegible]										1			2	1				Welding equipment
[illegible]	1									1	1	2	2	1							Lathe
[illegible]											1	1									Grinder
[illegible]															1	1					Milling machine
[illegible]														1	1	1	1	1	1	1	Drill press
[illegible]																					20-ton press
[illegible]																					Winding machine
[illegible]																					Dipping vat
[illegible]																					Oven
[illegible]																					Gas torch
[illegible]																					Stator winding inserting machine
[illegible]																					[illegible]
[illegible]																					[illegible]

Table IV-5

Notes

(a) Only direct production resources are listed. Overhead resources are not included.

(b) Production of larger-sized motors often entails a change in the mix of resources (processes) required for producing a component. This shift is indicated in a qualitative way by the specification of alternative activities for the production of each component, namely:

A1 - activity of producing the components for a motor rated in the lower horsepower ranges;

A2 - same, middle horsepower ranges;

A3 - same, highest horsepower ranges (larger than 1500 hp).

The horsepower rating at which a different activity is required will not necessarily be the same for all motor components, so that the ranges within which a given activity is likely to be employed are only indicated in a rough, qualitative manner ("lower", "middle" and "highest").

(c) Source: Information gathered from technical and commercial sources. See the sample worksheet in the appendix to Chapter IV.

Stator windings consist of insulated conductors formed into coils and inserted in the aligned slots of the stator laminations. Additional insulation is placed in the slots before the insulated conductors are inserted. Coil-winding machines are used to form the coils. Insulated copper wire is fed into a machine which automatically forms the wire into coils. The coils are then automatically spread to the proper size and shape. The coils are inserted in the slots with wedges of insulation. Slot insulating and coil inserting can be done separately but it is best to use a special stator winding-inserting machine to perform the combined operation unless the production seriality is quite small. The assembled stator is then dipped in varnish under vacuum impregnation and baked in an electric oven. There may be multiple dips and bakes for greater reliability.

(c) Rotor assembly. The rotor laminations are stamped out in the same press motion as the stator laminations using the centre portion of strip which is removed in forming the stator. The rotor-core stack is built up in a manner similar to that used for the stator-core stack. In small motors the lamination is of one piece; in larger motors, each lamination is made up of several segments which are fitted together.

Copper, brass or aluminium bars are used as the rotor conductors and are short-circuited by end rings. The bars are welded, brazed or bolted to the rings, although some manufacturers die-cast aluminium alloy bars integrally with the end rings as a single part. It is not necessary that these bars be insulated from the laminations. Cooling fans are either separately attached or integrally cast with the rotor. In small squirrel-cage rotors, the bars, end rings and cooling fans are of aluminium cast in one piece rather than being welded together.

The rotor-core stack keyed to the shaft, together with the rotor bars, end rings and cooling fans, constitute a rotor assembly. This entire assembly must be tested for rotational balance before it can be assembled into the completed motor. The shaft can be machined from bar stock or made by centreless grinding.

276. Product decomposition. It has proved nearly impossible to obtain satisfactory product-decomposition data from either published or commercial sources. It was necessary to canvass sources in manufacturing, and even here the volume of reliable data has been relatively small considering the number of inquiries made by letter or telephone.[89]

277. The decomposition data that have been collected consist mostly of weight measurements of motor components. Those data, which are a sample from the 10 hp to 3000 hp range, are displayed in Table IV-6.

Motor Part Weights [illegible] of Open Drip-Proof Motors

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Horsepower at 1800 rev/min		[illegible]	[illegible]	[illegible]	200	400	800	1500	3000
Frame number		215-T	[illegible]	[illegible]	445	507	685	688	808
Motor part	Material								
Shaft	Steel bar	10	45	59	100	160	192	230	1100[c]
Rotor-core laminations	Electrical sheet steel	22	67	93	311	600	934	1600	2400
Rotor bars	Aluminium bar	2	10	10	20	95[b]	132[b]	223[b]	590[b]
Stator windings	Insulated copper wire	8	47	41	108	105	470	484	990
Stator-core laminations	**Electrical** sheet steel	46	181	131	350	700	1390	2250	4900
Centre sheel or housing	Cast iron	16[a]	71[a]	152	260	300	480	600	3000[a]
End-shields (2 needed)	Cast iron	8 ea.	40 ea.	60 ea.	80 ea.	100 ea.	250 ea.	250 ea.	475[d] ea.
Conduit box	Cast iron	4	6[a]	23	31	75	95	95	100
Screws and bolts	Steel (purchased)	-	-	-	10	12	15	15	20
Ball-bearings	Steel (purchased)	-	-	-	16	22	30	30	50[e]
Total motor weight		124	507	629	1366	2269	4230	6027	

Sources: Data in columns 1, 2 and 3 are from Howell Electric Motors Company, Plainfield, New Jersey.
Data in columns 4, 5, 6, 7 and 8 are from General Cynamics Corp., Avenel, New Jersey.

[a] Steel in place of cast iron.
[b] Copper in place of aluminium bar.
[c] Welded construction.
[d] Consists of 350 lb of steel end-shields and 125 lb of cast-iron sleeve-bearing housing.
[e] Listed as "other", assumed to be sleeve-bearings.

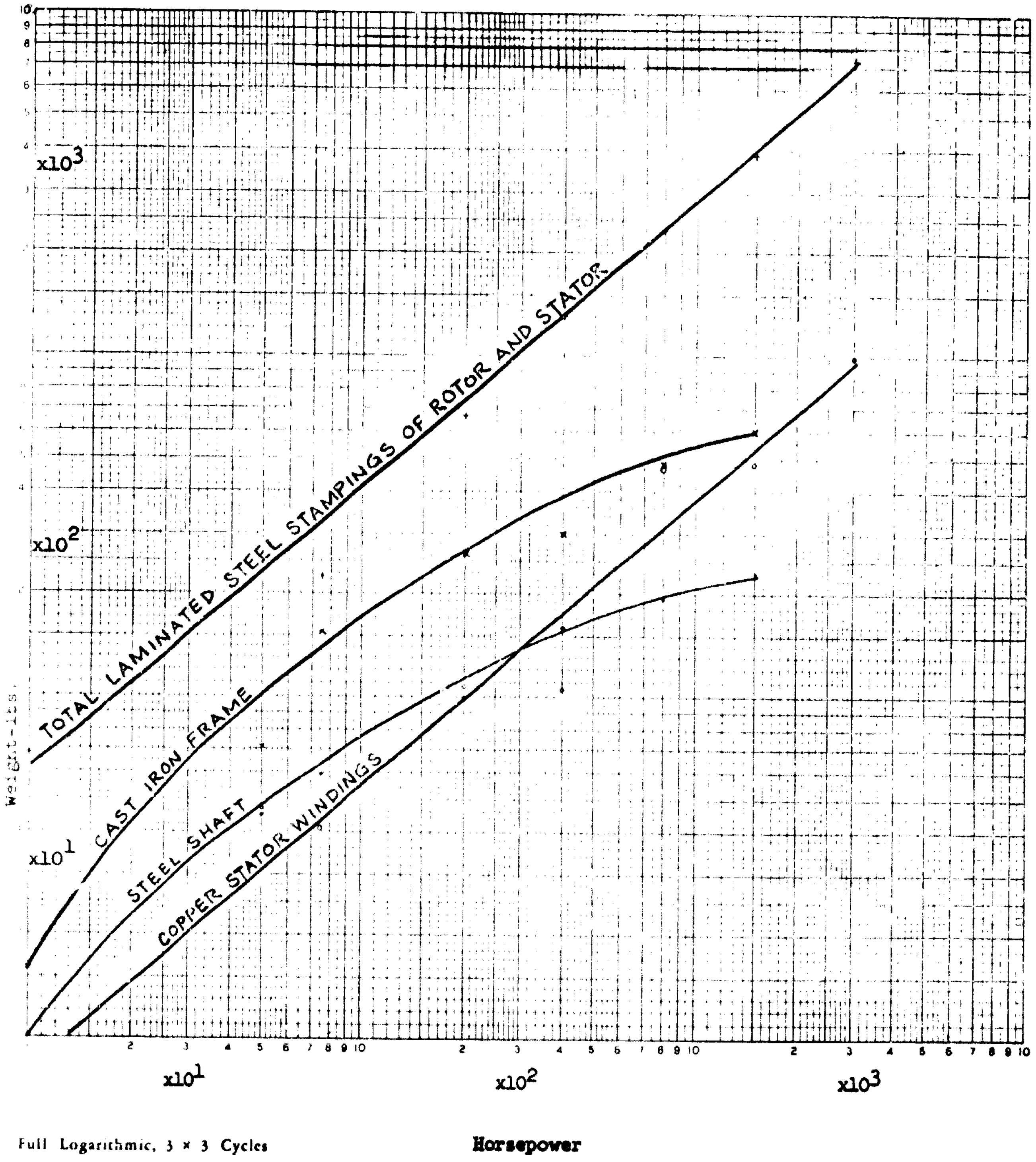
278. Individual components are typically not equivalent to the outputs of single resource elements. The definition of a component as distinguished from the output of a single resource element depends on how resource elements are defined (and vice versa). For instance, the stator core could be considered as the output of a single resource element if it were reasonable to envisage one whose task was to produce pre-wound stator cores. The stator core consists of laminations and coils, so that, as shown in Table IV-6, two critical processes are used to produce the total assembly: (1) die-stamping and (2) winding. Prima facie, it is illogical to combine them into a Stator-Core Resource Element. Of course, this decision cannot be made without consideration of other products which might conceivably use both of these processes. So instead of treating the stator core as an integral, indivisible component, it must be decomposed into laminations and coils. Conversely, only in a universe of relatively simple products can resource elements be defined independently of product decomposition. At least a rough decomposition of the more complex products will have to be made in order to ensure that no critical processes remain hidden.

279. Electric-motor decomposition has highlighted some other problems (already discussed in the theoretical sections of this chapter) in relating decomposition data to resource-elements, namely: (1) the definition of material-flow requirements and (2) the definition of stock requirements in terms of machine capacity used in the manufacture of a product. Product decomposition data by material and weight can answer most questions under the first of these headings[90] but not under the second one unless, for given material composition, process requirements can be completely specified by means of a one-to-one relation to weight, and unless any other part parameters are either a function of weight or are not significant to the process. In the simplest case, where a process is specialized to the production of a certain part of given size and shape, the weight-to-process requirement relation is unambiguously one-to-one. In the general case, however, a process (a machine or related group of machines) not only produces a whole range of sizes of a given part but may also produce several different parts. In this case the sufficiency of part-weight as a measure of process requirements must be examined critically. It is moreover questionable whether any single parameter will suffice to measure process requirements.

280. Figure IV-3 shows finished weights of motor parts as a function of horsepower rating. From this information material-input coefficients can be readily derived if an adjustment factor is applied for wastage of material in process.

Figure IV-3

Finished weights of motor parts as a function of motor horsepower for open drip-proof polyphase induction motors run at 1800 rev/min



Source: table IV-6

It is possible to estimate the adjustment factor in many cases by comparing part dimensions with standard metal stock sizes. This procedure has been illustrated for the motor shaft.[91]

281. Machining the shaft is a process of metal removal (cutting chips of metal from rough stock). If, following the University of North Carolina (UNC) study,[92] weight of chips-removed is used as a measure of machining requirements, the adjustment factor, when multiplied by finished weight of shaft, will serve to measure process as well as metal-usage. For the other processes used to produce motor parts, such as casting the frame, no metal-usage coefficients were estimated to compare with those in the UNC study. Manufacturers were reluctant to supply data from which estimates of material lost in process could be made.

282. Weight and material composition may not be the only part-parameters that are critical for the processes used to produce a component. Fortunately, in the case of motors, these parameters are reasonably close measures of the process requirements of most motor parts. For example, a set of casting resource elements has been defined.[93] The process used to produce motor housings in the 10 hp to 1500 hp range is primarily iron casting. The output of the UNC casting resource elements is given in terms of tons of castings (of given size and complexity class). Therefore, the part-weight of the frame serves as a measure of both the metal and the process requirements for its manufacture. The case of stator and rotor core (steel-alloy) laminations is somewhat less satisfactory. These laminations can be punched out together in a single stroke, just as a washer and its hole can be out in one motion. The weights of the laminations have been combined and their total plotted as a function of horsepower. The total weight of laminations is however a rather ambiguous measure of the process used to stamp laminations. The number and diameter of laminations per motor should be specified, since the capacity of a punch press is measured by the number of stampings of a certain size and thickness per hour. Weight is only equivalent to "number of stampings" if a punch-press is used to produce a single size and gauge of stamping, since in this case weight is proportional to the number of stampings. If a punch press is capable of producing several different sizes and shares of stampings, then weight of stampings is not an indication of the degree to which press capacity is used. In the UNC study, this problem is handled by estimating capacity (process) usage coefficients for a typical component or semi-fabricate and then calculating correction factors to adjust for variations in component sise or complexity. If the variation from the definition of typical product becomes too large, then the component in question must be manufactured by a

different process, that is, a different resource element. In the case of laminations, for a given gauge of steel alloy, it would be necessary to specify one other parameter (diameter) in order to determine the number of core laminations from core weight.

283. What parameters are required in order to describe the coil winding process? The stator winding is produced on a winding machine, and the number of hours it takes to produce a winding on such a machine is dependent on the wire gauge and the number of coils in the winding. Weight of copper in the winding is thus insufficient to determine the time needed to produce it, since weight is roughly proportional to the product of wire-gauge (pounds per foot) and the number of coils. Again, in addition to weight, another parameter must be known.

284. The above discussion indicates some of the problems involved in deriving characteristic input requirements from part-decomposition data in the case of electric motors. Part or component weight is only one of the critical parameters, but it is one which, while necessary in every case to permit the computation of material inputs, may, in many cases, be insufficient or even irrelevant in the specification of process requirements. The resource-element approach as developed so far is based on the assumption that a single parameter can be used as a measure of process usage. The viability of this assumption hinges on the degree of specialization of process to part, as seen in the case of stampings. To the extent that resource elements are of a more general-purpose nature rather than of a specialized one, it will often be necessary to measure more than one part parameter in order to estimate correctly the process requirements of producing the part, or at least to provide a reasonable correction factor for the estimate based on part-weight alone. In the course of further work on product decomposition, it will be desirable to re-examine machine-tools and manufacturing processes in order to determine which parameters should be measured in addition to, or instead of, part-weight. Much of this information can probably be obtained at little cost from the manufacturers of machines which produce metal end-products, especially since manufacturers supplying this information would be describing the operating characteristics and requirements of their product rather than disclosing confidential manufacturing information. This source of information has not yet been exploited.

285. Machine requirements. The right-hand column of Table IV-5 gives an indication of the types of machines used in motor production. A machine park capable of producing 100 motors of fractional horsepower, 75 of 0.75 or 1 hp, 40 of 5 hp or 25 of 10 hp daily is shown in a United States International Cooperation

Table IV-7

Electric Motor Manufacture: Tool and Equipment Requirements[14]

Item	Number required
75-ton press	1
40-ton press	1
20-ton press	1
5-ton press	1
Forming rolls	1
Lathe	3
Drill-press	3
Metal-shear	3
Mica-undercutting machine	1
Coil-taping machine	2
Coil-spreader	1
Arbor press	3
Weighing-scale	3
Spray-gun	1
Vise	4
Insulation-former	1
Air-compressor	1
Screw machine	1
Rotor -coil winder	1
Stator-coil winder	3
Winding head	6
Power hack-saw	1
Gas welding kit	1
Electric arc-welding machine	1
Spot-welding machine	1
Power buffer	2
Power grinder	2
Hand-truck	5
Testing equipment	
a. Dynanometer	2
b. Stator-winding tester	1
c. Growler	1
d. Voltage tester	1
Work-bench	(as required custom)
Spray-booth	1
Baking-oven	1 (custom)
Varnish vat	2 (custom)
Cleaning vat	4 (custom)
Dust-collector system	(custom)
Parts bin	(as required)
Expendable tools	(as required)
Hard-tools	(as required)
Motor-truck	1
Conveyor section	300 feet (estimate)
Overhead conveyance system	(custom)
Armature extractor	1
Office equipment	
Desk and chair (set)	4
Filing cabinet	10
Drawing board	2
Typewriter	2
Adding machine	1
General fixtures	allowable

Administration (ICA) source,[94] and reproduced here as Table IV-7. The important question, which cannot be answered at this time, is how this machine-park changes, that is, what additions and substitutions are made as motor manufacture shifts to larger sizes or higher seriality.

286. The machine-park given in this ICA source is contingent upon the following three assumptions: (a) the plant is operated on a one-shift basis, (b) only skilled labour is employed and (c) casting or forming of the frame, end-shields and base is subcontracted.

287. The cluster of machines shown in Table IV-7 cannot be considered as "motor resource element" for two reasons: (a) the considerations given imply that the machine park must change significantly in order to manufacture much larger motors, and (b) the resource element, as constituted, contains two processes (stamping and machining) which are input to many products besides motors. These processes should be defined as separate resource elements, since variation in the definition or requirements of these tasks due to changes in size of part or seriality are liable to effect significantly the composition of the machine park. If casting and machining are excluded from the motor shop, we are left with a core of processes peculiar to the production of electric motors and which cluster about the resources of winding (the stator), stamping (the rotor and stator core) and assembly (the rotor and the motor as a whole).

288. Flow requirements. Figure IV-3 above gives approximations of the weights of metals needed per motor component for a range of horsepower sizes. Lacking estimates of the proportion of metal lost in process, this is as close as one can come to coefficients of direct primary materials used to produce motor components.

289. Estimates of indirect materials and direct and indirect labour requirements for the manufacture of motors rated at 10 hp or less can be found in the aforementioned source and have been reproduced as Table IV-8.[94] These estimates are consistent with the machine-park and production seriality assumed by the same source. Unfortunately, the indirect material requirements are given as aggregate 30-day stocks and cannot be manipulated to yield the indirect material flow required per motor. The labour requirements are associated with production flows distinguished according to labour specialization, which in this case happens to correspond closely to type of process, as this table shows. Thus, this portion of the data, after some re-working, could be used as the basis for labour-flow coefficients of a "motor resource element". Such coefficients would be limited

Table IV-8

Electric motor manufacture: flow requirements[94]

	Approximate labour hours required for the production of the indicated number of units per day of motors of the following horsepower ratings					
	1/6(100)	1/4(100)	3/4(75)	1.0(75)	5(40)	10(25)
Direct labour						
Superintendent	8	8	8	8	8	8
Tool and die maker	8	8	8	16	24	32
Machine operators						
a. skilled	16	16	24	40	40	48
b. semi-skilled	16	16	16	24	32	32
Winders						
a. skilled	24	24	40	72	96	120
b. semi-skilled	8	16	32	56	80	90
c. beginners	8	8	16	16	24	40
Finishers						
a. painters	8	8	8	8	16	24
b. oven operator	8	8	8	8	16	24
Final assemblers						
a. skilled	16	16	16	24	32	40
b. semi-skilled	8	8	8	16	24	32
c. beginners	8	8	8	8	8	16
Welders and brazers						
a. skilled	8	8	8	24	32	48
b. machine operator (spot-welder)	8	8	8	8	8	8
Inspectors						
a. skilled	8	8	16	16	32	40
b. semi-skilled	8	8	8	16	16	24
c. beginners	8	8	8	8	8	8
Material handlers						
a. group leader (expeditor)	8	8	8	8	8	8
b. assistants	8	8	8	24	32	32
Indirect labour						
Shipping and receiving clerk	8	8	8	16	16	32
Packing and packaging clerks	8	8	8	16	24	32
Truck driver	8	8	8	8	8	8
Janitor	8	8	8	8	8	8
Plant engineer	8	8	8	8	8	8
Office personnel						
Book-keeper	8	8	8	8	8	8
Secretary	8	8	8	8	8	8
Typist	8	8	8	8	8	8
File clerk and general worker	8	8	8	8	8	8
Office boy	8	8	8	8	8	8

by the fact that it is impossible to tell to what degree, if at all, they would remain valid beyond the specified horsepower range. It is interesting to note that the machine-park defined in Table IV-7 is sufficient to manufacture the full range of 1/6 to 10 horsepower ratings, and the only effect of shifting from the manufacture of one size to a different one is to alter the seriality of production. It is evident that at some point in the process of moving beyond this range to the manufacture of larger-sized motors, not only a quantitative but a qualitative change in the type of equipment or processes used will become necessary. Lacking further information, this type of shift is only denoted in a rough fashion by the alternative production activities for some motor components shown in Table IV-6. The 3000 hp motor, especially, is shown to require a qualitatively different mode of manufacture from any of the smaller sizes, since many of the components are fabricated by welding.

90. The effects of technological advance and engineering design on electric motor manufacturing requirements

(a) Changes in total weight. Standards for motors have existed for decades, but advances in technology continue to change the construction and production of these ubiquitous devices. Electric motors are an excellent example of how material input coefficients can change caused by technological improvements. The availability of newer materials (primarily insulation materials that can withstand higher temperatures) have made it possible to decrease the amounts of materials required to produce a motor of a given horsepower rating. This is shown in Figure IV-4 as a function of the decreasing total weight of motor. Motors were re-rated[95] by the National Electrical Manufacturers Association (NEMA) in 1953 and again in 1964. The frame assignments for open, 40-cycles polyphase induction motors[96] run at 1800 rev/min were changed as shown in Table IV-9 and Fig. IV-4. Insulating materials constitute but a miniscule proportion of total motor weight, determine the temperature at which a motor can be operated and hence how compactly it can be built; therefore improvements in insulation efficiency have led to considerable reductions in the weight of the motor-housing, laminated cores, conductors and some decrease in the length of shaft for a given horsepower rating. In recent years, aluminium has been substituted for both steel or iron (in the housing) and copper (for rotor conductors). What is the significance of these observed technological changes for countries hoping to develop motor-manufacturing capacity, especially for export? Technological improvements arise continuously, but (at least in the case of motors and in the United States) they only appear in production discontinuously, after a considerable time-lag.

Table IV-9

Weight-horsepower relationships in different time periods

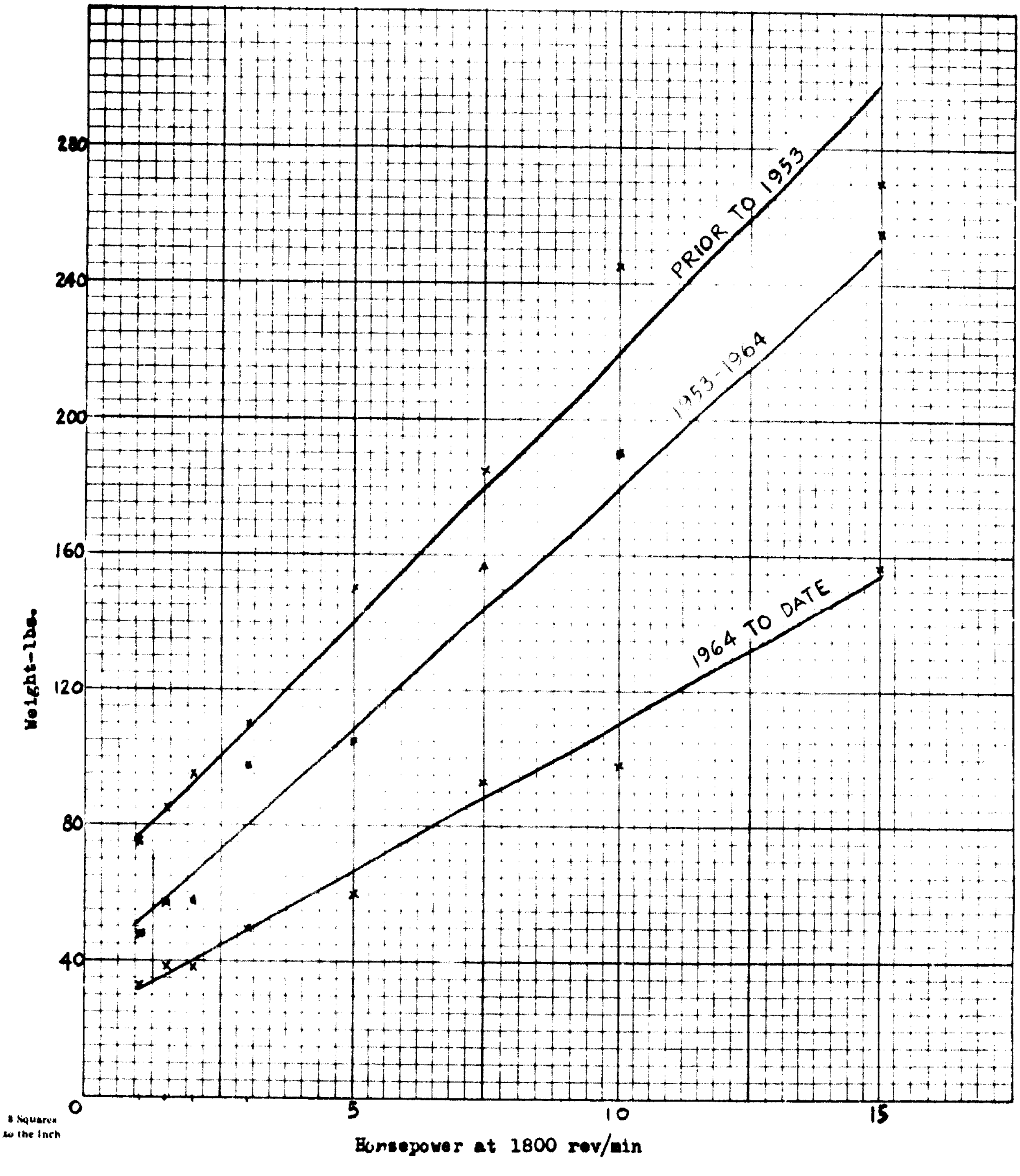
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Prior to 1953		1953 to 1964		1964 to present	
Horsepower rating at 1800 rev/min	NEMA Frame size	Weight (lb)	NEMA Frame size	Weight (lb)	NEMA Frame size	Weight (lb)
1	203	75	182	48	143T	33
1 1/2	204	85	184	57	145T	38
2	224	95	184	57	145T	38
3	225	110	213	97	182T	49
5	254	150	215	105	184T	60
7 1/2	284	185	254U	157	213T	93
10	324	245	256U	190	215T	98
15	326	270	284U	255	254T	157

Sources: (a) The weights listed in the columns (3) and (5) are from Charles C. Libby, Motor Selection and Application, McGraw-Hill, New York, 1960, Table 4-12, page 178.

(b) The weights listed in column (7) are from General Electric Co. Catalog No.HEK0321, page 107 (July 6, 1964)

Figure IV-4

Weight-horsepower relationships for NEMA standard motors in different time periods (re-rating due to changing technology)



Source: table IV-9

Figure IV-4 shows that major improvements in motors have been statndardized at intervals of about 10 to 15 years. Therefore it would be advantageous for a developing country to enter the market just <u>after</u> a technological improvement, such as a re-rating had manifested itself in order to avoid the disadvantage of producing with considerable plant capacity tied to obsolete processes.

(b) <u>Component changes: the shaft</u>. The previous section showed changes in the total weights of motors caused by advances in technology. A similar analysis can be made for the individual parts that comprise the motor. As an example, consider the 5-hp motors shown in Table IV-9 above. The diameters of the shafts of these motors (not shown in table) are unchanged because the load requirements (5-hp at 1800 rev/min) remain the same. Only the length of shaft decreases with changing technology. The weight of the shaft therefore varies only with its approximate length. Prior to 1953 the over-all length was 20-1/8 inches.[97] From 1953 to 1964 the length was 17 inches,[98] resulting in a saving of 15 per cent in the weight of the shaft. After 1964 the length was 13-3/4 inches,[99] resulting in a further saving of 19 per cent in the weight of the shaft. Translating these percentages into weights, the figures become 14 lb prior to 1953, 12 lb between 1953 and 1964 and 10 lb after 1964. The significance of these changes for production requirements is discussed below.

(c) <u>Chips removed in machining the motor shaft</u>. It is necessary to know the amount of chips removed in order to estimate the direct material input, the machine hours and the labour time for producing the shaft. The following method shows how it is possible to estimate the amount of steel bar stock that is removed in machining the motor shaft.

Industry standards and manufacturers' catalogues give the length of the shaft and also the diameter of that portion of the shaft which extends beyond the housing. These data are insufficient for the present purpose since the shaft diameter is larger at the bearings and also where the rotor-core stack of laminations is keyed to the shaft.[100] (In the interest of simplicity, only the core stack will be considered.) It is necessary to estimate the diameter at the core and the stack length. The dimensions of a rotor lamination were taken from Libby.[101] The shaft diameter at the stack was 1-3/4 inches and the stack diameter was 6-1/2 inches. Using a rule of thumb that the stack length equals the stack diameter,[102] the stack length is 6-1/2 inches. The diameter beyond the housing is given as 1-1/8 inches, while the over-all length is 20-1/8 inches.[10 The bar stock before machining has to be at least 1-3/4 inches in diameter by 20-1/8 inches long.

By reference to the geometry of the shaft, it is readily determined that the original bar stock must have weighed at least two thirds more than the finished shaft. The exact amount of additional weight depends on the small amount lost in cutting the work-piece from stock lengths and the amount lost in machining the rough finish of the bar stock. This latter loss depends on how close the bar stock diameter is to the maximum shaft diameter. The availability of a large assortment of stock diameters will decrease the loss on machining but will increase the cost of inventory. An economic balance must be struck between the increasing and decreasing costs.

291. Sources of decomposition data and data collection methods. The data were collected in three ways: (1) by telephone conferences with experts, (2) by recourse to catalogues and documents and (3) by inspection of end-products.

292. The first step was to contact the industry trade association in the electrical-goods branch to determine whether published data were available. NEMA, unfortunately, had only commercial, not technical, data and even these were unpublished. NEMA therefore referred the authors to individual manufacturing companies who, hopefully, would co-operate in the search for data.

293. The second step was to conduct a library search principally at The Engineering Societies Library in New York, N.Y., to determine if there were any published data unknown to NEMA. This study was conducted because it seemed incredible that there should be no published decomposition data on so important branch of the metalworking industry. The results of the library search were disappointing and confirmed the lack of such published data. There was some out-of-date information on fractional-horsepower motors and also some useful information on manufacturing processes. A listing of material required for an out-of-date fractional-horsepower motor is given in Table IV-10. This has been done in order to indicate precisely what data are required so that data unrevealed by this search might be brought to light.

294. The third step was to contact the individual manufacturing companies and solicit their co-operation. Catalogues were easily obtained by telephone request to the local sales representatives. These catalogues give total weights, prices, photographs and descriptions of manufacturing processes and materials used. However, they do not give part weights for decompositions. Sales representatives were willing to estimate part weight, but their estimates were limited to an insufficient number of parts and were very inaccurate. For example, one salesman estimated the weight of the shaft of a 100-hp motor as 1 per cent of total weight, while another estimated it as 15 per cent.

Table IV-10

Materials requirements for a 1/8 HP induction motor

Castings:

2 end covers (aluminium)
1 outer casing (aluminium)
2 bearings (gun metal)
2 lubricator rings (brass)
2 lubricator covers (aluminium)
2 rotor spiders (aluminium)
2 rotor short-circuiting rings (copper)

Stampings:

8 dozen stator stampings, as specified
8 dozen rotor stampings, as specified
Stalloy

Wire and insulating material:

1 1/4 lb No. 25 S.W.G. copper wire, enamelled and single cotton-covered
1/2 lb No. 32 S.W.G. copper wire, double cotton-covered
6 ft. No. 8 S.W.G. copper wire, bare
1 sheet 10 mils (0.010 in.) leatheroid, 10 in. x 9 in.
1 sheet vulcanized fibre, 32 mils (0.032 in.) thick, size 6 x 3 in.
6 yards cotton tape, 1/2 in. wide
2 yards 5-emp flex
2 in. ebonite rod, 1 in. diameter

Raw metallic material:

1 foot 9/16-in. round bright mild steel
1 foot 1/8-in. round bright mild steel
3 inches 1/16 in. brass pin wire
1/2 inch 3/16 in. round bright mild steel
2 mild steel nuts, tapped 1/2-in., 26 threads per inch
3 mild steel bolts, 1/4-in. diameter, 3 3/4 in. long under head
3 1/4-in. Whiteworth nuts for the above
2 7/16-in. steel washers
2 3/32 x 1 1/4 in. split-pins
Small quantity of tinman's solder, Chatterton's compound, oil-resisting varnish for windings, and paint for motor metalwork

Source: Molloy, Edward, ed., Practical Design of Small Motors and Transformers, Chemical Publishing Co. Inc., New York, 1940, page 106.

295. Letters were therefore sent to persons at the factories who, according to the salesman, could supply decomposition and other data. A data-collection work sheet in tabular form (see Appendix Table IV-2) was included to increase uniformity and compliance with the requests. These letters elicited generally negative replies to the effect that the data were either proprietary or that their collection would be very difficult and would be an imposition on busy production men. However, the data are in fact not proprietary that degree since anyone who wishes can purchase a motor, take it apart and weigh the part. When this was pointed out to one electrical manufacturer, it found it easier (and probably cheaper) to present to the project a small motor as a gift rather than to supply the part weights. Nevertheless, it is true that manufacturers have difficulty in collecting data, since only the person responsible for a long-series production run is interested in estimating part weights. The degree of estimating accuracy required depends on inventory levels of materials out of which the parts are made, and as long as inventory levels are adequate, there is no need to know the part weights.

296. Even though part-weights data are not readily available at the factory, a visit there is worth-while because production men, unlike salesmen, can make reliable estimates. However, factory visits were generally not made, since they are expensive and require travel. The telephone was used as a less expensive alternative even though a great many calls had to be made in order to get concrete information in place of estimates of but limited reliability. Many calls were needed because many manufacturers did not co-operate. However, a few individuals were willing to be helpful, and part weights by individual motor horsepower rating could thus be assembled.

Transformers

297. Product list. A product list (Table IV-11) for transformers has been constructed from United States Department of Commerce (USDC) statistics in exactly the same way that a product list was constructed for motors. (See section 1 (g) of this chapter.) It is a list of about 200 products of the branch that is grouped according to the USDC classification categories and which comprises at least 80 per cent of the United States transformer market. Identification of significant individual product items under the USDC category-headings was accomplished by reference to the product-catalogs of several United States electrical manufacturers. Each transformer is distinguished by a kilovolt-ampere designation which is a widely used reference unit in the industry,[104] and also by the primary and secondary voltages.

Table IV-11

Transformer Product List

Control, signalling, doorbell and toy transformers, control transformers single-phase enclosed

KVA rating	Voltage Primary	Secondary
0.25	120/240	12, 32, 120
0.50	120/240	32
0.75	120/240	32
1.00	240/480	120/240
1.50		
2.00	600	120/240
3.00		
0.50	240	120 automobile transformers
0.75	240	120 automobile transformers
1.00	240	120 automobile transformers
1.50	240	120 automobile transformers
2.00	240	120 automobile transformers
0.50	600	120/240 no taps
0.075	600	120/240 no taps
0.100	600	120/240 no taps
0.150	600	120/240 no taps

Single-phase, nonenclosed

KVA rating	Primary	Secondary
0.025	115	24
0.050	230	115
0.075	460	115,230
0.100	460	115,230
0.150	460	115,290
0.200	460	115,230

General-purpose transformers (dry type) less than 600 v., single phase

kVA rating	Voltage Primary	Secondary
3	240/480	120/240
5	240/480	120/240
7.5	240/480	120/240
10.0	240/480	120/240
15.0	240/480	120/240
25.0	240/480	120/240
37.5	240/480	120/240
50.0	240/480	120/240
75.0	240/480	120/240
100.0	240/480	120/240
167		

Table IV-11 (continued)

3-Phase, less than 600 v

	Voltage	
kvA rating	Primary	Secondary
3	480 Y[a]	208 Y/120
6	480 Y	208 Y/120
9	480 Y	208 Y/120
15	480 Y	208 Y/120
30	480 Y	208 Y/120
45	480 Y	208 Y/120
75	480 Y	208 Y/120
112.5	480 Y	208 Y/120
150	480 Y	208 Y/120
225	480 Y	208 Y/120
300	480 Y	208 Y/120
500	480 Y	208 Y/120

Lighting transformers street distribution

	Voltage	
Kilowatts	Primary	Secondary
10	2400	2160 6.6 A
15	2400	2160 20 A
20	7200	6480 6.6 A
25	7200	6480 6.6 A
30	7200	6480 6.6 A

Watts	Mercury-vapour pallasts	
400	Single-lamp	High reactance and regulated output
250	Single-lamp	High reactance
175	Single-lamp	High reactance
425	Single-lamp	Reactor-type
700	Single-lamp	Reactor-type
700	Single-lamp	High-reactance
1000	Single-lamp	Reactor-type
1000	Single-lamp	High-reactance
1000	Single-lamp	Regulated output
400	Two-lamp	
425	Two-lamp	

/ctd.....

Table IV-11 (continued)

Power and distribution transformers

Less than or equal to 15 kVA, and less than or equal to 15 kVA

KVA	Voltage		
	Primary	Secondary	
3	2400/4160	120/240	Single-phase, dry-type
5	2400/4160	120/240	Single-phase, dry-type
10	2400/4160	120/240	Single-phase, dry-type
15	2400/4160	120/240	Single-phase, dry-type
9	2400/4160	120/240	3-phase, dry-type
15	2400/4160	120/240	3-phase, dry-type
25	2400/4160	120/240	Single-phase, dry-type
37.5	2400/4160	120/240	Single-phase, dry-type
50	2400/4160	120/240	Single-phase, dry-type
30	2400/4160	120/240	3-phase, dry-type
45	2400/4160	120/240	3-phase, dry-type
75	2400/4160	120/240	Single-phase, dry-type
100	2400/4160	120/240	Single-phase, dry-type
167	2400/4160	120/240	Single-phase, dry-type
75	2400/4160	120/240	3-phase, dry-type
112.5	2400/4160	120/240	3-phase, dry-type
150	2400/4160	120/240	3-phase, dry-type

From 169 to 500 kVA inclusive, single-phase, dry type

KVA	Primary	Secondary
250	2400/4160 Y	120/240
250	2400/4160 Y	240/480
250	7200/12470 Y	120/240
250	7200/12470 Y	240/480
250	7200/12470 Y	2400/4800
333	4800/8320 Y	120/240
333	4800/8320 Y	240/480
333	7260/13200 Y	120/240
333	7260/13200 Y	240/480
333	7200/12470 Y	2400/4800
333	7200/12470 Y	2520/5040
333	13200	120/240
333	13200	240/480
333	13200	2400/4800
333	13200	2520/5240
333	22900	240/480
333	22900	2400/4800
333	22900	6900/7200
333	34400	240/480
333	34400	2400/4800
333	34400	6900/7200
333	43800	2400/4800
333	43800	6900/7200

/ctd.....

Table IV-11 (continued)

Power and distribution transformers (continued)

From 169 to 500 kVA inclusive, single-phase, dry type (continued)

kVA	Voltage		
	Primary	Secondary	
333	67000	2400, 4800, 2520, 5040	
333	67000	240/480	
333	67000	6900, 7200	
500	2400x4800	120/240	
500	2400x4800	240/480	
500	7260x13200 Y	120/240	
500	7260x13200 Y	240/480	
500	7200/12470 Y	2400/4800	
500	7200/12470 Y	2520, 5040	
500	13200	120/240	
500	13200	240/480	
500	13200	2400, 4800	
500	13200	2520, 5240	
500	22900	240x480	
500	22900	2400, 4800	
500	22900	6900, 7200	
500	34400	240x480	
500	34400	2400, 4800	
500	34400	6900, 7200	
500	43800	240x480	
500	43800	2400, 4800	
500	43800	7200	
500	67000	240x480	
500	67000	2400, 4800	**Single-phase**
500	67000	6900, 7200	**Single-phase**
225	2400Δ	240/480Δ	3-phase
225	4160Y2400	208Y/120Δ	3-phase
225	4160Y	240x480	3-phase
225	4160Δ	203Y1120	3-phase
225	7200Δ	240x480Δ	3-phase
225	12000Δ	240x480Δ	3-phase
225	12740 Y/7200 13200 Y/7620	208Y/120	3-phase
225	12470Y or 13200Y	240x480Δ	3-phase
225	13200, 13800	240x480	3-phase
300	2400Δ	240x480Δ	3-phase
300	4160Y2400	208Y/120Δ	3-phase
300	4160Y	240x480	3-phase
300	4160Δ	208Y1120	3-phase
300	4800Δ	240x480Δ	3-phase
300	8320Y/4800	208Y/120	3-phase
300	8320Y	240x480Δ	3-phase
300	7200Δ	240x480Δ	3-phase

/ctd.....

Table IV-11 (continued)

Power and distribution transformers (continued)

From 169 to 500 kVA inclusive, single-phase, dry type (continued)

kVA	Voltage		
	Primary	Secondary	
300	12000Δ	240x480Δ	3-phase
300	12000Δ	2400 ,4800Δ	3-phase
300	12740Y/7200 13200Y/7620	208Y/120	3-phase
300	13200 or 13800	2400Δ, 4800Δ	3-phase
300	13800 or	208Y/120 or 240x480	3-phase
500	208Y/120	2400Δ	3-phase
500	208Y/120Δ	4160Y2400	3/phase
500	240x480	4160Y	3-phase
500	208YL120	4160Y	3-phase
500	240x480Δ	4800Δ	3-phase
500	208Y/120	8320Y/4800	3-phase
500	240x480Δ	8320Y	3-phase
500	240x480Δ	7200Δ	3-phase
500	2400Δ, 4800Δ	12000Δ	3-phase
500	208Y/120	12000Δ	3-phase
500	240x480Δ	13200Y/7620	3-phase
500	2400Δ, 4800Δ	13200Y	3-phase
500	240x480	13200	3-phase

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a/ Y = admittance

298. Parts and processes. A transformer, from the mechanical point of view, is a relatively simple device consisting basically of a laminated magnetic core and a current-carrying coil. The coil usually surrounds the core (core-type) but also, the core may surround the coil (shell-type). The basic unit of core and coil is usually mounted on a supporting form and enclosed by a housing or container. For higher power-rated units, the container will be filled with oil to facilitate insulation and cooling of the transformer parts. Oil insulation is advantageous for use in high-power units for two reasons: (a) oil circulates in convection currents, facilitating heat transfer from the coils, and (b) its insulating effect is self-healing after coil insulation breakdown.

299. Only a few basic processes are used to produce transformers. These processes are relatively unchanged over most of the branch. In sequential order, they are as follows:

(a) Transformer coils are wound by a winding machine. Fractional kilovolt-ampere-rated transformer coils can be wound several at a time on multiple winding machines with capacities as high as a dozen coils, attended by a single operator, in a matter of 15 to 30 minutes. Coils for transformers rated larger than 2 kVA must be wound one at a time. The winding process which can be used is determined by the transformer rating, as follows:[105] Up to 0.3 kVA - multiple winding machine; 0.1 - 2 kVA - either single or multiple winding machine; over 2 kVA - single winding machine only.

As the coil is wound, insulation is inserted between successive layers of wire. A common type of insulation used for this purpose is a glass-composition sheet with an asbestos base. Asbestos or fibreglass spacers are also inserted between layers at intervals to dissipate heat.

(b) After winding, the coil is dried in an electric oven to ensure that no moisture will be trapped in the coil by the next process (dipping).

(c) The coil is then immersed in a vat of varnish until it has been thoroughly impregnated with it. The varnish coating has special heat-resistant and electrical characteristics.

(d) The varnish is allowed to drip dry, and the coil then is re-baked until the varnish is cured.

(e) The coil is given a preliminary (turns-ratio) test. This is necessary because the voltage transformation depends on the ratio of the number of turns of secondary to primary windings.

(f) The core is formed by stacking silicon-steel laminations which have been stamped out on a press.

(g) The components are assembled and finished.

(h) Final electrical tests are given before storage or shipping.

300. Product decomposition. Data on the weights and material composition of transformer component parts were obtained from manufacturers and consultants.

301. The weights of copper (windings) and steel (core) for a sample of various transformer sizes are given in Table IV-12. These figures confirm the rule of thumb given by a transformer-design consultant; namely, that weights ratios between the copper and steel used in a transformer are (approximately): 4:1 for kVA ratings under 3 kVA, 3:1 for kVA ratings 3-60 kVA, and 2:1 for kVA ratings over 60 kVA.

302. The decomposition data of Table IV-12 are plotted in Figure IV-5; these graphs tend to confirm the rules of thumb given above. It will be necessary to collect data on transformer sizes larger than 60 kVA in order to test the rule that a 2:1 steel-copper ratio continues to hold true in the higher ranges.

303. As noted earlier, there has been a marked trend in transformer design and manufacture towards substitution of materials and reduction in unit weight. Moreover, this trend is continuing, so that decomposition data will have to be revised every few years. Decisive improvements have arisen from the use of better insulating materials which have been developed through the commercial research activities of the large chemical companies or, more recently, as by-products of military and space research. Materials such as paper and bakelite, long used for coil-separation, have been displaced by composite materials such as asbestos-fibreglass, and these may be displaced in turn by newer chemical composites. Turn-to-turn insulation, traditionally of enamel, varnish or the like, is gradually being taken over by "solidable polyurethenes", which are plastic compounds saturated with solid particles that improve heat conduction and reduce temperature expansion coefficients. Some large-sized transformers, which were traditionally oil insulated, are now being redesigned with dry insulation by epoxy or polyurethene plastics. The significant aspect of such developments from the point of view of costing is that improvements in insulation allow large reductions in the weights of other materials used. Insulation itself comprises only a small portion of unit weight (less than 10 per cent) but an improvement in insulation can lead to significant reductions in the weight of copper used.

Table IV-12

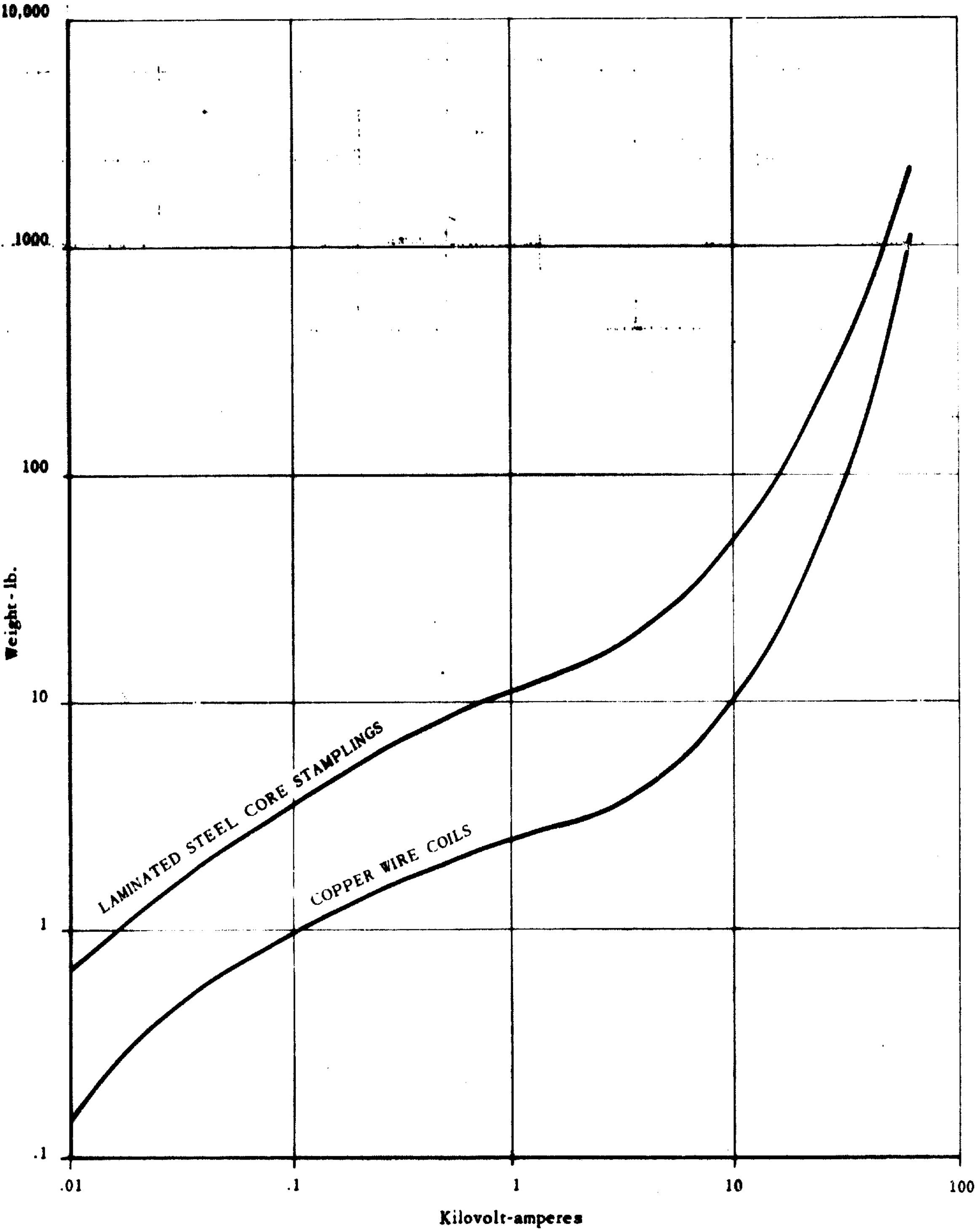
Part-Decomposition Data (in Pounds)

kVA rating / Component parts	0.002	0.01	0.1	0.5	1.0	1.2	48	60
Copper wire	0.049	0.14	1.0	1.9	2.5	3.0	226	1080
Core laminations	0.146	0.7	3.2	3.5	12.0	14.0	679	2173
Housing					1.0	0.5		
Insulation					0.5	0.5		

Source: Consultants and Ajax Transformer Co., Bronx, N.Y.

Figure IV-5

Weights of transformer parts as a function of transformer kVA for low-power, low-voltage, single-phase, dry-type transformers



Source: table IV-12

304. As in motor design, in transformers there has been some substitution of aluminium for copper, mostly in the range of heavy power transformers. The use of aluminium conductors allows a considerable cost saving for equivalent electrical performance. This substitution, however, requires a complete redesign of the unit, and the design change will not usually be profitable for a small firm producing in small series.

305. Other material substitutions have been made in lamination manufacture, such as the use of nickel or of alloys with high nickel content, but the high cost of these materials has thus far restricted them to military applications.

306. Resource element requirements. The question arises whether a separate "transformer resource element" should be defined.[106] The distinctive process in transformer manufacture is coil-winding. This process is peculiar to transformers in that it is not used to produce components for any other product. Thus the machine used to wind coils for electric motors cannot be used to wind transformer coils. Nevertheless, it may be desirable to construct a general coil-winding resource element since all coils undergo the same subsidiary treatment after winding; namely, dipping (or insulating) and baking; moreover a common set of parameters (weight and number of coils) can be used to characterize all coil-winding operations.

307. In order to define a coil-winding resource element, it is necessary to have: (a) labour requirements per unit output (kilovolt amperes); (b) a list of the tools and machines needed to produce the products and (c) a measure of machine capacity (that is, hours per kilovolt ampere).

308. Current data cover only the first two of these. Labour and equipment requirements for a small transformer plant have been found in a published source,[107] and are reproduced directly in Tables IV-13 and IV-14.

309. The labour requirements are given according to skill categories including those needed to produce only windings. A winding resource element would require winders, an oven operator, a vat operator and an inspector. The labour-hours for these skills, shown under "Direct Labour" in Table IV-13 can be adopted as labour requirements for a coil-winding resource element which produces coils for smaller-sized transformers and motors.

310. The machine requirements given in Table IV-14 are illustrated in the original source by a transformer shop layout (Figure IV-6 below) which is quite similar to the shop layout (Figure IV-7) of a small local manufacturer[108] of control and

Table IV-13

Labour Requirements for Transformer Manufacture

Skill	Approximate labour hours for production of the indicated number of units per day of the size transformers indicated	
	Fractional kVA (100)	1-10 kVA (25)
Direct labour		
Superintendent	8	8
Winders	8	40
Assemblers	24	24
Painter	8	8
Oven operator	8	8
Vat operator	8	8
Testers	16	8
Inspector	16	8
Material handlers	8	8
Indirect labour		
Shipping and receiving clerk	8	8
Packing clerk	16	8
Truck-driver	8	8
Janitor	8	8
Plant engineer	8	8
Design engineer	8	8
Office personnel		
Bookkeeper	8	8
Secretary	8	8
Typist	8	8
File clerk	8	8
Office boy	8	8

Source: International Co-operation Administration, Technical Inquiry Service, Electric Motors and Transformers, February 1960, pp.41-42.

Table IV-14

Requirements of Tools and Equipment for Transformer Manufacture[a]

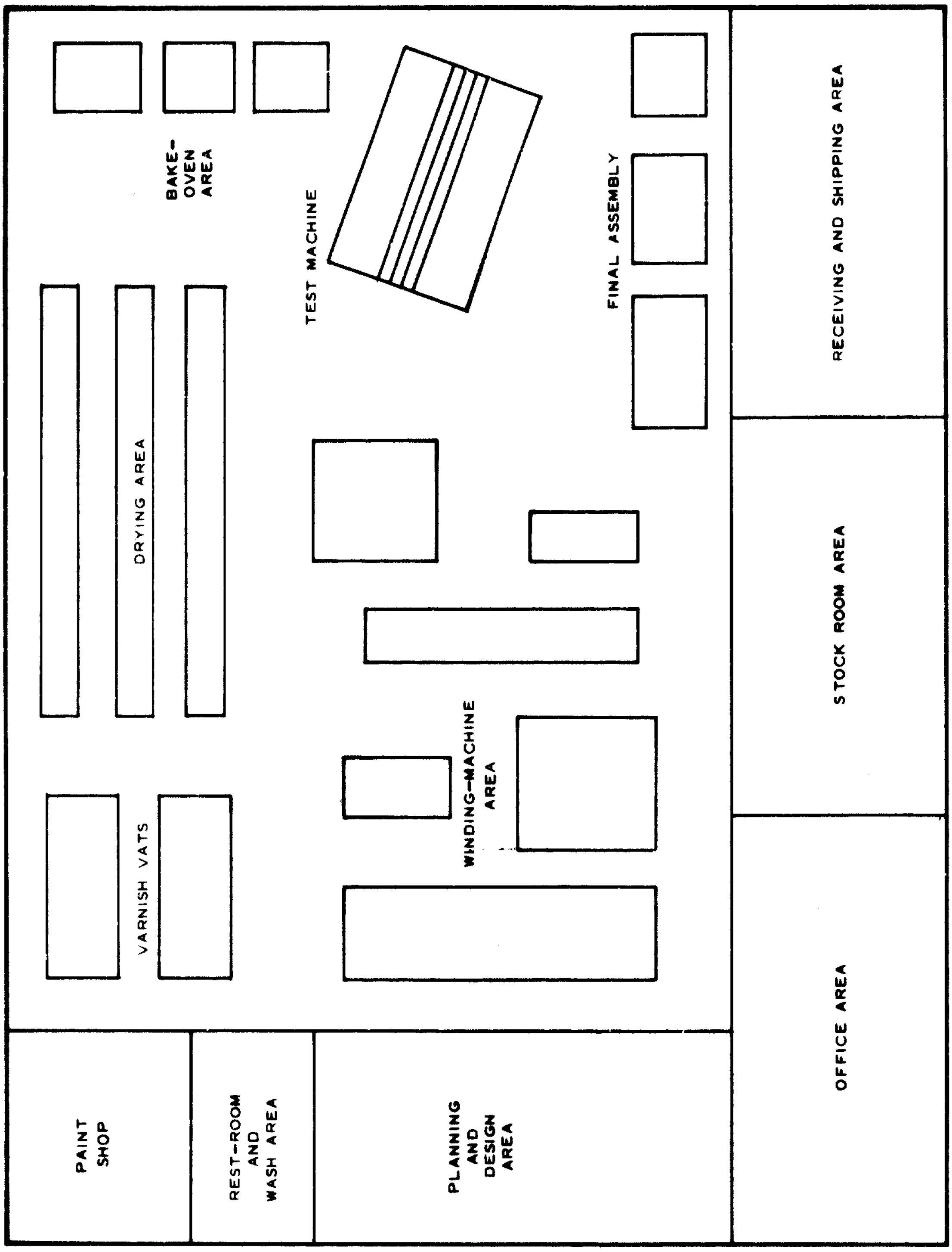
Item	Number required
Multiple-winding machine (10-12 windings) fractional	1
Winding machines (for 1-10 kVA)	5
Bake ovens	2 (custom)
Varnish vat	3 (custom)
Overhead conveyance system	1 (custom)
Conveyor section	1 (custom) 300-500 ft.
Spray booth	1
Spray gun	1
Hand-tools	as required
Electric arc welding machine	1
Vacuum pump	1
Hand-truck	4
Oil-pump	1
Motor-truck	1
Scales	1
Testing equipment	
Turns-ratio test equipment	1
High-potential test equipment	1
High-frequency test equipment	1
Polarity test equipment	1

Source: International Co-operation Administration, Technical Inquiry Service, Electric Motors and Transformers, February 1960, pp. 44-45.

[a] Product assortment is identical with the one given in Table IV-13.

Figure IV-6

Sample (A) shop layout for transformer manufacture

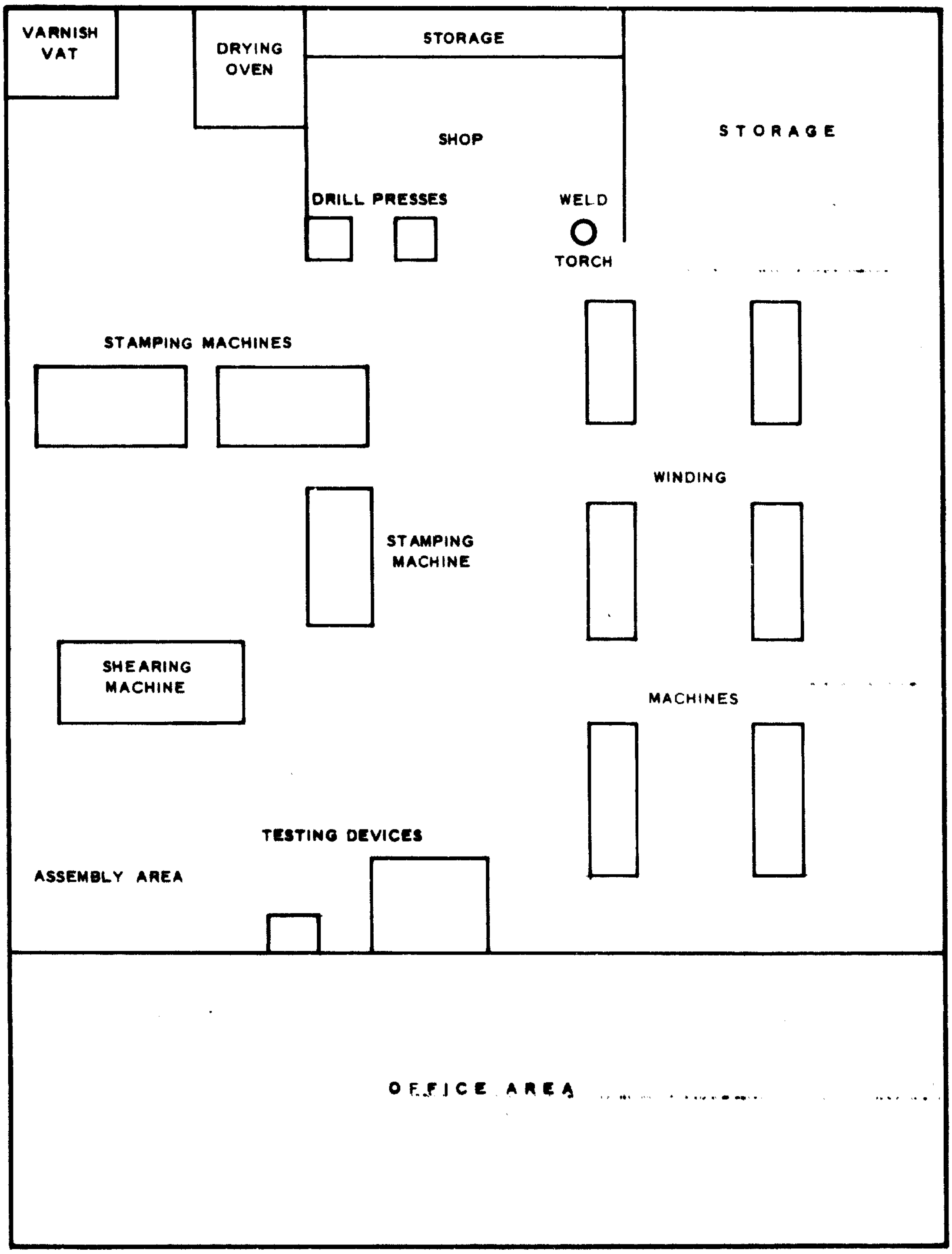


Source: International Cooperation Administration, Technical Inquiry Service, Electric Motors and Transformers, February 1960, page 52.

Note: The plant covers 10,000 square feet.

Figure IV-7

Sample (B) shop layout for transformer manufacture



Source: Factory visit, Ajax Transformer Co., Bronx, New York.

Notes: (a) This plant manufactures transfers from 1 - 2,000, mostly custom, low-seriality production.

(b) Personnel - (24) Production workers (2) Management/Design (1) Section.

general-purpose transformers that was visited. The only significant difference is that the ICA plant does not have a stamping facility to produce laminations and therefore purchases these parts. The local manufacturer , a producer of transformers rated at 1 kVA or higher, reported that he purchased laminations for transformers rated less than 10 kVA but produced his own for larger sizes. This practice is consistent with the ICA set-up. For purposes of resource element definition, however, it is not possible to include the stamping process in a coil-winding resource element.

311. Transformer design. Some estimates of design cost have been obtained. Costs of design and quality control usually constitute about 5 per cent of the cost of a mass-produced transformer. It is feasible to carry out the redesign of an item if the estimated design cost is no more than 10 per cent of the estimated production cost of the item. This figure, supplied by a consultant, agrees with that of a small manufacturer who estimated the design of a custom transformer to be 8 to 10 per cent of its total cost. Generally, design- and quality-control costs of custom-made items of seriality less than 50 units can become as high as 15 per cent of total cost.

312. The data search. The data for the transformer branch came from three sources: (a) manufacturers; (b) a consultant and (c) a plant visit. About a dozen manufacturers, most of them within a radius of 150 miles of New York City, were canvassed, primarily via telephone. As in the case of motors, only a small proportion of the telephone inquiries were in any way fruitful. The New York Public Library, the Engineering Societies Library and the libraries of the Massachusetts Institute of Technology were checked for published data; but in most cases the only material that could be found was either manufacturers' sales material (brochures, catalogues) or highly technical engineering design information

Electrical distribution and control apparatus

313. Product list. As a starting point, the 1963 United States Census of Manufactures data on the "Switchgear and Switchboards" and "Industrial Controls" industries was considered the universe of the products composing the branch. For each listing a dollar value is given, and from this it is possible to determine the percentage of value of a specific item based on the total value of the industr
At the outset it was decided to aim for approximately 200 listed items for representing the branch. In 1963, the Switchgear and Switchboards and Industrial Controls industries had a reported value of shipments of $1.5 thousand million. Dividing this figure by 200, a cut-off figure was determined below which a categor

of products would not be considered. This figure is $7.5 million and represents 0.5 per cent of the total industry value. In all, 10 categories were thus eliminated from the 1963 Census of Manufactures listing leaving 42 categories to disaggregate into a list of 200 specific products. The approximate number of specific products to be allocated to each census category was ascertained by calculating what percentage of the whole a category represented and then multiplying 200 by this percentage. For example, duct busways had a reported value of shipments of $31 million, which is 2.1 per cent of the total industry value and should thus be limited to 2.1 per cent of the 200 products, or approximately four specific items. In this way a provisional listing was initiated.

14. A thorough examination of industrial catalogues quickly revealed that a useful selection of typical products from a category can only be accomplished by persons who have a working knowledge of the industry. An attempt was made to approach large companies for assistance in verifying the coverage of the preliminary list and choosing typical products. The results are encouraging but have so far provided no more than a beginning.

15. At one of the large companies, for example, contact was made with a specialist in switchgear. Although he tried to be helpful the amount of specific information he supplied was meagre. In the first place, he found the concept of selecting typical products from a product group difficult to handle, since his basic function is to recommend specific equipment for a specific task. He feels that the switchgear industry is too specialized for an easy choice of typical products. In the second place, the area of his experience proved limited, and he referred to other sources for most of the categories discussed. Primarily, this meant a supply subsidiary. At this subsidiary, another contact was able to supply more information, but there were times when this secondary source did not have the necessary information available. This may have been due to his lack of familiarity with the product group or to the fact that the product group cannot easily be represented by a few typical products. Material such as panelboards, distribution switchboards and power switching equipment are reported to be items that are made to order and thus would not be easy to represent by typical products.

16. In order to overcome this difficulty, other sources of data were investigated by interviewing trade association representatives. An interview with the executive secretary of the Spring Manufacture Institute (SMI) disclosed that this organization is at this writing trying to gather data regarding the metal content of each type of spring, by metal type and weight, and the seriality (length of production run)

of each spring. This interview disclosed a resistance on the part of manufacturer to supply such information and revealed that the trade association was attempting to counter this resistance by means of a third-party arrangement. As explained during the interview, one party would have a list of companies, each with a number and another party would have information sent to it by each company on the basis of its number. If information from a given company were found missing, the first party would be asked to request that company to send in the desired information. By this procedure, the SMI would obtain the desired information and the anonymity of the companies would be protected. The results of the attempt of SMI to establi this system were not known when this report was written.

317. Another interview was conducted with an official of the Copper Development Association, which is primarily interested in publicizing and promulgating the us of copper. The figures he had on the use of copper, aluminium and steel were aggregate figures which were taken from the 1963 United States Census of Manufactur However, the person interviewed expressed confidence that consultants could be found for assembling data on product decomposition.

318. Conclusions concerning sources of data and data collection methods. The results are encouraging but not satisfactory, primarily because there are big gaps and question-marks in the preliminary long list (Appendix Table IV-1) which has been composed to date. This branch, owing to the great variety of products, will be difficult to describe adequately by the approach so far used. Undoubtedly, if enough people are approached the results will improve, but this raises the question of the required time and effort. Thus far the persons in the industry who provided information have granted interview time as a favour during company business hours, and the time they could devote to the task was, of course, limited. One person could only be of assistance in the morning before office hours.

319. The efficacy of this research procedure, which depends on interviews by economic researchers, is seriously open to question. This material is presented here primarily to indicate the need for reliance, from the outset, on consultants who are fully qualified technically. One informant believed that, with a few phone calls to strategic individuals whom he knew personally, results could be forthcoming very rapidly. Another theoretical possibility is enlistment of the aid of a large corporation which could formulate a provisional product list much more quickly and accurately than a researcher alien to the field and could have any product rapidly decomposed if so desired. The utilization of a third-party approach through trade association channels, similar to the current SMI project,

might also be considered. These possibilities, however, depend on a degree of voluntary co-operation that is seldom forthcoming. If it is essential to have assurance that the necessary tasks are smoothly accomplished, the only reliable strategy is to abandon the usual channels of academic research and to invest in the project the resources needed for the systematic retention of highly qualified industrial consultants. It is at the same time indispensable to deal with persons who have sufficient flexibility to be able to operate within the unaccustomed conceptual framework imposed by the needs of the sectoral planning task.

APPENDIX TO CHAPTER IV

1. Provisional classification of the activities of the metalworking sector for purposes of technical-economic description

The provisional classification presented here is intended for the purposes of technical-economic description of the sector by means of typical products and listed products as discussed in the body of this chapter. The same classification is also intended as a framework for the technical-economic description at a semi-quantitative level, to be discussed in Chapter V.

The classification has been prepared by the Export Industries Section of the United Nations Industrial Development Organization in co-operation with the present study. The purpose of adding yet another classification to the several major and innumerable minor ones already in existence is to facilitate a reasonably uniform coverage of those activities of the sector that are of major interest to developing countries, by means of typical and listed products. Existing classifications are patterned either on the classifications serving purposes of industrial statistics in the highly industrialized countries (such as the United Nations International Standard Industrial Classification) or are aimed at the description of trade (such as the Standard International Trade Classification).

The present provisional classification provides 13 major groups and 93 branches. The sources of the classification were the major United Nations classifications mentioned above, national statistical classifications and classifications used for planning the sector by means of material balances in centrally planned economies. A noteworthy feature of the classification is the provision of major groups, among others, for farm machinery, construction and mining machinery, chemical processing machinery and equipment, food processing machinery and equipment, textile and shoe machinery, and household and service machines, each of which represents a logical focus of attention from the point of view of developing countries.

It is anticipated that this provisional classification will be revised as the technical-economic description of the sector progresses.

Appendix Table IV-1

Provisional classification of the activities of the metalworking sector into 13 major groups, comprising 93 branches

Major Group A - Manufacture of Metal Products (16 branches)

1. Tin-cans and other tinware manufacture
   - a) metal cans
   - b) milk shipping containers
   - c) other tinware
2. Hand-tool manufacture
   - a) wrenches
   - b) hammers
   - c) screwdrivers
   - d) pliers
   - e) shovels
3. Edged tools manufacture
   - a) scythes
   - b) adzes
   - c) paper-cutting die
   - d) planes
   - e) can-openers
4. Handsaw and saw-blades manufacture
   - a) heavy hand-saws
   - b) hacksaws
   - c) carpenter's crosscuts
   - d) woodworking power-saw blades
   - e) metalworking power-saw blades
5. Cutlery manufacture
   - a) knives
   - b) knife-blades
   - c) razors and razor-blades
   - d) scissors and scissors-blades
6. Furniture and builders' hardware manufacture
   - a) furniture hardware
   - b) door locks
   - c) radiators
   - d) stoves
   - e) window hardware

7. Transportation equipment hardware manufacture

a) marine shackles
b) aircraft hardware
c) motor-vehicle lock units
d) railroad-car hardware

8. Structural and sheet-metal work

a) metal doors and frames
b) stairs and staircases
c) store fronts
d) cornices
e) ventilators

9. Boiler shop manufacture

a) boilers
b) tanks
    i) light tanks
    ii) heavy tanks
c) gas cylinders

10. Metal-stamping manufacture

a) spoons
b) stamped and spun hospital utensils
c) aviation equipment stampings
d) agricultural equipment stampings
e) radio and television stampings

11. Bolts, nuts, rivets and screw machine manufacture

a) bolts
b) nuts
c) rivets
d) screws

12. Lighting fixtures manufacture

a) incandescent lighting fixtures
b) incandescent portable lamps
c) motor-vehicle headlights
d) flashlights
e) airway lighting fixtures
f) kerosene and gasoline lamps

13. Nail and spike manufacture

a) steel wire nails
b) steel wire spikes
c) steel cut nails
d) steel cut spikes

14. Wire manufacture

a) noninsulated wire cables
b) upholstery wire springs
c) precision mechanical springs
d) composite cables

15. Steel springs manufacture

a) helical automobile springs
b) helical locomotive and railroad-car springs
c) leaf automotive springs
d) leaf tractor springs
e) leaf locomotive and railroad-car springs

16. Safe and vault manufacture

a) fire-resistant safes
b) burglary resistant safes
c) safe-deposit boxes
d) bank security lockers

Major Group B - Machine Tool Industry (12 branches)

1. Boring and drilling machines industry

a) horizontal boring machines
b) vertical boring machines
c) precision boring machines
d) vertical drilling machines
e) radial drilling machines
f) multiple-spindle drilling machines

2. Gear-cutting and finishing machines industry

a) gear-hobbing machines
b) gear-cutters
c) gear-lapping machines
d) gear-tooth grinding machines
e) gear-boring machines

3. Grinding and polishing machines industry

a) external cylindrical grinding machines
b) internal cylindrical grinding machines
c) surface grinding machines
d) boring machines
e) lapping machines

4. **Lathes industry (except woodworking lathes)**

a) bench lathes
b) engine lathes (swing dimensions)
c) automatic between-centre lathes
d) automatic screw machines
e) turret lathes

5. Special machine-tools industry

a) bench and hand-milling machines
b) bed-type milling machines
c) centering machines
d) shapers
e) sawing machines

6. Metalworking presses and forging presses industry

a) mechanical inclinable presses
b) mechanical end-wheel presses
c) mechanical vertical arch-frame presses
  i) 500 tons and under
  ii) 501 tons and over
d) high-speed automatic presses
e) hydraulic and pneumatic presses
  i) 500 tons and under
  ii) 501 tons and over
f) manual presses

7. Forging machines industry

a) steam and air hammers
b) mechanical hammers
c) headers and upsetters
d) swaging machines
e) bulldozers

8. Shearing, bending and forming machines industry

a) manually driven shearing machines
b) power-driver shearing machines
c) manually driven bending and forming machines
d) power-driven shearing and forming machines
e) welding and cutting acetylene apparatus

9. Power-driven hand-tools industry

a) electric drills
b) electric hammers
c) electric saws
d) pneumatic drills
e) pneumatic hammers
f) pneumatic saws

10. **Cutting rools, dies and jigs industry**

a) broaches
b) drills
c) reamers
d) gear-cutters
e) special dies and jigs

11. Precision measuring tools **industry**

a) micrometers
b) gauges
c) calipers
d) dial indicators
e) comparators

12. Woodworking machinery **industry**

a) sawmill equipment
b) lathes
c) planing machines
d) surfacing machines
e) sawing machines

Major Group C - Power Engine and General Industrial Machinery (5 branches)

1. Steam-engines and turbine industry

a) steam-engines
b) steam-turbines
  i)
  ii) characteristics
  iii)
c) hydraulic turbines
d) steam-turbine generator **sets**
  i)
  ii) characteristics
  iii)
e) hydraulic turbine generator **sets**
f) gas turbine generator sets

2. Internal-combustion engines **industry**

a) gasoline engines
  i)
  ii) characteristics
  iii)
b) diesel, engines
c) gas engines

3. **Nuclear reactors industry**

   a) power reactors
      i) thermal reactors
      ii) intermediate reactors
      iii) fast reactors
   b) research reactors
   c) cooling system
   d) control system

4. Pumps and compressors industry

   a) pumps
   b) air compressors
      i)
      ii) characteristics
   c) gas compressors
      i)
      ii) characteristics
   d) blowers and fans

5. Bearings industry

   a) ball-bearings
   b) roller-bearings
   c) mounted bearings
      i) ball
      ii) roller

Major Group D - Transportation Equipment Industry (10 branches)

1. Passenger automobile industry

   a) passenger automobiles
      i)
      ii) characteristics
      iii)
   b) engines
   c) carburettors
   d) pistons

2. Trucks and buses industry

   a) trucks
      i)
      ii) characteristics
      iii)
   b) truck trailers
   c) automobile trailers
   d) buses

3. **Aircraft industry**

- a) aircraft
  - i) commercial type
  - ii) sport type
  - iii) military type
- b) aircraft engines
- c) aircraft propellers

4. **Shipbuilding and shiprepairing**

- a) non-propelled ships
- b) self-propelled ships
  - i) other than military
  - ii) military
- c) ship repair

5. **Boat building and repairing**

- a) boats
  - i) non-military
  - ii) military
- b) boat repair
  - i) non-military
  - ii) military

6. **Locomotive industry**

- a) steam locomotives
- b) diesel-electric locomotives
  - i) characteristics
  - ii)
- c) industrial locomotives
  - i) diesel-electric type
  - ii) electric type
- d) mining locomotives
- e) locomotive tenders

7. **Railroad equipment industry**

- a) passenger-train cars
  - i) coach
  - ii) sleeping
  - iii) dining
- b) freight-train cars
  - i) box
  - ii) flat
  - iii) tank
  - iv) refrigerator

8. **City transport industry**

- a) street-railway cars
- b) trolleybuses
- c) subway cars

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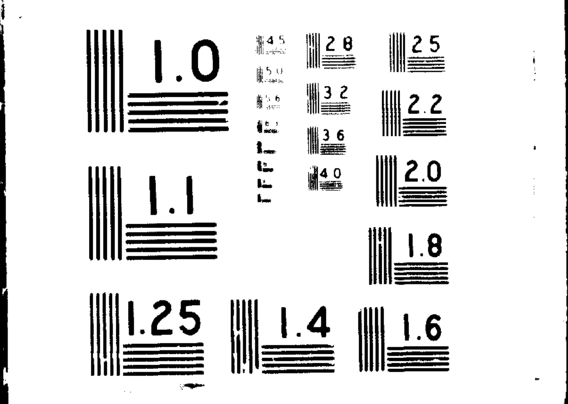

9. **Motorcycles and bicycles industry**

- a) motorcycles
- b) motorscooters
- c) motorbikes
- d) bicycles

10. Elevators and conveyors industry

- a) elevators
- b) escalators
- c) conveyors

Major Group E - Farm Machinery and Equipment Industry (3 branches)

1. Tractors

- a) wheeled tractors
  - i)
  - ii) characteristics
- b) garden tractors
- c) track-laying tractors

2. Soil-preparing and cultivating farm machinery

- a) ploughs
- b) harrows
- c) rollers
- d) corn-planters
- e) broadcast seeders
- f) sprayers and dusters

3. Harvesting and dairy machinery

- a) combines
  - i) pull type
  - ii) self-propelled
- b) corn-pickers
- c) dairy machines
  - i) cream separators
  - ii) other dairy machines

Major Group F - Heavy Machinebuilding Industry (4 branches)

1. Metallurgical machinery

- a) converters
- b) ladles
- c) ingot moulds
- d) casting machines

2. **Foundry machinery**

- a) core-making machines
- b) moulding machines
- c) blast-cleaning machines
- d) foundry machines

3. Industrial furnaces and ovens industry

- a) electric industrial furnaces
  - i) metal melting
  - ii) metal processing
- b) fuel-fired industrial furnaces
  - i) metal melting
  - ii) metal processing
- c) industrial ovens
  - i) electric
  - ii) infra-red

4. Rolling mill machinery

- a) rolling mills
  - i)
  - ii) characteristics
  - iii)
- b) rolling-mill equipment

Major Group G - Construction and Mining Machinery (4 branches)

1. Construction machinery industry

- a) contractors wheeled tractors
- b) cranes
- c) scrapers
- d) graders
- e) road-rollers

2. Mineral crushing and sorting machinery industry

- a) crushers
- b) grinding machines
- c) mixers
- d) dimension stone cutting machines

3. Mining machinery industry

- a) coal-cutting machines
- b) continuous mining machines
- c) creeper underground roaders

4. Oilfield machinery industry

- a) drilling surface machines
- b) drilling subsurface equipment

Major Group H - Electrical Machinery and Equipment Industry (12 branches)

1. Motors and generators industry

   a) fractional-horsepower motors
      i) under 0.05hp
      ii) 0.05 - 1 hp
   b) integral horsepower motors and generators
      i) single-phase
      ii) polyphase induction
         1 - 50 hp
         50 - 500 hp
      iii) synchronous
         1 - 50 hp
         50 - 500 hp
         over 500 hp
   c) gasoline-engine-driven generator sets
   d) diesel-engine-driven generator sets
   e) wind-driven generator sets

2. Transformers industry

   a) power and distribution transformers
      i)
      ii) characteristics
   b) specialty transformers (under 600 V)
   c) power regulators
   d) boosters
   e) reactors

3. Electrical distribution and control apparatus industry

   a) distribution switchboards
   b) switches
   c) circuit-breakers
      i)
      ii) characteristics
   d) power switchboards
   e) relays
   f) fuses and fuse equipment

4. Welding machinery industry

   a) arc-welding machines
      i)
      ii) characteristics
   b) arc-welding electrodes, metal
   c) resistence welders
   d) special welding apparatus

5. **Electrical measuring instruments industry**

a) integrating instruments
  i) watt-hour meters
  ii) demand meters
b) test equipment
  i) oscilloscopes
  ii) volt-ohm-miliammeters
  iii) microwave test equipment
  iv) radio-frequency measuring equipment

6. Electrical appliances industry

a) fans
b) water-heaters
c) cooling appliances
d) heating appliances
e) electric irons
f) household ranges

7. Engine electrical equipment industry

a) ignition-harness sets
b) battery-charging generators for internal-combustion engines
c) cranking motors for internal-combustion engines
  i) passenger cars and light trucks
  ii) heavy trucks and tractors
  iii) aircraft engines
d) condensers

8. Electric lamps industry

a) large irridescent lamps
b) miniature irridescent lamps
c) electrical discharge lamps

9. Radio and television sets industry

a) home radio receivers
b) portable radio receivers
c) photographs
d) Television receivers
e) radio and television transmitters

10. Electronic tubes industry

a) cathode ray tubes, television picture tubes
b) transistors
c) diodes
d) other electronic tubes

11. **Telephone and telegraph equipment industry**

a) telephone sets
b) telephone switchboards
c) telegraph apparatus and equipment
d) radar equipment

12. X-ray and therapeutic apparatus industry

a) medical X-ray units
b) dental X-ray units
c) industrial X-ray units
d) ultraviolet health-lamp fixtures
e) cardiographs

Major Group I - Chemical Processing Machinery and Equipment Industry (10 branches)

1. Petroleum refinery machinery and equipment industry

a) petroleum pumps
b) petroleum refinery
c) benzene-producing apparatus
d) benzol-producing apparatus
e) gas-producing apparatus

2. Pulp and paper-mill machinery industry

a) pulp-mill digesters
b) pulp-mill grinders
c) pulp-mill deckers
d) paper-mill machinery

3. Paper machines industry

a) foundriniers
b) cylinders
c) calenders
d) bag-making machines
e) box-making machines

4. Printing trade machinery industry

a) letterpress
b) offset lithographic
c) typesetting machines
d) electrotyping machines
e) bookbinding machines

5. Plastics-working machinery industry

a) compression-moulding machines
b) extrusion-moulding machines
c) injection-moulding machines

6. Rubber-working machinery industry

a) mill-mixing machines
b) calendering machines
c) extruding machines
d) vulcanizing presses
e) tire-building machines.

7. Cement-making machinery industry

a) natural cement machines
b) hydraulic cement machines
c) high-temperature cement machines
d) fibro-cement machines

8. Glass-making machinery industry

a) bottle machines
b) laboratory glass-ware machines
c) window-glass machines
d) industrial glass machines
e) electric bulb blank machines

9. Chemical-processing machinery industry

a) distillery apparatus
b) purifiers
c) condensers
d) centrifuges

10. Clay-working machinery industry

a) clay-tempering furnace
b) clay-brick machines
c) clay-tile machines
d) clay-pipe machines
e) stove-lining machines

Major Group J - Food products Machinery and Equipment Industry (4 branches)

1. Dairy and milk-products plant machinery industry

a) bottling machinery
b) pasteurizers
c) cheese-making machines
d) cheese presses
e) cream separators

2. Bakery machinery industry

a) flour-mill machinery
b) grain-mill machinery
c) dough-mixers
d) bake-ovens

3. **Food processing machinery industry**

   a) sugar-plant machinery
   b) fruit and vegetable canning machines
   c) bottling machinery
      i) filling-capping machines
      ii) bottle washers

4. Cigarettes and cigars machinery industry

   a) cigarette-making machines
   b) cigar-making machines

Major Group K - Textile and shoe-making machinery industry (3 branches)

1. Textile fibre-to-fabric machinery industry

   a) garnetting machines
   b) picker machines
   c) carding machines
   d) combing machines
   e) spinning and twisting machines
   f) winding machines

2. Textile-fabric machinery industry

   a) power looms
   b) knitting machines
   c) weaving machines
   d) braiding machines

3. Shoemaking and repairing machinery industry

   a) hide-, skin- and leather-preparing machines
   b) shoe-making machines
   c) shoe-repairing machines

Major Group L - Office and Store Machines Industry (4 branches)

1. Computing machines industry

   a) adding machines
      i) electric
      ii) non-electric
   b) calculating machines
   c) punch-card-system machines
   d) cash registers

2. Typewriter industry

   a) electric typewriters
   b) non-electric typewriters
   c) special and automatic typewriters

3. **Electronic data-processing machines and computers industry**

a) analogue machines
b) analogue machines with added memory
c) digital computers
d) electronic data-processors

4. Scales and balances industry

a) railroad-truck and motor-truck scales
b) retail and commercial scales
c) household scales
d) personal weighing scales
e) laboratory precision scales

Major Group M - Household and Service Machines Industry (6 branches)

1. Household washing-machines industry

a) fully automatic washing machines
b) semi-automatic washing machines
c) non-automatic washing machines
d) driers
e) ironers

2. Laundry and dry-cleaning machines industry

a) washers
b) extractors
c) drying tumblers
d) laundry presses
e) dry-cleaning presses

3. Sewing machines industry

a) household sewing-machines
b) industrial sewing-machines
    i)
    ii) specifications
    iii)

4. Vacuum cleaners and other household equipment industry

a) household vacuum cleaners
b) industrial vacuum cleaners
c) other household cleaning equipment
    i)
    ii) characteristics

5. Refrigeration machinery industry

a) household refrigerators
    i) gas
    ii) electric

- b) home and farm freezers
  - i)
  - ii) dimensions
- c) industrial and commercial refrigerators
  - i)
  - ii) dimensions

6. Clocks and watches industry

- a) electric clocks
- b) spring-wound clocks
- c) men's wrist watches
- d) women's wrist watches
- e) pocket watches

2. Worksheets for the decomposition of electric motors

The actual worksheet for a 200 hp, open drip-proof polyphase induction motor run at 1800 rev/min (frame 445) is reproduced on the following page as furnished by General Dynamics Corporation, Avenel, New Jersey, December 1966. Data were furnished from the same source for the following sizes of motors:

horsepower	frame size
400	507
800	685
1500	688
3000	808

Part weights are tabulated in Table IV-6. The processes used to produce these parts are shown in Table IV-5.

Appendix Table IV-2

Worksheet for a 200-hp, open, drip-proof polyphase induction motor

	Motor part	Material	Part weight	Processing of part					
1	Housing, frame or enclosure	Cast iron	260 lb ±	Bore	Mill	Drill			
2	Stator core	Electrical sheet stock	350 lb ±	Blank	Notch	Assemble in frame			
3	Stator windings	Copper wire	106 lb ±	Wind loops	Form	Insert into core		[illegible]	
4	Rotor core	Electrical sheet stock	211 lb ±	Blank	Notch	Assemble core			
5	Rotor conductors	Aluminium	20 lb ±	Fabricated assembly: brazed die-cast					
6	Shaft	Steel	100 lb ±	Cut-off	Turn	Grind			
7	End shields	Cast-iron	50 lb ± each	Bore	Drill				
8	Ball-bearings	Steel	16 lb ±	Purchased					
9	Conduit box	Cast-iron	31 lb ±	Drill					
10	Screws & bolts	Steel	10 lb ±	Purchased					
11	Other								

Notes to Chapter IV

1 Referred to in previous chapters as the UNC study. See Chapter I, note (3).

2 Except for some engineering-type information borrowed very occasionally from sources in the United States of America when a critical data gap was impossible to fill otherwise. See Soviet Planning Study No. 7, op. cit., p. III-5C.

3 The description given hereafter has been based, in addition to the original study, on the following papers:
(a) O. Gallik, Explorations in the Development of Pre-Investment Data for the Mathematical Transformation Sector, United Nations Centre for Industrial Development consulting report; abridged version reproduced for the Expert Working Group on Industrial Development Programming Data, meeting of 17-19 May 1961, Document IDP/EWG.6, 12 May 1961, (dittoed). (Page references are given to original report.)
(b) United Nations Economic Commission for Latin America, op. cit., Chap. II, note (34).
(c) T. Vietorisz, Metalworking Process Analysis and Industrial Development Planning, International Business Machines Corp. Research Report No. RC-715, Yorktown Heights, New York, 29 July 1962.
(d) T. Vietorisz, "Alternative approaches to metalworking process analysis", in A.S. Manne and H.M. Markowitz, eds., Studies in Process Analysis: Economy-Wide Production Capabilities, Cowles Foundation Monograph No. 18, New York, Wiley, 1963, Chap. 15.
These sources are quoted passim as required.

4 See Chenery (1955), Chenery and Kretschmer (1956), op. cit., both in Chapter II, note 35.

5 See Chapter III (B) Indivisibilities and economies of scale.

6 The standard task as here defined does not coincide with the definition of a standard task as used by Markowitz and Rowe in their study of machine tool substitution possibilities. (See chap. 12 in Manne and Markowitz, eds., op.cit.). Markowitz and Rowe worked at a far more detailed level of aggregation; for example, they distinguished their standard machining tasks by geometrical contour shapes.

7 Op. cit.,see Chapter I, note (3), also the United Nations supplement to the cited study, op. cit., Chapter II, note (26).

8 See proposed classification in part I of the Appendix to this chapter.

9 For a detailed exposition of the technique in a national planning context, see D. Szabadits, Parametric Price Construction (in Hungarian), Economic and Legal Publishing House, Budapest, 1965.

10 UNC, Soviet Planning Study No. 7, op. cit., p. II-1.

11 See note 3 (a) Gallik, P.I.

12 UNC, Soviet Planning Study No. 7, op. cit., p. II-2. Tool-making is shown in this table but is actually not included in the report.

13 Production processes are described individually and their exact terminology is defined in UNC, Soviet Planning Study No. 7, op. cit., Chapter II. Forging is defined in the UNC study as the application of pressure to heated metal to form roughly finished parts. Free forging and die forging are distinguished by the fact that the latter uses specially shaped moulds called dies in applying the pressure, while the former is essentially a mechanized and greatly enlarged version of the hammering of hot metal in a smithy, except for the fact that not only hammers but also presses are used in applying the pressure. Casting (in a foundry) is the pouring of metal into molten specially prepared moulds called "patterns" that are made of sand or of metal. Stamping, as defined in the UNC study, covers a variety of cold-working metal processes including all punch-press, squeezing and cutting processes. Upsetting is a variation of the forging process in which metal parts are formed into desired shapes in dies affixed to special upsetting presses and then finished on various types of equipment which are primarily automatic or semi-automatic in nature, fasteners (bolts, nuts, cotter pins, washers, rivets, screws, etc.) being the main parts produced by this process.

14 United Nations Economic Commission for Latin America, op. cit., Chapter II, note (26). This reference also contains valuable previously unpublished appendices by the original authors of the UNC study to the definition of all major resource element groups, and an analysis of the product classes falling within the shipbuilding industry.

15 UNC, Soviet Planning Study No. 7, op. cit., pp. II-1 to II-33. Most of points (a)-(f) are taken from this source.

16 Op. cit., p. II-6, for example, for forging, presses over 1000 tons were assumed to work three shifts. Normally 2330 hours per year per shift was considered the available time-fund for forging.

17 Op. cit., p. II-59.

18 Gallik, op. cit., p.2.

19 UNC, Soviet Planning Study No. 7, op. cit., p. I-5.

20 Op. cit., Tables II-29 to II-42, pp. II-66 through II-94.

21 Op. cit., p. I-6 to I-7.

22 Op. cit., p. II-3.

23 Op. cit., p. I-7.

24 Gallik, op. cit., p. 2 (passim).

25 Op. cit., p. 8.

26 Op. cit.; see note (4), Chapter I.

27 Consulting report entitled "Critique of resource elements", by Professor Van Court Hare of Columbia University, dated November 30, 1966. This was the first contribution of Professor Hare to the project. He suggested certain simplifications of the overall technical-economic description problem that eventually lead to the development of the semiquantitative programming data approach of Chapter V.

28 At this point the consulting report goes on to make suggestions about possible simplification procedures cited in note (27).

29 UNC, Soviet Planning Study No. 7, op. cit., p. II-98.

30 Since this error is inherent in any modular description of productive facilities within the sector, it can be handled properly only within a sequential decision-making process. See Chapter III, sections A-5, B-3 and B-4.

31 See Chapter IV, sections B-3, C-1.

32 Gallik, op. cit., p. 13.

33 Gallik, op. cit., p. 9 (passim).

34 Op. cit., Tables 1 and 2, pp. 6-7.

35 Op. cit., p. 19.

36 Op. cit., p. 8.

37 Arthur D. Little, op. cit., Chapter II, note (27).

38 Gallik (op. cit.) pp. 12-13 and Tables 3-4.

39 These results were consonant with the findings of Seymour Melman in "Aspects of the design of machinery production during economic development", United Nations, Industrialization and Productivity Bulletin No. 8 (1964), p. 67, on relative prices of labour and electricity versus relative labour productivities in a number of countries.

40 Gallik, op. cit., p. 11.

41 Kurz and Manne, op. cit., Chapter II, note (48).

42 Op. cit.; see Chapter I, note (4).

43 Q = output (pieces per daily 8-hour shift).
K = capital investment (thousands of 1962 US dollars).
L = labour input (number of men per 8-hour shift).

The unit elasticity of substitution typical of the Cobb-Douglas function was confirmed by an independent estimate of the elasticity of substitution treating the latter as a variable parameter. The estimate of this parameter was .989 with an excellent correlation coefficient, and the estimates of the other parameters were also very close to the ones obtained on the basis of the simple Cobb-Douglas function, indicating that the original specification of such a function was essentially a good one. See Chapter II, note (48).Kurz and Manne, p. 676).

44 On the basis of one shift, the range for all machining operations is from $ 200 per worker to $ 450,000 per worker. With multiple shifts there is a corresponding reduction in these figures. This overall range is of course much too wide for individual machining tasks. The three widest ranges observed (one shift basis) were: (1) *Task No. 91*: Screw thread, very small, semi-precision); $ 200 (sensitive and upright drills, single spindle), to $ 22,000 (automatic screw machine, single spindle, ½ - 3 in. bar capacity). *Task No. 78*: Drilled hole, very small, semi-precision, long run; $ 200 (sensitive and upright drills, single spindle), to $ 8,500 (automatic drills, 1-10 stations, up to 7 in. stroke); (3) *Task No. 2*: flat surface, no contour, small, semi-precision, long run; $ 700 (grinders: disc, snag, bench, under 10 in. diameter work), to $ 26,000 (automatic chucking machine, under 16 in. swing, single spindle).

45 Boon (1965), *op. cit.*, Chapter II, note (49).

46 *Op. cit.*, p. 30.

47 *Op. cit.*, p. 15.

48 *Op. cit.*, Table 4, pp. 12-13, Patterns II and III.

49 See United Nations Economic Commission for Latin America, *Some methodological problems...* (1962), *op. cit.*,(note (34), Chap. II) for a comparison of actual capacity in the machine tool industry in Brazil with two estimates based on the data of the Markowitz-Rowe study (*op. cit.*) and the UNC Study (*op. cit.*). See Chapter I, notes (2) and (3).

50 See the above argument by Melman, *op.cit.*, (note 39) especially pp. 63-64.

51 See the listing of organizational functions among the processes not yet covered in the UNC study, Sec. IV-C-1 and Sec. IV-C-5. See also the summary discussion of the role of organizational standard tasks (i.e., standard tasks defined for representing organizational functions) in section B-3.

52 See section C-4, subsections (c)-(i).

53 See Chapter III, section C-1.

54 The experience gained with semiquantitative programming data (see Chapter V) indicates that the suggested list of standard tasks may be subject to revision as further semiquantitative materials accumulate covering substantial portions of the sector.

55 One of the senior participants of the original UNC study, in a report written for the United Nations concerning the applicability of the UNC material to development programming (Gallik, *op. cit.*, pp. 13-15) has recommended raising the number of resource elements to improve the estimation of investment requirements. In particular he suggested: *a.* taking fuller account of the seriality variable; *b.* reducing the range of applicability to end-products; *c.* ascribing more homogeneous technological processes to each. The third suggestion, requiring only minor modifications, does not raise the number of resource elements significantly. In regard to seriality a different suggestion is made for the present project, namely the device of handling exact serialities by secondary corrections; still, a small increase in the major seriality categories would do no harm.

The suggestion concerning product-assortment narrowing is rejected, since in developing countries it is often necessary to integrate the fabrication of intermediates for a great many diverse end-products, cutting across the horizontal integrations usual for the industrialized countries. Instead, specialization to product assortment is to be treated as one of the local adaptations; in reporting locally-adapted resource elements, however, the additional freedom is provided that more than one typical product assortment may be given, i.e., two variants of the same resource element based on different product assortments may be reported, instead of just one standard variant.

56 Gallik, op. cit., p. 15.

57 The potential of numerical control in the metalworking industries of developing countries has been explored in T. Vietorisz, "The potential of the computer and high-speed information-processing techniques for industrial development", United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, Geneva, 1963, Conference paper D/185. Also in "Science, technology and development", United States paper prepared for the same conference. United States Government Printing Office, Washington, 1963, Vol. 4, pp. 103-117.

58 Gallik, op. cit., pp. 13,15.

59 See section C, part 3-c.

60 Classes 35-39, International Standard Industrial Classification.

See Chapter I, section A.

61 T. Fabian, "Process Analysis of the U.S. Iron and Steel Industry", in Manne and Markowitz, Studies in Process Analysis (1963), op. cit., Chap.9.

62 See section B. For a concise discussion of the need to distinguish between lot-size and resource-element-scale economies, see Gallik, op. cit., pp. 5-7 and Tables 1-2.

63 For all resource elements except machining and assembly, the flow inputs into the end-product are obtained by multiplying the coefficient of the resource-element input into the end-product (from Table II-2) by the coefficient of the flow input into the resource elements (tables given in UNC Study, Chap. II). Capacity utilization percentages are derived by dividing the coefficient of resource element input into the end-product by the normal monthly capacity of the resource element. For machining, the UNC tabulation of flow data is inconsistent, since flow inputs are not on the basis of the same unit (effective machine hours) in which input requirements are expressed, but on the basis of full-capacity utilization; therefore, the foregoing flow-input computation procedure must be modified by dividing through by yearly effective machine hours of the resource element. Percentage of capacity is computed normally. For assembly, flow inputs are not directly proportional to level of utilization expressed in square-meter years, and a special computation is required for deriving these (see UNC study, op. cit., pp. II-147-159). Percentage of capacity is again computed normally.

64 UNC Study, *op. cit.*, pp. III-18 to III-23.

65 *Op. cit.*, p. III-5.

66 *Op. cit.*, p. III-5B.

67 *Op. cit.*, pp. III-53 to III-5D.

68 In previous UNC publications: Soviet Planning Studies No. 5, 5A, 6, 6A, *op. cit.*; see Chapter I, note (3).

69 UNC Soviet Planning Study No. 7, *op. cit.*, p. III-5E.

70 *Op. cit.*, p. III-5F; see also tables II-68, II-69, II-70, pp. II-157-159.

71 *Op. cit.*, pp. 5F-5G and Table III-2, p. 5-G.

72 Gallik, *op. cit.*, 13, 15.

73 United Nations Economic Commission for Latin America, *op. cit.*, note (14); Chapter II, note (26), pp. 183-187.

74 This suggestion is due to V.N. Vasilev of United Nations Centre for Industrial Development who has also been the source of a number of other valuable suggestions aimed at rationalizing the research procedure, to be attributed below.

75 V.N. Vasilev, verbal communication.

76 Verbal communication by a former small subcontracter who, in the meantime, has been successful in another branch of the sector.

77 Incidentally, these firms would also be prime sources of information concerning the structure of demand within some branches of the sector, in considerably more detail than available in conventional statistics. The probability of obtaining this information is, however, not rated as high.

78 It would seem to be more esthetically satisfying not to prejudge this issue by the very definition of a list but to allow the model itself to decide which items should be treated individually and which should be merged into the description of a composite product. Throughout the programming approach there is a recurring need for such simplifying prejudgements without which the complexities of programming the sector would be utterly dumbfounding.

79 United Nations Economic Commission for Latin America, *op. cit.*, note (14), p. 184.

80 *Op. cit.*, p. 183, 184.

81 *Op. cit.*, p. II-9, pp. 147-150; Markowitz and Rowe (1963), *op. cit.*, Chapter I, note (4) pp. 338-344.

82 Percentage of time losses due to various of these reasons (except the first) are cited in United Nations Economic Commission for Latin America (1961), *op. cit.*, p. 149. They are typically of the order of 0.5-2 per cent for each category and add up to some 12 per cent in the illustration cited. This excludes planned underloading which was almost 20 per cent in the same case. For worker fatigue, see Markowitz and Rowe (1963), *op. cit.*, p. 34.

83 Total and average effective hours are calculated for a series as follows:

$$TT = a + b.S$$
$$AT = (a + b.S)/t.S$$

where a = set-up time, effective hours
b = marginal time, i.e., handling plus production time, effective hours
S = length of series (lot size)
t = weight of a unit of end-product, tons
Y = number of effective hours per year available from the given resource element
TT = total time for series, effective hours
AT = average time for series, effective hours per ton.

Denoting concepts referring to the standard series by barred symbols,

$$\overline{AT} = (a + b.\bar{S})/t.\bar{S}$$

Correspondingly, capacity utilizations are:

$$C = AT/Y \quad ; \quad \bar{C} = \overline{AT}/Y.$$

From the last two equations, $C = \bar{C}.AT/\overline{AT}$,

where $AT/\overline{AT}$ is the required correction factor which is applied to the capacity utilization per ton characteristic of the standard series.

84 UNC study, *op. cit.*, p. II-98.

85 A classification of all the branches of the metalworking sector is given in the Appendix to Chapter IV, part 1. The electrical machinery and equipment industry is listed as Major Group H. The work covers the first three branches of this major group on a pilot basis. The coverage is not exhaustive.

86 References on motor construction include the following:

- a Andersen, Edwin P., Andel's Electric Motor Guide, Theodore Andel & Co., New York, 1965;
- b Libby, Charles C., Motor Selection and Application, McGraw-Hill, New York, 1960;
- c Liwschitz-Garick and Whipple, Electric Machinery, Vol. II, A.C. Machines, Van Nostrand, New York, 1946;
- d Pender and Del Mar, Electrical Engineer's Handbook, Electric Power, John Wiley & Sons, New York, 1949;
- e Puchstein and Lloyd, Alternating Current Machines, John Wiley & Sons, New York, 1942.

87 Figure IV-1 shows a three-phase induction motor; its power source must be three-phase alternating current.

88 This part of the technical-economic description is closely related to the semiquantitative programming data discussed at length in Chapter V.

89 See sub-section (h) for a description of the data-collection procedure.

90 Some flow input requirements may be of the overhead type, such as heat and light.

91 A technique for estimating the adjustment factor of the motor shaft is illustrated in sub-section (g), part (iii) of this chapter.

92 Op. cit., (see note (3), Chap. I), Soviet Planning Study No. 5, pp. 409.

93 Op. cit.

94 United States Government, International Cooperation Administration, Technical Inquiry Service, Fractional and Small Horsepower Electric Motors and Direct Starters for Squirrel Cage Motors, Washington, D.C., June 1958, pp. 22-23.

95 Re-rating means assigning a higher standard horsepower rating to a motor of given physical (frame size) dimensions.

96 The definition of a 40°C, polyphase induction motor has the following components: An induction motor is one in which the stator winding is connected to an alternating current power source and the motor winding carries induced current. A polyphase motor has more than one stator winding - usually three. A 40°C motor is one which develops full rated power when the insulated conductor temperature is permitted to rise 40°C above an initial 40°C ambient of the operating environment.

97 Libby, op. cit., p. 131, Table 4-76.

98 Libby, op. cit., p. 130, Table 4-7A.

99 Machine Design, Electric Motor Reference Issue, Penton, Cleveland, December 16, 1965, p. 6, Table 1.

100 See Figure IV-1 for an illustration of the various diameters on a shaft.

101 Libby, op. cit., p. 55.

102 This approximation results in minimum volume per horsepower, which is the criterion for minimum cost.

103 Libby, op. cit., p. 131. Table 4-76 shows that for frame 254 the diameter "U" is 1-1/8 inches. By adding twice "(F+BA)" to "(N-W)" the overall shaft length is calculated as 20-1/8 inches.

104 The kilovolt-ampere (kVA) is a measure of the power output of a transformer. Lighting transformers are also rated by kilowatts (kW). A kilovolt-ampere is exactly equal to a kilowatt if the phase angle between the current and the potential equals zero. Motors and transformers change the phase angle of a current; lighting fixtures do not.

105 These data were originally reported by kilowatts.

106 No "transformer resource element" is listed in any of the University of North Carolina studies.

107 United States Government, International Cooperation Administration, Technical Inquiry Service, Electric Motors and Transformers, February 1960.

108 Ajax Transformer Co., Stillwell Avenue, Bronx, New York.

V. SEMIQUANTITATIVE PROGRAMMING DATA: CONCEPTS AND PILOT EMPIRICAL WORK

320. The semiquantitative level of technical-economic description adopted in this study has grown out of a critique of the resource-element approach. While this critique initially appeared to imply that this entire approach should be abandoned, parallel work on both the concepts and the empirical data-gathering tasks of both the semiquantitative and the fully quantified levels indicated that, far from being mutually exclusive, the two levels are complementary and mutually supporting, both in regard to the data-gathering effort and in regard to the logic of programming. This represents the latest thinking in respect to these problems at the time the present report is being written and is accordingly embodied in the presentation of the key features of the project in Chapter III.

321. The semiquantitative level is a level of general orientation and of the initial formation of concepts and classifications for the subsequent more detailed work. The logic of this level is that of the initial organization of an information system and is introduced as such below.

A. General considerations

322. The most significant texts in the field of mathematical programming and resource allocation are those that expound theory. Their pages of proof and explanation relate the manipulations required to reach an optimum allocation of limited resources by adjusting the mix of activities or alternate uses to which the resources can be put, so that a specified formula, called the objective function, is made as large (or as small) as possible.

323. Invariably, a certain sameness pervades these works. All of them assume the resources available, the activities to be mixed and the objective function that will rate the success of any trial allocation are given at the outset. Even texts represented as being practical and filled with examples, necessarily begin with a given but limited set of facts.

324. In short, we are deluded. All of the literature on programming, begins in the middle of the problem. The definition of resources to be considered, the activities to be juggled, the scale of success that will rate our results and compare our trials at pie-cutting are pre-ordained. We are committed to a set of definitions and a problem structure that inexorably lead to a given result; we cannot know, because the authors do not tell us, how the fundamental first commitment was made. There are no handbooks on how to begin programming.

325. Nevertheless, the essence of the programming problem lies not in crank-turning, although the importance of that ability is enormous, but in the formulation and definition of problems. It is the purpose of this section to examine the fundamental problem of starting a programming analysis, with special reference to the metalworking industries in developing nations.

The basic classification and combinatorial problems

326. To see the distinction between the pre-set problems and the textbook case, let us consider first three sets of symbols, or three fundamental classification groups, as defined by the programming procedure: (a) a set of possible resources, which may or may not now be available to us, but which represent potentially useful tools, materials, and skills; (b) a similar set of possible activities, which in reality represent technologically useful clusters of resource application (in specific ratios), most frequently described by an end-product, or intermediate-product name; and (c) a final listing of possible formulae for evaluating success.

327. Each of these three lists must be available to provide, in combination, the starting point for the process of programming. If one or more is missing or incomplete, we have an undefined or incompletely defined problem. In general, an alternation or reorganization of one or more of these lists will alter the results of the programming effort. Moreover, the way in which these three major lists above can be detailed presents the investigator with an initial complexity of classification and combination for which he is not prepared. Indeed, the variety of consideration at the outset - the range of possibilities available for classification and simplification - is infinitely greater than the variety of computation required in the procedural phase of analysis for even the most extensive programming tableau.

328. A simple example should convince the reader of this all-important confrontation. Let us consider an electric sign composed of a square of 400 light bulbs arranged in a 20 x 20 grid. Let each of these bulbs be controlled by an individual electric switch, so that any bulb, or group of bulbs, may be turned on or off by the selection of a switch position. Since there are 400 bulbs, each of which may be either on or off, the number of different patterns that may be displayed on this board is 2^{400} or approximately 10^{120}. No draughtsman could ever draw all of these possibilities, no investigator could ever try or see all of them, and even the fastest computer available, showing the patterns automatically, could never complete the entire combinational possibilities. For 10^{120} combinations, or patterns, is a number greater than astronomical: the best estimate of the number of atoms in the known universe is 10^{76}.

329. Nevertheless, this crude electric sign is a simple affair when compared to the patterns or combinations of, say 1,000 resource elements which might be considered in combination as shops, productive units or work centres. The same argument holds for activities, or productive levels for given end- and by-products. The potential for grouping components, sub-assemblies, and even final products represents a similar combinatorial impasse. For example, how many different households could be constructed from the products listed in the widely available catalogue of the great American mail-order house of Sears, Roebuck & Co.? [1]

330. This short discourse on the potential variety of combination should convince the reader that certain drastic measures must be invoked to simplify the programming problem to human, or even computer capability. The simplification process - which uses the steps of elimination, grouping, threshold discrimination, partitioning and the like - appears both during the actual programming computation, after the problem has been defined as best the investigator can, and in the initial phases of problem formulation. As we have seen, by far the greatest amount of simplification is required at the outset.

Initial simplification procedures

331. The most obvious form of simplification of the list we have discussed is elimination, that is, restriction of the lists for resource elements, activities, and possible objectives to a sub-class of what might be considered.

332. In the case of an economy, we may simplify the resource-element list, or at least its range, by considering only one industry, metalworking for example, leaving the other industries for later. This implies a similar constraint on the activities listing and possibly on the list of objectives as well. This is the first simplification procedure employed in the present study.[2]

333. A more difficult decision arises when the detail within the metalworking resource (and activity) list must be specified. From the myriad combinations, we seek a list of resource elements which has several requirements: [3]

(a) Exhaustiveness. The list should provide a complete scan of the metalworking resources presently or potentially employed in metalwork production.

(b) Exclusiveness. The elements of the list should, to the degree possible, not overlap, so that in the computation phase of analysis modest adjustments in resource element capacity can be evaluated.

(c) Clarity. The list must be readily understood by both those who supply data and those who must interpret the results of the analysis. No great study of catalogues, dossiers or footnotes should be required to interpret resource-element designations. Furthermore, the elemental names chosen should be sufficiently general that they are universally understood in different languages.

(d) Combinatorial ability. The detailed resource categories should be stated so they are amenable to later grouping or partitioning as the need arises. Since at the outset the investigator cannot know his final needs, he must provide some flexibility for later modification.

(e) Usefulness for planning. The detailed resource categories should also be stated to agree, at least by transformation, with known statistics, economic classifications and trade data to provide both realism and practicality to the end result.

(f) Stability. To provide a meaningful and generally useful result, the categories chosen in the detailed listing must be sufficiently stable in description and content from time to time and place to place that the results of analysis may be transferred from the time and place of analysis to applications after the analysis is completed.

334. A brief consideration of these specifications for a resource-element list suggests that reliance on specific machine names or shop configurations in one country or at one time may be neither transferrable, clearly understood, nor stable as technology and practice change. Shops, moreover, would not be mutually exclusive in their capabilities or make-up. They would vary from place to place and would not be known to an information source without extensive cross-reference.

335. Although a discussion of this type could be continued, little more argument would be needed to suggest a hierarchy of resource-element description that has the required characteristics.[4]

B. Description of the sector by semiquantitative programming data

A hierarchy of resource-element descriptions

336. The most unchanging and most general classifications for a list of productive facilities will be found in the functions performed by given tools, processes, and methods, for example, metal-removal versus metal-forming. In outline form, if "metalworking processes" is the genus, metal-removal, metal-forming, metal-fastening, etc., all become inferior species or sub-classifications which can be made both exhaustive, and reasonably exclusive. Moreover, such categories are highly stable, internationally understood, and incorporated in most production tests.[5]

337. Continuing in the same way, specific metal-removal processes become species of the class "metal-removal", with turning, drilling, boring, reaming, broaching, grinding, etc. becoming sub-sub-classifications. Furthermore, under "turning" the detail may continue to hand lathes, semi-automatic lathes, fully-automatic lathes, etc., and within each of these sub-sub-sub-categories to specific equipment model numbers, as may be required for local custom or specific implementation.

338. Summarizing, the hierarchy of classification would appear as:

I. metalworking processes
  A. metal-removal
    (1) turning
      (a) hand lathes
        (i) Warney & Swasey Model XXXX

339. With this arrangement, any level of generality desired can be obtained, so the list of productive facilities may be constricted or expanded as desired. Moreover, data organized on this basis can be coded for later ease of extraction, combination, sorting, and programming by hand or by computer. As an additional advantage, an investigator can collect information about the relation between fundamental process types and specific end-products from informants who have different degrees of specific knowledge and later organize the results of the data collection on a consistent basis.

40. A two-level hierarchy of listings of productive facilities is shown in Table V-1 the large fold-out sheet) as rows to the left.

41. This two-level hierarchical classification is closely related to the concepts of standard task and resource-element that were developed in Chapter IV, but it coincides with neither of these. The lower of the two levels corresponds most closely to standard tasks, since at this stage of data-organization the functions (processes) specified in the lower level are not tied to the specific machine park that defines a resource-element. As compared with standard tasks, the rows of Table V-1 show two main differences:

(a) The weight class of output handled is not specified but is left implicit. Since information concerning the net weights of the individual products has been collected, it should be readily possible, at a later stage, to break down each standard task into weight classes corresponding to approximate component weights. The present undifferentiated form is convenient, since it leaves open the issue of

TABLE V-a

Resources required for the manufacture of some typical metal products

	Product No.: **Commodity:**	(5) **Small motor (internal combustion) 3 hp long run**	(24) **Outboard motor 3 hp**	(31) **16 in. Chain-saw**	(38) **Portable sewing-machine**	(8) **Piston compressor 2 cylinders, 100 lb/in^2 Medium-short-run**
No.	**Resource**					
1000	Metal-forming					
1120	Forge, die (2)	1	1	1		1
1200	Casting, iron (6)					
1205	sand					1
1250	Casting, non-ferrous (3)					
1265	die	2A	2A	2A	2	1A
1270	Casting, precision (1)				2	
1700	Press, draw (tubs etc.)	1	1			
1720	Press, bend (brakes)	1	1			
2000	Metal-removal					
2100	Turn (lathe)	1	1		1	1
2200	Bore (drill)	2	2	2	1	1
2210	Ream	1	1	1		1
2300	Grind	1	1	1		
2400	Mill		1B			1
2410	Shape (plane)	1	1	1		1
2600	Tap (inside thread by die)	1	1	1	1	
3000	Metal-cutting					
3100	Press, shear	1	1		1	
3200	Press, punch	1	1		1	
4000	Heat-treatment operations					
4100	Furnace	1	1	1		
4300	Quench	1	1	1		
5000	Fastening operations					
5110	Nuts/bolts	1	1		1	1
6000	Finishing operations					
6200	Dip (to clean, prime)					1
6300	Spray, paint (short run)					1
6310	Spray, paint (auto-line)	1	1	1	1	
6400	Electroplate	1B				
7000	Final assembly and packing					
7120	Hand (long-run paced)			1	1A	
7400	Standard performance test	1	1	1		1
7520	Semi-automatic packing				1	
8000	Materials handling					
8210	Conveyors (automatic)	1	1	1	1	1
8500	Transfer machine	2	2	1		
9000	Purchased items					
9100	Electrical motors				1	1
9190	Electrical supplies - other	10	1	1	1	1A
9500	Service functions					
9560	Sub-assembly co-ordination (critical)	1	1		1	
9570	Tool- and die-making	1	1			1

Notes:

Product (5): A - Copper aluminium alloy; B - Chrome plate piston
Product (24): A - Die-cast aluminium total unit; B - Hob gears for transmission
Product (31): A - Magnesium frame
Product (38): A - Buy plastic parts
Product (8) : A - Use 3 hp gas motor or 2 hp electric motor - no tank assembly

TABLE V-1b

	Product No.:	(12)	(13)	(14)	(4)	(3)
	Commodity:	Electric clothes dryer	Electric clothes washer	30 in. gas kitchen range	Water-pump (centrifugal) short-run	Sinks and tubs for washing machines
No.	Resource					
1000	**Metal forming**					
1120	Forge, die (2)		1B			
1200	Casting, iron (6)					
1205	sand				1	
1210	mold			1		
1250	Casting, non-ferrous (3)					
1255	sand				1	
1265	die	1				
1700	Press, draw (tubs etc.)	1	1	1		2A
1720	Press, bend (brakes)	1	1	1		
2000	Metal-removal					
2100	Turn (lathe)			1	2	
2600	Tap (inside thread by die)			1		
2610	Thread (outside thread by die)			1		
3000	Metal-cutting					
3100	Press, shear	1	1	1		
3200	Press, punch	1	1	1		
4000	Heat-treatment operations					
4100	Furnace					2B
5000	Fastening operations					
5100	Self-tapping screws	1	1	1		
5110	Nuts/bolts				1	
5210	Weld, spot (long-run)	1	1	1		
5400	Designed (catch, interlock, plug)	1	1			
6000	Finishing operations					
6200	Dip (to clean, prime)	1	1	1		1
6300	Spray, paint (short-run)	1	1		1	
6310	Spray, paint (auto-line)	2	2			
6320	Spray, vitreous enamel (short-run)	2	2	2		
6330	Spray, vitreous enamel (auto-line)					2
7000	Final assembly and packing					
7100	Hand (short-run, no pace, light)				1	
7120	Hand (long-run, paced)	1	1	1		
7400	Standard performance test	1	1			
7500	Hand pack (short-run, no pace, light)				1	
7520	Semi-automatic packing	1	1	1		
8000	Materials handling					
8200	Conveyors (manual)				1	
8210	Conveyors (automatic)	1	1	1		1
9000	Purchased items					
9100	Electrical motors	1A	1	1A	1	
9110	Electrical controls (simple)	1				
9120	Electrical controls (complex)		1A			
9190	Electrical supplies (other)			1B		
9500	Service functions					
9560	Sub-assembly co-ordination (critical)	1	1			
9570	Tool- and die-making	1	1	1		2

Notes:

Product (12): A - Buy fan-blades
Product (13): A - Sequence timer and electric valves; B - Transmission parts; Buy belts
Product (14): A - Buy clock; B - Light plug
Product (3) : A - Very deep draw; B - Anneal (usually in steps)

TABLE V-1c

No.	Resource	Product No.: (1) Commodity: Refrigerator 12 ft^3 long-run	(18) Refrigerator 2 ft^3	(2) Metal cabinets (excluding sinks)	(41) 30-drawer steel cabinet	(40) De-luxe 11,000 Btu air-conditioner
1000	**Metal-forming**					
1500	Roll (tube, shapes)					2
1700	Press, draw (tubs etc.)	2				
1720	Press, bend (brakes)	1	1	1	1	1
2000	**Metal-removal**					
3000	**Metal-cutting**					
3100	Press, shear	1	1	1	1	1
3200	Press, punch	1	1	1	1	1
4000	**Heat-treatment operations**					
5000	**Fastening operations**					
5100	Self-tapping screws	1	1	1		
5210	Weld, spot (long-run)	1	1	2	1	
5320	Braze (silver solder)	1				
5400	Designed (catch, interlock, plug)	1	1	1		
5500	Glue	1	1			
6000	**Finishing operations**					
6200	Dip (to clean, prime)	1	1	1	1	
6310	Spray, paint (auto-line)	2	1	2	2	
6330	Spray, vitreous enamel (auto-line)	1				1
7000	**Final assembly and packing**					
7120	Hand (long-run, paced)	1	1	1	1	
7400	Standard performance test	1	1			
7430	Critical adjustment needed	2A		2A		2A
7440	Critical assembly equipment needed	1B	1A			
7520	Semi-automatic packing			1	1	
8000	**Materials handling**					
8210	Conveyors (automatic)	1	1	1	1	
9000	**Purchased items**					
9100	Electrical motors	1C				1B
9110	Electrical controls (simple)	1				1
9190	Electrical supplies (other)	1	1B			1
9500	**Service functions**					
9550	Production sequence (critical)	1				
9560	Sub-assembly co-ordination (critical)	1				1
9570	Tool- and die-making	1		1		
9580	Jigs and fixtures			1B		

Notes:

Product (1): A - Door; B - Vacuum; C - Motor compressor
Product (18): A - Vacuum; B - Motor compressor (this small unit may be made internally)
Product (2): A - Door; B - Assembly jigs
Product (40): A - Critical fin assembly. Hot and cold coils sub-assembly;
B - Buy motor compressor unit

TABLE V-1d

No.	Resource	(9) Pressure tank for air, water	(17) 10 in.x 10 in. light fixture	(15) 20 in. portable fan	(16) 1650 W portable electric heater	(11) Complete hot-air heating system
	Product No.: **Commodity:**					
1000	Metal-forming					
1250	Casting, non-ferrous (3)					
1265	die					1
1500	Roll (tubs, shapes)	1		1		2
1700	Press, draw (tubs etc.)	1				
1720	Press, bend (brakes)	1	1	1	1	
2000	Metal-removal					
3000	Metal-cutting					
3100	Press, shear	1	1	1	1	1
3200	Press, punch	1	1	1	1	1
4000	Heat-treatment operations					
5000	Fastening operations					
5100	Self-tapping screws		1	1		1
5210	Weld, spot (long-run)		1	1	1	1
5220	Weld, continuous	1				
5400	Designed (catch, interlook, plug)					1
6000	Finishing operations					
6200	Dip (to clean, prime)	1	1	1	1	
6300	Spray, paint (short-run)	1		1	1	1
6310	Spray, paint (auto-line)		1			
7000	Final assembly and packing					
7100	Hand (short-run, no pace, light)					1
7120	Hand (long-run, paced)			1	1	
7400	Standard performance test			1	1	
7420	Critical test needed	1A				
7520	Semi-automatic packing			1	1	
8000	Materials handling					
8210	Conveyors (automatic)		1	1	1	
8300	Trucks (lift, pallets, bins etc.)	1				1
9000	Purchased items					
9100	Electrical motors			1	1	1
9110	Electrical controls (simple)			1A	1A	1
9190	Electrical supplies (other)		1	1	1B	1A
9500	Service functions					

Notes:

Product (9): A - Leak
Product (17): A - Lamp socket and glass
Product (15): A - Thermostat
Product (16): A - Thermostat and switch; B - heating element
Product (11): A - Gas valves and controls; probably buy rotary fan unit

TABLE V-1e

	Product No.:	(23)	(25)	(20)	(21)	(35)
	Commodity:	Aluminium boat 13.5 ft	Aluminium camp unit	Aluminium skillet	Aluminium ladder 16 ft	De-luxe ironing board
No.	**Resource**					
1000	Metal-forming					
1400	Extrusion (tubes, shapes)				1A	
1500	Roll (tube, shapes)	2	2			2
1600	Draw (tube, wire)		1			
1700	Press, draw (tubs etc.)			1		
1720	Press, bend (brakes)		1			1
2000	Metal-removal					
3000	Metal-cutting					
3100	Press, shear	1	1	1		1
3200	Press, punch	1	1	1		1
3300	Saw				1	
4000	Heat-treatment operations					
5000	Fastening operations					
5120	Rivets	1	1	1	1	1
5400	Designed (catch, interlock, plug)		1A			
6000	Finishing operations					
6130	Brush and polish				1	
6310	Spray, paint (auto-line)					1
6390	Spray, other finishes than above			1A		
7000	Final assembly and packing					
7100	Hand (short-run, no pace, light)	1A	1		1	
7120	Hand (long-run, paced)					1
7420	Critical test needed	1B				
7500	Hand-pack (short-run, no pace, light)		1	1	1	
7520	Semi-automatic packing					1
8000	Materials handling					
8060	Manual (simple wheels and skids)			1	1	
8200	Conveyors (manual)	1				
8300	Trucks (lift, pallets, bins etc.)		1			
9000	Purchased items					
9500	Service functions					
9580	Jigs and fixtures	1	1			

Notes:

Product (23): A - Buy foam floats, wood transom; B - leak
Product (25): A - Buy extruded shapes and cast corners
Product (20): A - Teflon
Product (21): A - Usually purchased

TABLE V-1f

No.	Product No.: Commodity: Resource	(26) 1/2 in. electric drill	(29) Contractor's wheel-barrow	(32) Compost mill 3 hp	(33) Portable cement mixer	(39) Cannister vacuum cleaner 1 hp
1000	Metal-forming					
1120	Forge, die (2)			1		
1250	Casting, non-ferrous (3)					
1260	mould	1				
1500	Roll (tube, shapes)				2	
1700	Press, draw (tube etc.)		2			2A
1720	Press, bend (brakes)		1	1	1	
1800	Wind (motors, transformers etc.)	2A				
2000	Metal-removal					
2100	Turn (lathe)	1				
2610	Thread (outside thread by die)	1				
3000	Metal-cutting					
3100	Press, shear	1	1	1	1	
3200	Press, punch	1		1	1	
4000	Heat-treatment operations					
4100	Furnace		1			
5000	Fastening operations					
5100	Self-tapping screws					1
5110	Nuts/bolts	1	1			1
5220	Weld, continuous				1	
5400	Designed (catch, interlock, plug)	1				
6000	Finishing operations					
6130	Brush and polish	1				
6200	Dip (to clean, prime)		1			
6210	Dip (to finish)		1			
6300	Spray, paint (short-run)			1	1	
6310	Spray, paint (auto-line)					1
7000	Final assembly and packing					
7100	Hand (short-run, no pace, light)		1A	1A	1A	
7120	Hand (long-run, paced)	1				1
7510	Hand-pack (unit and short-run, no pace, heavy)			1		
7520	Semi-automatic packing	1				1
8000	Materials handling					
8060	Manual (simple wheels and skids)			1		
8200	Conveyors (manual)	1				1
8210	Conveyors (automatic)					1
8300	Trucks (lift, pallets, bins etc.)				1	
9000	Purchased items					
9100	Electrical motors					1
9190	Electrical supplies (other)	1				1
9500	Service functions					
9580	Jigs and fixtures				1	

Notes:

Product (26): A - Integral motor
Product (29): A - User assembly; uses purchased wheel
Product (32): A - Buy 3 hp gas motor and wheels
Product (33): A - Buy wheels and bearings
Product (39): A - Cited unit uses fiberglass but others use drawn shapes

TABLE V-1g

No.	Product No.: Commodity: Resource	(27) 5 in. bench vise	(28) Hand shovel	(30) 18 in. rotary lawnmower	(37) Commercial hand truck	(42) Open-end wrench set
1000	**Metal-forming**					
1120	Forge, die (2)	2	2	2A		2
1500	Roll (tube, shapes)				2	
1720	Press, bend (brakes)				1	
2000	**Metal-removal**					
2100	Turn (lathe)	1				
2200	Bore (drill)	1				
2300	Grind			1		
2400	Mill	1				
2500	Broach					2A
3000	**Metal-cutting**					
3100	Press, shear		1	1	1	
3200	Press, punch		1	1	1	
4000	**Heat-treatment operations**					
4100	Furnace	1	1			1
4300	Quench	1	1			1
5000	**Fastening operations**					
5110	Nuts/bolts			1		
5120	Rivets		1	1		
5220	Weld, continuous		1		1	
6000	**Finishing operations**					
6200	Dip (to clean, prime)				1	
6210	Dip (to finish)		1		1	
6300	Spray, paint (short-run)	1				
6310	Spray, paint (auto-line)			1		
7000	**Final assembly and packing**					
7100	Hand (short-run, no pace, light)	1			1	
7120	Hand (long-run, paced)			1B		
7400	Standard performance test			1		
7510	Hand pack (unit and short-run, no pace, heavy)	1				
7520	Semi-automatic packing		1A			1
8000	**Materials handling**					
8060	Manual (simple wheels and skids)	1				
8210	Conveyors (automatic)			1		
8300	Trucks (lift, pallets, bins etc.)		1		1	1
9000	**Purchased items**					
9500	**Service functions**					
9580	Jigs and fixtures				1	

Notes:

Product (28): A - Buy handle
Product (30): A - Magnesium frame; B - Buy 3 hp gas motor
Product (42): A - Broach hex box to nut size

standard task classification by weight until considerably more data are collected on typical products in many branches of the sector. In this way the semiquantitative data organization facilitates the definition of proper standard task categories for subsequent fully quantified empirical work.

(b) The seriality class of output from a process is not specified but is again left implicit by reference to the seriality characterizing a given product as listed in an activity column. The remarks made under (a) above apply to this case in an analogous manner.

342. In order to avoid confusion with either the standard-task or the resource-element concepts, the rows of Table V-1 will be referred to simply as "resources". This designation is convenient since it corresponds to the usual interpretation of activity-analysis models as describing resource inputs into specific activities. The resources corresponding to the rows of Table V-1 are then processes (or processing functions) used to characterize production facilities at a rather high level of generality within the hierarchical classification.

343. Although the hierarchical approach to the organization of productive facilities is not new - indeed, in general, the hierarchy of classification and structure suggested is common to systems such as the Dewey Decimal System used in libraries and Standard Industrial Classifications used in government statistics - its specific extension to the organization of preliminary programming data has not been exploited widely, if at all. The advantages of such an approach here, however, are the same as those generally found in information-retrieval situations involving mass data files, plus those inherent in research flexibility and data-collection from diverse professional sources.

44. At the same time the hierarchical approach exhibits here, as elsewhere, some ell-recognized shortcomings. Foremost among these is the ambiguity of classification hen there are several classificatory criteria which give rise to mutually inconsistent lassifications. In the present case these shortcomings are not significant at the evel of generality represented by Table V-1. At a more detailed level a different ind of problem arises, in that there will typically not exist a one-to-one correspondence between processing functions and productive facilities. Thus it is true hat (in the illustrative hierarchy presented above) a lathe of a given model may required for the performance of a given turning operation; but if the workpiece heavy there will also be a requirement for hoists or other materials-handling uipment. The resource-element concept is an attempt to quantify such complementarities; in addition, however, it also creates a higher-level aggregate in that,

for example, in machining many kinds of metal-removal processes (turning, drilling, planing, milling, etc.) are brought together into a single shop that defines the resource-element. This higher-level aggregate, however, does not coincide with a higher level in the hierarchical classification given above. For operational purposes we shall use the concept of resource (in the sense of a metalworking process or function) as defined above for use in Table V-1.

Some special problems in activity classification

345. The resource listing structured as above can be made both relatively exhaustive and complete, both stable and clear, and both flexible and useful in planning. However, a more difficult assignment faces the coder when he looks at possible activity lists.

346. This is so, because designers of products have exploited the principal of combinatorial variety by using many combinations of production processes, and many combinations of common parts to produce from a small list of resources a cornucopia of end-products, which could be considered activities.

347. This result poses at least two major problems for the investigator: (a) he must find a way to group products and thereby reduce the number of activities to a reasonable total; (b) he must contend not only with commonality of components and resources consumed but also with the seriality of production, that is, the changes in tooling and design that would follow the specification of longer or shorter production runs.[6]

348. One approach to this twofold problem is via the route used in specific manufacturing practice, namely, the decomposition of many assemblies into their components, sub-assemblies, materials requirements and machine-labour requirements, with summarization at each level of requirement in assembly. This so-called parts-explosion or resource-explosion problem is a standard data-processing task in industrial factory planning but, because of the detail involved, only the more sophisticated firms such as the automotive industry in the United States have mastered it. Most firms pay for lack of such detailed organization by increases of in-process inventories, work halts, and similar disturbances; indeed, the cost of such detailed planning is often justified only by extremely high seriality in a competitive economy.

349. The techniques of decomposition for electric motors are illustrated in Chapter IV of this report. However, it should be noted that the resources required for a detailed decomposition study of even a short list of typical products is extensive if it attempts to be exhaustive. The analyst again faces the

combinatorial dilemma described at the beginning of this chapter. Even with unlimited financial resources, the time factor would remain, and technology would change faster than a truly exhaustive decomposition study could be completed. In other words, the analyst comes to the unyielding basic theorem of planning and control; namely, the inputs and corrections made to a process must be at least as rapid as the variations and changes to be controlled or he is doomed to failure.

350. There are, however, levels of control that can be exploited. Just as a hierarchy of resource classification permits flexibility (as well as the other classification virtues described), a hierarchy of product types, or activities, also permits a multiple-stage or sequential approach to programming.

351. If the over-all aspect of planning that must be comprehensive is handled at a lesser level of detail, with the more detailed planning handled selectively at successively lower levels of control, it is possible to adjust the capabilities of the planner-controller to the demands of the task at hand. In short, it is possible, using a combination of analytical approaches to have both general and comprehensive planning at one level, and simultaneously to have detailed and specific planning at selected lower levels, and on a consistent basis.

352. The subsequent discussion describes how this principle can be applied to the metalworking field in particular.

The semiquantitative resource/activity matrix and its virtues

353. Many of the problems of resource listing are overcome by resort to the hierarchy of description described previously. Since the listing at the higher levels of the hierarchy require few categories, and since the detail of the listing can always be consistently expanded by adding further lower levels, the work done initially to construct a crude table of resources *versus* activities is not wasted but rather serves as a guide to further investigation.

354. Because of the great commonality in the components of finished products, however, it is difficult to isolate categories of products that produce clear-cut blocks of resources and activities. Here we must resort to a partial separation of classes, hoping to achieve, to the extent possible, the desired characteristics of a classification scheme.

355. The matrix of Table V-1 suggests a mechanical route to the desired classification and partition of activities. If a large sample of products - one that shows the detailed checklist of resources needed to produce them - can be obtained quickly and cheaply and if this sample is representative of the metalworking sector and its various branches, then various mechanical sorting and

grouping procedures can be used to construct product groups or product prototypes that will be useful for planning. Moreover, we can by this means scan only those products that have some immediate interest, should an extensive sample be beyond our resources. Temporarily, both finished end-items and components are considered as activities; they are both shown as columns in Table V-1.

356. Ease and speed of data collection. By restricting the variety of data collected about a given product and its resource elements to a checklist (indicated in Table V-1 by a "1" for a needed resource and a blank for an unused resource in the manufacture of each product), we can provide a large scan of possible products, collect data inexpensively, as described hereafter, and produce a table which has both immediate quantitative possibilities and the potential for later refinement of selected resource activity blocks.

357. In Table V-1, the checklist aspect of display provides two semiquantitative guides to activity importance as well as a check of need. A number "2" is inserted for processes which are considered in some sense critical to the production of a given product. In this notation, the definition of critical may be related to one or more of several criteria: mass seriality, current technology, complexity of product, or difficulty of assembly and test operations. In addition, lettered notes are provided for a resource activity cell when further information is pertinent. These notes are provided briefly at the foot of each product column.

358. Self-grouping activity classes. It is interesting, before we go on, to describe parenthetically how such a table can be used to provide a mechanical self-grouping of products by their similarity (with respect to resources required in their manufacture).

359. For this purpose, consider the much-simplified resource/activity matrix, often called an incidence matrix, or binary matrix, shown as Figure V-1. (For simplicity, we temporarily drop the criticality designation, and technical notes as shown in Table V-1.)

360. Using such an initial source document, it is now possible by very simple means to perform a number of quantitative manipulations which, although as yet highly unrefined, provide us with ranks of product and resource similarity.

361. For example, we may now compute an activity/activity or product/product similarity table, as follows. Take each column of Figure V-1 and find the number of "matches" between its elements and those of the other columns of the figure,

Figure V-1: A resource/activity incidence matrix, showing a list of resources as rows (1,2,3....) and a list of products as columns (A,B,C.....). This basic form is followed in the examples that follow.

Activities

		A	B	C	D	E
	1	1	1		1	1
Resources	2	1		1	1	1
	3		1			1

Figure V-2: An activity/activity similarity matrix.

	A	B	C	D	E
A	2	1	1	2	2
B	1	2	0	1	2
C	1	0	1	1	1
D	2	1	1	2	2
E	2	2	1	2	3
Column totals	8	6	4	8	10

where a match is defined as an equal cell incidence of "1s". (Mathematically, this corresponds to matrix multiplication of Figure V-2 by its "transpose", that is, an quivalent table with rows and columns interchanged.) The result, shown as igure V-2, demonstrates how one product or activity is related to another by the umber of common resources employed in production.

62. Figure V-2 is read by first noting the numbers on the diagonal, which give he number of self-matches, or the number of "1s" in a given product column. eading to the right, in any given row, we see the number of resources required or that given product's production that are also common to other products; for xample, product A required 2 resources, which are also required by products D and E.

Only one common resource (not necessarily the same) appears for products B and C. Thus, by a simple count of common resources, products D and E are more similar to product A then are products B and C. This measurement is one of many that could be used. It has at least one defect, namely, that it does not indicate which products could be made if others also could be; for example, consider the difference between products B and C, given resources 1 and 2. However, this deficiency can be overcome by other simple manipulations, and the product/product matrix does provide one way to group products by commonality of resources required.

363. Continuing by analogy, a resource/resource table may be produced, as shown for the example of Figure V-1 in Figure V-3. Here we have counted the matches between one row and all other rows of Figure V-1. (Mathematically, this corresponds to the multiplication of Figure V-1 by its transpose. Again, the interpretation is the same. We see that process 2 is more similar to process 1 than to process 3, in the sense that more products in our list require the common resources 1 and 2 than 1 and 3 or 2 and 3.

364. Thus, using the concept of similarity matrices or tables, we may group mechanically, for the initial listing of resources and activities, those which are mutually common, specifically by rearrangement of the rows and columns of Table V-1 to produce blocks of "1" entries.

365. One method of creating such blocks mechanically is to produce a table, such as Figure V-4, which reorders the rows and columns of Figure V-1 by the similarity sums of Figures V-4 and V-3. Thus, if the numbers computed for the resource/resource matrix of Figure V-2 are added, striking a column total for each column and if the row entries of Figure V-3 are added across for each row, striking a row total for each row and if, in addition, a new table is constructed with rows and columns rearranged in order of their scores in this computation (with the highest-scored columns to the left, the highest-scored rows above), then we have a new table in which resources and activities of highest commonality, as previously defined, will appear in the upper left corner of the new table. The result, Figure V-4, shows a grouping of resources and activities as suggested. In such a table, the products having the greatest number of resource requirements will probably, though not necessarily, appear to the left; resources entering the greatest number of products will usually, though not necessarily, appear at the top. Although such a mechanical manipulation of the data does not guarantee a clean partitioning of the data into separated blocks (which may be considered independent for later analysis), it does point generally to the products that require the greatest number of resources (to the left) and the resources of the greatest common use (to the top).

Such a display not only has immediate use in suggesting resources of great generality, but also in suggesting "easy" versus "difficult" products. For a given row, indicating generality of resource-need by its rank, the easier products will usually appear to the right, the more difficult ones to the left.

366. Other manipulations of this sort may be advanced, given the semiquantitative data of Table V-1 or Figure V-1.

Figure V-3: A resource/resource similarity matrix.

	1	2	3		
1	4	3	2	9	
2	3	3	1	7	
3	2	1	2	5	**Row totals**

Figure V-4: The reordered incidence matrix of resources and activities. The rows and columns are ordered by the total-similarity scores shown in Figures V-2 and V-3.

	E	A	D	B	C	New order
	A	B	C	D	E	Old order
1	1	1	1	1		
2	1	1	1		1	
3	1			1		

Figure V-5: A comparison of resource counts for the complete resource activity matrix, by activity, verus the same count for a constrained resource list, as described in the text. Equality of count indicates feasibility; difference in count gives number of resources lacking.

A	B	C	D	E	
2	2	1	2	3	Full matrix
2	1	1	2	2	Reduced matrix

367. Feasibility checks. The semiquantitative resource/activity matrix may also be used for feasibility checks and to compute a comparative count of needed but unavailable resources. Although the index thus produced is simple, it is informative and permits quick comparison of needed *versus* available resources.

368. For example, using the simplified resource/activity matrix of Figure V-1, compute the column total for each column. This will be a simple count of all the resources required to make a given product. Next, make a list of the resources available presently, for illustration, say resources 1 and 2. Extract these rows from the full resource/activity matrix to produce a constrained matrix, and again strike a column total. The result of applying these steps to Figure V-1 is shown in Figure V-5.

369. If the full matrix and constrained matrix column totals are equal for a given product, then all the resources required for that product are available, and a scan across the product listing will produce all of the feasible products, with respect to the resource classification. Such a check is, of course, a preliminary feasibility check, that is, we are only assured that the right kind of resources are available, not the specifically correct capacities. The crude approach does indicate, however, where potential capability may lie and is necessary for further refinement and quantification.

370. In the same way a comparison of the scores computed for the full and constrained matrix columns gives an indication of the number of missing resources for products that are not at first feasible. The lesser count for these products specifically shows the number of resource categories lacking, not which ones. Again, however, such a quick comparison, with its large possible scan indicates generally which products are likely candidates to be added to the list of feasible products. In other words, a product that requires but one resource that we do not now have is a more likely candidate than a product for which we have none of the required resources; one possible ordering is according to the deficiency.

371. Further extensions of such applications are possible, such as the introduction of criticality, weighting and normalization of scores, although they are not considered here. Our purpose has been only to indicate some of the useful properties of a semiquantitative resource activity matrix *per se*.

Immediate Practical Uses

372. In short, data collected and presented in a semiquantitative display such as Table V-1 provides a master file of large scope that can be constructed easily

and inexpensively, that can be used to find resource and activity similarities and that can provide initial feasibility checks and scales for rating candidate products and resources.

373. Using this initial screening approach, the investigator is able to get a comprehensive scan of possibilities, then direct his attention to a smaller number of interesting possibilities, which must be investigated in further detail. Moreover, by noting the criticality and special notes, the second-stage investigation is further directed to areas of special interest. Thus, in its own right, the presentation in Table V-1 is a useful diagnostic tool.

Further refinement of product classification

374. As larger lists of activities are added to Table V-1, the problem of common components and sub-assemblies enters the picture. This is so because not only commonality of resources, but also commonality of components and sub-assemblies may be of interest in marketing, design, and selection of feasible activities.

375. In viewing the sub-assembly problem, two forms of "treeing" processes are of interest, the first the decision tree, and other the "requirements explosion" tree. See Figuros V-6 and V-7.

376. The decision tree, shown in Figure V-6, illustrates the hierarchy of choices in a selection process which leads eventually to a specific design or instance of that class of objects which would satisfy the general objective at the apex of the tree. Thus, if the general objective were to provide flexible ground transportation under the constraints of certain terrain, environment, etc., we find at once that certain functions must be filled; for example, a prime-mover is needed, there must be some method of control for direction, speed, etc., there must be some physical way to contain the passengers and so on. There is essentially no choice at this first step. Next, however, each function may have many modes of implementation, so alternative choice is possible. For example, the alternatives for a given function may be different sub-assemblies; when the sub-assemblies performing each function are combined, they produce a product meeting the general requirements stated.

377. The more detailed tree of Figure V-7, called a design or "explosion" tree, provides more detailed information, but is usually without choice. It is usually the result of a sequence of decisions, as in Figure V-6, and is used to describe a specific group of products as they have been specified for production. The purpose of the tree is to evaluate, in detail, the volume of lower-level resources needed once a finished product-mix has been agreed upon. Figure V-8 shows the matrix

equivalents of the tree of Figure V-7. When matrix [B] is multiplied by matrix [A] (in that order), we have matrix [C], the parts list for the two end-products. The extension of this computation is shown in Figure V-9. There the product mix for the final products, 500 and 200 respectively, is converted into a parts requirement by a further matrix multiplication. This type of computation is often a routine production-planning task for inventory control, machine loading and the like.

378. In terms of our previous discussion, Table V-1, the resource activity matrix is more analogous to Figure V-7 than to Figure V-6, since it is assumed that, at the level of generality illustrated, design specifications have been fixed by the world market. In addition, using the incidence-matrix format of Table V-1, no exact count has been made of the level of component or sub-assembly use in the list of finished products presented, and indeed components, sub-assemblies and finished products have been listed in Table V-1 as activities without distinction.

379. In sum, planning goes forward in two, not necessarily independent stages, as illustrated by the trees of Figures V-6 and V-7. However, at the detailed planning level, we lean more toward evaluation of chosen plans, rather than at the comparison of alternatives, so the deterministic, choiceless tree becomes relatively more important.

380. Furthermore, if our initial purpose is only to detect the incidence of commonalit between resources and possible activities, then the approach of Figures V-7 and V-8 permits us to treat the sub-assembly problem as either a series of tables, in which, for example, components would be considered resource inputs into sub-assemblies, and sub-assemblies as resource inputs into finished products, or as a table of direct plus indirect inputs, showing the elemental resources going into a given independent column. In the latter case, all columns in the basic table would show an incidence entry for every pertinent resource whether that incidence occurred directly or indirectly.[7]

381. This explanation should further explain the rationale of Table V-1, in which sub-assemblies, finished products and even components have been commingled. In it we have attempted to show a complete incidence check-off, as would be necessary for such a grouping. Although the contribution of sub-assemblies is lost in this grouping for a given item (a defect which can be remedied by construction of higher-level tables as desired) the check-off is complete and does give the comprehensive scan needed in one table.

382. Thus, even though finished products and sub-assemblies are shown together, product families and inherent similarities by resource element will not be lost.

Figure V-6: A decision or option "tree". A general method or objective is proposed. Acceptance of that proposal requires the fulfilment of given functions, shown in the half-boxes (or, in the case of risk situations, may require the listed functions). At the lowest level, we see that the stated functions may be alternately performed by two or more choices of method. If the table were continued, so would the choice - requirement hierarchy. Decisions are made to select a full box; necessity or chance determine the functional requirements.

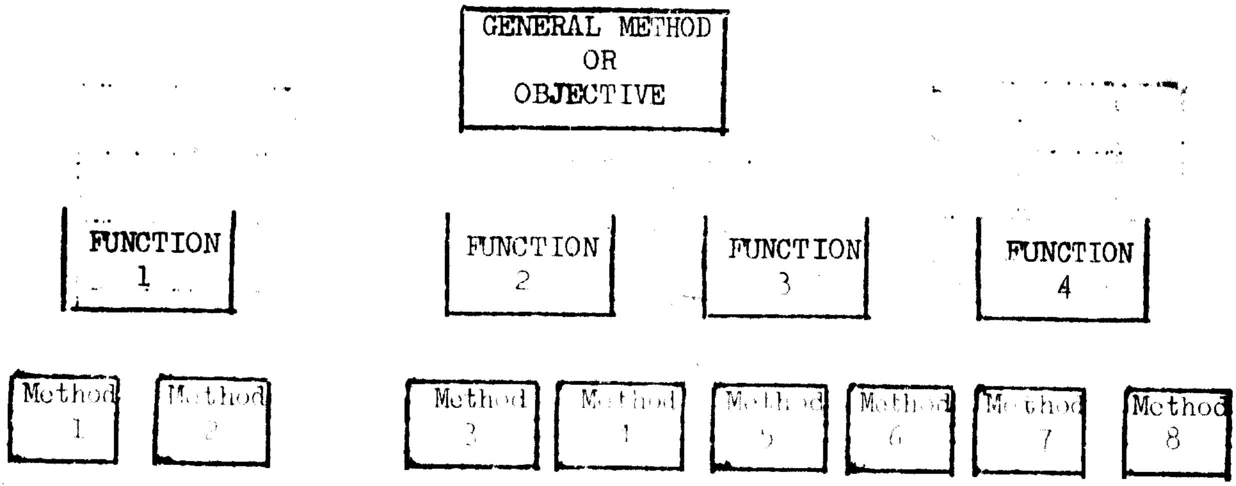

Figure V-7: A deterministic design "tree". Two end-products, denoted by P_1 and P_2 are designed to be made from three sub-assemblies, which in turn are designed for production from four common products, or parts. (Only design arrows from the first product and sub-assembly are shown for clarity.) No choice is available in this "explosion" after the initial family of design has been made.

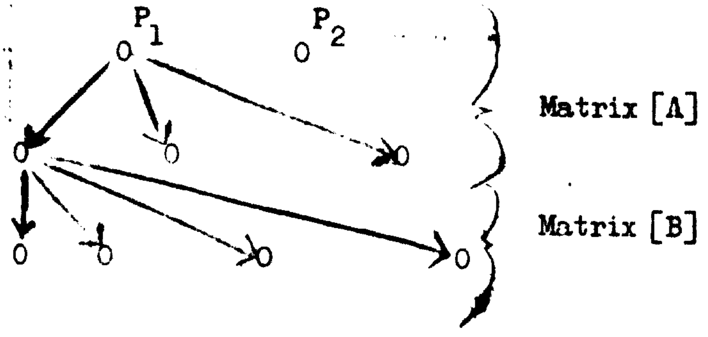

Figure V-8: A matrix display of Figure V-7. Matrix A shows the number of sub-assemblies of each kind entering each final product. Matrix B shows the number of parts of each kind entering each sub-assembly. When multiplied together, following the rules of matrix multiplication, this parts list is "exploded", giving the detailed relationship between parts and final products. The idea may be continued to go from parts to machine and man-hour resources, etc.

$$\begin{array}{c|c|c|c|}
 & A & B & C \\ \hline
1 & 1 & 4 & 1 \\ \hline
2 & 2 & 1 & 3 \\ \hline
3 & 1 & 1 & 0 \\ \hline
4 & 0 & 2 & 5 \\ \hline
\end{array}
\times
\begin{array}{c|c|c|}
 & P_1 & P_2 \\ \hline
A & 1 & 2 \\ \hline
B & 3 & 1 \\ \hline
C & 1 & 3 \\ \hline
\end{array}
=
\begin{array}{c|c|c|}
 & P_1 & P_2 \\ \hline
1 & 13 & 9 \\ \hline
2 & 8 & 14 \\ \hline
3 & 4 & 3 \\ \hline
4 & 11 & 17 \\ \hline
\end{array}$$

Figure V-9: Computation of "exploded" requirements by matrix multiplication. Multiplication of the master parts list by the mix of finished items needed produces the elemental requirements, which by extension of the same process, can be converted into elemental machine, man-hour, and material resources.

$$\begin{array}{c|c|c|}
 & P_1 & P_2 \\ \hline
1 & 13 & 9 \\ \hline
2 & 8 & 14 \\ \hline
3 & 4 & 3 \\ \hline
4 & 11 & 17 \\ \hline
\end{array}
\times
\begin{array}{c|c|}
 & \text{Total needed} \\ \hline
P_1 & 500 \\ \hline
P_2 & 200 \\ \hline
\end{array}
=
\begin{array}{c|c|}
 & \text{Total needed} \\ \hline
1 & 8300 \\ \hline
2 & 6800 \\ \hline
3 & 2600 \\ \hline
4 & 8950 \\ \hline
\end{array}$$

383. After selection of general product families (and therefore resources elements), however, the multi-level analysis will be required to assess the breakdown in manufacturing stages, avoid duplication in any decomposition studies and serve as a design guide to alternative decisions of the type illustrated in Figure V-6.

384. As a rough illustration of the higher-stage incidence table, see Figure V-10.

C. Combining fully quantified and semiquantitative data by levels

385. Based on what has just been said, the incidence matrix, Table V-1, is useful in producing a wide scan, so that products or activities, may be clustered by common resources needed. This will produce, although roughly, families of products. It can be readily determined, for example, that certain products differ from each other by small degrees that can often be accounted for by a variation in purchased parts, trim, etc. For example, a basic metal-product cluster may be found to be centered about the metal cabinet business. The addition of purchased electrical parts produces small home appliances, and the further addition of a deep-draw process - to produce sinks and tubs - leads to the production of washers and dryers, kitchen sinks and the like.

386. Similarly, product clusters will be found centered about the piston pumps compressors, small internal combustion engines, refrigeration equipment and hydraulic items all employ essentially the same processes in their construction. Small rotating machines, such as jet water-pumps, motors, generators, alternators, and the like require the same initial processes, with differentiation in the final stages of manufacture, for example, inserting laminations and windings in a motor or generator.

387. When such forms of production grouping have been defined, with much of the variation being taken up by purchased items, it is possible to consider seriality of the product group, devoting attention to the specific tooling required for various production levels of the group type.

Figure V-10: **Part description versus final product description. The column designations are defined in the column at the right.**

	1	2	3	4	5	6	7	8
Small stampings	0	1	1	1	0	0	0	0
Metal cabinets	1	0	0	0	1	1	1	1
Electric motors	0	1	0	1	1	1	0	1
Compressors	0	0	0	0	1	1	0	0
Deep-draw items	0	0	0	0	0	0	1	1
Electrical controls	0	0	0	0	1	1	0	1
Electrical parts	0	1	1	0	1	1	0	1
Die castings	0	0	0	1	0	0	0	1

Final products (Columns)

1. Kitchen cabinets
2. Electric fans
3. Electric heaters
4. Household electric mixers
5. Refrigerators
6. Air conditioners
7. Kitchen sinks
8. Washing machines (automatic)

388. The route to further refinement lies in noting, from here on, the characteristics that are shared versus those that distinguish the isolated product groups. By inspection of re-shuffled incidence matrices, it is usual to find that one or more resources is a "liaison" resource between product clusters. These common links provide routes to growth from production of one cluster to another and should be sought here. At the higher levels, inspection of sub-assembly tables will often show sub-assemblies as these liaison resources, with perhaps easier detection.

389. The refinement now follows a divided approach: (1) the development of more quantified programming data for a prototype of each product cluster, and (2) the quantification of programming data for the liaison products or product clusters. At first, this form of refinement must be restricted to fairly high-level groupings, or else to products within each group that may be considered typical, for example, to crude coefficients between the basic metal operations (forming, removal, fastening, etc.) versus product families on a per-ton or a per-unit basis. As a matter of experience, something on the order of a 10 x 10 or a 20 x 20 matrix is considered as a reasonable start in this direction by the author of this section.

390. In other words, based on the manipulations, ranking, grouping and other semiquantitative investigations now under way, we could reasonably hope for a relatively small table for which some crude (one or two significant figures at most; perhaps order of magnitude only) coefficients could be estimated. Upon this base, the programming analysis could proceed in stages to greater refinement.

D. Procedures for developing semiquantitative data

391. The data for Table V-1 were collected in three ways: (1) by conference with experts, (2) by recourse to catalogues and documents, and (3) by inspection of end-products and factory visits.

392. As noted elsewhere in this report, although the factory visit is the quickest source of information in depth about a given product and is recommended for data collection once product groups have been defined, it is also expensive and requires travel. Some difficulty in making visiting arrangements may also be expected. A next alternative, employed here, involved visits to distributors or jobbers who stocked the end-products described. These distributors are not usually familiar with component detail, but they do have catalogues and parts lists on hand and can answer a range of semi-technical questions on machine operation.

393. The catalogues and parts lists that might be obtained by visit or correspondence usually show total product weight and price, with a listing of parts. Part weights are usually not shown, and parts photographs are not given. Customarily, one or more photographs of a product and its accessories are provided, as in the Sears, Roebuck catalogue and in equipment catalogues for machine tools, etc., although some component specialists have parts catalogues with pictures.

394. We stress the availability of photographs or assembly drawings for end-products and sub-assemblies since the availability of these materials permits intelligent questions of a specific type to be posed for experts who may act as consultants. Total weight and price figures, in addition to photographs and a brief description of special features, also serve to establish the range of possible production processes that could have been employed in a product's manufacture, thus permiting a check on expert statements when combined.

395. We should note that experts in the tooling and production area, like many engineers, find it difficult to generalize. Thus, we found it impossible to hand an expert a list of resource elements and a list of products and let the expert create incidence entries on his own. Typically, the expert will think in terms of a narrow range of product types, a short list of machines with which he is closely familiar, or fear to generalize to avoid mistakes. This is particularly true of an intermediate level of detail, which is precisely level needed here.

396. On the one hand, the expert is able to give complete manufacturing details for a few products or processes; on the other, to give broad generalizations ("stampings are replacing forgings in this type of product"). Thus, if detailed information is sought, the number of experts needed approaches the number of activities considered.

At the other extreme the process and trend information obtained is not even semi-quantitative (although it is important and interesting).

397. Since discussions with experts appeared to be the only feasible way to collect semiquantitative data quickly and inexpensively for this study, a combination of approaches was used in formulating interviews and collecting data. First, an expert was located who was known to have some specific design, production, or planning experience for a given group of products, perhaps farm implements or refrigerators. The man was interviewed briefly by phone to determine his specialty, if any, and the sub-group of specialization, for example, hydraulic controls for tractors. With this information, a list of products was made up that might be of interest both to the expert and for the study. If possible, photographs of these products with a short description, price, and weight were assembled before the interview. The resource element list was also made available, although usually not shown immediately to the respondent expert; to avoid confusing him the whole of Table V-1 was never displayed.

398. The interview then proceeded typically with the questions shown below.

(a) What are some of the characteristics of your industry?

(b) What are some of the more important processes, if any, that set your industry apart from others?

(c) What special groups of processes within this industry are most familiar to you? Please describe them generally; the sequence of steps, types of machines used, etc.

(d) Here is a photograph of a product in the class you have mentioned; can you tell me what forms of tooling and machines are required in its production? Are there any special sub-assemblies? If so, please describe their make-up and manufacture.

(e) (The expert will have warmed up by this time and can now be given more products from the pre-constructed list.) We have now reviewed a number of products and their detailed manufacture. Are there any other products like them you can think of? If so, what are they and how are they similar, or how do they differ, from those we have already done?

399. An interview of this type will generally not extend, at one sitting, more than an hour or two at most, so the interviewer should always request further evidence in case of necessity, gather up his documents, and depart before his welcome is worn out.

400. During the interview, the interviewer is making several kinds of notes.

(a) Notes on general process types and clusters mentioned and described by the expert.

(b) Notes on product families and their composition in production and marketing.

(c) A check-off against his resource list (Table V-1).

(d) Any peculiar engineering, design, testing, or assembly techniques or trends that are mentioned.

401. Some care is needed to guide the expert's thought to the level of generality desired, to make sure that the terms used are understood and to avoid wandering tales about old associates, obsolete but interesting methods and the politics of a given organization.

402. Unfortunately, there is a vast difference in the time and cost required to collect semiquantitative data of the type described above (which may range from $5-$10 per activity in volume) and the time and cost required to collect standard hours and material standards per unit for a given product run size, and thereafter to investigate the tooling and other changes required for variations in run size, or seriality. Because the latter type of information requires consultation with a far greater number of experts who are now exploiting their professional knowledge - and may indeed have to do some looking-up on their own account - the cost of analysis for a thorough job can jump one-hundredfold (to the $500-$1000 range per product or activity). (These are the consulting rates in the New York area;it may therefore pay to look for sources for a volume of detailed product investigation beyond the semiquantitative data collection elsewhere than in the United States.) This is another argument for selecting carefully the prototype products or product clusters to be detailed by semiquantitative means.

403. Several interesting side-lights emerged from expert interviews. First, the experts used could not easily follow the volume of detail in the UNC studies, found the nomenclature and shop composition "strange" and could often not identify a stated machine in one of the shops in the Soviet Union with an American equivalent. For example, a "cam-operated press" in the Union of Soviet Socialist Republics is often called a "knuckle press" in the United States - a distinction between mechanical and hydraulic presses is indicated in either case. Slight changes in terminology and machine description sometimes proved confusing, slowed down the data collection, and in general proved damaging to the interview. Indeed, the data from the Union of Soviet Socialist Republics often alarmed the respondents

by raising visions of international intrigue. We abandoned any mention of the previous work in later interviews, with improved interviewing efficiency.

404. The importance of vocabulary choice in interviewing - as well as classification of activities and resources - also became apparent in the interviews conducted. For example, if an expert is asked to describe the steps required in the manufacture of gear trains and transmissions (a critical product group requiring extreme precision tooling), he will usually respond in terms of the second-level classification in the resource list of Table V-1, namely casting, broaching, turning, hobbing, grinding, jig bore, heat-treatment and annealing and the like. If pressed to the next level of detail, the expert may be able to provide the name of specific machines of each type in shops he has seen. In most cases he will not venture (or be willing to provide without the specification of a detailed product mix) any statement about production volume, either in run length, pounds, or dollars. Conversely, given a specified product mix, the expert will not be able to say at once what selection of specific tools (at the level of manufacturer's model number) should be chosen to make up a suitable shop. Two reasons contribute to this inability. First, the new level of detail presents an engineering problem with many alternatives; second, the respondent is now brought back to his habitual level for precision and is generally not willing to make off-hand guesses. In short, the question produces a project, not a short answer, and the whole scale of investigation is changed by movement to the next level of detail.

E. Empirical materials

405. Within the scope of the present study only a modest amount of testing of the concepts and procedures developed in Sections V-A through V-D could be undertaken. Data were collected on a pilot basis for a limited range of products, in order to construct the incidence matrix shown in Table V-1 and to test the amount of time and effort needed for a given coverage of industrial branches. This work is continuing at the present writing within the broader United Nations project of which this study is a part.

An empirical resource/activity matrix

406. The chief results of the empirical work have been presented in Table V-1, which contains 42 columns, each representing an individual product. Table V-2 lists these products according to left-to-right column entry in Table V-1. Weights range from 0.5 lb through 618 lb. The Sears, Roebuck and Co. stock number, taken from the Philadelphia Mail Order House Edition 232P (Spring through Summer 1966) has been provided for reference to photographs and further descriptive information.

Book prices are also shown for the products selected, together with a short description, rewritten to indicate some tooling and material detail.

407. The selected products are representative of a wide range of manufacturing processes in the metalworking industries. Electrical, plastic, and similar component parts are assumed to have been purchased or made in a subsidiary facility, as are necessary fasteners, springs, drive belts, and similar stock components. In many manufacturing processes involved in the products described, a much wider range of parts and materials such as extruded aluminium shapes will also be purchased by many manufacturers and, depending upon available tooling, many component parts will be subcontracted, for example, initial foundry steps to a rough casting. Large integrated manufacturers will produce all of the necessary component parts, including fasteners, but such a firm would be a giant in its industry.

Table V-2

Product Explanation for Table V-1

Column number	Typical Sears, Roebuck stock number [a]	Shipping weight (pounds)	Retail (book) cost (US dollars)	Short description
1.	W46P66221	312	199.95	12.3 ft^3 refrigerator-freezer, frostless, standard trim, sealed compressor
2.	W65P1790N	94	45.95	66 in. wall cabinet, white sheet metal, for above sink
3.	W65P5933L2	40	42.95	33 in.x22 in. dual-bowl white stamped kitchen sink with faucets and fittings
4.	W42P2504N	84	105.00	Jet water-pump, centrifugal, for 30-50 lb/in^2, uses 1-hp electric motor (included)
5.	32P2231L	35	63.50	Small internal-combustion engine, Briggs & Stratton 3 hp heavy duty, 3600 rev/min copper-aluminium die-cast plated piston, 1 cyl., 4-cycle

Table V-2 (continued)

Column number	Typical Sears, Roebuck stock number a/	Shipping weight (pounds)	Retail (book) cost (US dollars)	Short description
6.	42P12633 42P12693	0.8 0.5	.20 .13	3/4 in. gal steel "tee" 3/4 in. gal steel "elbow" (typical very-long-run plumbing-supply items)
7.	W42P1358C	18	4.95	Cast-iron floor drain, 8 in., with integral trap. (typical short- to medium-run plumbing item)
8.	30P15206N	166	224.95	Contractor's piston air compressor, 100 lb/in^2, 2 cyl, includes pressure tank, controls, 3 hp gas. motor (see Col.5) on wheels.
9.	W42P3179N	120	50.00	Pressure tank for water 82 gal, uninsulated, glasslined, tapped inlet/outlet
10.	F42P84203N	290	79.95	Hand-cast iron stove for wood and coal (Franklin type)
11.	W42P78271N9	618	299.00	Complete forced warm-air heating system, 75,000 Btu for small home, includes furnace, ducts, returns, controls, registers, etc.
12.	W26P6870N	164	134.95	Electric clothes-dryer, automatic, with timer and controls, motor blower
13.	W26P6470N	247	189.50	Electric clothes-washer, automatic, sequence timer, drive motor, heavy vitreous-coated deep-drawn wash-tub, sealed transmission, electric water valves
14.	W22P733460N	164	149.95	30 in. Gas cooking stove, oven thermostat, clock, light electric outlet, die-cast burners, cast-iron supports.
15.	34P8135N	37	37.95	20 in. portable fan, 1/12 hp motor, thermostat, 3-speed switch

Table V-2 (continued)

Column number	Typical Sears, Roebuck stock number [a]	Shipping weight (pounds)	Retail (book cost (US dollars)	Short description
16.	34P7165	9.5	18.95	1650W Portable electric heater, fan, thermostat, safety switch
17.	32P3240C	10	7.95	10 in.x10 in. Recessed lighting fixture, for ceiling, in terminal box, with glass
18.	34P7390N	85	97.95	2 ft^3 Refrigerator for office or ice cubes, no deep draws, plastic interior, compressor type (imported from Japan)
19.	11P2428	6.3	2.89	Cast-iron skillet, 11-3/4in. with polished inner surface
20.	11P551	1.25	1.78	Aluminium skillet 10 in. with Teflon coating
21.	30P42542N	20	22.95	16 ft Aluminium ladder, medium loads, 6 rivets each rung, extruded "I-beam" rails and rungs, rope and pulley.
22.	3P5924N	45	184.50	Spirit duplicator (Ditto type) for office, manual but heavy duty, with automatic feed
23.	6P36145N	150 135 actual	210.00	6.050 Gauge aluminium boat, 13 ft-7 in., takes to 15 hp outboard motor
24.	6P6092N	39	107.00	3.5 hp Outboard motor, die cast aluminium manual start, 1 cyl., magneto speed control, remote tank to 7 m.p.h.
25.	F28P49198NF	185	299.00	Aluminium truck camper, converts pickup truck to small house, safety-glass windows, 66 in. wide
26.	921102	5.8	44.44	Commercial-grade 1/2 in. electric drill, full ball and needle bearings, geared chuck, reduction gears, aluminium-alloy housing, 3/8 hp at 300-500 rev/min

Table V-2 (continued)

Column number	Typical Sears, Roebuck stock number [a]	Shipping weight (pounds)	Retail (book) cost (US dollars)	Short description
27.	99P5181L	42	18.20	Bench vise, 5 in. jaw, forged from stock, Acme screw, plated handle, screw, nut
28.	99P8295L	5	4.77	Round-blade, hand-shovel, forged and tempered, blade 9x11 1/2 in., wood handle 47 in. (Government Specification GGG-S-00326C)
29.	99P8711N3	64	$28.22	Contractor's wheelbarrow, 5 ft^3, 500 lb capacity, ball-bearing tyre, one-piece seamless drawn tray, 1/8 in. steel legs
30.	W99P9139N	49	63.50	18 in. rotary lawnmover with cast magnesium frame 3 hp gas motor
31.	10P9184L2	27 24 actual	149.95	16 in. Direct-drive gasoline chain-saw, roller tip bar, die-cast magnesium frame, 4 1/2 hp S.A.E.-rated motor
32.	32P7500N	87	97.50	3 hp Compost mill. Uses standard gasoline engine, direct drive to rotating *versus* fixed blades, on wheels
33.	F64P7510N	190	119.95	Portable cement mixer, can be towed, 24 in. steel drum, 2 blades, 2 paddles, 2 1/2 ft^3 mix in 60 sec., uses 1/2 hp electric motor included, roller-bearing wheel
34.	11P7013N	29	24.88	30 in. Bar stool, 2 1/2 in. steel column, welded legs at base, adjustable (tapped) glides, chrome plate foot rest, ball-bearing swivel, 4 bolts to vinyl seat
35.	11P5624L	16	12.99	De-luxe ironing board, hexagonal tube legs, perforated steel table, wheels, foot adjustment

Table V-2 (continued)

Column number	Typical Sears, Roebuck stock number[a]	Shipping weight (pounds)	Retail (book) cost (US dollars)	Short description
36.	11P7400	2.5	9.67	Stainless-steel flatware (knives, forks, spoons) for table, 24 piece service for 6, various embossed designs
37.	99P8727N	39	19.44	Commercial-grade hand truck, welded steel tube and strip, ball-bearing wheels, punctureproof tires, to 600 lb.
38.	W20P25985L2	54	139.95	Portable sewing-machine, with zig-zag feature, in plastic case, electric motor with accessories (die-cast parts), from Japan
39.	20P6740L	19	38.88	Cannister vacuum cleaner, 1 hp, fiberglass body, vinyl trim, tubing and plastic attachments
40.	W47P6619N	193	244.95	De-luxe 11,000 Btu air conditioner, thermostat, humidistat, zinc-dipped parts, plastic trim
41.	3P60852N	85	39.95	30-Drawer steel cabinet, for files
42.	9P4455	2.2	5.13	6-Piece open-end wrench set, drop-forged, then broached, nickel-chrome plated alloy-steel

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[a] Taken from the Philadelphia Mail-Order House Edition 232P (Spring through Summer 1966).

Additional empirical materials

408. The data-collection effort at the semiquantitative level readily yields assorted additional technical-economic information as a by-product that can often be obtained at negligible marginal cost. Such information may include crude quantitative data on gross product weights and weight distribution between components and sub-assemblies, special processing and tooling information, design and marketing considerations, and other related material.

409. As an example of this kind of additional empirical materials, a variety of detailed technical-economic data concerning refrigerators is presented below:

Product: Refrigerators

Specifications

Cubic ft. rating	5.2	9.1	12.3
Gross weight (lb)	125	225	315
Reference model #	Spiegel M78X8462	Ward L69A1015R00	Sears W46P66220N
Cost each (US dollars)	150	170	200
Compressor/motor hp	1/8	1/5	1/4

Weight analysis in pounds (estimated)

1. Box assembly	59	120	183
a. main box assembly	40	80	130
b. door assembly	15	30	43
c. tray and fixture	4	10	10
2. Refrigeration assembly	45	70	90
a. compressor/motor	25	40	55
b. cold coils	6	10	12
c. hot coils	6	10	12
d. plumbing	7	7	7
e. refrigerant	1	3	4
3. Electrical assembly	8	10	12
a. thermostat assem.	3	3	4
b. door switch	1	1	1
c. light	1	2	2
d. cord and box	3	4	5
4. Packing assembly	13	25	30
a. carton and filler	8	10	10
b. wood sled/frame	5	15	20
Gross total (pounds)	125	225	315

Added features:

For automatic ice-cubemaker, add 20 lb and \$50; for frost-free feature add 10-20 lb and \$20-\$70. For increases in size over 12 ft^3, add approximately 15 lb/ft^3 and \$25/ft^3. Special colours other than white, panel inserts, and high-style units will run 10-20 per cent higher.

Range of unit size:

United States sales indicate breaks in production sizes as follows: 3-7 ft^3, (considered small size) use about 1/8 hp motor/compressor, gross 100-170 lbs; 9-13 ft^3 (considered average, medium, or typical United States unit) use about 1/5 hp motor/compressor unit, gross 200-300 lb; above 14 ft^3 in home size (consider large) use about 1/4 hp motor/compressor, gross 300-400 lb.

Manufacturing details:

1. Metalworking

Tooling varies largely depending upon run-size and style. For standard 12 ft^3 refrigerator, run is typically 3,000-5,000 per week. Model or style may be changed after two or three days, with sequence of progression scheduled to use as many common parts as possible (e.g., from standard to deluxe of the same model without change in cu.ft.).

Typical machines for manufacture follow:

Front door/s	2,000-ton press	(required for deep-draw and volume production)
Bottom, back etc.	200-ton press	(possible because flat shapes)
Frame	**2,000-ton press**	(usually 1/8 in. steel in small parts, made when large press is otherwise idle)
Expansion/compression units (stamped coil units)	**50-200-ton press**	(larger press for multiple units)
Trays, inserts, etc.	**50-200-ton press**	(depending upon multiple units desired at one time)

2. **Motor/compressor** — **Purchased** or supplied by subsidiary

3. **Tubes and fittings** — **Purchased** or supplied by subsidiary

4. Electrical control assembly — Purchased or supplied by subsidiary

5. Special processes required. **A brazing operation** (using silver solder or similar procedures) often required in some designs of stamped compression coils. Expansion coils, often of aluminum, require special assembly procedures, or if tube instead of stamping, special fabricating and bending processes. Critical to the construction of the box are two finishing processes for sheet metal (not detailed in the resource elements): spray painting and its associated priming operations and vitreous enamel operations with associated spray, bake, and handling processes. The over-all speed of production often rests with these critical steps. In most assembly operations, a combination of spot-welding and sheet-metal screws is used, with assembly on a conveyor production line. In the assembly process, a critical step is the installation of the front doors, which must set tightly against the frame. Test doors are usually fitted early in assembly to assure squareness of the frame, which is reworked if not square. Refrigeration units are pretested before reaching assembly, but installation usually demands vacuum equipment and instrumentation at the assembly point. Packing operations

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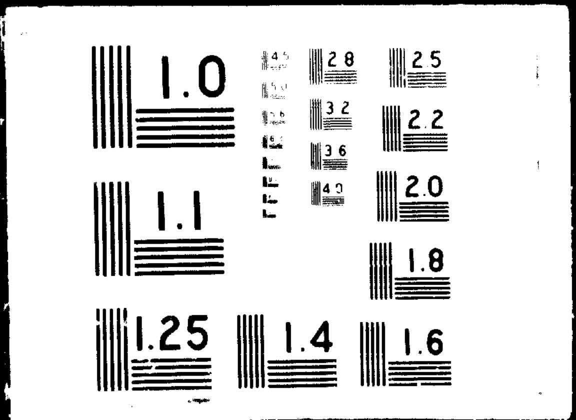

are usually an integral part of the production line and, as in most appliance installations, the efficiency of terminal packing and material handling must be geared to the production line to avoid massive in-process inventories, damage, etc.

Design considerations

Several special design problems are worth noting. The trend in the United States is toward larger boxes, frequently replacing smaller ones in the home. Thus, designers tend to work to old outside dimensions if possible so that new units will fit into cabinet areas already constructed for former units. (In the United States, kitchens usually conform to a 36 in. module.) An increase in the cubic feet of storage is obtained by using thinner walls, better insulation, and decreases in the size of refrigeration components.

A similar design compromise affects unit weight. The refrigerator is the heaviest appliance in the average home. Since American families often move, often live in apartments and often want to move the refrigerator for cleaning, the problem of handling the finished unit in delivery and later use becomes important. Small weight is desired. However, because moving often misalign doors, rendering the unit worthless, the frame must be sufficiently rugged to reduce the likelyhood of such damage. As a result, frames are usually heavy welded units. Weight reductions in stamping, via structural bends, use of angles and gussets, etc., become important. Similarly, internal box detail, trays, shelves, fixtures, tend to be of plastic, aluminum, and similar materials, with bands for stiffness rather than weight.

Finally, designers usually have a limited number of motor/compressor standards with which to work (ranging from 1/8, through 1/5 and 1/6, to 1/4 and 1/3 hp ratings). Design practice is to use the "maximum design" box for a given motor/compressor unit to give the maximum cubic foot rating per purchase dollar. This may be at the expanse of higher operating costs for the motor/compressor, but since cost is a determining factor in sales, such practices are often employed.

Variations in design often lean to style and special convenience features that offer higher profit margins (compared to a basic unit) but which do not materially alter the basic design structure. Thus, variations in hardware, colour, trim, internal shelf design, and special features such as automatic ice-cube makers provide the designer with means for price-building without major reorganization of the manufacturing process. (This route to product variation is common to all appliances, cabinets and other household items.)

The long runs inherent in production in the United States are required for efficiency in the stamping, painting, assembly and packing operations. However, in developing countries, other forms of cabinet production might be considered, using purchased motor/compressor units. If not-purchased parts external to the economy can be obtained, than first attention should be given to construction of motor/compressor units or to compressor units driven by purchased motor assemblies. (See notes on compressors in products (1), (18) and (40) in Table V-1.)

Notes for Chapter V

1/ Theoretically, the number of combinations possible through the combination of the DNA molecule, which determines hereditary traits, is 22,400,000,000. Fortunately, all of these instances do not appear on our planet today.

2/ The dangers in even this first step are evident with substitution of materials - plastic, say, for steel - the constraint to all-metal end-products may give a distorted picture of the end-uses to which entire range of metal components can be put. This fault can be overcome by carrying a miscellaneous category of "other resources" and "other products".

3/ To make what follows entirely clear, we restrict our discussion to the resource list. What is said, however, also applies to the remaining two lists, as shown below.

4/ For a further expansion of this form of reasoning for the more general reader, see Chapters 4-8 of Systems Analysis: A Diagnostic Approach, by V.C. Hare, Jr., Harcourt, Brace and World, Inc., New York: March, 1967.

5/ For example, see A.R. Dooley et al., "Casebooks in Production Management: Basic Problems, Concepts and Techniques", John Wiley and Sons, New York: 1964.

6/ From the activity standpoint, an end-product made by two different modes because of seriality, design, substitution of materials, or custom, must be described as a distinctly different pair of activity specifications, a requirement which, contrary to the investigator's hope, greatly expands, rather than contracts, his list of possibilities.

7/ The similarity of this data organization to input-output tables of the conventional kind should be obvious. While not developed in detail within the present study, the key to the systematic handling of components sub-assemblies is the strategy of treating products whether end-products, sub-assemblies or components, both as input resources and as production activities. Treated in this manner, a resource activity table will have two major groups of resources: (a) final and intermediate products including end-products, sub-assemblies and components, each of which can be produced endogenously by activities occurring in the table; and (b) primary resources (standard tasks) that do not occur as output from any activity of the table. When handled in this fashion, inputs must be distinguished from outputs by algebraic sign. All inputs are taken to be direct inputs only.

A table so constructed will have an "inter-industry" part corresponding to (a) above and a "value added" part corresponding to (b). In a purely hierarchical decomposition such as that of Figure V-7, the inter-industry part will be rearrangeable into triangular form. In order to get direct plus indirect activity-level requirements corresponding to any pattern of demand, the inter-industry part of the matrix must be invested endogenously; direct plus indirect requirements for primary resources (processes) follow from the above inverse.

When alternate ways of performing a function exist (as in a design tree such as Fig. V-6) we must pass from an input-output format to a linear programming format. In all of these manipulations, however, the 0-1 incidence indication is to be preserved, without further quantification.

VI. GUIDELINES FOR COUNTRY STUDIES

410. This chapter attempts to focus the experience gained in the course of the project on the provision of guidelines for two country studies to be undertaken in Israel and in Hungary. While the staff of the project collaborated in the preparation of the country studies, these are being handled as independent parts of the broader United Nations effort in the field of production and expert planning for the metalworking sector. Exploratory work is under way in both countries but was at a too early stage for coverage in this report.

411. This chapter has two principal parts. Section A offers an outline of the principal tasks to be undertaken, comprising a preliminary stage of semiquantitative orientation on the basis of simple listings of major project and process categories, and a quantification stage. A third stage of programming proper remains to be covered in work subsequent to the present study. Section B covers the techniques for executing country studies. It offers suggestions for the statistical groundwork that must be laid prior to detailed questionnaire surveys, discusses the organization of questionnaires, offers suggestions for techniques of product decomposition and demand serialization and indicates a method of using the technical-economic description of the sector for trial programmes.

412. The techniques of information gathering discussed here are focussed primarily on the needs of the country study in Israel and in other countries with mixed economies. In Hungary and other countries with centrally planned economies some of the information that is discussed here as being subject to solicitation by means of questionnaire surveys may be readily available at the Ministry of Metallurgy and Machine Building or in the individual state enterprises to this extent the task is simplified. It is anticipated, nevertheless, that the pre-existing information will not be complete even in the latter countries, and thus the questionnaire technique might prove useful as a supplement to the information that can be secured by more simple and direct means.

A. Stages of the task

413. The stages to be discussed in this part of the chapter comprise, first orientation and second, quantification. Both of these stages aim at giving

a self-contained over-all view of the sector as a whole, but an effort has been made to add detail and to increase precision from stage 1 to stage 2.

Orientation: semiquantitative programming data

414. The purpose of the orientation stage is to establish lists of products, subassemblies, and components, and to revise and expand the existing list of resources.[1] On the basis of an analysis of input requirements by orders of magnitude and a similar analysis of the principal destinations of product and semi-manufacture outputs, it is then possible to arrive at a cross-tabulation of products and inputs.[2] This cross-tabulation is intended to have sufficient accuracy to distinguish between just three kinds of flows: those that are negligible, those that are significant, and those that are regarded as dominant (coded by 0-1-2). This rudimentary analysis of the sector, nevertheless, already has a range of practical applications: it permits matching actual and potential resource availabilities against the requirements of expanded production, and thus leads to a preliminary selection of interesting potential lines of development for the sector.

415. While the intention is to gather a considerable amount of semiquantitative data in the United States in a subsequent phase of the present project, this effort is designed to complement rather than to replace similar work to be undertaken in connexion with the individual country studies, for the following reasons:

(a) It would be undesirable to allow the technical-economic description of existing resources and activities within a country to rest entirely on borrowed foreign coefficients,

(b) It is unlikely that the description of the sector could be made comprehensive without local complementation of material collected in the United States,

(c) The performance of the tasks of data-collection serves an indispensable training function for later programming work,

(d) It is anticipated that a division of labour will develop between the two country studies and the data-gathering effort in the United States that will speed up the comprehensive coverage of the sector as a whole. While this is of the greatest interest for the collection of fully quantified programming data, it is by no means a negligible asset for the semiquantitative work either,

(e) Some duplication in the data-gathering effort is desirable between countries in order to allow cross-checking of data from different sources.

416. Cross-tabulation. The principal tasks that must be undertaken to arrive at a cross-tabulation such as the one indicated above are (a) product listing, (b) product decomposition into subassemblies and components, (c) product destination analysis, (d) further decomposition into process or resource element inputs, (e) process or resource element destination analysis and (f) reconciliation.

417. Product listing. In each branch of production, it is desired to distinguish some 200 "listed products", that is, products that do not represent statistically aggregated classes but unique individual designs. The listed products should jointly cover some 80-90 per cent of the total volume of demand within the branch. The concept "product" is intended to cover end-products in the usual sense, such as refrigerators, subassemblies, such as motor-compressor units or condensers; and components, such as nuts and bolts. In each branch only those products are to be listed that characterize the branch as a whole. Thus, while nuts and bolts are components of refrigerators, they are not to be included among the listed products of this industrial branch. In some cases a question may arise whether a given subassembly or component properly belongs to a branch or not. Thus in some factories a wide range of components may be manufactured prior to assembly while in another factory the same components might be purchased from a plant whose main activities centre on another branch. In the case of nuts and bolts, there is little question that these would not be classed in the refrigeration branch even if a factory were found which manufactured its own nuts and bolts, while in the case of compressors or condensers the opposite would be the case. In borderline instances it will be necessary to make reasonable ad hoc decisions. Such decisions will, of course, often result in multiple classifications of the same product which later have to be reconciled and made mutually consistent.

418. The further question arises: what is a "single" product? For example, is an electric motor of 5 hp and 110 V the same product as a motor of 5 hp and 125 V or 220 V? Or are two 5 hp 110 V motors the same product if they differ somewhat in design specifications, in response to export requirements to distinct markets? While it is desired to work exclusively with individual,

unaggregated products rather than product classes, reasonably small variations of a design that fit into the continuity of the production process need not be individually distinguished, since this would lead to an intolerable proliferation of distinct product types. In the case of small design variations, a single design can be taken as typical of all variants, provided that this single design is acceptable in all uses. This is, of course, a matter of standardization. If different variants are <u>de facto</u> required due to prescribed performance characteristcs or institutional constraints, then the question is still left open if these variants are sufficiently close to each other so that they can be produced essentially as a single series. Thus, let us suppose that a product is produced in a seriality of 10,000 items, 5,000 of variant A and 5,000 of variant B; and that the production process is automatic and requires no more than a five-minute readjustment of a machine between the two half-series, each of which runs for many hours or days: then it would certainly be justified to treat the two variants as belonging to a single series. Nevertheless, how long, how drastic and how costly can the readjustments between variants become before we decide that we are no longer dealing with a single series? This again becomes a question of common-sense decision-making that can be verified and for which exact criteria can be furnished only after the analysis has been completed and it has become known how sensitive the results are to the readjustment costs. As a preliminary rule of thumb it is suggested that variants be treated as forming a single series if intermediate readjustments do not raise the costs of the entire series by more than 5-10 per cent.

419. In preparing product lists for a particular country it is essential to keep in mind that the list should include not only domestic production but also imports (since the items on the latter list are required for the study of import substitution possibilities) and potential exports. The best way of checking whether a potential-export list is reasonably complete is to use the corresponding production and import lists of large advanced countries like the United States as a source of reference. Of course such lists cannot be procured as a part of the country studies, but an effort will have to be made to make them available to the country-study groups. An additional source of such reference lists is the universe of published norms of centrally planned economies. Collections of industrial standards are also useful sources of reference.

420. Product decomposition into subassemblies and components. This decomposition must not be confused with decomposition into resource-element input levels, which it precedes. As indicated in the previous section, subassemblies and components characteristic of the branch are included in the listing of products of the branch. The decomposition at this stage is concentrated on the establishment of an input list and need not be carried beyond the order-of-magnitude level, that is beyond a 0,1,2 flagging of items as negligible, significant, and dominant. At the same time provision can easily be made for the recording of any incidental quantitative information that may be turned up as by-product.

421. Product decomposition into sub-products can, of course, lead to several hierarchical levels. There are two main classes of inputs that are distinguished in the course of these decompositions. These are subassemblies and components produced within the metalworking sector, and other purchased items originating outside the sector. In the course of a questionnaire inquiry, purchased items of domestic or imported origin can, in addition, easily be distinguished.

422. Product-destination analysis. Using the broad definition of "products" that covers subassemblies and components, the purpose of this task is to list the major destinations of the items produced, that is, major products into which the product in question is an input, or final destinations. By "final destinations" we mean exports or sales to final demand. Domestic sales to other sectors occupy an intermediate position between intra-sectoral sales and sales to final demand. They do not necessarily require the same product-by-product distinction of destinations as sales within the sector, even though it is convenient to have a narrowly defined destination if the information is available. Generally, however, it is sufficient to specify the inter-sectoral destination by statistical class.

423. Insofar as the captive production of inputs for assembly is concerned, the product-destination analysis yields no new information, but it does add significantly to the available data in regard to subcontracting and commercial transfers of products within the sector. Product-destination analysis complements and furnishes a cross-check on product decomposition into sub-products. This is particularly important in view of the fact that both the product-input and product-destination lists are open-ended; in other words, the categories

of the analusis are established as information is gathered, rather than data being poured into a pre-designed classification.

424. Further decomposition into primary resource inputs. Products, broadly interpreted as above, must next be decomposed into required input levels of production processes. At the level of generality represented by Table V-1 these are referred to as resources.[3] In order to aid in this decomposition, the preliminary list of resources given in the form of the rows of Table V-1 is a suitable starting point, but this list is to be regarded as flexible in that additional resources may be listed as inputs, or the existing classification may be relaxed in ways calculated to improve the description of input categories. The decomposition is again to be of the order-of-magnitude kind, that is, flagging inputs by a 0,1,2 system, with provision made for capturing more accurate quantitative information if available.

425. A question arises in this decomposition that refers back to the earlier question of decomposition into sub-products. Under what conditions is a subassembly or a component to be broken out for treatment as an individually listed product, and under what conditions is it to be treated as an implicit part of a whole product that is directly decomposed into resource inputs? For example, a condenser may be treated as a part of a refrigerator, and its resource inputs may thus be merged into other resource inputs such as stampings, castings or forgings given for the refrigerator as a whole, or the condenser, the motor, the compressor and so on may severally or individually be treated as listed products in their own right and may thus be decomposed into resources one by one. A general criterion for separate listing is the sharing of a subassembly among several end-products which permits raising the seriality of the shared item. Minor mass-produced components such as nuts and bolts, however, are not listed individually but are treated as outputs from a special class of resources (upsettings).

426. Resource-destination analysis. This task is similar to product-destination analysis its purpose is to list, first, the major products to which the output of the resource element is transferred as a required input, and second, possible final destinations of the same output. The list of destinations is again open-ended in order to permit organization of the information into classes that are significant from the point of view of the production activities themselves, rather than the data being forced into the

mold of preconceived classification. Matching input lists (resource inputs into given individual products) against output lists derived from the present destination analysis (individual products that serve as destinations for the outputs of given resources) leads to the final cross-tabulation that is the objective of the present stage of the work.

427. Reconciliation of input and output listings. This task must be undertaken both in regard to resources, as just noted, and in regard to products that are inputs to other products. The present task, however, differs in two regards from conventional input-output analysis. First, the classification is open-ended: thus the output categories may not match the product classes by which inputs are organized, and the input categories may not match the resource element and product classes by which the destinations are orgazed. If the two kinds of information (namely the input information that is conventionally organized into columns, and the output information that is conventionally organized into rows) are condensed into a single table, inconsistencies and overlappings will frequently occur that must be resolved by reclassifying both rows and columns into classes that cover all activities and resources without overlap. Secondly, at this stage the information is largely of a 0-1-2 order-of-magnitude character that is useful in arriving at a classification but forms only the initial stage of quantitative programming.

428. Preselection of attractive lines of development. While the cross-tabulation of inputs and outputs by order of magnitude is a quite primitive tool, it nevertheless opens the possibility for powerful practical applications, provided it is understood that its limits of error are broad and that only preliminary guidelines are to be expected at this stage. What can be confidently hoped for is a delineation of the main directions of potential progress for the sector as a whole.

429. A further caveat is in order. Future potentialities can never be predicted solely on the basis of current status or even of historical trends, because the essence of the growth process is structural change. This principle applies with particular force in the metalworking sector where predictions must necessarily rely on a careful study of combinations of alternatives, many of which have not been practiced in the past or current workings of the sector. Thus, no cross-tabulation derived from a country study is

sufficient, in and of itself, for predictions; however, it can be complemented by data organized in a similar fashion that are taken from up-to-date engineering practice or the experience of more developed countries, and this expanded tabulation can then be used as a planning tool.

430. The use of this tool for the pre-selection of attractive lines of development requires the following tasks: (a) expansion of the data base, as indicated above, (b) compilation of a resource-element inventory, and (c) matching the expansion of production against resource element additions.

431. Expansion of the data base. As indicated, for inherent reasons this task cannot be based on the historical data of the country in which the study is to be undertaken nevertheless, to a limited extent, outside data can and should be collected in this country proper. In every enterprise there is some knowledge, at times even considerable knowledge, of the technology of potential activities that are under consideration for future expansion, moreover, technical specialists working either in domestic production activities or available for limited periods as visiting experts have a fund of additional knowledge that can be fruitfully applied to the planning task if only such knowledge is systematically recorded and compiled. In other words, there are definite ways in which a country study can raise itself above the limitations of local historical data. These ways must be kept ever present while the questionnaire survey is being organized.

432. It is of course highly beneficial whenever possible to make systematic provision for infusing into the country study additional outside data taken from the practice of more advanced countries, as a means of enriching the data base. In the course of the subsequent phase of the present project there will be an opportunity for such an infusion from at least two sources, namely, data based on United States practice, and the interchange of data between the country studies themselves (within the limits imposed by the possible confidential nature of these data). The latter interchange is expected to be beneficial, since each country has some relatively advanced industries within the metalworking sector.

433. Resource inventory. In order to be meaningful for inventory purposes, resources must be subclassified by main seriality classes (unit and small-scale, medium, large-scale, mass production) and by ranges of workpiece weights; that is, the inventory must be conducted in terms of standard tasks.[4]

Given a list of standard tasks, however, it is possible to construct an approximate resource inventory without incurring the tremendous complexities and effort attendant upon a detailed census of productive facilities. This inventory should have the following key features:

(i) It should establish in a qualitative way whether a given resource is present in the country or not.

(ii) It should establish in a semiquantitative way whether a given resource is represented by just one or a few instances, or whether it is available in larger numbers. This is crucial for deciding whether the combined capacity of the given resource can be expanded only in large discontinuous steps or whether, within tolerable limits of error, this capacity can be regarded as a continuous variable.

(iii) It should establish in a 0-1-2 order-of-magnitude fashion the extent of available capacity reserves for each resource, both on a conventional shift-load basis and on the basis of continuous year-round 24-hour operation.

434. In compiling the inventory both captive facilities and facilities working for delivery outside the plant should be taken into account. The purpose of the resource inventory is to provide an overview of the available productive facilities within the country.

435. Exactly what is to be regarded as a resource for the purpose of the inventory will surely lead to a great many ambiguities of detail, since existing production departments or shops will never coincide perfectly with the process definitions, seriality ranges, and weight ranges adopted for typical, but necessarily hypothetical, standard tasks. Thus in spite of the fact that there is a great degree of flexibility in the conceptual transition from the standard task to the standard shop[5] allowing for different degrees of mechanization and other sources of variation in the embodiment of standard tasks in concrete production facilities, there will be difficulties in assigning given production facilities even to standard-task categories. If, for example, the range of weights handled in a standard forge is between 100 and 1000 kg and a given existing forge has a range of 20 to 400 kg, where should it be classed? If it were necessary to take an exact census, problems such as this would be almost insoluble, but for the purposes of an approximate inventory, great simplifications are entirely tolerable. The forge cited as an illustrative example may, accordingly, be classed in the 100-1000 kg resource-element class and, in addition, also in the next-lower weight class. Qualitative annotations may accompany the numerical data collected to call attention to similar adjustments; these can later be taken

into account in the practical application of the information.

436. Among the various resources the organizational resources (design, research and development, marketing, production scheduling, administration)[6] require particular attention, and information concerning these must by all means be sought in the questionnaire survey. These resources play an important role even at the semiquantitative orientation stage of planning since it appears that much of the information pertaining to them cannot be adequately further quantified in any event, and therefore much of their influence on planning decisions will be exercised at the (semiquantitative) orientation stage. Should this influence not be adequately exerted at this stage, the further quantification of the inputs of other resource elements describing physical processes cannot decisively improve the over-all quality of the resulting planning decisions.

437. Matching the expansion of production against resource additions. This task constitutes the key practical application of the information compiled during the orientation stage.

438. The expansion of existing production by adding new products or product lines generally requires new kinds of resources. This qualitative expansion of the resource element inventory can accordingly be readily predicted on the basis of the information made available at the orientation stage. A convenient way of organizing the search for attractive product additions is to match the column of resource-element inputs for a given product against the existing resource-element inventory that is concensed into a single column. A row-by-row comparison of the two columns will immediately call attention to needed process inputs that are not available in the inventory.[7] In this fashion, it is possible to work out additions of new products by integrated groups in such a way that each group should require one or few new resource elements of the same kind. This approach will automatically raise the degree of utilization of new capacity, since it brings together lines of production that jointly draw upon this new capacity. These lines of production, of course, must be assured of domestic or export markets, otherwise the entire exercise would be futile.

439. Expanded production not only requires qualitatively new resources but also increases the load upon existing capacity. The problems created by this can be handled in a semiquantitative fashion by forming a column of 0,1,2

indicators of the reserve capacities of resources on the basis of the information contained in the inventory. When matching the columns of resource inputs into the products whose outputs are to be expanded against the reserve-capacity column, a row-by-row comparison will indicate whether the additional requirements for pre-existing kinds of resources meet ample, some, or no reserve capacity. Since the inventory of reserve capacities is to be compiled both at conventional and at round-the-clock shift loadings, the implied expansion requirements can be semiquantitatively appraised for both conditions. The attraction of this approach is that it signals the availability of capacity reserves in the sector that may exist outside the plant of an enterprise contemplating expansion this approach thus calls attention to the possibility of subcontracting arrangements. These offer the double advantage of raising capacity utilization (this improves the capital/output ratio of the sector) and expanding domestic production without new investments. In the instances when resource bottlenecks are signalled even after taking into account subconstracting possibilities, the needed additions can be appraised in relation to all products that might be able to draw on this expanded capacity, thus attention need not be restricted to the products which are being considered for addition within the same enterprise.

440. Finally, the above semiquantitative appraisal of expansion requirements also calls attention to the continuous or discontinuous nature of the resulting cost increases, from the point of view of the sector as a whole. If expansion requirements occur in regard to resources that are already present in significant numbers of units, the addition can well be regarded as continuous in nature, and the costs of capacity expansion can be charged against the capacity-using products on the basis of a simple accounting of average costs. If, on the other hand, the expansion requirements occur in regard to a resource element that is either new or present in only one or a very few units, the investment represents a discontinuous jump in costs. In the latter case it is essential to group the capacity-using product lines in such a way that there shall be an approximate match between the capacity to be newly created and the total demand for this new capacity. In estimating this match, it has to be taken into account that demand typically shows a steady annual increase, whereas production facilities can be expanded only in jumps; thus the plan involving such production facilities must be worked out explicitly over a number of future years. This kind of planning will typically involve

gradually shifting proportions between domestic and export marketings whose disadvantages must be offset against the alternative of serious capacity underutilization problems in the initial years following the large discontinuous expansion. At the orientation stage a semiquantitative evaluation of these aspects of a sectoral expansion plan is entirely adequate. In this sense, even an approximate awareness of the main problem areas, such as can be imparted by the information assembled during the orientation stage, can be of great benefit in planning the main directions of future expansion within the sector.

Quantification

441. In undertaking the country studies, the orientation stage is followed by the quantification stage in which the technical-economic description of the sector is improved from an order-of-magnitude characterization to a numerical estimate of the principal input requirements and other programming data. Even at this stage, however, the margin of error is likely to be wide. It is hoped that individual errors can be held to about 20 per cent, but this is by no means assured. This is not a particularly respectable standard in comparison, for example, with econometric studies, but even so it is a difficult goal to achieve, given the grave data problems, the problems introduced by the modular nature of resource elements, and other obstacles that must be overcome in dealing with the metalworking sector. In sum, the objective of the quantification stage is to arrive at a numerical characterization of the sector within a first approximation.

442. The problems of quantification will be discussed in three parts: (a) determination of standard input structure, (b) local adaptation and (c) trial programmes. While the rigorous application of programming techniques forms a part of a subsequent third main stage that is not discussed in the present paper, the technical-economic description at the quantification stage can again be used for obtaining a second panoramic look at the sector as a whole, more detailed than the first one afforded by the semiquantitative orientation stage.

443. "Standard input structure" is taken to refer to a specification of resource (metalworking process) inputs without the identification of seriality or exact weight of workpiece in the definition of resource classes. In other words, at this stage of the quantification task it is sufficient to give an

input in terms such as: "X tons of steel castings per ton of Hercules gasoline engine". The productive resource for steel castings need not be serialized (i.e., "medium" or "mass" seriality) and need not be subclassified by range of weight of workpiece handled (i.e., 100-1000 kg).

444. This general way of referring to input resources permits the description of an input structure that is independent of the seriality determined by local demand conditions, and also independent of the distribution of the weights of workpieces that also depends on local demand condition. Local adaptation of resources to demand conditions will thus involve the selection of the seriality and workpiece-weight ranges on which the specific resource elements are focussed; that is, the seriality and weights classification of resource elements can be adopted in such a way that the individual seriality and weight classes are centred on the most frequently occurring serialities and workpiece weights. In addition local adaptation will also involve questions of capital/labour substitution and questions of scale.

445. Standard input structures for given products can be transferred far more readily between countries than locally adapted descriptions in terms of resource elements. Thus it will be possible to interchange data between the United States project group and the country-study groups in Israel and Hungary, a division of labour can be worked out and data from different countries can be compared and utilized for mutual checking purposes.

446. Determination of standard input structure. The tasks to be undertaken under this heading can be covered very briefly by reference to previous discussion. The main tasks are: (a) choice of typical products[8] in each branch, (b) decomposition of typical products into intermediate-product and resource inputs (c) preparation of "long lists", and (d) parametric transfer of inputs of typical products to listed products.

(a) Choice of typical products. The objective is to cover a branch by a sufficiently wide range of typical products to assure that there will be some typical product (or products) similar to any product on the "long list". For most branches, it is assumed, ten to fifteen typical products should suffice, and in some cases the number might be even lower. The typical products may be complete end-products or they may be intermediate products such as subassemblies or components.

The orientation provided by the semiquantitative work preceding the quantification stage should be of great help in choosing typical products, since it gives an overview of the scope and development potentialities of each branch. The choice of typical products should be undertaken with particular attention to products that have favourable development prospects.

(b) Decomposition of typical products into intermediate-product and resource inputs. In executing this task two main questions arise. First, what inputs should be carried as individually distinguished intermediate products and what inputs should be given directly in terms of resource (process) inputs? Second, what should be the resource categories in terms of which the decompositions are given?

The first question has been discussed earlier.[9] The decision is not particularly critical in any one case. If there is an ambiguity, there is no objection to including two alternate decompositions, one incorporating more intermediate-product input detail, the other going directly to the resource inputs.

The choice of resource categories is, however, fundamental to the success of the approach. It is for this precise reason that a final decision on this matter is withheld until the detailed consideration of questions of local adaptation. The resource classes used at the present stage can be taken over from the semiquantitative work. While the present input estimates are quantified, in one respect they remain more general than the semiquantitative information, since the resource inventory undertaken for the latter could not avoid at least approximate seriality and weight distinctions. There is no need to adopt these distinctions when deriving a standard input structure.

(c) Preparation of long lists. The work of listing the most important products of a branch is essentially identical at the stages of orientation and quantification. Lists can be taken over from the preceding semiquantitative work; at most they will require some complementation. It is held desirable to cover some 85-90 per cent of the volume of total demand (including demand generated by exports) by listed products. To this end, it is anticipated, the lists will contain from 100 to 200 items.

(d) Parametric transfer of inputs of typical products to listed products. This question is discussed at length in Chapter IV. The present task is simplified by omitting seriality and weight-class corrections. In the simplest case the inputs of a typical product on a per-ton basis can be taken over unchanged for characterizing a listed product that is taken to be similar to the former; if more accuracy is desired, use can be made of some simple correlating parameter or rule-of-thumb estimating factor. Examples of such parametric correlations are given for the decomposition of electric motors of different horsepower ratings in Chapter IV.

447. Local adaptation. The main aspects of local adaptation have been presented above. The tasks involved comprise: (a) determination of yearly demand for each listed product, (b) adoption of subclassifications for resources by seriality and weights class; (c) specification of resource elements by labour intensity, scale, and other locally adapted features; and (d) revision of standard input structure for listed products on the basis of seriality and weight corrections.

(a) Determination of yearly demands for listed products. Much of the required information is identical with data previously collected at the orientation (semiquantitative) stage and will probably require only some complementation. The main problem is passing from total existing demand (sum of domestic production plus imports) to the scale of domestic production. This step requires a decision on what to manufacture versus what to import, and also a correct anticipation of export markets. In the course of programming these decisions follow from the logic of the model itself; the problem at present, however, is that undertaking the technical-economic description itself requires a knowledge of seriality in domestic production which in turn requires import substitution and export estimates; these, finally, depend on cost considerations that cannot be quantified without a previous technical-economic description. The way out of this circularity is either a comprehensive programming formulation (which will not be discussed in the present report) or a trial-and-error procedure based on a preliminary estimate of production, imports and exports that will permit the technical-economic description to get under way. Eventually the final estimates must be checked against tentative planning decisions emerging from the analysis. If there is an excessive gap between the final estimates and the calculated results, the procedure must be repeated with revised trial estimates. The quality of the trial estimates is crucial to a rapid convergence of the revisions; this quality can be greatly improved by reference to the results of the semiquantitative (orientation) stage.[10]

(b) Adoption of subclassifications for resources by seriality and weight class. The aim here is to achieve a reasonably efficient readjustment between the seriality and workpiece-weight classes used for classifying inputs and for defining resource elements, and the most heavily represented (model) seriality and workpiece-weight ranges that result from the actual planning decisions within the sector. In other words, the procedure contains a circularity that is handled by trial and error: the subclassification of resources is made to depend on the ultimate productive structure emerging from the planning decisions; yet these planning decisions themselves depend on the concepts (including the resource classes) in terms of which the available choices are described. If the initial classification is reasonable (as it should be on the basis of the preceding orientation stage) a few revisions should produce a consistent set of concepts and decisions.[10]

(c) Specification of resource elements by labour intensity scale and other locally adapted features. This is the point of transition from generilized processing functions in the abstract to concrete hardware and material flows. Resource elements must be specified in terms of their machine-park, associated floor-space, labour inputs, material inputs and all the detailed stock and flow input characteristics. The resource elements of the UNC study[11] furnish a model for this task that necessarily must be undertaken by the country-study groups giving detailed consideration to prevailing local conditions. Some of the problems of local adaptation of resource elements are considered in Chapter IV.

(d) Revision of standard input structure of listed products on the basis of seriality and weight corrections. The details of these corrections have been explored theoretically in Chapter IV.[12] The end result of these corrections is a modified input structure for each listed product expressed in terms of resource-element capacity requirements and material input flow requirements measured in physical units.

448. Trial programmes. Given the technical-economic description in a quantified form, as described above, it is readily feasible to construct simple trial programmes for the sector by fitting together building-blocks of information. This is not programming proper, first, since the procedure is not systematized and there is no attempt of arriving at an optimal solution and second, since there are no iterative revisions between the various components of the trial programme, especially between prices and the scales of production, imports, and exports. Nonetheless, the ability to construct trial programmes even on an exploratory basis is a worth-while step forward

in planning for the sector and offers the promise of immediate returns as soon as a significant body of information has been compiled.

449. The construction of trial programmes, as the local adaptation of the standard input structure, takes its departure from preliminary production, import and export estimates (see section "local adaption" (a) above). Following this starting point, the main tasks in the construction of trial programmes are: (a) the estimation of appropriate social accounting prices for stock (machinery, buildings) and flow (intermediate products, raw materials, primary factors) requirements and for products, (b) the costing-out of selected listed products and (c) comparison of production costs with export and import prices. In addition, the estimation of the anticipated imports and exports of the selected products (already covered in the previous section) plays a key role in constructing trial programmes since it determines serialities and thus the levels of several crucial inputs.

(a) The estimation of social accounting prices. Since the technical-economic description of the sector is undertaken in terms of input requirements expressed in physical units, a set of prices is needed for reaching cost estimates. These may be market prices, administered prices, or specially estimated social accounting prices that summarize the social valuations of factors and commodities.[13] In particular, such prices are needed for all inputs including stock inputs (machines and buildings) and for all outputs including end-products, subassemblies, and components. World market prices are often a useful guide to estimating social accounting prices.

(b) The costing-out of selected listed products. Given a set of prices, input costs can be summed for the production activity of any listed product.

(c) Comparison of production costs with import and export prices. This comparison will indicate that there is a substantial dispersion among production costs for different products per unit of foreign-exchange value of these products. Import substitution and/or exports are indicated for products whose domestic production costs per unit of foreign-exchange value (adjusted for marketing, transport and similar cost items) are less than the social-accounting foreign exchange rate. In this fashion it is possible to identify selected attractive lines of import substitution and exports. A trial programme consisting of these, together with the corresponding domestic production scales, can in turn be checked back against the original import and export assumptions.

450. While subject to a variety of shortcomings, this procedure is adequate for the exploration of trial programmes. At various points, rough approximations must be relied upon which will require considerable elaboration and refinement in the course of the later stage of full-fledged programming.

451. First, there is a question about the proper charges for resource capacity utilization. The charges should, in theory, be either zero whenever there is a slack or the sum of all accumulated back payments when the slack disappears. In practice the resulting price instability is moderated by two considerations: flexibility in capacity utilization, and flexibility obtained via variations in foreign trade.

452. Second, in a complete programming approach there must be a feedback from production, import and export decisions to seriality determinations; these (as pointed out in section "local adaption" above) influence the seriality class into which a given product is classified, and the secondary seriality corrections applied to resource inputs.

453. Third, there must likewise be a feedback on the structure of prices. Thus the social-accounting foreign exchange rate will depend on the production, import and export possibilities of this sector as well as other sectors.

454. Fourth, the decisions about individual products jointly determine the degree of utilization of key resource capacities which in turn feed back on the decision of whether or not to invest in certain resource capacity expansions. So long as these expansions can be handled as though they were continuous, the average costs of capacity can be charged against users otherwise the problem will be complicated by large decreasing costs that require special handling within a programming framework.

455. The need for these elaborations can readily be pointed out, but they cannot be undertaken within the limits of the present study. It is anticipated that there will be an opportunity to tackle them explicitly during the following phase of the broader project.

B. Techniques of executing country studies

456. The objective of the present section is to discuss the working tools and procedures by means of which the tasks and activities described in the

previous section can be put into practice in the course of the country studies. This will comprise the discussion of: (a) the statistical groundwork for country studies; (b) questionnaires and (c) the effectiveness of questionnaire surveys.

Statistical groundwork

457. Prior to the collection of any information from primary sources it is convenient to survey the metalworking sector as a whole by compiling and reconciling such secondary statistical information as might be available from various governmental and private sources. Foremost among these is an industrial census, if it is of recent date, the results of any sample surveys of domestic production and series on imports and exports.

458. Reconciliation of standard statistics. Since the classification system used for domestic industries is likely to be different from the one used in international trade statistics, the first task is to reconcile these classification systems and to get consistent production, import, and export series. Based on past experience this is a considerable task in itself unless a similar pre-existing effort can be turned to good use by the project. This task will not be discussed further, since the techniques it requires are well known: it is a matter of establishing cross-correspondences between conflicting classifications and using clerical assistance to reclassify the mass of data accordingly. For the future planning of the sector it is a great convenience to set up, at the outset if possible, an information system for handling statistical data that is capable of furnishing not only standard statistical output but also the reconciled production-import-export series. Using elementary computerized data-processing techniques, such a task is easy to accomplish at near-zero marginal cost for the reconciled data.

459. Breakdown of statistical categories. The above task is, however, only a starting point for the breakdown of statistical categories into finer detail, as required for programming purposes. The programming task is undertaken through listed products[2] which ideally represent individual engineering designs free of statistical aggregation. (In practice, several product variants may be treated as a single series under certain conditions, as discussed above.) Statistical categories very seldom coincide with individual listed products as here defined; in fact, compiling the list of the most

important products is itself a considerable task. Once lists are available, statistical totals characterizing a branch must be allocated between the items on the list plus a residual.

460. List compilation. Sources for the compilation of the required products lists by branches of the sector are the following:

(a) Engineering and manufacturing standards, both domestic and foreign. Within a census category, such as "Electric motors, 5-15 hp", such standards often establish the required product list, since horsepower rating and other performance characteristics such as voltage or kind of current vary in discrete steps. For each combination of standard ratings there can still be some design variation, but the intention is to handle most of this source of variation by reliance on typical designs and by subsuming minor changes of production under a single series, as explained earlier.

(b) Outside information supplied as an aid to the country study. Lists established for the United States, if available, are useful sources of reference; likewise, product lists used in the planning practice of countries with centrally planned economies might be useful guides in the preliminary definition of the lists.

(c) Information obtained in the course of the subsequent questionnaire survey. Preliminary lists, from whatever source, are to be refined and double-checked in the course of the questionnaire survey of primary statistical sources that follows the tasks of initial statistical orientation. Thus the statistical groundwork overlaps to some extent with the tasks that follow. The stages of the work are, of course, not as sharply separable in practice as they are in a discussion such as this.

461. Allocation of statistical totals between list items. This task must be undertaken separately for domestic production, imports, and exports. For domestic production the best sources are marketing organizations, large manufacturers who provide sizable fractions of the total supply, and large buyers. For imports, not only importers but also large domestic users and possibly exporters in the main supplying countries are potential sources of information. For exports, domestic manufacturers, export firms and possibly large importers in the foreign markets may provide useful data. All of these sources should be complemented by the store of information that accumulates in various government organizations concerned in one way or another with the regulation or supervision of these industries or having commercial relations with them.

462. It should be noted that the kind of data sought here is not primary statistical information, despite the fact that much of it must be collected from sources usually relied upon for primary data. At this stage of the over-all task what is wanted is the best estimate, or even guess, that a selected source can furnish in regard to the quantitative distribution of a given market between individual listed products. Any businessman will usually have an excellent approximate idea of the over-all status of a market in which he participates; his estimate to this effect, then, is a secondary statistical source whose use is proper if its wide margin of error is recognized. This source, of course, has a completely different standing from statistical data collected directly from all sellers and from which market percentages can be established. At the stage of laying a preliminary statistical groundwork for the questionnaire surveys and the other subsequent tasks of the country studies, the objective is merely to obtain good order-of-magnitude estimates of the phenomena that are to be studied in more detail at a later stage. To this end reliance can be placed upon interviews with selected sources of information that would carry little weight in a more rigorous statistical inquiry. Clearly this approach not only results in a great saving of effort but also has the best chance of bypassing problems connected with confidential business information that would critically hamper any attempt at statistical rigour.

463. <u>Formulation of questionnaires</u>. One key objective of the statistical groundwork is to help in setting up the cross-tabulation of information for the semiquantitative orientation stage of the country studies. It is generally recognized that the more specific a questionnaire is, and the more closely it conforms to the categories of thought in which the informants are accustomed to deal in their day-to-day work, the greater are its chances of success. Thus the statistical groundwork should culminate in the thorough revision of the preliminary questionnaires that are being tentatively outlined at the present time.

464. It is desirable to perform part of the questionnaire survey on a pilot basis for a few selected branches of the sector before a comprehensive effort is initiated. To this end, the help that may be furnished by technical experts in given branches or in given production processes is very considerable and may in fact prove to be critical for success. Such experts, if available, should be drawn into the later phases of the statistical

groundwork, and should be consulted intensively in regard to the survey of technical standards, the preparation of lists, the evaluation of potential sources of information for market breakdowns and the final revision of the questionnaires. The assistance of the same experts can also be of great help in the practical execution of the pilot questionnaire surveys.

Questionnaires

465. Five main types of questionnaire are suggested for the collection of primary information for programming purposes: (a) questionnaire on production inputs, addressed primarily to technical personnel by branch of production, (b) questionnaire on the destination of products, addressed to business or sales managers, by branch of production, (c) questionnaire on prodictive resources, addressed to engineers and managers by type of production process, (d) questionnaire on imports, addressed to importers and major users, and (e) questionnaire on exports, addressed to exporters and major suppliers.

466. It has been found convenient to organize questionnaires as above by function, since the same establishment or enterprise may unite several functions, and thus it would be difficult to evolve standard questionnaires by establishment or enterprise type. In administering the questionnaires, lists of establishments will have to be matched against the above five functions to decide which questionnaire or questionnaires are to be sent to which establishments. In the covering text for the questionnaires, it will have to be pointed out that duplicate questions need be answered but once; alternately, the repetitive parts may be united. These questions of style and presentation may best be left to local decision. In addition, provision will have to be made for offering extensive technical help to the enterprises in answering the questionnaires through personal visits by trained assistants, since no satisfactory response can be expected to a mail survey.

467. Questionnaire on production inputs. The key questions to be included in questionnaire No. 1, apart from identifying information, are the following:

(a) List the products, subassemblies and components manufactured, and yearly amount of each. Treat subassemblies and components separately in all cases where there is an imbalance between successive stages, that is, where there is either a net surplus of a subassembly or component (outside sales) or a net dificit (wholly or partly purchased item). In the absence of such an imbalance, define a reasonable hierarchy of subassemblies and components for individual listing, in keeping with industry practice.

(b) For each product, subassembly, or component listed, give the following input structure:

(i) Amounts or 0-1-2 orders of magnitude of lower-order subassemblies or components required as inputs. Specify if the input is a product of the metalworking sector, also specify if the input is of imported, domestic or mixed origin. In the latter case, give percentage of imports.

(ii) Amounts or 0-1-2 orders of magnitude of inputs of major resources. As a guide, the questionnaire should furnish a reference list of resources but it should also permit showing other resources as inputs (that is, the process-input structure should be open ended).

(iii) Where the resource inputs do not imply it directly, give also the inputs of metals, if possible, both on a gross and a net basis. (Gross input is the amount of metal needed to start the manufacturing process, net input is the amount actually incorporated in the product after losses.)

(iv) List additional products, subassemblies and components that could be manufactured either with the existing production facilities or with specified additions.

(v) For each item of the list under d., give input structure on the same basis as under b., to the extent that information is available.

468. These questionnaires are to be addressed primarily to engineers and other technical personnel by branches of production. In order to test the questionnaires prepared under the above guidelines, it would be highly desirable to apply them in a limited number of pilot cases with the assistance of experts familiar with the respective branches of production. In order to make these questionnaires more effective, open-ended lists of products, subassemblies and components should also be furnished branch by branch, to call attention to the main resource classes. The assistance of experts, as pointed out earlier, can be of crucial importance to further adapting the questionnaires to specific branches. Such experts can also help in improving the answers under point e. above.

469. <u>Questionnaire on the destination of products</u>. While questionnaire No. 1, discussed above, requests primarily technical, input-type information and is accordingly addressed to technically trained personnel, the present questionnaire No. 2 is designed to gather data related to markets and is often

more properly addressed to business or sales managers, again by branches of production.

470. The key questions are the following:

(a) Same as for questionnaire No. 1.

(b) For each product, subassembly, or component listed, give the following market-type information:

(i) Principal destinations of the output, by other products into which it is a required input, or by final destination. For each market, give percentage share or 0-1-2 order-of-magnitude indication.

(ii) For each market as above, specify if it is a domestic, export or mixed market. In the latter case, give percentages or 0-1-2 order of magnitude.

(iii) For each market as above, characterize the degree of stability or variability.

(iv) For each market as above, indicate the basis for estimating future growth, both in the short and long runs.

(c) List potential future domestic and export markets.

(d) Indicate the extent of potential markets, in absolute terms, if possible, or otherwise on a 0-1-2 order-of-magnitude basis. An open-ended reference list of markets by branch would be exceedingly helpful in answering these questionnaires.

471. Questionnaire on production processes. Questionnaire No. 3 is addressed both to managers and to engineering personnel associated with the operation of production processes (productive resources). The key questions are the following:

(a) Using a reference list of resources[14] as a guide, specify which resources are present in the establishment. Indicate whether the given resource classification is a convenient way of representing the productive processes of the establishment and comment on its fit or lack of fit to the actual productive structure. If necessary, define resources in a different way from that given in the reference list and answer subsequent questions in terms of the latter definitions.

(b) For each resource included in the inventory give the following input-type information (at capacity and/or at other specified levels of operation) that refers to the concrete embodiment of the productive process in an actual resource element:[3]

(i) machine-park and building floor-space;

(ii) metal inputs;

(iii) labour inputs classified by skill levels and auxiliary material flow inputs.

(c) For each resource element give the following capacity-type information:

(i) Total capacity on conventional shift basis. Specify number of shifts, total yearly working hours.

(ii) Average and peak-capacity utilization; capacity reserve either quantitatively or on a 0-1-2 basis, both for the conventional number of shifts and for round-the-clock operation.

(iii) Capacity variation with average seriality of outputs, and variation of capacity as deviations from this average seriality occur. What physical input changes determine the latter variations of capacity?

(iv) Capacity variations in response to other typical production conditions such as average weight or average complexity of part produced.

(v) Capacity variations in response to deviation from typical output. Specify characteristics of current output and effects of deviations on physical inputs that determine capacity. What are the bottleneck capacities at present? How would this change if production assortment were changed?

(vi) What other potential output could be produced with currently available capacity?

(d) For each resource element give the following market-type information:

(i) Principal destinations of the output, but products into which it is an input or by final destinations. For each destination, specify percentage share or 0-1-2 order of magnitude.

(ii) For each destination specify if it is domestic, export, or mixed. In latter case give percentage shares or 0-1-2 orders of magnitude.

(iii) List potential future markets for the output of this resource element.

(e) For each resource element, specify variation of input structure if resource element were smaller or larger than it actually is. The purpose of this query is to probe for economies of scale in response to the variation of the yearly capacity of resource elements.

(f) For each resource element, discuss qualitatively the relationship of existing operations to best current international practice. Discuss in relation to degree of automation, obsolescence of machine-park or any other relevant factors.

(g) For each resource element, discuss potential expansions or additions. What is the role of current bottleneck capacity in defining the cost of such additions? How would over-all capacity respond?

It would be of great benefit to have the assistance of technical experts in the final revision of these questionnaires, and particularly in their adaptation to distinct production processes.

472. Questionnaire on imports. Questionnaire No. 4, to be addressed to importers and large users, should contain the following key questions:

(a) List products, subassemblies, and components imported, and quantity of each.

(b) Principal destination of each import, by product into which it is an input or by final destination.

(c) Basis for estimating the growth of each import, both in the short and long runs.

(d) Potential future imports and estimated quantities or 0-1-2 orders of magnitude of each.

473. Questionnaire on exports. Questionnaire No. 5, to be addressed to exporters and large suppliers, should contain the following key questions:

(a) List products, subassemblies and components exported and quantity of each.

(b) Principal markets for each export, by percentage or 0-1-2 order of magnitude.

(c) Basis for estimating the growth of each export, both in the short and long runs.

(d) Potential future exports and estimated quantities or 0-1-2 orders of magnitude of each.

The effectiveness of questionnaire surveys

474. There is a considerable uncertainty about how effective the proposed questionnaires will be in gathering information needed for planning decisions within the sector. In order to ensure the attainment of minimum objectives the questionnaires have been aimed at capturing semiquantitative information whenever fully quantified data might not be obtained. The questions should, however, be directed at the collection of all quantitative information that might be forthcoming.

475. Mail surveys, as indicated above, are essentially valueless. Useful results cannot be expected from them without the investment of considerable effort in the testing of pilot questionnaires and the training of technical information gatherers whose task it would be to assist the informants in answering the questionnaires in a meaningful and reasonably uniform way.

476. For maximum effectiveness the questionnaire survey should be carefully fitted together with the technical work to be undertaken in connexion with the country studies, especially the decomposition of typical products. Most of the information for these decompositions will have to be derived by means of specific technical studies undertaken by engineers or experts associated with the staffs of the country studies.[15]

477. It is expected that the interchange of experience between the staffs of the country studies and of the continuing project in the United States will lead to a rapid improvement in the effectiveness of data-gathering methods and will permit a gradual improvement of planning decisions based on the programmes and other background information developed in the course of the country studies. An early test of these data and methods in the actual planning decisions of developing countries is the target at which the efforts of the country studies are to be aimed in the next phase of the broader project.

Notes for Chapter VI

[1] The only available list of precisely defined resource elements at present is the one included in the University of North Carolina study (UNC, op. cit., see Chapter I, note (2). Other than this, there is only the list of rows of the resource/activity table of Chapter V (Table V-1). These rows are referred to in Chapter V as resources.

[2] In the resource/activity table of Chapter V (Table V-1) information concerning products is organized into corresponding production activities into which resources (and possibly subassemblies and components) enter as inputs. Since there is, however, a close correspondence between a listing of these activities used for describing a branch of the sector and the long list defined in Chapter IV, it is legitimate to extend the concept of the long list and of listed products to data gathered at the semiquantitative level.

[3] The relationship of the resource concept both to resource elements and to standard tasks is classified in Chapter V, section B-1.

[4] See Chapter IV for a definition of standard tasks and a discussion of their relationship to resource elements. See Chapter V for a discussion of the relationship of both of the above concepts to the less precisely delimited resource concept.

[5] "Standard shop" is used here as an exact synonym of "resource element".

[6] "Organizational standard tasks" have been defined in Chapter IV. Organizational resources are taken here to correspond to these in the same way as standard tasks in general correspond to the resources defined in Chapter V.

[7] Some short-cut procedures for manipulating the semiquantitative data are discussed in Chapter V.

[8] For a definition of the concepts used in this section, refer to Chapter IV.

[9] What is to be regarded an intermediate product and what an end-product has been discussed in section A - 1-a-(i) of this chapter.

[10] The question is raised in Chapter III whether there is any assurance that such iterations converge to a global rather than a merely local optimum. The answer was that in general they need not do so. An exact analysis of this question requires a programming formulation that admits alternative production and trade strategies as explicit choices in the search for an optimal programme. Once this is done, data analysis can show whether large nonconvexities do or do not play a critical role in the programme, and the potential error of the procedure can be bounded.

[11] See Chapter I, note (3).

[12] See also the previous discussion of the orientation stage, in section A-1.

[13] Standard references on the theory and estimation of social accounting prices are the following. H.B. Chenery, in "Development policy and programs", Economic Bulletin for Latin America. United Nations, Vol.III, No.1, March 1958, defines a "social marginal productivity" concept, illustrates its uses in programming and gives a history of the development of the concept. References cited include A.E. Kahn, "Investment Criteria in Development Programs", Quarterly Journal of Economics, February 1951, pp.38-61; H.B. Chenery, "The application of investment criteria", id., February 1953; J. Tinbergen, The design of development, 1956, Chapter III. "The fallacy of using simpler criteria such as capital/labour or labour/output ratios is shown in the first two articles. The use of long-run equilibrium prices for labour and foreign exchange was suggested in the last two. A good summary of the case for using "accounting prices" is given by J. Tinbergen, pp.23-25. (Chenery, 1958, *op. cit.*, p.64.) The rationale of using social accounting prices in planning, with an empirical approximation method, is given in Chenery, "The role of industrialization in development programs" (   ), *op.cit.*, note (35), Chapter II. The same concepts are further developed and translated into simple terms for practical programming purposes in United Nations Economic Commission for Asia and the Far East, "Formulating industrial development programmes" (1961), *op. cit.*, Chapter III, note (2).

[14] As discussed under "Resource inventory" in section A, part 1-b-ii, for inventory purposes resources must be subclassified by seriality and weight of workpiece handled.

[15] Some of the techniques for undertaking decompositions have been discussed in Chapter IV.

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