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

AGRICULTURAL IMPLEMENTS AND EQUIPMENT: PRODUCTION METHODS[1]

by

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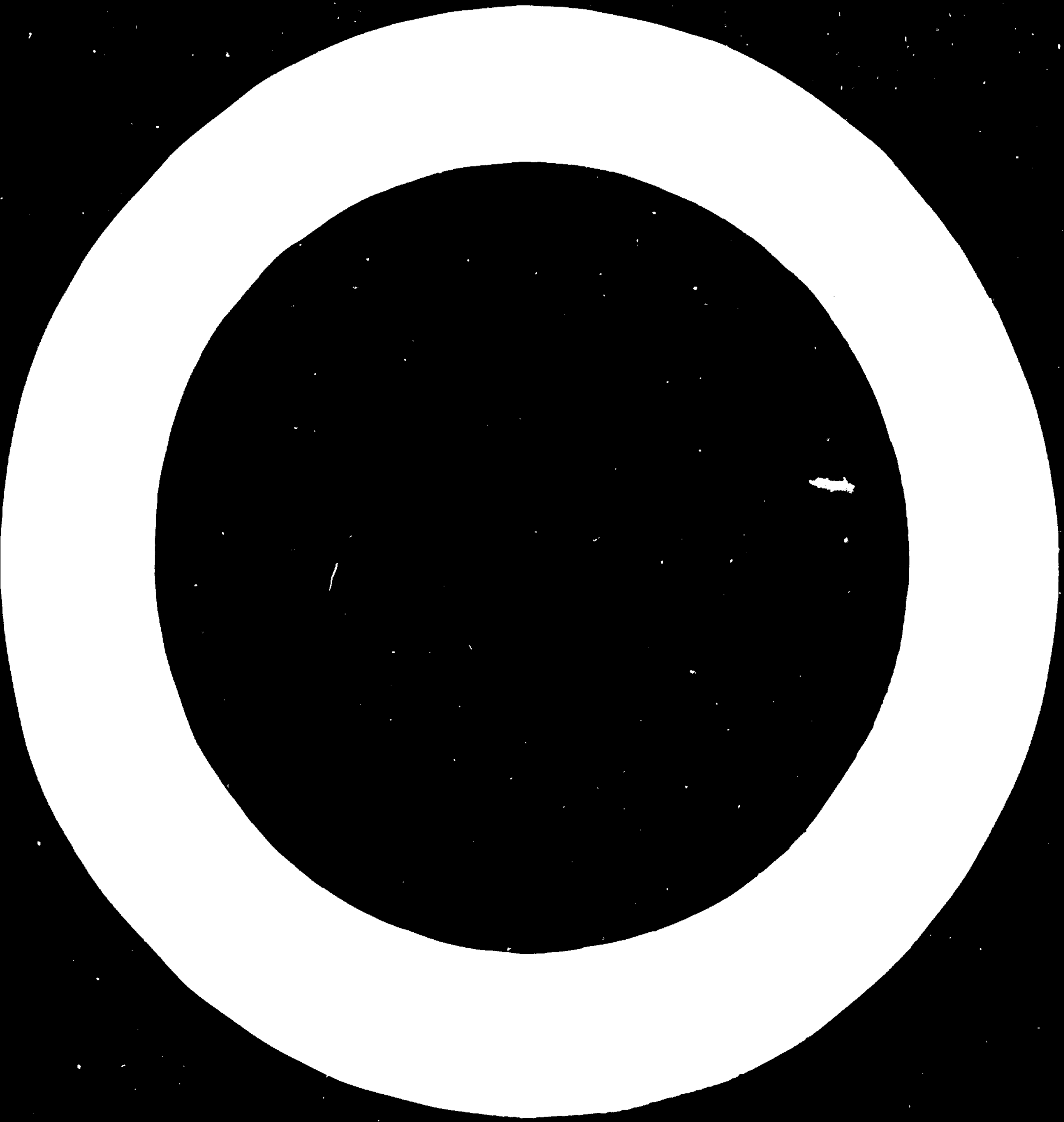
[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.



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A. Implements and equipment

1. International production of agricultural implements and equipment may be subdivided into two main categories: (a) production of heavy self-propelled equipment; and (b) production of light-weight "non-powered" equipment powered by an external prime mover (power takeoff), or powered by standard small purchased sources such as a fractional horsepower electric motor or small internal combustion engine.

2. A few very large producers dominate the heavy equipment market: International Harvester, Massey-Ferguson, John Deere, J.I. Case are examples. In the second category a large number of small manufacturers can be found in various countries - manufacturers of simple hand tools, small trailers, conveyors, farm accessories and the like.

3. In the large-industry field a wide product line is the rule, based upon heavy specialization and large volume component production such as hydraulic controls, gear trains and engines. In the light-weight equipment field specialization is by product, or small product group, determined by a small combination of tools in a shop at a specific location. In other words, large manufacturers generate variety in the product line by using components in various combinations; small manufacturers generate variety by using tools in various combinations - a much more limiting and inefficient mode of operation.

4. In both the large and small manufacturing classes, there is a relatively high percentage of purchased materials and parts. For example, although large firms such as International Harvester make bolts and fasteners, by-and-large such items, in addition to plastic and rubber parts (tyres), some electrical parts (spark plugs), and various specialty metal parts (bearings) are purchased. Large manufacturers also distribute specialized products designed and conceived by smaller firms, with the large firm acting as a component supplier and finished goods distributor. For example, the International Harvester payloader, a $15,000 self-propelled back-hoe widely used in light construction, is manufactured by the Frank G. Hough Co., an International Harvester subsidiary in Libertyville, Illinois. Attachments for heavy machinery such as specialized bulldozer blades are often supplied by small firms. In most cases production of prime movers and tractors is restricted to very large firms.

5 Volume component production of large firms producing, for example, ignition parts, engine blocks and hydraulic cylinders for control, benefits from highly specialized automated methods. Such automated production is used internationally to maintain quality standards, to limit the need for skilled labour, and to prevent waste as well as to create volume production at low cost. Thus, it is not unusual to find numerically controlled machine tools in an International Harvester plant, even though that plant is remotely located from United States domestic operations.

6. Strategy and production organisation of large agricultural firms differs markedly from that of small firms. To understand fully the extent of this difference, as it relates to planning for production, a comparison of the structure of resources used in component oriented firms and that used in product oriented firms will be beneficial.

7. In the component oriented firm, which is also a large-scale operation, it is typical to speak of "levels" of assembly complexity, with components considered as Level (0). In the sequence of assembly, components are combined to generate the first sub-assemblies. These first sub-assemblies are then combined, in various ways, to generate the second sub-assemblies (possibly also requiring the direct use of some non-assembled parts in addition to those already combined in the first sub-assemblies). This process continues down the line until the final product results. A simplified four-level operation is shown in figure 1.

8. As the number of levels increases, the number of ways that parts (and therefore resources) can enter into the final assemblies also increases rapidly. Each possible path that can be traced from the components, Level (0), to the final products, four in the case of figure 1, represents a distinctly possible demand for parts.

B. Matrix evaluation of production structure

9. The exact resource requirements (as well as the requirements for output at intermediate stages, or levels) can be evaluated by straightforward computations. Although these computations will, in general, require much arithmetic, they are not difficult.

10. What is needed before any planning computations can be done, however, is a set of tables showing the exact input/output requirements for parts and sub-assemblies at each stage of assembly, in particular one such table for each arrow in figure 1. The definition of each such table is given below figure 1. With such tables in hand, (figure 2 is a simplified example) only matrix multiplication and addition are required to develop final resource requirements, given a desired list of final products.1/

11. A final parts list can be developed in this way, as shown in figure 3. Similarly, a list of final product requirements can be converted into a parts requirement list, or a machine-hour requirement list by specifying the volume of final products needed, as shown in figure 4. By extending the computations of figure 4 backwards in stages from the finished product level through the sub-assembly stages to the parts and

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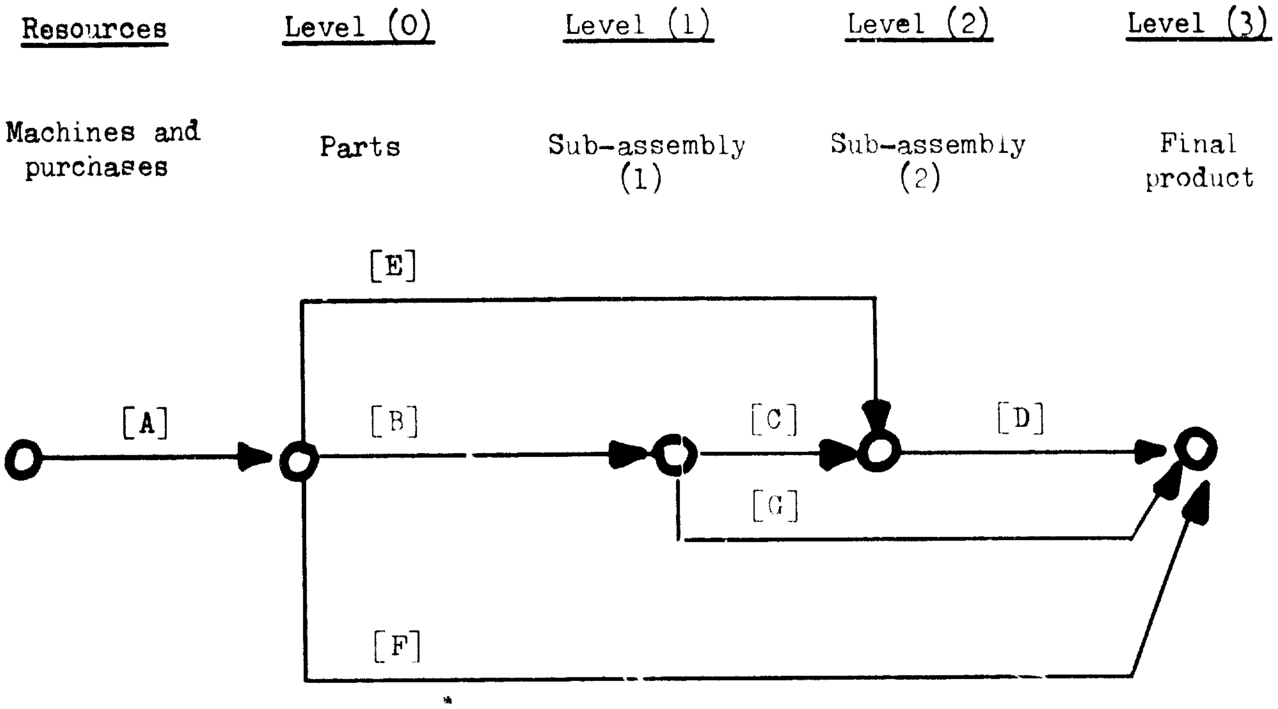
1/ We assume the reader is familiar with these matrix operations and the standard nomenclature used in describing them. If not, consult appendix A of V.C. Hare, Jr., Systems Analysis: A Diagnostic Approach, Harcourt, Brace & World, Inc., 1967, New York, or other introductory texts.

Figure 1

A four-level assembly process

(The letters in brackets refer to detailed data required, as specified below)



Input/output tables required for detailed planning:

[A] Machine hours and purchases required as inputs for the basic parts or components list

[B] Parts that go into sub-assembly (1) directly

[C] Sub-assemblies (1) that go into sub-assemblies (2)

[D] Sub-assemblies (2) that go into the final products

[E] Parts that go directly into sub-assemblies (2)

[F] Parts that go directly into the finished products

[G] Sub-assemblies (1) that go directly into the finished products

Figure 2

Simplified planning problem for four-level assembly process with structure of figure 1

Parts

Mach.	1	2	3
1	0.5	0.5	
2		1.0	0.5
3	0.4		0.6

[A]

Hours per unit part

SA(1)

Parts	1	2	3
1	1	1	
2		2	1
3	1		1

[B]

Parts in **SA**(1)

SA(2)

SA(1)	1	2
1	1	
2	1	2
3		1

[C]

SA(1) in **SA**(2)

Final products

SA(2)	1	2	3
1	1	1	1
2	2	0	1

[D]

SA(2) in final products

SA(2)

Parts	1	2
1	3	1
2	0	2
3	1	1

[E]

Direct parts to **SA**(2)

Final products

Parts	1	2	3
1	1	0	4
2	0	1	0
3	1	1	0

[F]

Direct parts to final products

Final products

SA(1)	1	2	3
1	0	2	0
2	1	0	0
3	0	0	1

[G]

SA(1) Direct to final products

Figure 3

Evaluation of parts and machine requirements per unit of finished product for data of figure 2

$$E \times D = \begin{bmatrix}3 & 1\\ 0 & 2\\ 1 & 1\end{bmatrix} \times \begin{bmatrix}1 & 1 & 1\\ 2 & 0 & 1\end{bmatrix} = \begin{bmatrix}5 & 3 & 4\\ 4 & 0 & 2\\ 3 & 1 & 2\end{bmatrix}$$

$$C \times D = \begin{bmatrix}1 & 0\\ 1 & 2\\ 0 & 1\end{bmatrix} \times \begin{bmatrix}1 & 1 & 1\\ 2 & 0 & 1\end{bmatrix} = \begin{bmatrix}1 & 1 & 1\\ 5 & 1 & 3\\ 2 & 0 & 1\end{bmatrix}$$

$$(C \times D) + G = \begin{bmatrix}1 & 1 & 1\\ 5 & 1 & 3\\ 2 & 0 & 1\end{bmatrix} + \begin{bmatrix}0 & 2 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix} = \begin{bmatrix}1 & 3 & 1\\ 6 & 1 & 3\\ 2 & 0 & 1\end{bmatrix}$$

$$B\left\{(C \times D) + G\right\} = \begin{bmatrix}1 & 1 & 0\\ 0 & 2 & 1\\ 1 & 0 & 1\end{bmatrix} \times \begin{bmatrix}1 & 3 & 1\\ 6 & 1 & 3\\ 2 & 0 & 1\end{bmatrix} = \begin{bmatrix}7 & 4 & 4\\ 14 & 2 & 7\\ 3 & 3 & 2\end{bmatrix}$$

$$B\left\{(C \times D) + G\right\} + (E \times D) + F = \begin{bmatrix}7 & 4 & 4\\ 14 & 2 & 7\\ 3 & 3 & 2\end{bmatrix} + \begin{bmatrix}5 & 3 & 4\\ 4 & 0 & 2\\ 3 & 1 & 2\end{bmatrix} + \begin{bmatrix}1 & 0 & 4\\ 0 & 1 & 0\\ 1 & 1 & 0\end{bmatrix} \quad \begin{array}{cccc} & & \text{Final} & \\ \text{Part} & 1 & 2 & 3\\ 1 & 13 & 7 & 8\\ 2 & 18 & 3 & 7\\ 3 & 7 & 5 & 4\end{array}$$

Final parts required per unit of finished product

$$A\left[B\left\{(C \times D) + E\right\} + (E \times D) + F\right] = \begin{bmatrix}0.5 & 0.5 & 0\\ 0 & 1.0 & 0.5\\ 0.4 & 0 & 0.6\end{bmatrix} \times \begin{bmatrix}13 & 7 & 8\\ 18 & 3 & 7\\ 7 & 5 & 4\end{bmatrix} \quad \begin{array}{cccc} & & \text{Final} & \\ \text{Mach.} & 1 & 2 & 3\\ 1 & 15.5 & 5.0 & 7.5\\ 2 & 21.5 & 5.5 & 9.0\\ 3 & 9.4 & 5.8 & 5.6\end{array}$$

Final mach. resource Req. (in hrs) Per unit of finished product

Figure 4

Extension of requirements from per unit basis to requirements for a given production requirement

Let (P) be the total production required for the finished products:

$$\begin{array}{cccccc} & & \multicolumn{3}{c}{\text{Finished products}} & \\ & & 1 & 2 & 3 & \\ (P) & = & \boxed{50} & \boxed{100} & \boxed{200} & \text{Units required} \end{array}$$

Then total parts required will be (final parts list) x (P)

$$= \begin{bmatrix} 13 & 7 & 8 \\ 18 & 3 & 7 \\ 7 & 5 & 4 \end{bmatrix} \times \begin{bmatrix} 50 \\ 100 \\ 200 \end{bmatrix} = \begin{array}{cc} \underline{\text{Part}} & \text{Total need} \\ \begin{array}{c} 1 \\ 2 \\ 3 \end{array} & \begin{bmatrix} 2950 \\ 1650 \\ 1900 \end{bmatrix} \end{array}$$

And total machine hours required will be

(Final machine resources required) x (P)

$$= \begin{bmatrix} 15.5 & 5.0 & 7.5 \\ 21.5 & 5.5 & 9.0 \\ 9.4 & 5.8 & 5.6 \end{bmatrix} \times \begin{bmatrix} 50 \\ 100 \\ 200 \end{bmatrix}$$

$$= \begin{array}{cc} \underline{\text{Mach.}} & \text{Total hrs. req.} \\ \begin{array}{c} 1 \\ 2 \\ 3 \end{array} & \begin{bmatrix} 4805 \\ 3060 \\ 2395 \end{bmatrix} \end{array}$$

machine-hour stages, the exact number of pieces of each type may be computed for each level. (Total parts, or machine hours, will equal those that go directly or indirectly into each level's operations.)

12. It is assumed that parts, machine hours, or even sub-assemblies at any level can be purchased or manufactured as costs and manufacturing restrictions may dictate. The computations in no way differ. Purchased items are simply split off from the "explosion" computation and designated purchase rather than make.

13. Thus, it may be found desirable to purchase components rather than make them. Although the complete list of components, manufactured and purchased would appear in the Level (C) listing, or matrices showing inputs to higher stages, the evaluation of machine hours needed would be restricted to manufactured parts only. (It is assumed in the example that no purchased parts enter the computations of figures 1 to 4. In most general cases purchased items could enter at any level, including the sub-assembly levels. However, this extension has been avoided for clarity in the example shown.)

C. The levels concept in process description

14. The purpose of this digression has been to show that exact planning is possible in the multi-level production organization, but to do so a large amount of precise design and engineering data is required. Further, in terms of this form of planning, the simpler manufacturing organizations deal with only one level of assembly (or very few) whereas the more complex deal with many. (Up to 20 levels of the type just described are not uncommon in large-scale manufacturing operations based on component specialization.) Note that the planning tables illustrated in figures 1 to 4 may be summarized at any of the levels, as was done for finished goods parts, and finished goods and machine hours, so it is possible to go from a listing of final product requirements to the requirements at any level, or from the specification of need at any level to machine hours. Further, given the planning tables relating requirements per unit at any level and available resources or needs the feasible and optimum mix of final product can be computed using linear programming techniques.

15. One fundamental complication enters this planning picture. Unfortunately, although it is indeed possible to plan exactly using the methods above, that is to say, to create part and sub-assembly counts, load machines, or even optimize product mix at one stage of the process, it is not possible, in general, to simultaneously optimize inventory control and scheduling or sequencing operations in such systems.

16. For example, to gain longer production runs and to "decouple" the production process between levels, it is common to introduce intermediate in-process inventories of parts, sub-assemblies, and even finished goods in the process. When such inventories are present, the immediate need for parts and sub-assemblies may be evaluated as described in figures 1 to 4, but at each level the actual count to be produced (as opposed to inventory withdrawals) becomes a function of inventory policy at each stage of the total production process.

17. In the same way, if different production sequences are required on several machines or assembly fixtures, machine interference created by a given production plan, as modified by the inventory policy, may in effect reduce drastically effective machine capacity by creating alternate slack and overload periods in time.

18. The result of these complications is an interdependence among planning, inventory policy, and sequencing which does not permit an analytic optimization of the total process in one step, but rather requires a sequential approach in which a plan is made, its effect on inventory levels is evaluated, and finally the effect of sequence interference checked. The result of this sequence may well be a modification of the original plan, and so on until a "satisfactory" set of total specifications has been reached.

19. Several practical approaches to this total problem are used in industry. On the one hand, it is possible to plan total production on a sets of parts basis by eliminating inventory and building all parts and sub-assemblies to order. This reduces planning computations to those illustrated in figures 1 to 4 by eliminating inventory at intermediate levels and by reliance on sufficient over-capacity in tooling to eliminate sequencing bottlenecks. On the other hand, it is possible to have large inventories between stages, so that levels are essentially uncoupled over a short time period, in which case inventory control policies tend to dominate, and the planning operation, as illustrated, acts only as a data processing technique for generating a feasibility check on available stock levels before assembly starts. Various intermediate mixtures of these extreme simplifications can be found in current practice.

20. Although it is difficult to generalize, the sets of parts approach is usually employed for long-range planning under the assumption that over the long haul problems of capacity can be ironed out in a variety of ways (purchases, overtime, more equipment, shifts in loads over time, inventories, etc.) so that although it is possible to use the planning computation to compute a necessary minimum capacity it is generally understood that this minimum must be supplemented to obtain a practical or sufficient capacity to carry out a long-range programme. As a rule of thumb, an excess capacity

of 20 to 30 per cent is often required above the minimum requirement to handle the problems of mix interference. Such rough rules permit practical planning to go ahead in a simplified way.

D. Component specialization

21. Turning once again to the agricultural implements field in particular, the component oriented sector of the industry may be illustrated by the pictures of figures 5, 6 and 7, which show, respectively, several "complex" agricultural products and the output of one component supplier. The prevalence of certain repetitively used components may be noted in these pictures, and the degree of component specialization suggested. The figure legends give details.

22. The equipment shown in figures 5 and [illegible] is of the multi-level type just described, with many sub-assemblies and common parts prevailing. Because of such commonality, manufactured equipment of the type shown is often organized into component shops, which as a gross level would include the shops described below.

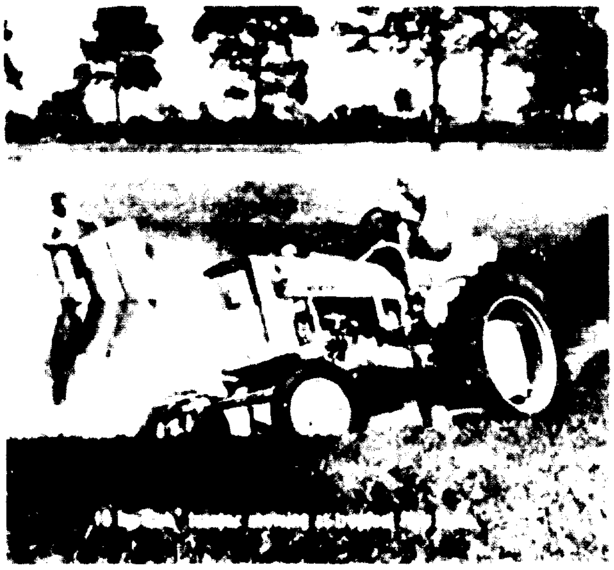
23. Engine shops: including the machining steps required to convert an engine block casting from the rough form to the finished engine, including assembly and test of the finished items. Equipment would include milling, reaming, grinding, drilling, tapping, honing, sub-assembly assembly, and final assembly and test, often using at each stage automated equipment transfer machines, and automated test stands. Electrical and die-cast components, as well as rough engine blocks, may or may not be purchased or made by other departments, depending upon the degree of integration. In general, most electrical, fuel, gear, and similar specialized sub-assemblies would be supplied by other shops.

24. Gear shops: these shops are distinguished by the specialized machining and heat-treating operations required in gear manufacture, and by the degree of precision required in gear manufacture as opposed to other operations. Jig bore and hobbing machines, as well as precision broaching machines, heat treating ovens, and precision mechanical quality control equipment make up such shops; highest skills in machining are required of the labour force. Specialized alloys and other materials are usually employed, such as special coolants and quenching operations. Low speed, low stressed gears may be cast, either in this shop or obtained as blanks from other departments or suppliers. High speed, high stress gears are forged then machined; again either in the gear shop or as blanks from suppliers. Assembly of gears, housings, clutch assemblies, and hydraulic parts, together with testing of the finished sub-assemblies occurs here. In general, this is a precision shop, working to a few ten-thousandths of an inch - often the heart of the complex prime mover.

Figure [illegible]

Small and large tractors

Small and large tractors illustrate castings (transmission and gear housings, frame parts, brake drums, etc.) and stampings (motor housing, fenders, [illegible], etc.). In lower cut, sheepsfoot earth packer is constructed of welded forged parts. [illegible] and machined parts go into front end steering mechanism of tired units.



[illegible] copy below indicates width of International Harvester tractor product line, shows [illegible]. Flexibility of financing, [illegible] the industry, is also indicated.

[illegible] you wouldn't find a tractor except [illegible] earthmoving projects.

[illegible] see them working at junk yards and zoos [illegible] stations and [illegible] movies. They're [illegible] the holds of ships to unload sugar.

[illegible] course they work at better known jobs [illegible], grading, construction, land- [illegible] logging and turf maintenance.

[illegible] any place a tractor can do a job [illegible] cheaper than hand labour.

[illegible] you get the feeling you see more [illegible] tractors than any other make, it [illegible]

International offers [illegible] different tractors [illegible] 135 hp. International offers 13 [illegible] earth moving attachments and 10 fork lifts [illegible] and every kind of [illegible] attachment. Plus snow removal [illegible]. Yes, and their attachments for the grow- [illegible] needs.

[illegible] your needs with your IH dealer. Chances [illegible] have a rig to fit your special needs.

And while you're there, talk money. Your dealer [illegible], two and three-year financing. Up to [illegible] deferred payments a year during slack seasons. [illegible] leasing. Leasing with purchase option. [illegible] suggest something. He wants to make a deal!

Source: International Harvester, from Business Week, May [illegible], 1967, pp.108-109.

Figure 6

Special components

International skidder [illegible] [illegible]

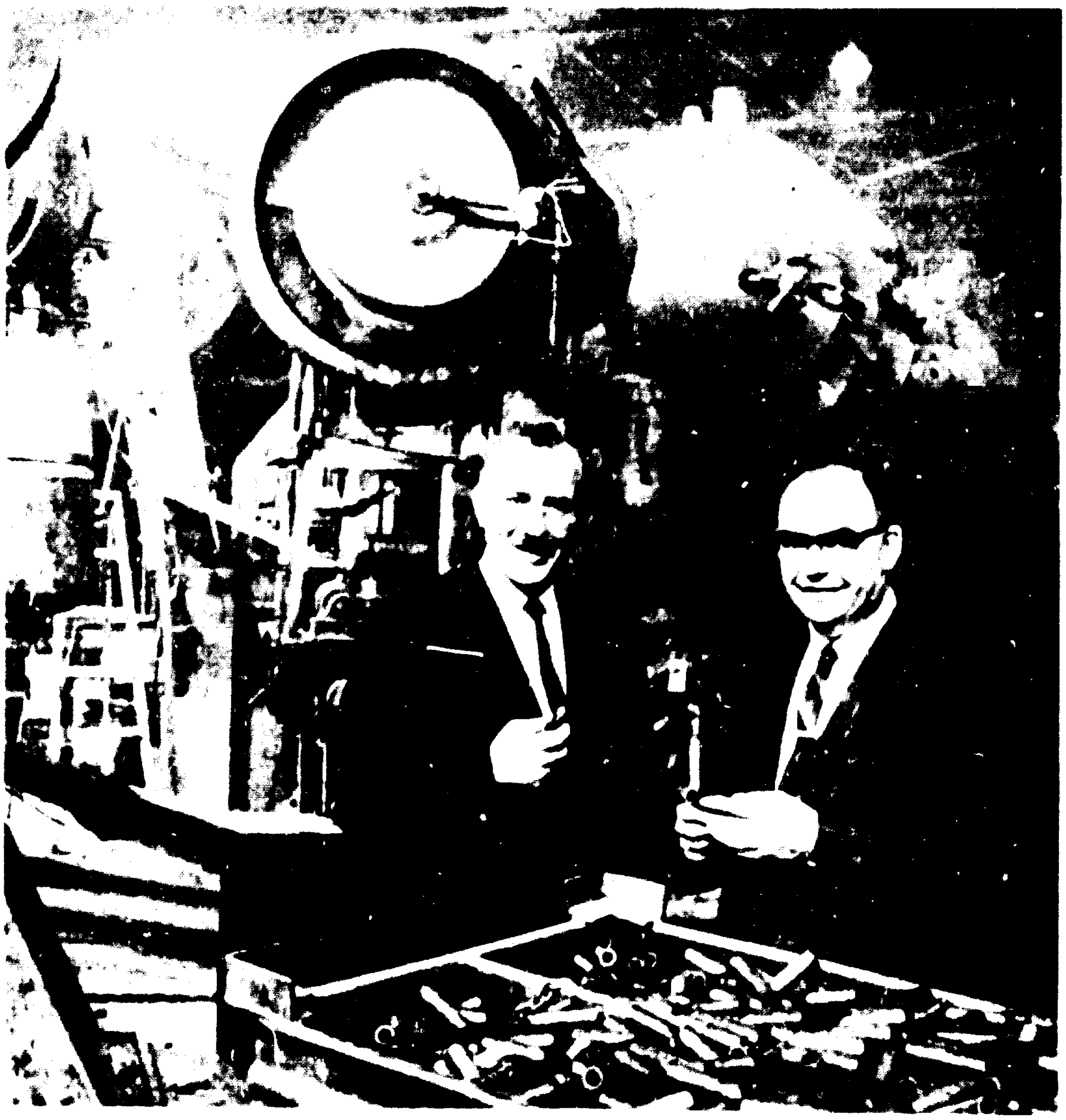
International 500 crawler loading top soil

20-foot fork lift hoisting bricks to masons

Special components are illustrated in these pictures. All three machines contain heavy-duty hydraulic cylinders for control of attachments. Note heavy cast counterweight to rear of fork lift unit, forged tiger blade on skidder, standardized power unit on all three.

[illegible]

[illegible]



Brothers Alfred, left, and Frederick Braun depend on such high volume items as piston pins to amortize costly **machinery.**

Component specialists of Braun Engineering, Inc., Detroit, stand beside bin of output from cold extrusion operation. Heavy and expensive dies used in the process require extremely long runs, but cut material waste [illegible] per cent. In this "cold flow" operation a steel slug, cold or slightly warmed, is pressed into die by heavy hydraulic or mechanical press. Extreme pressure causes metal to flow into intricate shapes -- such as spark plug shells, bearing caps, piston pins -- complete with threads, knurled sections, indents and hex flanges to eliminate or reduce later machining operations. Total part cost reduction comes from both material and labour savings. "High-pressure process wins Detroit's heart", Business Week, May 6, 1967, pp.112-115.

25. Electrical shops: supplied with winding machines, often small stamping presses to manufacture laminations, a multitude of test equipment, and with an input of wire (hardly ever made except by specialists) and other multitudinous components, this shop makes ignition coils, distributors, generators, simple electric controls, wiring harnesses, magnetos, and similar components. Small electric motors and generators may also be made, usually from components, bearings, housings, etc. partially supplied by other shops or outside vendors.

26. Hydraulic shops: here, the hydraulic control cylinders, valves, hoses, and other fittings are manufactured and assembled to the finished component state. The control cylinder and valve operations, which require precision machining, reaming, honing, and fitting, are the critical steps. Because of the volume of hydraulic controls used in current agricultural equipment, much of this machining is automated in the large shops; input from rough castings, exotic alloy suppliers, other external sources. Often plating may be required, inputs of springs, small screw machine parts, purchased tubing, plastics. Hydraulic testing equipment (for leaks, pressure, force, timing) also may be required. Hydraulic seals are either purchased or manufactured in a sub-department of this shop.

27. Stamping shops: these shops are often grouped because of the capital cost of basic equipment that must be utilized to a high degree for economy. However, heavy and light stampings can be separated, generally by the size of the presses required, and by the end-product made.

(a) Heavy stamping: Presses of 50 tons or more capacity. Typical output is fenders, tire rims, stamped frames, structural members or equipment housing frames. (With current technology, heavy stampings can often be made to substitute for castings, with consequent decreases in production cost and weight and increases in volume of output per unit time. This is a design substitution possibility often exploited in newer products without loss of reliability or strength.)

(b) Light stamping: Under 50 ton press capacity. Typical output is fuel tanks for smaller units, small assembly parts for electric equipment (if not made in electrical shop), equipment covers, air filter assemblies, oil filter assemblies and various housings. To conserve cost, a number of small parts may be made at one stroke by the use of large presses thereby increasing volume of output.

(c) Variations: the heavy stamping or press shop may also produce cold flow parts (see figure 7) and contain equipment, such as specialized extrusion presses to produce, in a sub-department, various shapes required for later manufacture.

28. The light stamping or press department may also contain rolling equipment to produce light angle tubing, and similar shapes required in light sub-assemblies. Some normally stamped items may often be more economically produced by a rolling operation (Yoder machine).

29. Casting and forging shops: these shops are grouped together because they provide the basic shapes for later machining operations. Casting is basically a metal melting and pouring operation, in which metal is handled in molten form. Forging starts with a solid mass, usually heated, then hammered into shape. In either case, the large parts are handled as separate production items: sand casting, and manual forging are examples. In the case of smaller parts, die casting and die forging are common (for parts up to approximately 40 to 60 pounds weight as a typical upper limit). Typical die forged parts are piston connecting rods and timing shafts; typical die cast parts are small engine blocks, carburettor parts and highly detailed drim. Both die forging and die casting require large volume runs to be justified, but when used they can cut greatly material and machining costs. In either case the basic setup cost is in the production of dies (as in the case with stamping as opposed to sand casting).

30. Assembly shops: basic sub-assembly occurs in the engine, gear, electrical, and hydraulic shops, with final assembly dealing with heavier frames, covers, supporting members, and the convergence of sub-assemblies. Usually in the agricultural industry, as in the automotive industry, major investment in material handling equipment is required, with overhead conveyors or cranes, paced assembly lines or semi-paced assembly conveyors or skids the rule. In general, large square footage area is required. Usually, some heavy-duty welding equipment is also required, particularly for frame and attachment assembly; many jigs and fixtures are the rule to assure precision and uniformity of output. Spray painting, with or without baking, is the usual form of finish, with prime coats for most exposed metal parts. For severe environments, extensive finishing may be performed at intermediate sub-assembly stages, with pickling, prime coating, and semi-final coats applied at inferior departments or shops.

31. Variations of this general pattern will occur when the volume of manufacture warrants: tractor lines, lift truck lines, and the like may be set up either permanently or temporarily in parallel, or in sequence (using the same facility for different products at different times) depending upon the level of demand.

32. When volume is extreme, products may be assembled by groups having common characteristics at different locations. Thus, power take-off equipment of the "wagon" type such as manure spreaders, harvesters and pickers may be assembled separately from self-powered units, or at least on a different parallel assembly line. This distinction is usually a function of geographical demand and the material handling equipment is required in either case.

33. This, then, is the picture of the large manufacturer of a wide product line - who also has special distribution and financing problems to be described later.

34. Another "shop" or department that may be included is the inventory-production control function, which, from observation of the segmented component shops becomes an essential control function in the total manufacturing function.

35. As the agricultural implement manufacturer increases in size, he can exploit the advantages of multi-level purchasing and production organization. He can deal with combinations of components rather than combinations of his existing machines, thereby giving him the world market for components as his source of resources. At the very large volume extreme, the manufacturer in this industry will organize himself on a product line basis, rather than on a work centre or job-shop basis. But, seldom is volume so great that this can be done for all products, as indicated above in the discussion of shop types for large manufacturers. There will therefore, be some intermediate organization and decision-making along the way.

36. As a consequence at either extreme, the function of production planning and control will take on paramount importance in view of the complexity of most self-powered agricultural equipment design. Although the control function may lean either to purchasing or co-ordinated manufacture and supply from various internal sources, it is clear that if many components are required in assembly, considerable central control will be required to assure co-ordinated timely assembly and shipment of the finished product.

37. For various historical reasons, the planning and distribution function has not been co-ordinated with manufacture in large firms, with consequent disasters. The planning resource therefore should be considered an essential feature of the large agricultural implement manufacturer in addition to the shops noted above.

E. Special problems of the agriculture industry (big manufacturer)

38. Unlike many manufacturing industries, the agricultural industry is plagued with several special planning problems, the most serious of them is the need to make long-range production forecasts under highly variable demand conditions.

39. For example, since much of the agricultural implement output consists of large heavy end-products, the commitment to produce and distribute to various locations must often be made up to a year in advance of sale. Harvesters and special picking machines are an extreme example, but heavy tractors and earth-moving equipment come under the same category.

40. Moreover, the agricultural implement industry has traditionally distributed its products through local agents, often very small in size, often carrying other manufacturers' equipment. It has become a tradition in dealing with farmers to extend seasonal credit so that payments can be made after harvest, a practice that forces large manufacturers to carry extensive accounts receivable from dealers, that is to have large amounts of finished inventory "on consignment".

41. It is not uncommon for large manufacturers to have two to three thousand dealers, many of whom are not financially solid. Since agricultural implements are often stored outside, deterioration of dealer inventory that has been shipped is a major source of distribution cost, as are insolvent dealers. Many of the largest firms have attempted to overcome such shortcomings by setting up company-owned distribution outlets, but by-and-large, the distribution practices in the industry are archaic by consumer goods standards.

42. Weather and variable crop maturity dates are the source of the greatest demand variability. This is so because many specialized machines can be used only at peak harvest times, if that peak time is missed by lack of field inventory for example, the sale is lost until the next season. Because of their bulk and weight, it is generally not economical to tranship large agricultural units from one location to another to compensate for weather variations. As a consequence, the field inventories needed to support sales are considerably more than average, the probability of having to carry inventory over from one season to another is great with consequent deterioration; the possibility of customer, or dealer, insolvency over one or more bad seasons is higher than it would be in other forms of capital equipment distribution. Most large manufacturers have attempted to alleviate these severe distribution problems over the past ten years by installation of better communication and control systems, tighter inventory control and faster shipment, tighter co-ordination of assembly with local weather conditions, and more selective dealer franchises.

43. It is also common today to separate credit and financing operations from manufacturing and distribution operations. General Motors, for example, handles credit through the separate but company owned, General Motors Acceptance Corporation. Such separation not only permits greater leverage in financing paper, but also provides an automatic check on the acquisition of poor-risk dealers and customers, as well as a check on illogical distribution of inventory.

44. From the author's experience as a consultant to the J.I. Case Company and the investigation of other agricultural manufacturers, it is probably safe to generalize that reorganization of distribution and financing can have a more beneficial effect

on total company performance than changes in manufacturing methods. The distribution and financing operations of most agricultural implement makers not only represent the greatest proportion of sales cost, but also the greatest source of total financial loss. This is true for most manufacturers but the ratios are severely skewed towards high distribution and finance costs and risks in the agricultural field.

45. In particular, close co-ordination of distribution planning and manufacturing planning becomes essential for the successful agricultural equipment maker of large equipment. Such co-ordination problems become even more severe for exporters who must be concerned with world-wide weather and credit problems. For this reason, large manufacturers usually diversity their operations geographically, with duplication of component and assembly operations near the end consumer.

46. From the author's experience it was found that many agricultural suppliers carry on their books accounts receivable which are in fact inventory in dealers' hands. This is inventory that is not actually sold on consignment, but which is sold to dealers on extended credit. The dealer "owns" the equipment on paper, but does not have to pay for it until the season's end, or until it is sold. In many cases this equipment sales contract cannot be enforced because the dealer lacks financing on his own; the inventory cannot be repossessed because it has rusted and deteriorated in the field and shipment costs are high. The net result is that the manufacturer tends to prolong his collection, support non-productive dealers, and tends to deceive the investor in his stock by showing receivables that should be severely written down to be realistic. This situation is fairly well-known to industry accountants and experts, but not to the general public.

47. In short, the distribution, financing, the co-ordination problems described in the last few pages are a major argument against the proliferation of giants in the agricultural industry in contrast to the manufacturing efficiencies that are inherent in large-scale operations. Small firms that hope for international distribution should be made aware of these almost insuperable distribution and financing problems, and should not be encouraged to enter the market without strong subsidiary support from government; co-operative agreement with large manufacturers; or specialization in a rare component, equipment type, or material and labour-saving procedure that would provide them with a monopolistic advantage.

F. Product specialization

48. Opposing large-scale component specialization and assembly used by the giants, the other end of the spectrum contains the small volume and small organization custom manufacturers of agricultural implements and producers of light-weight tools and labour-saving devices.

49. Often the ratio of skill to capital tooling is greater in these specialty firms than in the giant manufacturing operations, because personnel must be versatile, tooling more general, and production runs shorter. Some examples of these forms of manufacture follow.

50. Custom manufacture: in many specialized segments of the agricultural industry, special tools are required, or desired, but the total market potential available is at the same time small. In this market, a few machines of high cost and high inventiveness are manufactured by general purpose shops, usually under the direction of the equipment designer. Typical machines of this type may be found in agricultural harvesting, the most time-consuming phase of agriculture. In some developing countries up to 90 per cent of the population is engaged in agriculture; some mechanization for harvesting would release personnel from the soil for industrial work. Typical photographs of newly developed harvesting equipment of this type may be found in an article by C.F. Kelly, "Mechanical Harvesting", Scientific American, August, 1967, pp.50-59

51. The general mechanical approach to harvesting machines follows two lines. In the first approach the mechanized device is a hauler with special mechanical conveyors scaled to the dimensions of crop rows. Workers ride on this device, rather than walk but crops are picked by hand and the output is deposited on a moving conveyor and carried mechanically to a truck. Harvesters of this type may be self-propelled, or pulled by a hauling truck. Pineapples, for example, are harvested in this manner in many places.

52. In this first approach to mechanization equipment design consists of an assembly of standard tractor, truck, and conveyor components, with a limited number of fixtures that can be manufactured by a small specialty shop. Skill in design and manufacture is tied closely to agricultural requirements, such as plant spacing and field layout. Cost of development and testing of equipment is high, however, and the number of machines needed in a given locality is low, because of crop specialization and the high productivity of the machines. Nevertheless, a firm engaged in the development and manufacture of proved machines of this type creates a small monopoly as new buyers seek proved equipment, rather than go through new development expenses.

53. The second approach to harvesting seeks complete mechanization. Completely mechanized equipment for harvesting cotton, citrus fruit, cherries, tomatoes, lettuce and similar fragile vegetables is now available. The efficiency of the latter machines and their intricate design requires even greater development and construction cost, and often agricultural research into new plant strains which show themselves suitable for harvesting.

54. For example, a ten-year period was required for the development of the tomato harvester now in common use in California. The United States Department of Agriculture and the University of California, in co-operation with a small specialty manufacturer undertook the project. A new tomato strain as well as a new machine were developed. The machine strips the whole tomato plant from the ground at harvest time, then shakes the ripe tomatoes onto a conveyor for deposit in a bin. Some idea of the productivity of this design - as well as the small production runs available - may be gathered from the fact that in 1966 only eight hundred tomato "combines" of the type described were in use in California, but these eight hundred machines harvested 80 per cent of the state's tomato crop!

55. Machines of this type, designed and tested for a given crop, provide a sufficient monopoly for export and can be doubly productive if both domestic and export crops can be handled. Usually, a large number of purchased parts will be required, but enough local assembly and fixture skills can be added to make such units interesting.

56. Small-run speciality manufacturing: a number of small weight end-products and component sub-assemblies also provide potential for small manufacturers. Figure 8 shows two products indicative of this class. The small animal trap and the RO-HO Gardner both require simple production processes and only semi-skilled labour. Small conveyor belts, attachments for power equipment and small carts and trailers also come under this category. Often simple sheet metal and casting or forging operations will produce the essential design parts, which, when combined with a few purchased parts such as bearings, will produce the end product. Since the competition among small manufacturers of this type can be severe, great care is needed to develop a product design that can be protected by patent, or that fills an obvious "local" need that can be exploited. Often small component specialisation is an introductory route to development for manufacturers of this class. Such component and sub-assembly suppliers often cluster geographically near a major assembly operation, or in the case of light-weight component and sub-assemblies (e.g. electronics) may be located some distance from the assembly point.

G. Marketing versus production ability

57. Most small manufacturers of the type just described suffer from alternate pains of marketing and production difficulty. First assembly of sufficient tools is the initial problem, then sales of the product becomes a major concern. As sales progress, production expansion and associated difficulties arise, so the cycle goes. For this reason an anticipation of marketing problems in advance of their realization is often a worthwhile pursuit for the prospective small manufacturer.

Figure 8

Specialty manufacturing

Havahart® Pigeon Trap

Pigeons are notorious people lovers. Unfortunately this affection is not usually returned. If you have been adopted by a flock of pigeons and would like to be relieved of the burden a Havahart Pigeon Trap is the answer to your problem. The trap is perfectly safe and humane. Catches up to ten pigeons at a time. Galvanized, rust resistant steel. No springs. Will last a life time.

9664 24 x 16 x 8 in., $13.25 each

RO-HO Gardener

Here is a garden tool that weeds, hoes, cultivates and mulches soil in a single operation. Besides a scuffle knife, which follows closely behind the 40 rotary hoe points, to break up clods and smooth soil there are five 6 in. shovels which can be employed for deep cultivation. As easy to use as a lawn mower.

9641 — $13.95 each

The RO-HO device, in modified form, is described as a "Rice Paddy Cultivator" in Report IR18370 PR February 1958 of the International Co-operation Administration's Office of Industrial Resources Technical Inquiry Service. The reported manufacturing cost in this report is over $US 13.00, almost the retail price of the RO-HO, clearly an overestimate. The design modifications, however, are of interest.

58. The approach taken by the University of Tennessee Industrial Engineering School in aiding small firm development in the hill region of that state may be illuminating. Under the direction of Prof. Dan C. Doulet, a community with little development was selected for a plant site, although at first no product had been selected. A maximum capital budget of about $100,000 was agreed upon on the grounds that this was the amount of capital that could be raised locally. Next, a survey was made of local industry as to purchasing agents' needs which were then being purchased in "foreign states". In fact, in deciding to set up the plant, no product decision was made until after some marketing work had been conducted. The product selected was not agricultural, but was related to local textile plants in the area that were purchasing zippers in the New York market. Based on the apparent volume of zipper demand, the product selected was finished metal zippers.

59. Students of the University of Tennessee Engineering School assisted in the design of productive facilities to be introduced in stages, and a graduate was proposed for plant supervisor. With these plans in hand, stock was sold to local residents to raise the required capital for development and expansion up to the original budget estimate. Operations started with a supervisor and one worker, who engaged in assembly-to-order of various lengths of zippers from stock purchased in New York. Then zipper manufacturing machines were purchased, so that fewer and fewer purchased parts would be required. Finally, with an increase of workers and installation of machines completely self-contained manufacturing was possible. The progression of steps always showed a profit and a formerly depressed community became a substantial source of industrial employment. Similar accomplishments in other fields have also been brought about by this approach, which has resulted in increased exports from the state. Products containing the zipper component are sold throughout the United States and the world.

60. Two factors helped to bring about the success of this experiment: first, the selection of a product to be made was based upon actual demand, second, substantial engineering and management skills were brought into the operation at its outset even though local personnel would operate it eventually. In many unsuccessful cases of manufacturing introduction a reverse procedure has been used, namely tooling up on a large scale before proved markets have been determined, contacted, and convinced to buy or rapid development without required engineering and management skills.

61. A similar set of problems and procedural sequences affects the agricultural implement maker, as exemplified by the tomato "combine" development example given earlier. In most cases of the small-run manufacturer, success appears to rest upon a blend of marketing, engineering, and management skills - as opposed to exotic production tooling at the beginning of operations. This is particularly so when a blend of technical expertise, such as agricultural and mechanical, is required.

E. Conclusion

62. We have seen that agricultural equipment manufacturers range from large-scale integrated manufacturers specializing in component and assembly of heavy and relatively complex finished products to smaller custom manufacturers and short-run manufacturers of light farm equipment. We have also seen some of the differences in approach used in each case.

63. For large manufacturers, co-ordination and planning requirements become severe if the benefit of common parts is to be exploited. However, when such planning is carried out, the large manufacturer has the ability to engage in a wide range of subsidiary product sales, often supplying some components to a specialty firm, then distributing its finished output. Such an association for a developing small manufacturer usually provides much greater capital resources, wider markets, and better technical and management skills than he could achieve swiftly on his own. For this reason, licence agreements, joint ventures, and similar co-operative arrangements are popular among domestic manufacturers, and are often essential to obtain rapid progress in developing regions. Throughout the world the most advanced tooling, planning, and marketing methods are employed by firms that have made such co-operative arrangements.

64. Custom manufacture of specialized products often requires less investment in tooling and less tooling specialization but also requires greater development cost and a higher degree of inventiveness. The co-operative route in this instance is often through a government agency or university research department. The small-run manufacturer also finds advance co-operation with his prospective customers a definite asset in promoting orderly and profitable growth.

65. The planner who seeks to select a given form of manufacturing for the agricultural field faces each of these alternatives, and their various combinations. The variety of alternatives open to him is so great that he cannot within reasonable expense hope to consider all of them in detail. If he is to get on with the job of manufacturing he cannot devote all of his resources and time to investigation, but must use simplified procedures at first so that a selected list of feasible possibilities may be evaluated later.

66. In other words gross scans of all products that might be feasible cannot, with given limited resources, produce the detail of evaluation required to come to a rational selection of one, or a group, of products to be manufactured in a given location. Some screening rules must be applied to narrow down the list, rules or guides that cannot be spelled out, but which must, nevertheless, be used.

67. The author's conclusion, as a result of this study, is that one of the most appealing rules that can be applied for screening is to investigate obvious needs in the agricultural field, then concentrate attention on the means of manufacture to fill those needs.

68. The opposite approach, which seeks to evaluate all products that could be made with existing facilities appears to generate too many alternatives to be handled. Although this approach has great theoretical appeal because an optimum selection of products and manufacturing organizations is hoped for, the cost and time required for such a grand scan, which must be included in the optimization calculations, offsets minor gains that might result from fine-choice methods. In short, it may not be as important to make an optimum choice as a grossly accurate choice, within grossly defined constraints.

69. If this conclusion is true, and it appears to be so for a field as wide as that of agricultural implements and associated products, then it would appear necessary to investigate the common agricultural needs of various regions to develop a small list of the most urgently needed implements and machines. Such an investigation need not be very extensive for each region. From this sound basis, detailed engineering and manufacturing investigation and planning can proceed in a realistic way towards the manufacture and distribution of products for both the domestic and export markets.

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