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

METALWORKING INDUSTRIES AS POTENTIAL EXPORT INDUSTRIES

presented by the secretariat of UNIDO

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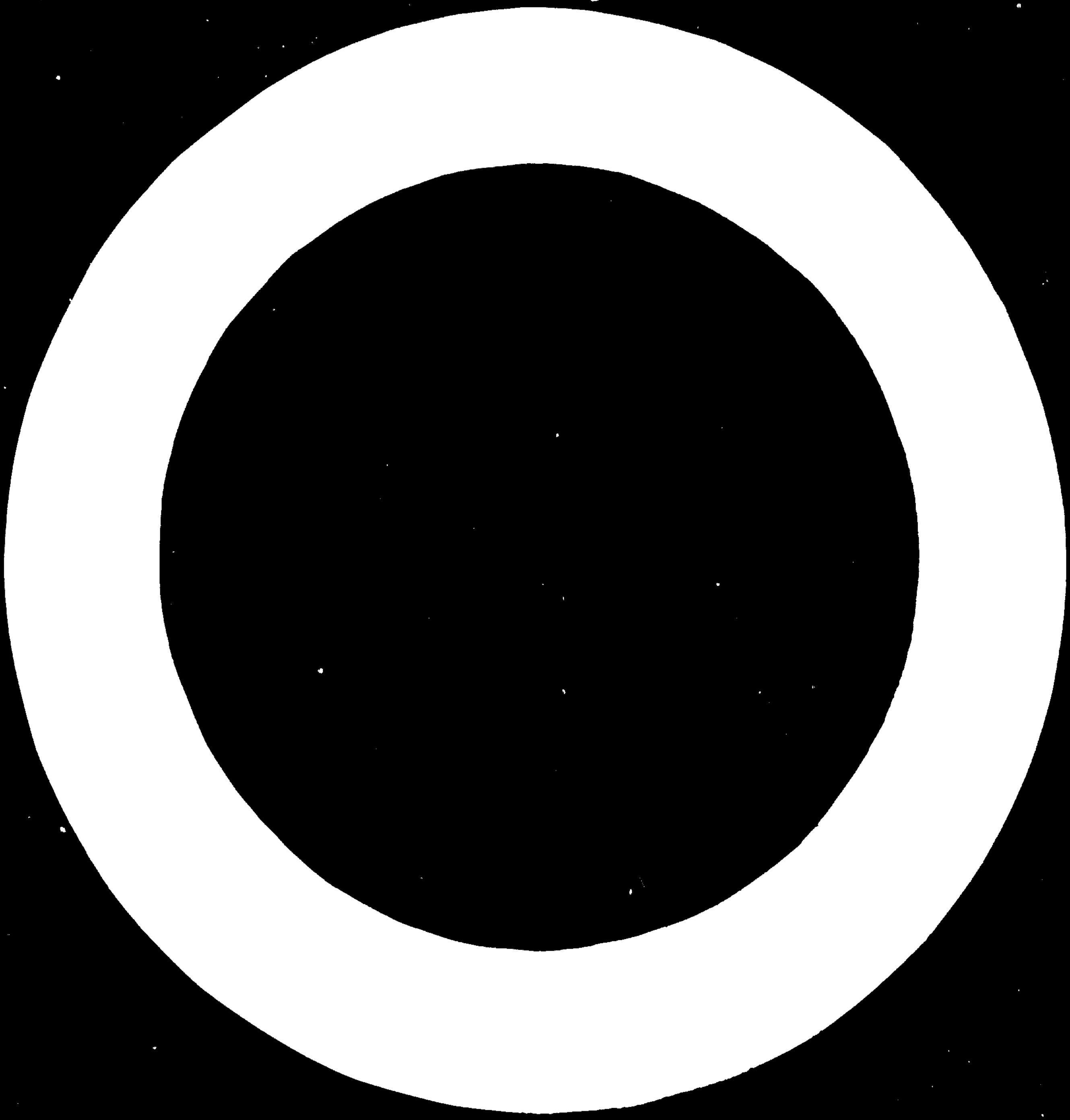

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Purpose of the project

1. The present project is part of a broader effort undertaken by the United Nations Industrial Development Organization to promote the growth of new and dynamic export industries in developing nations. The project aims to improve the techniques of production and export planning in the metalworking-engineering products sector. For the purposes of this project, the sector is defined as including major groups 35 through 39 (metal products, non-electrical and electric machinery, transport equipment, and miscellaneous manufacturing industries) of the International Standard Industrial Classification.

2. In particular, the efforts of the project are focused on the objective of providing policymakers with tools that will help to decide:

(1) what kinds of investments are economical in new or expanded productive resources;

(2) what branches of production, and within these branches what kinds of product assortments should receive the main emphasis;

(3) taking into account the potentialities of the world market, what exports deserve serious promotion efforts.

3. This paper is largely a summary of a report prepared for UNIDO at the Centre for Economic Planning of the New School for Social Research under the title "The Planning of Production and Exports in the Metalworking Industries". The director of the Centre, Thomas Vietorisz, has kindly given permission for his paper to be quoted liberally with this rather informal acknowledgement. The methodology presented in this summary was developed by Vietorisz at the Centre.

Requirements of a suitable planning methodology

4. What is required as a matter of first priority is a planning approach that will yield an approximate but essentially correct overview of the sector as a whole, in order to allow precisely the type of panoramic orientation that is missing today. As long as this defect continues, no amount of conscientious compilation of detail will resolve the doubt whether the sector as a whole is moving in the right direction. In line with the objectives of the present project, such a direction must strike a middle course between the extremes of insufficient and underutilized capacities, between uneconomical diversification and overspecialization, and between undue risks in producing for the open world market and excessive rigidities in commitments to long-term trade agreements.

5. The definition of a successful planning methodology presupposes: an adequate technical-economic description of the sector that nonetheless manages to avoid the danger of drowning in detail; and 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.

6. These two points are of course closely interrelated because it is not possible to cut across the welter of technical data unless there already exists an awareness of the type of detail that will play a key role in the course of programming; yet at the same time, 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.

7. 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 empirically explored).

8. Semi-quantitative programming data. These aim primarily to define lists of products and productive processes, and to establish incidences between these two, i.e., specifying whether a given productive process is used or not in the manufacture of an individual product. This kind of information can be assembled rapidly and at low cost, and in spite of its elementary nature it has a surprising range of planning applications. The power 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 notes 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, i.e. machining or heat treatment.

9. Fully quantified programming data. These aim to specify 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 undertaking approximate estimates of production costs on a comparable basis for products that are candidates for import substitution or exports. This requires, first of all, the decomposition of products into sub-assemblies and components; subsequently these have to be related to basic production processes such as machining or assembly. The endless variety of product design is represented by a restricted number of typical products; the limitless range of alternative production facilities is, in turn, reduced to combinations of standardized modules referred to as "resource elements". Together, these concepts permit a quantification of the technical-economic description of the sector.

10. Project-engineering data. These aim to provide the concrete level of analysis preparatory to the final go-ahead decision in plan execution. The three-fold classification corresponds closely to the one employed in general for project evaluation and sectoral-level planning within the United Nations and elsewhere. Data have been collected for this study on a pilot basis both at the semi-quantitative and fully quantified levels, leaving aside the third level of concrete project engineering as lying wholly outside the adopted terms of reference. Programming strategies are currently being explored at both the semi-quantitative and fully quantified levels of analysis.

Part one

KEY FEATURES OF METHODOLOGY

I. Problems

11. In order to provide a methodology for planning the metalworking sector, it is necessary to pose the problems that characterize metalworking operations in general. The three chief sources of difficulties in the technico-economic description of the sector are:

> The diversity of production facilities and products. The analyst of the metalworking sector is confronted with several thousand machine tools and several hundred thousand final products. Estimates indicate that there are over 1,500 metalcutting machine tools and that a fairly well developed metalworking sector for a country of ten million population and US$ 400 per capita income produces about 250,000 products. Since the machine tools may be ordered in almost any pattern for a producing facility, the possible number of production shapes is astronomical.
>
> The multi-purpose nature of productive facilities. Machinery in the metalworking sector characteristically has the capability of producing a wide range of products. Lathes, foundries, forges, etc., may not be tied to producing a single product or branch of products. Most frequently, they are employed in producing components for a wide variety of products. True, they may be specialized, but this frequently requires not more than the addition of jigs or fixtures.
>
> Decreasing costs in production. These are found in two guises in the metalworking sector. Firstly, costs decrease with the annual capacity of a facility. Secondly, and independently of annual capacity, costs decrease with the seriality (lot size) of production. As a result, there frequently exists a sharp lower limit to feasible seriality or annual capacity. This presents great difficulties for any programming procedure.

II. Key concepts

12. The two major problems that have to be overcome are the great diversity of products and machinery.

13. Product clusters. The vast majority of analyses in this sector concentrate on the feasibility of producing one or more products from the same industrial branch. What is overlooked are the interrelationships of products within and across branches when considered from the standpoint of the processes required to manufacture them. As a result, neither annual demand nor seriality is sufficient to bring about production at competitive prices. The aim of product clustering is to make these interrelationships explicit so that they may be taken into account from the viewpoint of annual capacity for a process across the whole sector, and that the possibilities for standardization of components and modules may be explored.

14. Products are clustered about resources through the use of an input-output format in which the information is at first at the semi-quantitative level (and therefore low-cost) and then clusters are further defined by the addition of quantitative information within an expanded format. In the expanded version, information on product sub-assemblies and components is also added. In this way, the interbranch similarities between products make it feasible to sum demand for a process across the whole sector.

15. Resource clusters. These are similar to the product clusters defined above. A resource represents a process requirement to manufacture a given product. A resource cluster denotes that group of resources, and their relative importance, required to manufacture a product cluster.

16. Resource elements. To overcome the diversity and multi-purpose nature of metalworking machinery, typical shops such as a casting shop, a forge, or a machine shop can be identified and classed as resource elements. The advantage of this concept is that it avoids the problem of keeping track of individual machines - an impossible task. However, the exact definition of these shops (which includes annual capacity, maximum size of workpiece, average seriality and possibly the degree of precision) requires a machine part. It is proposed that the machine part for a resource element be predicated upon reaching competitive international cost levels in an export-oriented economy.

17. The resource elements are defined by standard tasks such as the machining of a workpiece that weighs 10 to 100 kilograms, with a seriality of 250 to 1000. The purpose of these resource elements is to quantify costs of production in an approximate manner. That is, resource elements represent typical shops rather than any given actual shop. Although this will result in some distortion of costs, the relations between costs for given products will hold true. From this stage, it is considerably simpler to choose products for full engineering studies.

18. The resource element concept also serves to incorporate decreasing returns to scale in its own definition. Seriality is implicit. A significant change in product seriality is then handled as a move from one resource element to another of higher average seriality. Resource elements are employed at the fully quantified level of technical economic description along with fully quantified product clusters.

III. Orientation to exports

19. Decreasing costs in production require a planning approach that takes into account the potentialities for exports in the metalworking sector. The key to the problem lies in the difference between an analysis that concentrates only on one product or small group of products and a sectoral analysis that inter-relates data over both productive resources and products.

20. Firstly, decreasing costs due to the scale of yearly output can only be captured when products, in the sense of final products, sub-assemblies and components are summed across the entire sector so that the scale of operations for a given productive resource may be raised. In order to undertake this analysis, the productive process and the final product must be divorced. One of the main areas of discontent with the present mode of feasibility analysis in the sector is the continued dependence of the plant format on the range of final products under consideration. The tangible result of this dependence is the presence in many developing nations of underutilized capacity. When facilities are captive with respect to a limited number of products, and modern equipment is employed, demand is frequently insufficient to fully utilize the installed capacity. Where capacity utilization is extremely low or tariff protection relatively high, the cost structure will not reflect potential

production in the sector. In general, these high costs will persist as long as productive facilities are captive with respect to products. Even import substitution is not advanced to the margin under this system.

21. The initial divorcement of production processes and products does away with the aforementioned dependence. The decomposition of products into sub-assemblies and components and the linkage of this decomposition with processes allows for a clearer idea of the possible size range of machinery, opens the way for subcontracting to producers specializing in one or more processes, and provides a further [illegible] the sector. The immediate effect of this will be to lower the costs of production [illegible] and [illegible] the scale of yearly outputs [illegible] producers. The lowering of costs should [illegible] potential exports into clearer focus, as well as making present exports more competitive.

22. Secondly, decreasing costs due to seriality (lot size) require a fundamental orientation to exports from the start. Again, with limited domestic demand, seriality is liable to be insufficient for the economical use of special purpose equipment. This immediate disadvantage can be offset in two ways. The first is an increase in lot size resulting from standardization. At present, with facilities organized around products, the scope for greater seriality is limited; the only hope here can be standardization across branches which can only be achieved when products are organized around processes. While the increasing use of standardized components eventually presents difficulties for product design, there will frequently be ample room for a sufficient amount of standardization to lower costs of production for a wide range of products. Here again, lower costs will have a salutary effect on export potential.

23. For a number of products both decreasing costs due to the scale of yearly output and increased seriality through standardization of sub-assemblies and components will be insufficient to warrant their production for the domestic market. It is concerning these products that there is the greatest amount of difficulty. What is offered in this study is a way of going about making the routine decisions regarding products that are initially feasible to produce and a separation of the more difficult problems so that decisions regarding this second group can be made in the full light of their economic implications. It is felt that many of the more important products from the viewpoint of industrial development will have to be produced under conditions where exports are a necessity in order to increase seriality. However, the rationalization of

production should provide a more favourable climate for export promotion.

24. The close relationship between domestic production and exports in this sector is further underlined by the following institutional considerations. Both domestic and foreign purchasers can be expected to show a degree of distrust with regard to such things as the expected quality, performance, reliability of continuing service and spare parts supply of new product lines. With respect to domestic consumption, the high quality and performance required for export products should go far in convincing prospective purchasers to buy locally. At the same time, foreign purchasers are understandably reluctant to commit themselves to a source of supply that has not been proven out by the practical test of acceptance within the home market.

Part two

PLANNING METHODOLOGY

25. The elements of the planning process discussed below consist of a series of successive approximations, with additional information added at each step. In this sense, each step is a self-contained unit designed to yield data appropriate to the next step by defining the areas of maximum interest to planners. The planning procedure falls into two distinct areas: (1) technical description of the sector; and (2) economic description of the present manufacturing and demand structure. The analysis of these two areas should proceed concurrently, so that they may be both ready for the final step of syntheses. The order of discussion is technical description of the sector followed by economic description.

I. Technical description of the sector by semi-quantitative methods

26. The semi-quantitative level of technical-economic description is a level of general orientation and of the initial formation of concepts and classifications for the subsequent more detailed (fully quantified) work. The logic of this level is thus the logic of the initial organization of an information system, and will be introduced as such below.

A. General considerations

27. The most distinguished texts in the field of mathematical programming and resource allocation are those expounding 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.

28. 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 those texts represented as practical and filled with examples, start, of necessity, with a given set of facts that are limited.

29. In short, we are deluded. The whole business of programming, as it finds its way into print, takes up in the middle of the job. 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 die-cutting are pre-ordained. We are committed to a set of definitions and a problem structure that inexorably lead to a given result; we are not to know, because the authors do not tell us, how the fundamental first commitment was made. There are no handbooks on how to start.

30. Yet the essence of the programming problem lies not in crank-turning, although the importance of that ability is enormous, but in problem-formulation and definition. It is the purpose of this section to look at the fundamental problem of starting a programming analysis, with special reference to the metal-working industries in developing nations.

Basic classification and combinatorial problems

31. To see the distinction between the pre-set problems and the text-book case, consider first three sets of symbols, or three fundamental classification groups, as defined by the programming procedure: (1) a set of possible resources, which may or may not now be available to us, but which represent potentially useful tools, materials, and skills; (2) 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 (3) a final listing of possible formulas for evaluating success.

32. 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 alteration or reorganization of one (or more) of these lists will alter the results of the programming effort. Moreover, the way in which the three major lists described 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.

33. A short physical example should convince the reader of this all-important confrontation. 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 any bulb, or group of bulbs, may be lit (or not) 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 on this board is 2^{400} or approximately 10^{120}. No artist could ever draw all of these possibilities, no investigator could ever try or see all of them; and even the fastest computer, showing the patterns automatically, could ever complete the entire combinatorial show. 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^{75}.

34. Yet, the crude sign board is a simple affair when compared to the patterns, or combinations, of, say 1,000 resource elements that 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: how many different households could be constructed from the products listed in the widely distributed Sears-Roebuck catalogue?

35. 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

36. 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.

37. In the case of an economy, we may simplify the resource element list, or at least its range, by considering only one industry, say metalworking, leaving the other industries for later. This implies a similar constraint on the activities listing, and possibly on the list of objectives too.

38. 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:

(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. Further, the elemental names chosen should be sufficiently general so that they are universally understood in various 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.

39. 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 not be transferable or clearly understood, nor stable as technology and practice change. Shops, moreover, would not be mutually exclusive in their capability or makeup; they would vary from place to place, and would not be known to an information source without extensive cross-reference.

40. Although a discussion of the type above could be continued, not much more argument would be needed to suggest a hierarchy of resource element description that has the required characteristics.

B. Description of the sector by semi-quantitative programming data

Hierarchy of description of production facilities

41. 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, e.g., metal removal versus metal forming. In outline form, if "metal-working 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 texts.

42. 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. Further, 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.

Summarizing, the hierarchy of classification would appear as:

I. metalworking processes

A. metal removal

(1) turning

(a) hand lathes

(i) Warney & Swasey Model XXXX

43. 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.

44. A two-level hierarchy of listings of productive facilities is shown in table 1 as rows to the left.

45. This two-level hierarchical classification is closely related to the concepts of standard task and resource element but it does not coincide with either 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 down to a specific machine park that defines a resource element. As compared with standard tasks, the rows of table 1 show two main differences:

46. (a) The weight class of output handled is not specified, but is left implicit. Since information concerning the over-all 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 standard task classification by weight until considerably more data are collected on typical products in many branches of the sector. Thus, semi-quantitative data organization facilitates the definition of proper standard task categories for subsequent fully-quantified empirical work.

47. (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 of (a) above apply analogously to this case.

48. In order to avoid confusion with either the standard task or the resource element concepts, the rows of table 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 1 are then processes (or processing functions) used to characterize production facilities at a rather high level of generality within the hierarchical classification.

49. 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 the Dewey Decimal System used in libraries and the Standard Industrial Classifications used in government statistics - its specific extension to the organization of preliminary programming data has not been widely exploited, if at all. The advantages of such an approach 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.

50. At the same time the hierarchical approach exhibits here, as elsewhere, some well-recognized shortcomings. Foremost among these is the ambiguity of classification when there are several classifactory criteria that give rise to mutually inconsistent classifications. In the present case these shortcomings are not significant at the level of generality represented by table 1. At a more detailed level a different kind of problem arises, in that there will not usually exist a one-to-one correspondence between processing functions and productive facilities. Thus it is true that (in the illustrative hierarchy presented above) a lathe of a given model may be required for performing a given turning operation, but if the workpiece is heavy there will also be a requirement for hoists or other materials handling equipment. 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.

51. 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 1.

Some special problems in activity classification

52. 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.

53. This is so, because designers of products have exploited the principle of combinatorial variety by using many combinations of production processes, and many combinations of common parts to product from a small list of resources a cornucopia of end-products, which could be considered activities.

54. This result poses at least two major problems for the investigator: he must find a way to group products and thereby reduce the number of activities to a reasonable number, and 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.

55. One approach to this two-fold problem is via the route used in specific manufacturing practice, that is, 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 have mastered it such as the automotive industry in the United States of America. Most firms pay for lack of such detailed organization by increases of in-process inventories, work halts, and similar disturbances, and, indeed, the cost of such detailed planning is often justified only by extremely high seriality in a competitive economy.

56. The techniques of decomposition are discussed below in 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 initially described. Even with unlimited financial resources, time would remain, and technology would change faster than a truly exhaustive decomposition study could be completed. In other words, the analyst comes to the stone wall of the basic theorem of planning and control: The inputs and corrections made to a process must be at least as swift and as numerous as the variations and changes to be controlled, or he is forced to [illegible].

57 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 several-stage or sequential approach to programming.

58. If the over-all aspect of planning that has to 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 ... on a consistent basis.

59. The subsequent discussion describes how this principle can be applied to the metalworking field in particular.

The semi-quantitative resource activity matrix and its virtues

60. Many of the problems of resource listings 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, what is initially done to construct a crude table of resources vs. activities is not wasted, but rather serves as a guide to further investigation.

61. Because of the great commonality in the components of finished products, however, it is difficult to isolate categories of products that cleanly produce 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.

62. The matrix of table 1 suggests a mechanical route to the desired classification and partition of activities. If a large sample of products can be obtained quickly and cheaply - one which shows the detailed checklist of resources needed to produce them - 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, which will be useful for planning. Moreover, we can by these means, scan only those products that have some immediate interest, should an extensive sample be beyond our resources. (We will temporarily consider both finished end-items and components as activities, and so show both as columns in table 1.)

63. (a) Base 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 1 by a "1" for a needed resource, a blank for an unused resource, in the manufacture of each product), we are able to 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.

64. In table 1, the checklist aspect of display provides two semi-quantitative

guides to activity importance - as well as a check of need. A number "2" is inserted for processes that 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, difficulty of assembly and test operations, or export requirements. 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.

65. (b) 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).

66. For this purpose, consider the much-simplified resource/activity matrix, often called an incidence matrix, or binary matrix, shown as figure I. (for simplicity, we temporarily drop the criticality designation, and technical notes as shown in table 1).

Table 1

Listing of resources

The following is an initial listing of resources for orientation purposes. This list is currently being expanded. The tables (part a) through (part i) of table 2 present semi-quantative data.

1000 METAL FORMING
1100 Forge, free (8)
1120 Forge, die (2)
1130 Forge, mixed free/die (1)
1200 Casting, iron (6)
1205 sand
1210 mold
1220 Casting, malleable (1)
1230 Casting, steel (3)
1235 sand
1240 mould
1250 Casting, non-ferrous (3)
1255 sand
1260 mould
1265 die
1270 Casting, precision (1)
1275 mould
1280 die
1290 Casting, all others
1300 Upsetting (fasteners, etc.)
1300 Extrusion (tubes, shapes)
1500 Roll (tube, shapes)
1600 Draw (tube, wire)
1700 Press, draw (tubes, etc.)
1710 Press, coin (emboss, etc.)
1720 Press, bend (brake)
1800 Wind (motors, transformers, etc.)

2000	METAL REMOVAL
2100	Turn (lathe)
2200	Bore (drill)
2210	Ream
2300	Grind
2400	Mill
2410	Shape (plane)
2500	Broach
2600	Tap (inside thread by die)
2610	Thread (outside thread by die)
3000	METAL CUTTING
3100	Press shear
3200	Press punch
3300	Saw
3400	Torch
3900	Other cutting operations
4000	HEAT TREAT OPERATIONS
4100	Furnace
4200	Induction
4300	Quench
4900	Other heat treat operations
5000	FASTENING OPERATIONS
5100	Self-tap screws
5110	Nuts/bolts
5120	Rivets
5130	Special fasteners
5200	Weld, spot (short-run)
5210	Weld, spot (long-run)
5220	Weld, continuous
5300	Cold flow
5310	Force fit
5320	Braze (silver solder)
5340	Solder

5400 Designed (catch, interlock, plug)

5500 Glue

5900 Other fastening operations

6000 <u>FINISHING OPERATIONS</u>

6100 Tumble

6110 Straighten

6120 Finish grind

6130 Brush and polish

6200 Dip (to clean, prime)

6210 Dip (to finish)

6300 Spray, paint (short run)

6310 Spray, paint (auto line)

6320 Spray, vitreous enamel (short run)

6330 Spray, vitreous enamel (auto line)

6390 Spray, other finishes than above

6400 Electroplate

6500 Laminate

6600 Chemical finishes (anodize, etc.)

6950 Other finishing methods

7000 <u>FINAL ASSEMBLY AND PACK</u>

7100 Hand (short run, no pace, light)

7110 Hand (unit and short, no pace, heavy)

7120 Hand (long run paced)

7200 Semi-automatic

7300 Fully automatic

7400 Standard performance test

7410 Standard performance test (auto)

7420 Critical test needed (see note)

7430 Critical adjustment needed (see note)

7440 Critical assembly equipment needed (see note)

7500 Hand pack (short run, no pace, light)

7510 Hand pack (unit and short run, no pace, heavy)

7520	Semi-automatic pack
7530	Fully automatic pack
8000	MATERIAL HANDLING
8050	Manual
8060	Manual (simple wheels and skids)
8100	Cranes (overhead)
8200	Conveyors (manual)
8210	Conveyors (automatic)
8300	Trucks (lift, pallets, bins, etc.)
8310	Trucks (on rails)
8400	Elevators
8500	Transfer machine
8900	Other material handling
9000	PURCHASED ITEMS
9100	Electrical motors
9110	Electrical controls (simple)
9120	Electrical controls (complex)
9130	Electrical controls (very complex)
9190	Electrical supplies other
9500	SERVICE FUNCTIONS
9510	Laboratory (quality)
9520	Laboratory (design)
9530	Maintenance (critical)
9540	Inventory level (critical)
9550	Production sequence (critical)
9560	Sub-assembly co-ordination (critical)
9570	Tool and die-making
9580	Jigs and fixtures
9900	General design and specification

Table 2 (part a)

No.	Resource	(5) SMALL MOTOR (INT. COMB.) 3 H P.-LONG RUN	(24) OUTBOARD MOTOR 3.5 H.P.	(31) 16" CHAIN SAW	(38) PORTABLE SEWING MACHINE	(3) PISTON COMPRESSOR 2 CYL 100 P S I MED -SHORT RUN
1000	METAL FORMING					
1120	Forge, die (2)	1	1	1		1
1200	Casting, iron (6)					
1203	sand					1
1250	Casting, non-ferrous (3)					
1265	die	2A	2A	2A	2	1A
1270	Casting, precision (1)				2	
1700	Press, draw (tubes, etc.)	1	1			
1720	Press, bend (brake)	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 TREAT OPERATIONS					
4100	Furnace	1	1	1		
4300	Quench	1	1	1		
5000	FASTENING OPERATIONS					
5110	Nuts/bolts	1	1		1	1

Table 2 (part a)

No.	Resource	(5)	(24)	(31)	(38)	(8)
	Product No.:	(5)	(24)	(31)	(38)	(8)
6000	FINISHING OPERATION					
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 PACK					
7120	Hand (long run prod)			1	1A	
7400	Standard performance test	1	1	1		1
7520	Semi-automatic pack				1	
8000	MATERIAL 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	1C	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 - Cu-Al 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 - Bux plastic parts
Product (8): A - Use H.P. gas motor or 2 H.P. elec. motor no tank assembly

Table 2 (part b)

No.	Resource	(12) ELECTRIC CLOTHES DRYER	(13) ELECTRIC CLOTHES WASHER	(14) 30" GAS KITCHEN RANGE	(4) WATER PUMP (CENT.) SHORT RUN	(3) SINKS AND TUBS FOR WASHING MACHINES
	Product No.:	(12)	(13)	(14)	(4)	(3)
	Commodity:	ELECTRIC CLOTHES DRYER	ELECTRIC CLOTHES WASHER	30" GAS KITCHEN RANGE	WATER PUMP (CENT.) SHORT RUN	SINKS AND TUBS FOR WASHING MACHINES
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 (brake)	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 TREAT OPERATIONS					
4100	Furnace					1B
5000	FASTENING OPERATIONS					
5100	Self-tap 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

Table 2 (part b)

No.	Product No.: Resource	(12)	(13)	(14)	(4)	(3)
7000	FINAL ASSEMBLY AND PACK					
7100	Hand (short run, no pace, light)				1	
7120	Hand (long run paced)	1	1	1		
7400	Standard performance text	1	1			
7500	Hand pack (short run, no pace, light)				1	
7520	Semi-automatic pack	1	1	1		
8000	MATERIAL 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 - By fan blades
Product (13): A - Sequence timer and elect. valves; B - Transmission parts by belts
Product (14): A - By clock; B - Light plug
Product (3): A - Very deep draw; B - Anneal usually in steps

Table 2 (part c)

No.	Resource	(1) REFRIGERATOR 12 CU. FT. LONG RUN	(18) REFRIGERATOR 2 CU. FT.	(2) METAL CABINETS (EXCL. SINKS)	(41) 30 DRAWER STEEL CABINET	(40) DELUXE 11,000 B.T.U. AIR COND.
	Product No.: / **Commodity:**					
1000	METAL FORMING					
1500	Roll (tube, shapes)					2
1700	Press, draw (tubs etc.)	2				
1720	Press, bend (brake)	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 TREAT OPERATIONS					
5000	FASTENING OPERATIONS					
5100	Self-tap 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 PACK					
7120	Hand (long run paced)	1	1	1	1	
7400	Standard performance test	1	1			
7430	Critical adjustment needed (see note)	2A		2A		2A
7440	Critical assembly equipment needed (see note)	1B				
7520	Semi-automatic pack			1	1	
8000	MATERIAL HANDLING					
8210	Conveyors (automatic)	1	1	1	1	

Table 2 (part c)

No.	Resource	Product No.: (1)	(18)	(2)	(41)	(40)
9000	PURCHASED ITEMS					
9100	Electrical motors	1C				1B
9110	Electrical controls (simple)	1				1
9190	Electrical supplies other	1	1A			1
9500	SERVICE FUNCTIONS					
9550	Production sequence (critical)	1				
9560	Sub-assembly co-ordination (critical)	1				
9570	Tool and die making	1		1		1
9580	Jigs and fixtures			2B		

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 - Doors; B - Assembly jigs
Product (40): A - Critical fin assembly. Hot and cold coils sub-assembly; B - By motor compressor unit

Table 2 (part d)

No.	Resource	(9) PRESSURE TANK FOR AIR, WATER	(17) 10" x 10" LIGHT FIXTURE	(15) 20" PORTABLE FAN	(16) 1650 WATT PORTABLE ELEC. HEATER	(11) COMPLETE HOT AIR HEAT, SYSTEM
	Product No.: / **Commodity:**					
1000	METAL FORMING					
1250	Casting, non-ferrous (3)					
1265	Die					1
1500	Roll (tube, shapes)	1		1		2
1700	Press, draw (tubs, etc.)	1				
1750	Press, bend (brake)	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 TREAT OPERATIONS					
5000	FASTENING OPERATIONS					
5100	Self-tap screws		1	1		1
5210	Weld, spot (long run)		1	1	1	1
5220	Weld, continuous	1				1
5400	Designed (catch, interlock 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 PACK					
7100	Hand (short run, no pace, light)					1
7150	Hand (long run paced)			1	1	
7400	Standard performance test			1	1	
7450	Critical test needed (see note)	1A				
7500	Semi-automatic pack			1	1	
8000	MATERIAL HANDLING					
8210	Conveyors (automatic)		1	1	1	
8300	Trucks (lift, pallets, bins, etc.)	1				1

Table 2 (part d)

No.	Resource	Product No.: (9)	(17)	(15)	(16)	(11)
9000	PURCHASED ITEMS					
9100	Electrical motors			1	1	1
9110	Electrical controls (simple)			1A	1A	1
9190	Electrical supplies other		1	1	1B	1A

Notes:

Product (9): A - Leak
Product (17): A - Lamp socket and glass
Product (15): A - Thermostat
Product (16): A - Thermostat and switch; B - Heat element
Product (11): A - Gas valves and controls. Probably by rotary fan unit

Table 2 (part e)

No.	Resource	(23) ALUMINUM BOAT 13.5 FT.	(25) ALUMINUM CAMP UNIT	(20) ALUMINUM SKILLET	(21) ALUMINUM LADDER 16 FT.	(35) DELUXE IRONING BOARD
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.)					
17[illegible]0	Press, bend (brake)		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 TREAT OPERATIONS					
5000	FASTENING OPERATIONS					
5100	Rivets	1	1	1	1	1
5400	Designed catch, interlock, plug)		1A			
6000	FINISHING OPERATIONS					
61	Brush and polish				1	
6[illegible]	Spray, paint (auto line)					1
63[illegible]	Spray, other finishes than above			1A		
7000	FINAL ASSEMBLY AND PACK					
7100	Hand (short run, no pace, light)	1B	1		1	
71[illegible]	Hand (long run paced)					1
7400	Critical test needed (see note)	1A				
7500	Hand pack (short run, no pace, light)		1	1	1	
75[illegible]0	Semi-automatic pack					1
8000	MATERIAL HANDLING					
8[illegible]00	Manual (simple wheels and skids)			1	1	
8200	Conveyors (manual)	1				
8300	Trucks (lift, pallets, bins, etc.)		1			

Table 2 (part e) (cont.)

No.	Resource	Product No.: (23)	(25)	(20)	(21)	(35)
9000	PURCHASED ITEMS					
9500	SERVICE FUNCTIONS					
9580	Jigs and fixtures	1	1			

Notes:

Product (23): A - Leak; B - By foam floats, Wood transom
Product (25): A - By extruded shapes and Cast corners
Product (20): A - Teflon
Product (21): A - Usually purchased

Table 2 (part f)

No.	Resource	(26) 1/2" ELECTRIC DRILL	(29) CONTRACTOR'S WHEEL BARROW	(32) COMPOST MILL 3 H.P.	(33) PORTABLE CEMENT MIXER	(39) CANNISTER VACUUM CLEANER 1 H.P.
1000	METAL FORMING					
1120	Forge, die (2)			1		
1250	Casting, non-ferrous (3)					
1260	Mould	1				
1500	Roll (tube, shapes)				2	
1700	Press, draw (tubs, etc.)		2			2A
1720	Press, bend (brake)		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 TREAT OPERATIONS					
4100	Furnace		1			
5000	FASTENING OPERATIONS					
5100	Self-tap 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

Table 2 (part f) (cont.)

No.	Resource	(26)	(29)	(32)	(33)	(39)
7000	FINAL ASSEMBLY AND PACK					
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 pack	1				1
8000	MATERIAL HANDLING					
8060	Manual (simple wheels and skids)			1		
8200	Conveyors (manual)	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 – By 3 H.P. gas motor and wheels
Product (33): A – By wheels and bearings
Product (39): A – Cited unit uses fibreglass. Other drawn shapes

Table 2 (part g)

No.	Resource	(27) 5" BENCH VISE	(28) HAND SHOVEL	(30) 18" 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, (brake)				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 TREAT 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 PACK					
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 pack		1A			1

Table 2 (part g) (cont.)

No.	Resource	Product No.: (27)	(28)	(30)	(37)	(42)
8000	MATERIAL 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 – By handle
Product (30): A – Magnesium frame; B – By 3 H.P. gas motor
Product (42): A – Broach hex box to nut size

Table 2 (part h)

No.	Resource	(10) CAST IRON STOVE	(19) CAST IRON SKILLET 11 3/4 IN.	(22) SPIRIT DUPLICATOR	(34) 30" BAR STOOL	(36) STAINLESS STEEL FLATWARE
	Product No.:	(10)	(19)	(22)	(34)	(36)
	Commodity:	CAST IRON STOVE	CAST IRON SKILLET 11 3/4 IN.	SPIRIT DUPLICATOR	30" BAR STOOL	STAINLESS STEEL FLATWARE
1000	METAL FORMING					
1200	Casting, iron (6)					
1205	Sand	1	1			
1250	Casting, non-ferrous (3)					
1260	Mould			1A		
1400	Extrusion (tubes, shapes)				2	
1710	Press, coin (emboss, etc.)					2
2000	METAL REMOVAL					
2100	Turn (lathe)			2	1	
2600	Tap (inside thread by die)			1	1	
3000	METAL CUTTING					
3100	Press shear				1	
3300	Saw				1	
4000	HEAT TREATING OPERATIONS					
5000	FASTENING OPERATIONS					
5110	Nuts/bolts	1		1	1	
5220	Weld, continuous				1	
5400	Designed (catch, interlock, plug)				1	
6000	FINISHING OPERATIONS					
6120	Finish grind	1	1A			
6130	Brush and polish					1
6200	Dip (to clean, prime)			1		
6310	Spray, paint (auto line)				1	
6400	Electroplate				1	
7000	FINAL ASSEMBLY AND PACK					
7100	Hand (short run, no pace, light)	1		1		
7120	Hand (long run paced)				1A	
7500	Hand pack (short run, no pace, light)		1	1		
7520	Semi-automatic pack				1	1

Table 2 (part h) (cont.)

No.	Resource	Product No.: (10)	(19)	(22)	(34)	(36)
8000	MATERIAL HANDLING					
8060	Manual (simple wheels and skids)		1			
8200	Conveyors (manual)			1	1	
9000	PURCHASED ITEMS					
9500	SERVICE FUNCTIONS					
9570	Tool and die making					2

Notes:

Product (19): A - Rotary bough
Product (22): A - By rubber rolls, belts, and bearings
Product (34): A - Vinyl seat made separate

Table 2 (part i)

No.	Resource	(6) PLUMBING ELBOW AND TEE MASS. PROD.	(7) PLUMBING SUPPLIES SHORT-MED-.RUN
	Product No.:	(6)	(7)
	Commodity:	PLUMBING ELBOW AND TEE MASS. PROD.	PLUMBING SUPPLIES SHORT-MED-.RUN
1000	METAL FORMING		
1200	Casting, iron (6)		
1210	Mould	2	
1250	Casting, non-ferrous (3)		
1251	Sand		1
2000	METAL REMOVAL		
2200	Bore (drill)	1	
2600	Tap (inside thread by die)	1	
3000	METAL JOINING		
4000	HEAT TREAT OPERATIONS		
5000	FASTENING OPERATIONS		
6000	FINISHING OPERATIONS		
7000	FINAL ASSEMBLY AND PACK		
7500	Hand pack (short run, no pace, light)		1
7520	Semi-automatic pack	1	
8000	MATERIAL HANDLING		
8300	Trucks (lift, pallets, bins, etc.)	1	1
8500	Transfer machine	1	
9000	PURCHASED ITEMS		
9500	SERVICE FUNCTIONS		

67. Using this binary-type matrix, the whole metalworking sector may be scanned and an incidence matrix of several thousand products can be constructed at low cost. The aim of this procedure is to gain a quick overview of the product inter-relationships without being concerned whether important products have been omitted. After the clustering of products and resources (discussed below) additional information regarding criticality is added to further define the clusters.

68. 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.

69. For example, we may now compute an activity/activity or product/product similarity table, as follows. Take each column of figure I and find the number of "matches" between the elements of that column and the other columns of the figure, where a match is defined as an equal cell incidence of "1's". (Mathematically, this corresponds to matrix multiplication of figure I by its transpose, an equivalent table with rows and columns interchanged.) The result, shown as figure II, shows how one product, or activity, is related to another by the number of common resources employed in production.

70. Figure II is read by first noting the numbers on the diagonal, which given the number of self-matches, or the number of "1's" in a given product column. Reading to the right, for any given row, we see the number of resources required for that given product's production, which are also common to other products, e.g. product A required two 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, than products B and C are. This measure is one of many that could be used. It has at least one defect: the illustrated measure does not indicate which products could be made if others can be made; for example, consider the difference between products B and C, given resources land 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.

Figure I

ACTIVITIES

RESOURCES		A	B	C	D	E
	1	1	1		1	1
	2	1		1	1	1
	3		1			1

A resource/activity incidence matrix, showing a list of resources as rows (1, 2, 3 ...) (A, B, C ...). This basic table will be used in the examples to follow.

Figure II

	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

An activity/activity similarity matrix. Interpretation is shown in text.

71. Continuing by analogy, a resource/resource table may be produced, as shown for the example of figure I in figure III. Here we have counted the matches between one row and all other rows of figure I. (Mathematically, this corresponds to multiplication of the transpose of figure I by figure I). 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.

72. Thus, using the concept of similarity matrices, or tables, we may mechanically group, for the initial listing of resources and activities, those which are mutually common, specifically by rearrangement of the rows and columns of table 1 to produce blocks of "1" entries.

73. One method of creating such blocks mechanically is to produce a table, such as figure IV, which reorders the rows and columns of figure I by the similarity sums of figures II and III. Thus, if the numbers computed for the resource/resource matrix of figure II are added, striking a column total for each column; and if the row entries of figure III are added across for each row, striking a row total for each row; and, ifin 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 north-west corner of the new table. The result, figure IV, 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 to the left.

Figure III

	1	2	3	
1	4	3	2	9
2	3		1	8
3	2	1	2	5 ROW TOTALS

A **resoure/resource** similarity matrix. Interpretation is shown in **text.**

Figure IV

	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		

The reordered incidence matrix of resources and activities. The rows and columns are ordered by the total similarity scores shown in Figures II and III.

Figure V

A	B	C	D	E	
2	2	1	2	3	FULL MATRIX
2	1	1	2	2	REDUCED MATRIX

A comparison of resource counts for the complete resource/activity matrix, by activity, versus 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.

74. Other manipulations of this sort may be advanced, given the semi-quantitative data of table 1.

75. (c) Feasibility checks. The semi-quantitative resource/activity matrix may also be used for feasibility checks, and to compute a comparative count if needed, but unavailable resources. Although the index produced is simple, it is informative and permits quick comparison of needed versus available resources.

76. For example, using the simplified resource/activity matrix of figure 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 I is shown in figure V.

77. 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; it assures only 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 a necessary requirement for further refinement and quantification.

78. In the same way a comparison of the scores 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. But again, such a quick comparison with its large possible scan indicates generally which products are likely candidates to be added to the feasible list. In other words, a product that requires only one missing resource may be a more likely candidate than a product for which there are none of the required resources, and one possible ordering is by that deficiency.

Immediate practical uses

79. In short, data collected and presented in a semi-quantitative display such as table 1 provides a master file of large scope that can be construsted 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.

80. 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, that 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.

Further refinement of product classification

81. As larger lists of activities are added to table 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.

82. In viewing the sub-assembly problem, two forms of "treeing" processes are of interest, the first the decision tree, and the other "requirements explosion" tree. See figures VI and VII.

83. The decision tree, shown in figure VI, illustrates the hierarchy of choices in a selection process that leads eventually to a specific design or instance of that class of objects that would satisfy the general objective at the apex of the tree. Thus, if the general objective were to provide humans with 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 way to physically contain and hold 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.

84. The more detailed tree of figure VII, 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 VI, 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 VIII shows the

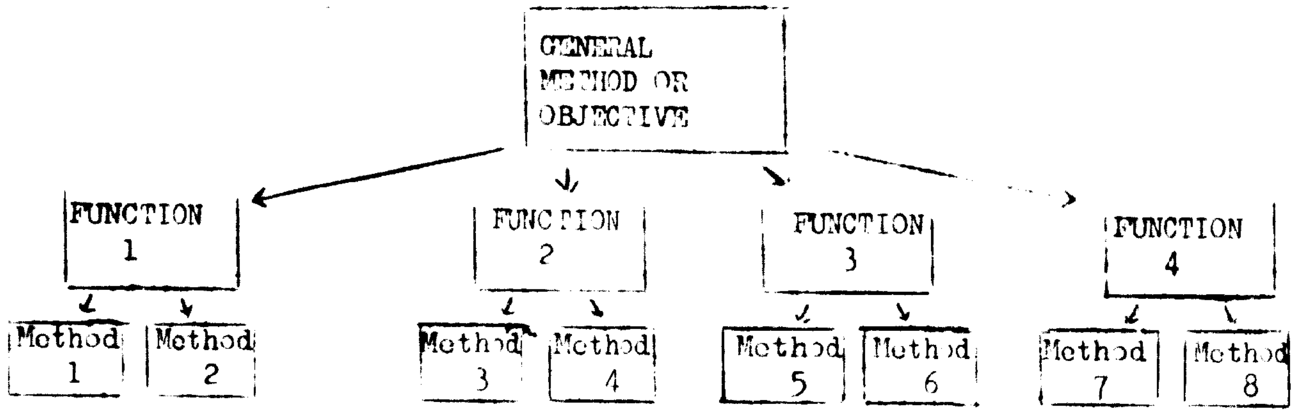
matrix equivalents of the tree of figure VII. When matrix /B/ is multiplied by matrix /A/ (in that order), we have matrix /C/, the parts list for the two end-products. The extension of this computation is shown in figure IX. There the product mix for the final products, 500 and 200 respectively, is converted 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.

85. In terms of our previous discussion, figure I, the resource/activity matrix is more analogous to figure VII than to figure VI, 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 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 1 as activities without distinction.

86. In sum, planning goes forward in two, not necessarily independent stages, as illustrated by the trees of figures VI and VII. However, at the detailed planning level, we lean more towards evaluation of chosen plans, rather than at the comparison of alternatives, so the deterministic, choiceless tree becomes relatively more important.

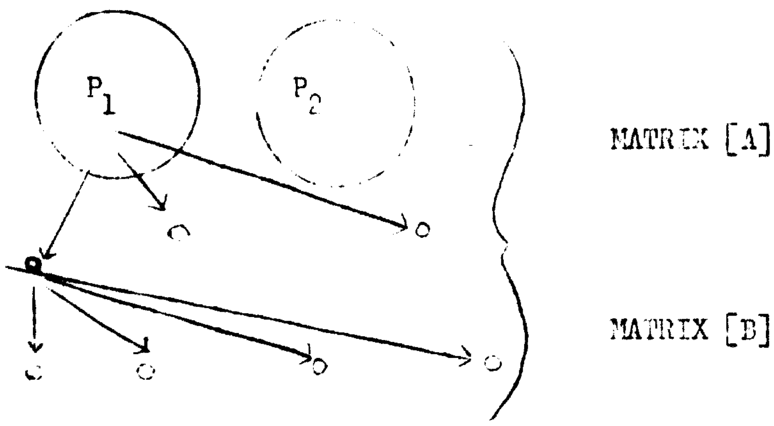
87. Further, if our initial purpose is only to detect the incidence of commonality between resources and possible activities, then the approach of figures VII and VIII permits us to treat the sub-assembly problem as either a series of tables, in which, for example, components would be considered resource inputs into sub-assemblies, and sub-assemblies resource inputs into finished products, or as a table of direct plus indirect inputs, showing the elemental resources going into a given column standing on its own. 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.

Figure VI



A decision or option tree. A general method, or objective is proposed. Acceptance of that proposal requires the [illegible] of given functions, shown in the half-boxes. (Or, in the case of risk situations may require the listed functions.) At the next lower 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 determined the functional requirements.

Figure VII



A deterministic design tree. Two end-products, denoted by P, 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 designs has been made.

Figure VIII

	A	B	C
1	1	4	1
2	2	1	3
3	1	1	0
4	0	2	5

X

	P_1	P_2
A	1	2
B	3	1
C	1	3

=

	P_1	P_2
1	13	9
2	8	14
3	4	3
4	11	17

[B] X [A] [C]

A matrix display of figure VII. 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 manhour resources, etc.

Figure IX

	P_1	P_2
1	13	9
2	8	14
3	4	3
4	11	17

X

	Total Needed
P_1	500
P_2	200

=

	Total Needed
1	8300
2	6800
3	2600
4	8950

Computation of "exploded" requirements by matrix multiplication. Multiplication of the master parts list by the mix of finished items needed produces the elemental parts requirements - which by extension of the same process can be converted into elemental machine, manhour, and materials resources.

88. This explanation should further explain the rationale of table 1, in which sub-assemblies, finished products, and even components have been commingled. In table 1 we have attempted to show a complete incidence checkoff, 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 that can be remedied by construction of higher level tables as desired) the checkoff is complete, and does give the comprehensive scan needed in one table.

89. Thus, even though finished products and sub-assemblies are shown together, product families and inherent similarities by resource element will not be lost.

Introduction of critical process

90. Although the concept of critical process was introduced in the discussion above, (see table 1) it actually comprises the second stage of the planning procedure. After products have been clustered using the binary system, it becomes a relatively simple matter to add the relevant data concerning critical processes. Thus, a number "2" is inserted for a "1" when a process is critical from the standpoint of the following possible criteria; mass seriality, current technology, complexity of product, difficulty of assembly and test operations and export requirements. The aim here is to gain the maximum possible correspondence between products before going on to more detailed work. Processes meriting special attention as potential bottlenecks for a particular product cluster will be evident.

91. This also presents a suitable time to initially decompose products into their constituent sub-assemblies and important components using the same 0,1,2 basis. Clusters are then defined using this new information. Although this may not be necessary for relatively simple products, the sub-assemblies and components of the more complex products will be necessary for the next fully quantified stage.

Process substitution

92. There will be many cases where it is possible to produce a product, sub-assembly or component with several alternative processes. A series of iterations using each process separately may then be carried out. For instance, it may be desirable to move out of machining and into drop-forging. In this case, in those products etc., where drop-forging is an alternative process, the 0,1,2 flagging should be changed from machining to drop-forging. The products will then cluster differently and once demand is known, annual capacity requirements may be calculated.

Link between semi-quantitative and fully quantified data

93. The aim of the semi-quantitative method is to uncover the relationships between products and processes across the whole sector. When this is done and compared with domestic demand, there will be a number of clusters which will be of special interest. The problem then arises as to whether or not these can be produced and at what cost. By use of the methods described above along with a census of the country's machine park, there can be no detailed answer to this problem. It is now necessary to further quantify the product and resource clusters for costing purposes. At first, only those clusters of major importance may be investigated. For products, no problem arises. However, for productive facilities, some standard must be chosen so that the country's machine park may be evaluated on a consistent basis.

II. Technical-economic description by means of fully quantified programming data

94. Fully quantified data, based on a modular description of productive facilities, represents an intermediate position between the two extremes of semi-quantitative data and project engineering data and is intended to be used for costing purposes. 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.

95. The term "fully quantified" must not be taken to mean that the respective data are the ultimate in precision and reliability. The term "rough quantitative" data could also have been used as a description. They are intended to be accurate within a reasonable margin of error (approximately 20 per cent) and to provide the material for a programming model of the sector which will identify the desirable productive facilities for a given domestic demand and export orientation. Feasibility studies, based on these data will be subject to costing errors, and all conclusions arrived at through their use will have to be re-worked for final decision-making by reference to project engineering data. Their purpose is the identification of the proper course of development of the sector as a whole - an area hitherto undefined.

96. The metalworking sector is characterized by the overwhelming use of multi-purpose production facilities. There are, of course, branches of the sector that use special purpose equipment, for example, a can line for making tin cans, machines for making wire products, or machinery for making components of electrical appliances such as television sets. Nonetheless, the essential core of the sector can be well represented by a common set of resource element inputs.

97. Loosely speaking, a multi-purpose resource element can be identified with a shop, such as a casting shop, a forge or a machine shop. The advantage of this concept is that it avoids the need of keeping track of individual machines which would be excessively burdensome.

98. One of the critical 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 hopeless, except perhaps in the large industrialized countries,

to achieve full utilization of such a resource element on the basis of the input requirements of a single industrial branch, such as agricultural equipment or electrical machinery. On the contrary, it is desirable that all the various branches in 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 the ones adapted to handling outsize or heavy work-pieces, and the ones designed for specialized jobs. In sum, since the proper utilization of productive capacity requires the sharing of this capacity between product branches, the planning process for this sector must necessarily cut across branches.

Fully quantified data

99. The technical-economic description of the sector is undertaken with the aid of the following concepts: (1) For the description of resources, standard tasks, and resource elements (standard shops) are defined; and (2) For the description of products and groups of products distinguished by branches of production, typical products, listed products, and extrapolated products are defined.

Resource elements

100. The main purpose of the definition of resource elements (standard shops) is to cut across the diversity of productive resources. Instead of attempting to keep track of thousands of individual kinds of metal-cutting machine tools, machining tasks are grouped into 10-20 standardized classes in accordance with weight of the work-piece, the average seriality (unit, small, medium and large series, and mass production) yearly capacity, raw material (ferrous or non-ferrous) and possibly the degree of precision. One such standard task might be the machining of a work-piece that weighs 10-100 kilograms, with a seriality of 250-1000, but without regard to whether the kind of machining required involved turning, milling, planning, drilling, other metalworking operations or combinations of these. The fundamental issue is the standardization of the tasks; once this is 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

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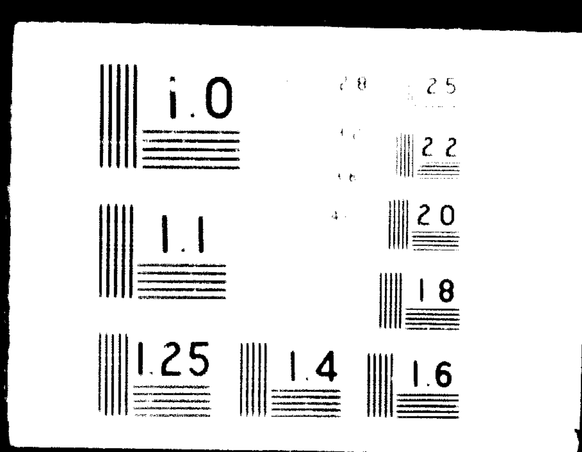

individual machine or equipment classes, but into inputs of standard tasks. Seriality and, therefore, the problem of decreasing costs is implicit in the definition of the resource element. A large change in product seriality requiring a different resource element is handled as a different product.

101. The most important groups of resource elements are foundries sub-classified into cast iron, steel, and non-ferrous; forges comprising both free and die forging; stamping shops, covering diverse cold forming operations; upsetting shops, covering screw machine and related processes; machine shops; welding and boiler shops; heat treating units; and assembly shops. The capacities of these shops and the input requirements may be measured in net standard-shop hours, tons, square feet of assembly area or other suitable physical units.

102. A standard task is performed by a suitably defined standard shop (resource element) with a machine park that is just capable of accomplishing the kinds of metalworking jobs that occur on the average in the flow of standard task units that are channelled to this resource element. By the use of the resource element concept, the labour, equipment and indirect material inputs (tools, lubricants, form sand, etc.) of a product are registered not directly, but via the resource elements, in two distinct phases. The first phase is the determination of the equipment and flow inputs going into the standard shops on the basis of full capacity utilization; the second phase is the decomposition of individual products into net standard-shop hour inputs of different kinds.

103. 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. In particular, as the proportions of capital and labour inputs vary between countries, only the input co-efficients of the first phase will change. This has no effect whatever on the input co-efficients of the second phase.

104. If desired, it is permissible to associate within a 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 to resource elements.

105. In the course of planning the sector, resource elements are balanced with given total demands. The procedure starts with an estimate of total demand; this is translated into net standard-shop-hour inputs (or other capacity measures) by means of a breakdown of the respective products. The comparison of the total of these shop-hours with the lower limits of economical operation for each resource element will immediately clarify the orders of magnitude of potentially reasonable investments in the sector.

106. In some instances, the structure of product demand will indicate only 2 or [illegible] per cent yearly capacity utilization for particular resource elements - usually the heavier and more specialized ones. Economical investment in such resource elements is out of the question. There will also exist certain other resource elements for which the sum of input requirements is a multiple of their yearly capacity; the total scale of operation of these elements can, therefore, within a tolerable margin of error, be regarded as a continuous variable for programming purposes. Finally, there will exist some resource elements whose total input requirements fall between the two extremes; the really difficult combinatorial problem will be restricted to these latter cases.

107. The task of choosing resource elements for detailed examination will be facilitated by the resource clusters derived from semi-quantitative data. That is, an interesting product cluster, or clusters, will have associated with it a number of required resources. These resources, which are generally at a more detailed level than required for fully quantified data, are combined into appropriate resource elements. This type of resource element construction should take place even if the resulting resource elements are not fully quantified. This analysis will enable planners to look carefully at possible requirements for specialized machinery. However, the basic problem here is the cost of fully quantifying from 50 to 150 of these shops.

108. One way to gain some help in this problem is to examine 'best' practice in those developed countries (this is especially true when labour costs are not significantly different from those in developed countries) which are direct

competitors. Existing shops in developed countries can either serve as models to be slightly modified or used 'as is' as resource elements. Still, where the fit due to seriality is limited or other significant technological progress is under way, construction of resource elements will be required.

109. The construction or selection of existing resource elements immediately sets up a standard for the comparison of costs on an international basis with present domestic costs, as well as providing a comparison of desirable machine parks with the existing machine park.

Description of products

110. Although an investigation of all of the one hundred or so branches in the metalworking sector is desirable, a more modest approach, based on examining those semi-quantitative product clusters of prime importance in the domestic economy and several groups of candidate export products will yield significant increases in capacity utilization and a more rational introduction of new facilities. The discussion below concentrates on sector-wide planning, but the same concepts are necessary for a less-than-full-sector orientation.

111. 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 that has to be decomposed into resource-element inputs, as well as direct material (metal), sub-assembly, and components inputs on the basis of detailed engineering information. Since it is desired to distinguish within the sector about one hundred branches, an average of six to ten products per branch will already impose a task of nearly a thousand decompositions. Though 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. The decomposition of typical products will already have been facilitated by the decomposition of product data at the semi-quantitative level into sub-assemblies and components. At this stage the key addition will be information concerning the weights of components, etc., which will allow a further clustering of the data as well as allowing some costing

using various resource elements of different seriality. It is necessary to introduce a note of caution at this point. Neither resource elements nor products can be accurately matched until there is some information concerning the weight and seriality ranges of both. In this sense, there must be development of data both on the resource element and typical product side before the match is made and adjustments will be necessary as more information is processed.

112. 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. The way this works is 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 (e.g., a range of 250-1000 for "medium series") by reference to exact yearly demand (e.g., 850 pieces per year). 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 thoroughly 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.

113. 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 both wihin large enterprises and within national planning organizations. 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.

114. The third concept required for product description is that of extrapolated products. This concept is based on the notion 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 sub-assemblies, 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 easily checked by reference to a few pilot branches. The extrapolated products, then, are the products 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.

115. 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 <u>ex ante</u> are approximately correct or strongly distorted. In the latter case the procedure has to be iterated with revised prices.

Organizational standard tasks

116. Standard tasks associated with the resource elements discussed above which refer to mechanical transformation processes are complemented by the following organizational standard tasks: (a) product design; (b) product engineering and cost control; (c) the planning and programming of production; (d) marketing; (e) technological research and development; and (f) general administration. 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 specialities, draftsmen, computing technicians and office help that can deal with all tasks of product design within a group of products or a branch of production; this is 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 transoformation 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; (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 mechanical-transformation-type resource elements 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 commodities. A mathematically simple case of such joint dependence is a fixed input (embodied for example in research and development work) that creates the possibility of starting up the production of an entire group of commodities.

117. 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 give rise to strongly decreasing costs in production. 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 effectively its quantitative and qualitative requirements, 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. Yet 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 on imported techniques; this, however, results not only in a loss of foreign exchange and in foreign technological dependency, but also deprives the country of the favourable external effects that result from the activities of a continuously operating group of specialists.

118. The above considerations are counterbalanced by the fact that the creation of adequate groups of specialists for the individual branches of production requires such large doses of scarce productive skills 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 either have to 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 else they have to be prepared to suffer the harmful consequences of high costs or low qualities, or both.

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

Country studies

120. The discussion of the technical economic description of the sector (above) has largely been couched in general terms. The key problem then for any country employing this methodology is the transition from general categories to their own specific demand and industrial structure. The procedure for this transition is outlined below.

III. Description of existing metalworking sector

121. The requirements for a country study are presented below in two sections. Section A outlines the principal tasks to be undertaken, comprising a preliminary stage of semi-quantitative orientation on the basis of simple listings of major product and process categories, and a quantification stage. Section B covers the formulation and collection of the statistical material required to execute a country study.

A. Stages of the task

122. The immediate task to be undertaken is orientation with regard to the sector as a whole, followed by quantification for those areas that appear to possess the most likely candidates for actual production.

Orientation: semi-quantitative programming data

123. 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. 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 thus possible to arrive at a cross tabulation of products and inputs. 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. While a considerable amount of semi-quantitative data is being gathered in the United States, it is desirable that any country undertaking analysis of its metalworking sector supplement this material to take local conditions into account.

124. In order to undertake the cross-tabulation of semi-quantitative data, the following materials must be prepared: (a) product listing; (b) product decomposition into sub-assemblies and components; (c) product destination analysis; and (d) process or resource destination analysis.

125. (a) <u>Product listing</u>. This requirement is the same as the 200 or so "listed products" for each branch discussed in relation to fully quantified data. Each product should reflect unique design considerations in the branch, and the list as a whole covers 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, for example, shelves or trays. 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. Product lists for a particular country should include not only domestic production but also imports and potential exports. An initial check on the completeness of the potential export list is to use the corresponding export and import lists of large advanced countries such as the United States as a source of reference.

126. (b) <u>Product decomposition into sub-assemblies and components</u>. 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. There are two main classes of inputs that are distinguished in the course of these decompositions. These are: sub-assemblies and components produced within the metalworking sector; and other purchased items originating outside the sector. Purchased items of domestic or imported origin can be distinguished by questionnaire.

127. (c) <u>Product destination analysis</u>. 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. Final destinations refer to exports or sales to final demand. Domestic sales to other sectors are also delineated but will probably require less precision in the information. In effect, 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 analysis are established as information is gathered, rather than data being poured into a pre-designed classification.

128. The next step is the decomposition of products, in the broad sense, into required input levels of production processes at the level of generality referred to as "resources". Lists of these resources are under construction but should be augmented by local practice. This is the heart of the semi-quantitative analysis and order of magnitude decompositions using the 0,1,2, coding system (as discussed in section I B above) are employed. Provision should be made for capturing more accurate quantitative information if available.

129. (d) 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 is transferred as 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. Matching input lists (resource inputs into given individual products) against output lists derived from the resource destinations analysis leads to the final cross-tabulation that is the objective of the present stage of work. The reconciliation of these two tables will involve the resolution of inconsistencies and overlaps through reclassifying both rows (outputs) and columns (inputs) so that the material may be condensed into a single table.

130. The tasks discussed above may be divided among countries such as Israel, Hungary, and the project staff in the United States so that work will not be duplicated. At present, a list of resources and decomposition of a number of products has been completed in the United States. Additional work on order of magnitude decomposition and further delineation of resources is under way. It is hoped that there will be time to provide a tentative "product" list at least for a number of branches.

131. In addition to the final cross-tabulation table defining the order of magnitude resource-product relationships, an analysis of existing resources and domestic and export demand is required for the pre-selection of attractive lines of development.

132. The resource inventory requirement is the most stringent. In order to be meaningful for inventory purposes, resources have to be sub-classified by main seriality classes (unit, small, medium and large series, and mass production) and by ranges of workpiece weights. In other words, existing capacity must be categorized in terms of the "standard tasks" defined above. Given a list of standard tasks, there will of course be some ambiguous cases, but in the main existing capacity will fall in the weight and seriality classes defined.

133. The inventory can be carried out initially at the semi-quantitative level by indicating whether a given resource exists or not, the relative amount of the resource in existence (the number of resource units) and the present and full capacity utilization of the resource. The last is necessary for the location of reserve capacity. Collection of this data will be discussed below in the section on questionnaires.

134. In addition, data from questionnaires on domestic production, imports, and exports of metalworking sector "products" should be decomposed initially in semi-quantitative fashion. The decomposition material being already in existence from the final cross-tabulation discussed above.

135. This local demand data is compared with the resource inventory to determine new facilities required on a pre-selection basis. The first step is the determination of possible new production using the capacity reserves discussed above. At the same time, it is immediately noticeable to what extent present capacity is being utilized rationally (are small series being produced in resource elements designed for large series, etc.)

136. The expansion of existing production, 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 to organize 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 condensed 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. 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 a 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 must be assured of domestic or export markets, otherwise the entire exercise would be futile.

137. Following this pre-selection criteria, it is possible to narrow down the range of possible alternatives that appear to lead along the path of correct development of the sector. After the alternatives have been developed, full quantification will further limit the number of alternatives to be explored at the project engineering level.

Quantification

138. In this stage the technical-economic description of the sector is improved from an order of magnitude characterization to a numerical estimate of the principal input requirements within a first approximation. The approach to be followed here is basically that outlined in the section (above) dealing with semi-quantitative data. However, several additional points in particular are worth mentioning.

139. The determination of a "standard input structure" will greatly facilitate the international exchange of data. This structure refers 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 Y gasoline engine". Local adaptation of resources to demand conditions will thus involve the selection of the seriality and workpiece weight ranges most frequently occurring within the country.

140. The full quantification of the sector for the purpose of cost estimation involves: (a) choosing typical sample products from the long lists discussed in section 1(a); (b) their decomposition on a weight basis; (c) parametric estimation of listed products from typical sample product data; and (d) local adaptation of this material leading to trial programmes.

(a) The choice of typical sample products will be greatly facilitated by the pre-selection of products already undertaken. To cover the 100 or so branches of the industry would be an onerous task for almost any developing economy. But, the analysis of a smaller number of branches is well within the capacity of a serious effort at planning the metal-working sector.

(b) Although these typical sample products will already have been decomposed in an order of magnitude fashion, it is now necessary to assign more precise weights to each sub-assembly and component. This step is required to obtain the most accurate cost of production information when products are matched with resource elements.

(c) At the same time, the remainder of products within a given chosen branch can be decomposed by use of the parameters developed for the typical sample products.

(d) The local adaptation of the methodology requires as well as the fully quantified data on yearly demand for each listed product, the specification of existing resource elements. That is, resource elements, after being classified into seriality and weight classes, 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. Products are then matched with resource elements on the basis of seriality and weight of workpiece. 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 in physical units.

141. Given the above data, the products may be costed out with a set of prices. These may be market prices or specially estimated social accounting prices, etc. The comparison of product costs with import prices and world market prices will identify attractive lines of import substitution and exports.

B. Development of information for country studies

142. The initial step in executing a country study is the compilation of lists of products, sub-assemblies and components. These together with the list of standard tasks form the basis for gathering empirical information prior to the application of semi-quantitative analysis. It is expected that work under way now will provide a large portion of the product lists and much of the required effort in the semi-quantitative analysis. In addition, a group of questionnaires is being prepared at the United Nations Industrial Development Organization to provide the kind of empirical data required for the analysis discussed above.

143. Five main types of questionnaire are suggested for the collection of primary information for programming purposes: (a) questionnaire on production inputs; (b) questionnaire on the destination of products; (c) questionnaire on productive resources; (d) questionnaire on imports; and (e) questionnaire on exports. The questionnaires are organized by functions since the same establishment or firm may be engaged in several functions making it difficult to evolve standard questionnaires by establishment or firm. Lists of establishments will have to be matched with the questionnaires to decide which questionnaire or questionnaires are to be sent to which establishments. It is expected that technical help in answering the questionnaires will have to be offered to firms as a satisfactory response by mail to the level of detail required will probably not be forthcoming. The key questions to be answered are the following:

(a) Questionnaire on production inputs, addressed primarily to technical personnel by branch of production designed to elicit information on type and yearly production of products, sub-assemblies and components. The format will initially be that of semi-quantitative data.

(b) Questionnaire on the destination of products, addressed to business or sales managers by branch of production. Destinations refer to inputs of sub-assemblies and components into end-products and end-product sales to domestic or export markets.

(c) Questionnaire on productive processes, addressed to engineers and managers by type of production process. Actual machine park, floor-space, metal and labour inputs, capacity (at present and full utilization).

(d) Questionnaire on imports, addressed to importers and major users. A listing of the quantity of products, sub-assemblies and components imported.

(e) Questionnaire on exports, addressed to exporters and major suppliers. A listing of the quantity of products, sub-assemblies and components exported.

144. There will be some duplication in these questionnaires and this of course may be disregarded by those establishments receiving more than one questionnaire. Following this initial orientation, the questionnaires will be repeated to gain fully quantified data for facility planning. The final goal is to gain the necessary information for a fully quantified description of the sector. The process described above will accordingly delimit the areas where this data is needed. The final planning problem of choosing products and new or expanded facilities is discussed below.

145. The final requirement is a forecast of demand for domestic and potential export requirements. The time horizon here should be a minimum of five years and some effort should be made to extend this horizon for more important product groups. This demand estimate is to serve initially as a guide in the choice of appropriate resource elements and should be considered flexible for the following reasons:

(a) Addition of new resource elements will expand production capabilities and therefore lower costs;

(b) Analysis of relative international costs will bring forth a number of possible export products which will further lower domestic prices; and,

(c) Over-all expansion of the sector will create its own demand for new products.

146. The demand estimate must take into account the interindustry demands for intermediate products, demand for replacement purposes, such as subassemblies and components, and demand for final products.

IV. Completion of analysis

147. The problems here are two-fold. The first concerns the general direction that the sector as a whole should take while the second requires that specific advice be given on upgrading the present machine park and establishment of new facilities.

A. Resource elements versus existing machine park

148. The first requirement is a comparison of projected demand, the cost levels of the resource elements derived from developed countries or constructed and those of the existing machine park. Where costs are the same, there is no problem. Where costs are significantly different, it must be determined whether it is possible to upgrade the existing facility or it is necessary to establish a new one. The results of these comparisons will determine the general course which the new sector should take.

B. Problem of seriality

149. The key to the whole issue of specific projects centres around the seriality of production. What is required here is a series of iterations in which changes in product seriality are matched against resource elements to determine which of these productive facilities are needed if the country is to compete on the international market. Candidate export products are chosen when their costs are in line with international prices as a result of increasing seriality. To some degree, this will also determine the machine park necessary in a country.

150. The whole concept of increasing seriality is directly tied to the export orientation of this methodology. Without including potential exports in the planning process seriality levels for a large number of products will be too low even for import substitution unless excessive protection is afforded domestic producers. The results of this excessive protection have already been considered above.

C. Unsolved problems

151. Despite the above process, there will remain a number of resource elements required for production, but too large for existing or planned home and export demand. Here decisions regarding the role of subsidies in promoting the growth of the sector must be taken. Where the process is crucial for production, it may be necessary for subsidies to be given. On the other hand, the importation of certain components produced by this process may be more feasible at the outset.

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