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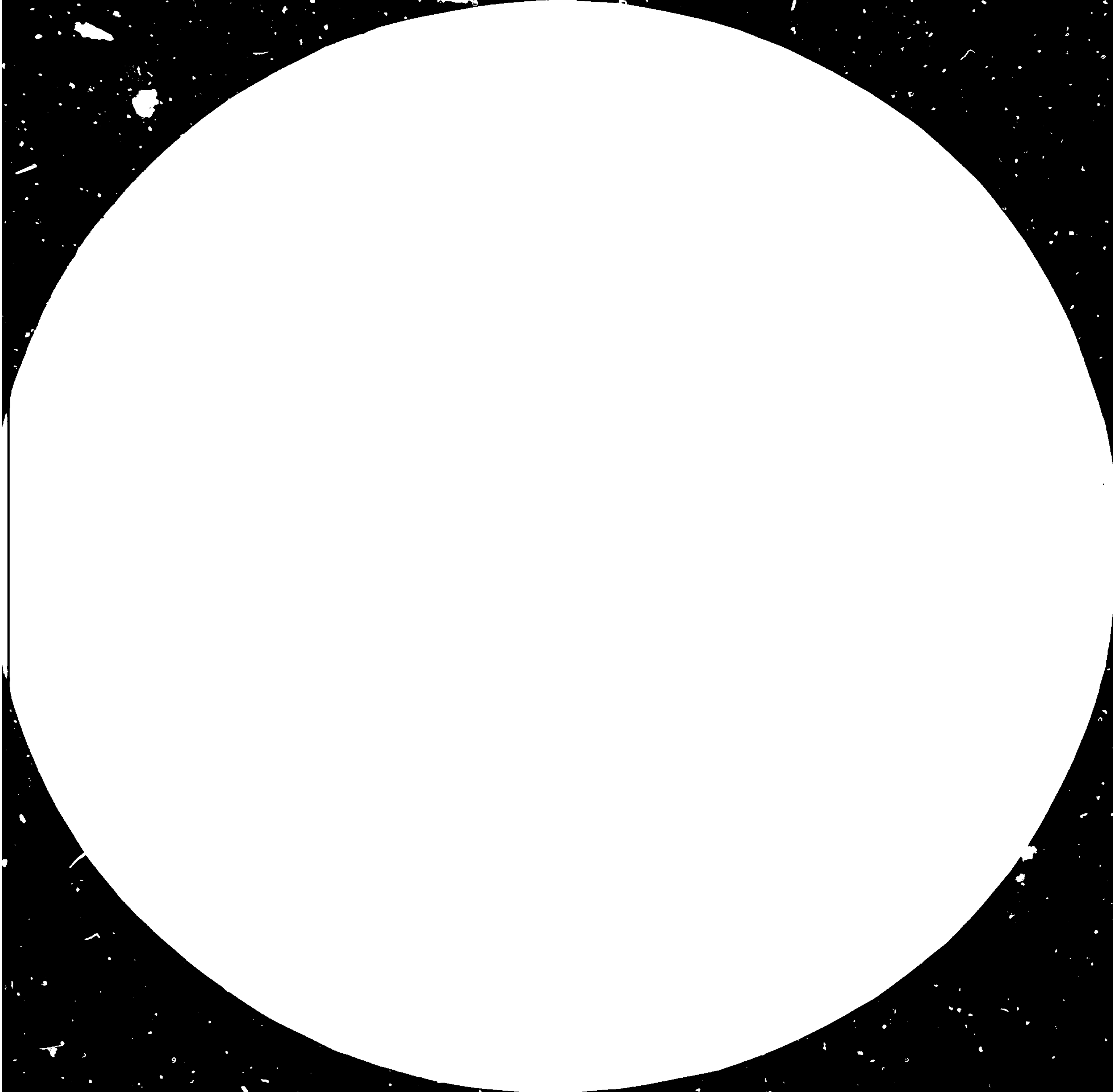

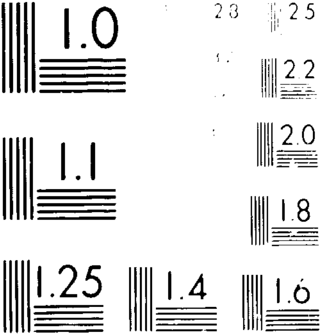
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THE DEVELOPMENT OF AFRICAN CAPACITIES FOR THE DESIGN AND MANUFACTURE OF BASIC AGRICULTURAL EQUIPMENT

Sectoral Working Paper Series

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SECTORAL WORKING PAPERS

During the course of work on major sectoral studies by UNIDO's Division for Industrial Studies, several working papers are produced by the secretariat and by outside experts. Selected papers that are believed to be of interest to a wider audience are presented as Sectoral Working Papers. These papers are more exploratory and tentative than the sectoral studies. They are therefore subject to revision and modifications before incorporation into the sectoral studies.

This paper is largely based on a contribution by Mr. Maurice Ogier, CINAM (Compagnie d'Etudes Industrielles et d'Amenagement du Territoire), Montpellier, France, as consultant to the UNIDO secretariat. The views expressed do not necessarily reflect the views of the UNIDO secretariat.

Preface

This study has been prepared as a specific contribution by the UNIDO secretariat to a Seminar on the Design and Development of Agricultural Equipment for Africa, organized by UNIDO, and held in Cairo, Egypt, 17-28 October 1982.

The Seminar was organized as a follow-up to the conclusions and recommendations of the First Regional Consultation Meeting on the Agricultural Machinery Industry, which was held in Addis Ababa in April 1982. The content of this document therefore relates closely to studies prepared for the Consultation Meeting and to the outcome of the Consultation. A major study, based on that documentation, the outcome of the Cairo Seminar and supplementary work, has recently been issued by UNIDO under the title "Agricultural Machinery and Rural Equipment in Africa - A new approach to a growing crisis" (UNIDO/IS.377) March 1983.

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Introduction[1/]

The possibility of African countries to increase the production of machinery in the agricultural sector in order to achieve reasonable targets for food self-sufficiency, thereby minimizing their dependence on foreign technology, is contingent upon two complementary factors:

1. The creation of appropriate designs for developing agricultural machinery, which is the key factor for practical adaptation of demand and production structure, and

2. The development of local production and maintenance structures.

The nature of supply and demand interrelationship is in fact determined by the degree to which the design of the equipment takes into account the requirements of the user, the performances expected of the equipment, the conditions of use in the environment concerned, the possibilities offered by the local production structures, either existing or to be created, and the materials available. Appropriate design could also lead to reductions in maintenance operations, by standardizing and reducing the number of items, and in technological dependence. Mastering of the design is the key to the development of an autonomous technology.

The development of manufacture and maintenance in the agricultural sector in African countries depends directly upon the design of the equipment. The alternatives need no longer be limited to one of two extremes: (1) local manufacturing enterprises that are designed on the basis of the technology and financial resources

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1/ This paper relates closely to the studies prepared for the Regional Consultation on Agricultural Machinery in Africa, held in Addis-Ababa, April 5-9 1982. UNIDO Documents UNIDO/IS.288, 20 February 1982, ID/WG.365/1 of 9 February 1982, ID/WG.365/2 of 8 February 1982, ID/WG.365/3 of 20 February 1982, ID/WG.365/7 of 30 March 1982. See also the report on the Consultation, ID/239.

of industrialized countries, or (2) the village blacksmith. The primary obstacles to the first alternative are the high investment costs, the size of production, the difficulty experienced by local labour in mastering the technical and organization elements and the continued dependence upon other countries for supplies of materials and component parts. However, this type of unit is suitable for the process industries, for thich there are few technological alternatives, and the production of complex conponents (engines, for example) for sufficiently large sub-regional or national markets. The village blacksmith likewise has both advantages and limits. Being close to the user, he can produce and maintain simple tools and equipment. However, his production capacity, the type of materials he uses and his level of technical ability limit his production potential.

In general, the small- and medium-sized manufacturing enterprises in urban areas predominate in African countries, but the problems encountered show that they are likewise unable to meet all of the requirements. Virtually none of the African countries has a basic, organized production network capable of fully satisfying the national market requirements for agricultural equipment.

It is essential to promote the emergence of new types of decentralized production units that are more closely adapted to the rural-user environment, with progressive mastery of the basic technological options and with flexibility depending on relatively multi-purpose production equipment to allow diversity in production. In view of the diversity of mechanical sub-assemblies contained in one item of equipment, the variety of tasks to be performed (design, construction, maintenance and repair, supply of spare parts, raw materials and components, etc.), all of the existing potential resources within or outside of a country must be exploited. Frequently the origins of technological innovations lie outside the agricultural mechanization sector. For example, automobile maintenance workshops fulfil the task of maintaining agricultural equipment. A tractor assembly line could be linked up with an automobile manufacturing and assembly units. In another sphere, a plastic injection moulding unit could supply a wide range of products required by agriculture (irrigation pipework, fermentation vats, tanks, etc.), including the forestry sector, which is all too often ignored.

The design and development of appropriate equipment is not currently possible in Africa for various reasons:

1. Engineering manpower capacities are inadequate,

2. Assessment of agricultural requirements is rare; where it exists, communication to the engineering and industrial sectors is poor, largely for institutional reasons (poor communication between the ministries of agriculture, research departments and experimental stations for agricultural mechanization, and between the ministry for industry and manufacturing companies); and

3. Transition between prototypes and the launching of a preliminary series is frequently found to be impossible due to financing difficulties, absence of a guaranteed market and a lack of confidence, even on the part of national authorities who for various reasons prefer to continue importing traditional foreign equipment.

The results obtained so far and work now in progress remain at the local level and therefore do not achieve sufficient attention. Conversely, countries rarely derive benefits from research and technological innovations outside the country.

There is also a basic cultural and political reason: the majority of private decision-makers and government departments in African countries do not favour the promotion of simple equipment, whether or not it is designed locally. They support, expressly or tacitly, the practice of importing equipment. Obstacles of all kinds, due in particular to the lack of interest and co-operation on the part of government departments, paralyse experiments while they are in progress or reduce them to mere diversion.

An awareness of these facts is not enough. A new, normative approach must be taken to design development and manufacture based on concrete assessment of the actual situation in African countries.

The question of the design and development of agricultural equipment which can be manufactured locally will be examined in this paper according to the following steps:

1. An examination will be made of the present situation with regard to production resources that can be mobilized in African countries. The following will be dealt with in succession:

a. small-scale production

b. small- and medium-sized suburban enterprises

c. large-scale enterprises

2. An order of preference will then be established for seven various categories of agricultural and rural equipment (a) hand tools and simple equipment, (b) animal-draught equipment, (c) portable equipment with ancillary motors, (d) stationary equipment with ancillary motors, (e) single-axle tractors, (f) simplified tractors of less than 30 hp, (g) heavy motorized equipment (tractors, combine harvesters) and civil-engineering equipment, etc.

3. An examination will then be made of the parameters governing the technological complexity of manufacturing equipment which can be implemented, distinguishing seven arbitrary characteristic levels of complexity, taking into account the nature of equipment, induction period, and size of investment.

4. Finally, design and development of equipment will be examined with regard to the promotion of a specific type of rural manufacturing workshop for the production and local maintenance of basic agricultural equipment vital to the general requirements of the peasant populus in African countries or regions which are not industrialized or industrialized only to a minor degree.

From the fourth section onwards this document concentrates on the target of manufacturing unsophisticated agricultural equipment in rural areas at the level of the artisan industry interface.

A programme of action is proposed with a view to effectively promoting the solutions and viewpoints offered.

1 Current Manufacturing Structures for the Production of Agricultural Equipment

Tools and equipment currently manufactured locally are produced mainly at three levels:

1.1 Manufacture by Artisans

A distinction is made among traditional blacksmiths, modern blacksmiths and rural mechanics.

Traditional blacksmiths constitute a self-contained, closed caste: only blacksmiths' children become blacksmiths. The income of a master-blacksmith is frequently high. His work is repetitive with little variation, including such items as hoes, gin traps, and special tools such as palm cutters. The communication of know-how is by internal apprenticeship. Value added onto the items manufactured is approaching 100 percent since they generally work with scrap iron (metal rails, lorry chassis, timber-lorry shafts, etc.) and locally manufactured charcoal.

The share of the market volume supplied in this way is very exten.ive. Assuming that a family of five people in rural Africa purchases 1 hoe per year on average, a rural population of 1 million inhabitants represents a market for forged hoes of some $ US 400,000. In contrast, this same population spends only a fraction of this amount for the purchase of agricultural tractors.

The caste of traditional blacksmiths has developed very little in term of the adoption of new equipment -- arc welding and tools for forging in a standing position are often rejected. However, it has lost little ground in its own traditional markets, except in the face of imports of certain products, machetes in particular.

For certain products, primarily animal-draught cultivation, modern blacksmiths have accepted new equipment, such as lever-shears, foot-operated vices, miscellaneous hand-tools (punches, swages, metal anvils, special pliers, etc.) and, in general, work in a standing position rather than seated on the ground. They have extended their production range to manufacturing parts for ploughs (ploughshares and mouldboards), and to servicing equipment occasionally used for animal-draught cultivation.

Modern rural mechanics fall into various categories. There are mechanics who specialize in the maintenance of bicycles, motor cycles, pneumatic tyre repairs, and those who specialize in the maintenance and repair of automobiles and lorries.

More rarely coach-builders can be found who are capable of transforming new pick-up trucks into panelled vans, and mechanics equipped with arc-welding sets who can produce various tools that are competitive with those made by blacksmiths, such as mechanically-welded hoes rather than forged hoes, metal beds, security grids, barbecues, and even precasting and decorative partition moulds.

Problems involved in artisan production

The following problems are virtually identical for the 3 categories of artisan workers.

a. Inefficient supply systems

Supplies of new or scrap iron are collected by taxis or lorries from large towns and routed to rural workshops. These supplies are delivered only on a daily basis, without any storage or group-purchase facilities, hence without the possibility of discounts for bulk. This method is expensive and undependable.

b. Financial restrictions

As a result of daily deliveries of supplies, the artisan spends from day to day what he earns. There is no accumulation of capital nor much development of equipment. The mechanic has virtually no working capital nor stocks of equipment.

It is difficult to earn money from maintenance and repair work since clients never make financial provisions for such work. It is easier to sell finished products, primarily at the weekly market because they are paid for in cash.

c. Seasonal work and diverse activities

The rural artisan is also a farmer with the exception of young former students who repair bicycles, motor-cycles, etc.

Agricultural work is intensely seasonal and it corresponds with the solvency period of clients. During this period the services of the rural mechanic or blacksmith are required for agricultural purposes. Mechanical servicing and work on the land thus coincide.

The dry season is a one of inactivity. This explains why the managers of agricultural projects have finally decided to pay maintenance staff a full-time salary, even though they are used principally in the rainy season. The traditional artisan solution was unsatisfactory.

One solution to this problem would be to promote non-farming artisans whose activities would consist of production work during the dry season and maintenance work during the rainy season.

d. Insufficient training and poor product quality

Often the artisan's activities are too numerous and the quality of his work low. Any improvement in quality as a result of further professional training is blocked since improvement in quality is linked with greater time spent. The invoiced price would be rivalled by the quotation from artisans whose work is of poorer quality.

To succeed, both the productivity and the quality of training must be improved to increase the artisan's profit as well as the quality of the product, without increasing the cost. This is sometimes possible, as will be seen later, by introducing machines to prepare kits of semi-finished materials, leaving more time for better-finished subsequent operations.

1.2 Manufacture by Small- and Medium-sized Suburban Enterprises

A distinction must be made between the traditional small- and medium-sized suburban enterprises, whether or not part of an "industrialized zone", that are not linked to a decentralized manufacturing network, and the manufacturing networks of COBEMAG, ARCOMA and COREMA in Western Africa in which a central urban workshop is linked to rural workshops in order to form an overall system to carry out production and local maintenance tasks, sometimes in conjunction with an agricultural project.

1.2.1 Traditional small- and medium-sized suburban enterprises

Traditional small- and medium-sized suburban companies are comprised of a few dozen workers at the most whose activities relate to outlets in the modern urban sector rather than to those in the traditional rural sector. Boiler-works can be found which deal in structural steelwork, metal beds, strong-boxes, metal cupboards and door-frames, wind-engines, dewatering pumps, block moulds, brick presses, and sometimes even equipment related to the mechanization of agriculture, such as cultivator mountings, farm trailers, decorticators, and mills. These will be accommodated in an industrial or small crafts complex where such a structure exists in the town.

Problems involved in traditional small- and medium-sized enterprises

a. Supplies remain a problem not so much because of transport, which is over a short distance, but because of the limited choice offered by local importers and frequent depletion of stocks.

b. Market limitations

The managers of these small- and medium-sized companies are unanimous in deploring the limitations of the market in the countries concerned, which makes profitability a difficult proposition for essential modern equipment such as high performance machine tools, presses, furnaces, etc.

Orders are for too low a quantity, the markets are irregular, and sometimes are barely at solvency level. Orders for one outlet are very diverse: each client presents a particular problem, e.g., the type of hoe used in the Sahel region cannot be used in forest areas or in rice-growing areas. and requires too small a number of identical items. Hence the fixed costs for modern equipment do not benefit from reduced costs through standardized manufacture.

c. Competition from imported equipment

The cost price is high, and competition exists from similar imported equipment, which is manufactured under better conditions. The result of this is that small- and medium-sized enterprises frequently tend to become local commercial agencies for foreign equipment, which is considerably more lucrative.

d. Poorly qualified staff

Small- and medium-sized enterprises have difficulty in finding qualified staff because technical training is in general poorly adapted to actual demand. There is little provision for permanent training facilities. Management is relatively difficult since the level of staff is low.

e. Limited financial resources

The job of entrepreneur is not as yet very well defined. It is difficult to obtain funds under acceptable conditions, e.g., low bank interest rates. Frequently the capital of these companies is brought in by an official who appoints a manager. The owner then endeavours to obtain an immediate income, to the detriment of the investment and of the long-term prospects for the company.

f. Lack of capacities for innovation

The small- and medium-sized enterprises need to conduct research into new areas and design new products (prototypes, tests). However, their volume of activity does not always warrant the expense of such research, and it is difficult to buy patents, licences, drawings, etc. which are adapted to the local market.

g. Client complaints

These companies offer products which are more expensive than those offered by local artisans. However, clients deem the quality to be better. A major source of complaint is the total lack of after-scales service (dewatering pumps, agricultural equipment, etc.). This also applies to imported equipment sold by these companies: they rarely have spares available, apart from a few basic essentials.

1.2.2 Manufacture by networks consisting of a central small- or medium-sized company and decentralized workshops

These networks undertake projects to construct agricultural equipment for animal-draught cultivation. For example, COBEMAG (Benin) and ARCOMA Corema (Upper Volta) manufacture, inter alia, ploughs and carts.

In general, the projects consist of structuring local artisan work (smiths, mechanics) with the central workshop as a consequence and not the initial core of the project.

The basic idea behind a network is to collect electric motor-driven machines in a central suburban workshop and link them up to an electrical grid in order to offer the possibility of manufacturing kits of semi-finished material. This material could then be distributed to rural manual workshops where finishing operations with hand-forging would be carried out, followed by assembly and paint-work. Local maintenance of the equipment sold would be carried out by these rural workshops.

Another concept is the complete manufacture of equipment in the central work-shop, sub-contracting manual operations to the rural workshops. The decentralized workshops could thus be equipped with an arc-welding set, which would mean subcontracting welding operations to them, thus improving local maintenance facilities by virtue of the welding equipment. Workers in the decentralized workshops could also be used as temporary labour to make up the work force in the central workshop. Accommodations would thus be needed in the vicinity of the central workshop.

Problems involved in manufacturing network

a. Institutional complications

If traditional suburban small- and medium-sized companies could be created by private enterprise (with assistance as required), it would be ideal if the structure of these could match the manufacturing networks in extent: in fact, the increased organisation required is not necessarily compensated by increased profit for the contractor. In addition, the mentality of rural artisans and that of local or foreign investors establishing these companies have little in common. These live alongside each other without any point of contact. An element of mutual contempt is not uncommon.

Moreover, Governments and, more particularly, their ministries responsible for technical training, labour, agriculture and industry have frequently analyzed the theoretical advantages involved in creating networks of this kind: integration into the same structure of an after-sales service, potential flexibility, versatility, possible integration of a training centre, possibility of assisting the artisan trade, improvement in the system of communication between the constructor and the peasant, who feels a closer affinity with the rural artisan than with the urban contractor, integration of the manufacturing project with agricultural development projects, etc. .

However, a legal structure must be found for such an arrangement. The idea of a co-operative has frequently been discussed. The State would be the owner of the infrastructures within the context of the initial project, thus providing a State-controlled system. A leasing system could also be envisaged whereby the co-operative would lease equipment to the State. In the first instance, an overseeing ministry would maintain the right of inspection over the co-operative. This right would possibly extend to the hiring of salaried officials to head it by creating a problem by virtue of the coexistence of salaried government officials with workers whose income is dependent upon the company's trading results.

In the second instance, the manufacturing network would be more independent, although the State would retain ownership.

The ideal solution would be for the workers in a co-operative to unite and borrow from the banks, thus enabling them to assemble the requisite capital for the company among themselves. In practice, it is only the States, with or without assistance from bilateral or multilateral assistance organizations, who are able to raise the requisite capital for investment and working capital to meet training costs and those involved in starting up production (with possible technical assistance from expatriate specialists).

b. <u>Organizational complexity</u>

Managing a manufacturing network is a complicated affair. From this point of view, the institution of a network is more complex than that of a suburban artisan sector.

In conclusion, this structure potentially offers all the advantages required in terms of supplies, on-going training, links with government projects and access to technological innovations when the State is involved.

It is sometimes advisable to go beyond the initial sectoral l[illegible]uch projects. For example by linking a wood-working or rural buildin[illegible] with a manufacturing network for animal-drawn cultivators, the profitability of a lorry or a certain item of equipment (e.g. planing machine) could be optimized and periods of low activity in one sector would be counterbalanced by those of greater activity in another sphere. This would lead to greater versatility and flexibility.

Ideally, a multi-purpose system of this type should be granted a privileged position from the Government for the performance of State contracts in this sector. A system of decontrolling duties could be envisaged to enable this official network to counteract foreign competition in such priority sectors as animal-draught cultivation and minor mechanisation.

1.3 Manufacture by Large-scale Local Enterprises

There are many examples in Africa of agricultural equipment enterprises which go beyond the framework of the small- and medium-sized companies. The majority of these are located in large countries which have already achieved a certain degree of industrialization, such as Algeria, Egypt and Zimbabwe and, to a more limited extent, Senegal, the Ivory Coast and the United Republic of Cameroon. Whilst these enterprises in general claim a regional interest, the level of inter-African exports is in fact extremely limited.

Experience over the last ten years has shown that the problems of the small- and medium-sized companies apply to the large-scale enterprises as well, with the added factor of size. The market is relatively more limited; the organizations and management problems, e.g. funding difficulties are more complex. Where these enterprises offer the assembly of imported equipment only, the low value added locally makes it a proposition of little attraction: 5 to 10 percent at best.

Finally, we have seen that in the event of a reduction in economic growth, and thus in the equipment rate of purchasing rural zones, large-scale enterprises have the requisite flexibility or adapt their production to the market. Disbanding is therefore inevitable, e.g. Ivoiroutils and Siscoma.

1.4 Summary and Conclusions

The extreme forms of manufacture referred to above come up against highly complex structural problems. Therefore the average African country cannot resort to them as a basis for an agricultural equipment production policy. The artisan blacksmiths, whose role as the supplier of traditional hand-tools remains essential have no possibility of further development beyond certain limits. The major industries encounter numerous obstacles, both internal (in particular the reduced size of the market), and external (competition from industrialized countries). The small- and medium-sized urban companies likewise face numerous problems and have difficulty with respect to clients, maintenance work, supply of spare parts and research and development of equipment adaptations.

It may be said that there is no ideal formula, except for alternative complimentary solutions adapted to the situation of individual countries and to geographical zones within these countries. Large-scale agricultural machinery industries or assembly units are clearly unsuitable for many of the poor sub-Saharan African countries.

2. Local Manufacture of Various Types of Agricultural and Rural Equipment

In this section we shall analyze the problems of local manufacture of seven types of agricultural and rural equipment.

2.1 Hand tools and simple equipment

As we saw earlier, traditional and modern blacksmiths and some modern mechanics and welders manufacture relatively good quality hand-tools, such as hoes, and machetes, agricultural equipment, such as gin traps, seeders, manual oil presses, cattle-troughs, irrigation gates, and valves, and building equipment such as grids and door-frames.

Production could be improved by the creation, in particular, of a central purchasing system to optimize their supply of quality raw materials (new, manganese silicon steel in place of scrap mild steel, for example). Training would have little effect, however, on these traditional sectors.

The failure to find steel alloys capable of competing with those used for imported tools has led to the smiths completely giving up producing machetes. Certain local works manufacture these items under licence.

Frequent studies have been made of projects to produce punched hoes in a similar way to machetes. The extremely wide variety of hoes required and the sluggishness of the market have discouraged these projects which, had they been implemented, would have had the direct effect of eliminating the basic activities of the blacksmith.

Workshops oriented towards cutting and welding instead of forging could thus, without any technical difficulty, construct equipment such as seeders, rotary dibbers, driers, cribs, threshers, palm-oil presses, stone presses for cattle-licks, hand maize-shellers, arabica coffee bean pulpers, silos of sheet-metal or reinforced concrete, small items of structural steelwork, security grids, door-frames and basic metal furniture, beds, strong-boxes for rural use, kitchen stoves, block and partition moulds, terra cotta brick presses, cattle-troughs, irrigation gates, various pipes, valves, and incubators. All of these items can be manufactured in a rural workshop with a mechanical saw, lever shears, a portable disc-grinder, an arc-welding set and drill, or in a manufacturing network. However, typical detailed drawings would have to be issued for this wide variety of objects and they are not generally available.

2.2 Animal-draught cultivating equipment

This type of equipment is already manufactured in a number of countries and does not present any insuperable problems. However, a welcome innovation would be ploughshares made of manganese silicon steel or a similar material, and ploughshare mould-boards made of triplex steel. As these steels are difficult to implement, it would seem expedient at present to import these items and build the remaining items --plough-slades, plough-beams, props, multicultivators -- locally. If necessary, plough-shares can be made locally, but mould-boards are too difficult to form.

In general there are two possible types of equipment design:

(1) Forging (hot-bedding of a semi-hard mass of steel). Holes are drilled by machine rather than at the forge, however. Similarly, handles and stilts are made by bending flat bars which are riveted or bolted to the ploughbeams. The equipment -- such as plough-beams -- obtained by this method is generally light and well-proportioned.

(2) Cutting and welding (welding rectangular or circular tubes with flat bars). Final assembly is carried out using bolts. The frames are angular in appearance and the equipment is generally somewhat heavier.

However, in principle excellent equipment can be constructed with both types of design. Forging seems to be less favoured in the face of the fast performance achieved with arc welding.

The cutting and welding workshop described briefly above together with a small joinery and painting workshop offer the possibility of constructing animal-drawn cultivators with welded tubular metal frames or wooden frames (ploughwright type construction). Pneumatic tyres and axles are generally imported. Axles could, however, be manufactured relatively easily.

2.3 Portable equipment with ancillary motors

Whilst portable equipment appears to be of simple construction, they are virtually impossible to manufacture in a local workshop. Hand-carried tools are in fact limited to an overall weight of approximately 15 kg. In view of this, they are generally constructed of pressed or die-cast aluminium alloy of low thickness.

The equipment have high-performance motors (maximum rating per kg). The gearing is made of high-strength treated steel to maintain the weight of the unit as low as possible; plastics are also used.

All of this implies a high complexity in the manufacture of these tools. They, e.g. chain saws, portable scrub-clearing machines, earth augers (for planting shrubs), back sprinklers, and even lawn-mowers (which are not carried but manipulated by hand) are produced in industrialized countries on a large scale, including keen competition.

Assembly is possible for these machines only at local level, but this is not an attractive proposition. The value added is low and the necessary increase in the basic technological level of the workers involved is small. However, maintenance of this equipment would have to be included in any local manufacturing project.

2.4 Stationary equipment with ancillary motors

The manufacture of equipment such as decorticators, mills, crushers, threshers, concrete mixers, irrigation pumps, planing machines and drills for joiners is not currently envisaged as being performed outside a company that possesses a casting foundry or, where aluminium alloys are not involved, a lathe, milling machine, etc.

In each case the electric motors or heat engines are imported. In addition, detailed drawings of the rotors for machines which frequently take a long time to produce are required, e.g. decorticators, crushers, mills, planing machines.

All of the above reasons explain why the majority of this equipment is imported. However, various special techniques, in particular in the mechanical welding field, offer the possibility of producing even bearing races without the use of machine tools, and this should pave the way for construction of this equipment solely by cutting and welding without the use of heavy machinery (see sections 3 and 4). With this in mind, prototypes would need to be developed, and drawings and the techniques of the trade peculiar to these simplified machines made available to the public.

2.5 Single-axle tractors (motor-driven cultivators)

Locally manufactured motor-driven cultivators or their accessories are virtually non-existent. The reason for this is apparently two-fold:

(1) These implements are rarely used for cultivation in hot regions, except for market gardening and irrigated rice-growing areas.

(2) There is such a large number of manufacturers of this equipment in industrialized countries where it is used for amateur farming, that, with all the competition among them, prices are sufficiently low to discourage any local manufacture. In addition, the complexity of single-axle tractors approaches that of 4-wheeled engines, which apparently give much better performance for little extra cost.

At best, local assembly of imported motor-driven cultivators could be envisaged, and this is recognized as being a proposition of little interest.

2.6 Simple tractors of less than 30 horsepower

The problem regarding simple, low-powered tractors is quite different:

(1) Competition from equipment manufactured in industrialized countries is very slight because these models, which were popular in the 1950's, have virtually disappeared from the market. Moreover, the vehicles remaining in these outlets are not particularly suited for agriculture in emerging countries where working conditions are very difficult: one can find articulated mini-tractors, which are insubstantial and unstable, or a few slightly better adapted models, left over from the 1950's, such as [illegible] little [illegible]AT 300, which may be suitable for use on a savannah type terrain [illegible] are virtually no multi-purpose minitractors suitable for [illegible]rain -- crawler mounted or other -- to cover vehicle requir[illegible] areas, or for maintenance

work in permanent plantations, e.g., coffee, cocoa, palm, hevea. Similarly there is very little equipment for flooded rice fields and marshy areas.

(2) Technical organisations specializing in the mechanisation of agriculture for development have popularized the concept of "intermediate mechanisation" in recent years, using simple adapted techniques, accessible to the largest number of people, with a view to optimizing technical non-independence for users.

There is thus a market for simple low-powered tractors. The volume of this market remains relatively small for the present, which, in a period of world-wide economic crisis, discourages manufacturers in wealthy countries from producing new models and exporting them.

Various types of equipment have already been produced locally, and the promotion of these types continues with a varying degree of activity. They include, for example, the hydrostatic TINKABI tractor and the PANGOLIN (which is currently considerably less advanced) in the Ivory Coast. Firms such as Citroen and Volkswagen also have various projects in progress, but with a different industrial logic in mind.

The first two cases do at least prove that local manufacture is possible, provided that engines, gear boxes, wheels and hydraulic components can be imported for the TINKABI.

The PANGOLIN Tractor uses a technique which does not involve any machine tools other than a saw and drill for its construction. Project development difficulties are not therefore linked with financial difficulties in equipping the workshops nor with the cost and duration of training, but with the lack of dynamism in publicizing and promoting the machine.

The problem of the limited market is eliminated if manufacture can be carried out in a workshop or multi-purpose production network that concentrates on a wide range of equipment, provided that no special or costly equipment is required for manufacture of the tractors. The manufacture of several machines per year would be in addition to the normal work-load.

2.7 Heavy agricultural tractors and civil engineering equipment

As discussed in the introduction, local manufacture of heavy tractors is not a feasible proposition. At best an assembly works could be envisaged. However, an interesting manufacturing line could be the satellite equipment to these machines: cutting and welded frames for cultivators, sub-soilers, tillers, farm trailers. Only the tines, plough-shares, points, complete axles and pneumatic tyres would have to be imported. It will be recalled that the cost of these mountings, frames and trailers represents several tenths of the cost of mechanized crawlers. It would not appear to be possible to construct civil engineering plant locally, particularly bearing in mind the current trend towards increasingly large machines. On this assumption, there are no mini-civil-engineering machines suitable for teams of youngsters to carry out maintenance of rural thoroughfares (under contract to the public works ministries), which would provide employment for a large number of school-leavers. A small basic agricultural tractor equipped with a mini-bulldozer blade, or a small trailer, could prove sufficient as equipment for these road maintenance gangs.

2.8 Summary and conclusions

The extent of possible lines for local manufacture is thus quite considerable, particularly if one goes beyond the context of agricultural equipment in its strict sense and includes all types of rural equipment, from home and farmyard equipment to agricultural equipment.

The guidelines for selecting these lines are as follows:

- research the fields free of competition from industrialized countries.

- research, as an initial phase, the types of equipment which can be produced without cast parts or difficult machining, relying solely on cutting and welding or boiler-making.

- import tilling implements made of special steels and complex mechanical components, such as engines, gear boxes, pneumatic tyres, and axles.

- research the possibility of finding an information source of detailed typical drawings.

3. Technical Complexity of Local Manufacturing Units

There is an infinite number of different types of workshops ranging from the most rudimentary employing archaic hand-forging techniques to the most highly complex using computer-controlled robots.

Each type of workshop requires a certain degree of know-how and an initial investment. Table 1. presents 7 types of manufacturing workshops in order of degree of increased complexity of equipment, and identifies the cost of the equipment (excluding buildings), the possible products of such equipment, and the training period for the necessary managerial staff.

Table 1. Identification of manufacturing workshop types according to the degree of increased complexity of equipment

Degree of complexity of equipment	Brief description of equipment	Cost of equipment (in thousands of 1982 $US)	Training period for managerial staff (in months)	Possible production
1	Traditional manual forging in a sitting position	3	6 (spread over a lifetime)	Hand-tools traps, steels/ hones
2	Manual forging in a standing position, with lever shears, anvils, foot-operated vices, files, taps, dies, spanners, etc. No electricity	2	2	Maintenance and manufacture of tools for animal-drawn cultivation and manual agricultural implements
3	Complexity level 2, plus welding by semi-portable heat-welding sets	4	12	As per complexity level 2 plus maintenance of all agricultural equipment, wider manufacturing range

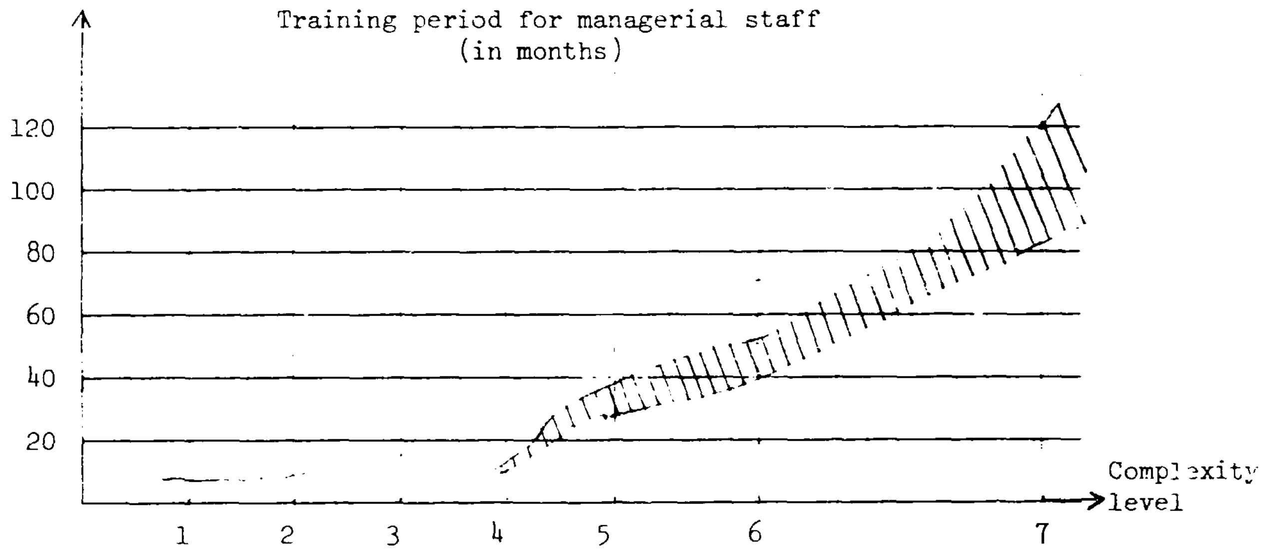
Degree of complexity of equipment	Brief description of equipment	Cost of equipment (in thousands of 1982 $US)	Training period for managerial staff (in months)	Possible production
4	No forging	7	9	As per level 3 plus manufacture of small tractors, etc.
	. Arc welding or using local electricity grid	7		
	. Pillar drill of 30 mm capacity			
	. Reciprocating saw of 180 mm capacity			
	. 2 portable disc grinders of 230 and 115.			
	. 5 mm lever shears			
	. Anvil, hammers, foot-operated vice, parallel vice			
	. Spanners			
	. Dies - taps -drills			
	. Files			
	. Paint sprays and compressors			
5	Level 4, plus machine tools . Lathe . Miller . Grinder . Bending press . Guillotine shears	25 to 100	36	All maintenance, all standard general machinery
6	Level 5, but with numerically controlled machines and gear-cutters, broaching machines, etc.	150 and more	50	Workshop for series manufacture and subcontracting

Degree of complexity of equipment	Brief description of equipment	Cost of equipment (in thousands of 1982 $US)	Training period for managerial staff (in months)	Possible production
7	"Flexible" work-shop with computer-controlled robot operation.	2000 and more	80	Large-scale vehicle manufacture

Two graphs below show the training period required for managerial staff and the cost of workshop equipment as a function of the degree of increased complexity. The first graph shows how the training period decreases, albeit to a slight extent at level 4 and then increases again rapidly. The second graph shows that there is a sharp upward trend in investment costs at level 4. Depending upon the level of production, it may be necessary to increase the number of similar machines; the cost given here is that for purchasing only one machine of each type. These costs are only an indication since each machine may be selected from a range covering the most basic unit to the most sophisticated. Nonetheless, the graphs are informative and highlight the advantages of level 4: this level combines considerable potential with a short training period for managerial staff and a low equipment cost. Better still, this workshop is transportable if the saw is replaced by a frame fitted with a portable circular saw and the drill is replaced by a frame fitted with a high-powered portable electric drill. These single-phase portable machines are produced by a high capacity thermal welding set with a 220 V/3kVA output. Hence repairs are possible by manufacturing cut and welded replacement parts on the tractor on site, as all of the above equipment will fit onto the platform of a light truck with a carrying capacity of 1,000 kg.

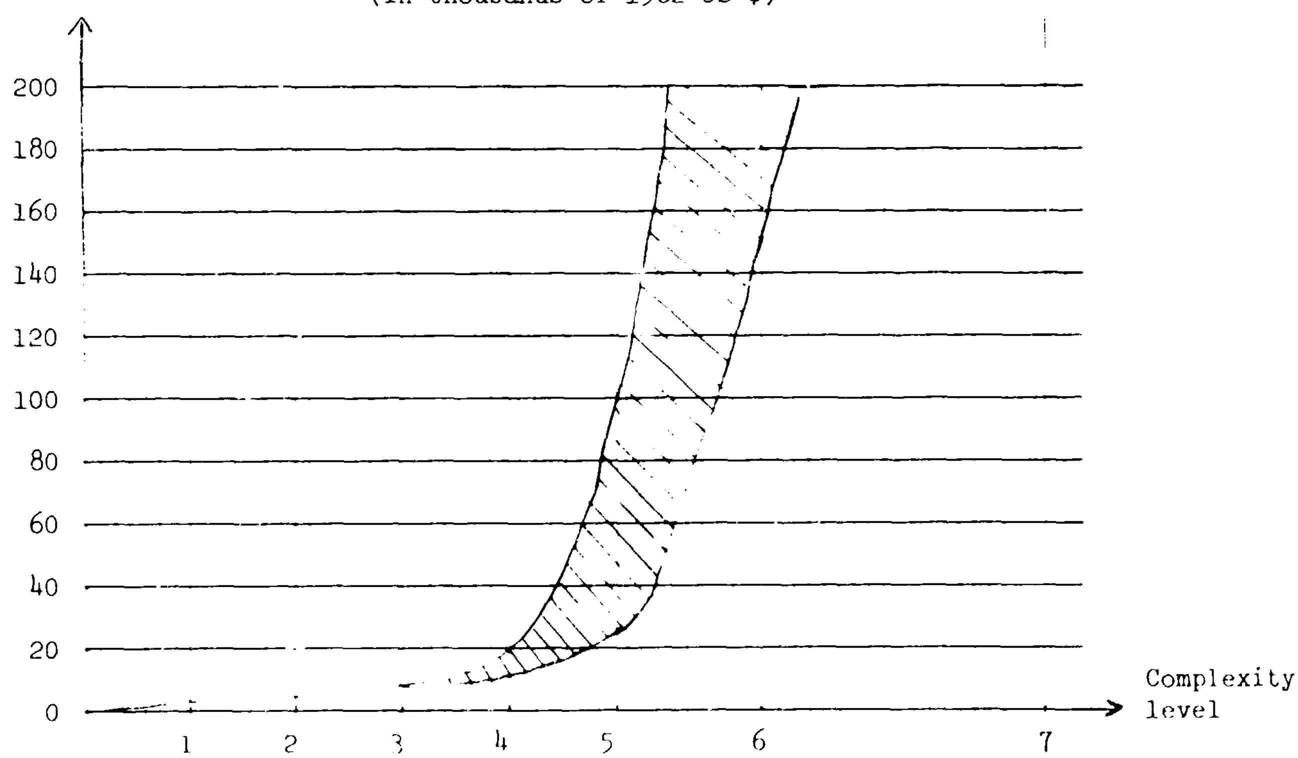
Graph 1

Training period for managerial staff
(in months)



Graph 2

Cost of equipment
(in thousands of 1982 US $)



This level 4 type of workshop can thus be set up in various ways, which are summarized briefly below:

- Option 1: A mobile workshop consisting of equipment transported by a flat-bed truck for the mechanical metalwork, with motors fed by a generator set.

- Option 2: A stationary workshop with no electric motor.
  This type of workshop (for which standardization is impossible) carries out metal-work only. Its equipment consists of various manually operated machines and tooling for sheet-metal work, forging and miscellaneous repair work.

- Option 3: A stationary workshop not linked up to an electric grid, with electric motors. The equipment is the same as that for option 1, with facilities for cutting and welding plus other manual machines and tools, to allow a more complete and careful service.

- Option 4: A decentralized workshop linked up to an electric grid. This level of workshop borders on that of small- and medium-sized industries. It can carry out all kinds of repair work on agricultural equipment and engines and can construct equipment ranging from the basic to the more complex, such as ploughs, trailers and small tractors.

The level 4 type of workshop offers great potential because it is adapted to local manufacturing restrictions vis-à-vis the size of production runs, the variety of equipment which can be manufactured or serviced, training of labour, and investment costs. It can be recommended as a basic step towards manufacturing for many of the African countries.

4. The Design of Agricultural Equipment for Local Manufacture:

Obviously the design of equipment must take into account the nature and complexity of the equipment in existing workshops or that which may reasonably be set up in African states, as well as the level of knowledge of manufacturing technology possessed by staff and managers.

Bearing in mind the great potential of the level 4 workshop, the design characteristics of equipment which can be manufactured in this type of workshop will be described in more detail below. The choice of the level 4 workshop is justified, especially as the design problems of products connected with the modern industry are much better known.

But the design of equipment must certainly also meet the requirements of consumers, offering the optimum level of performance desired by them, while reducing the level of restrictions and dependence on the outside world.

The various aspects are dealt with below, chiefly with reference to African countries or regions with low to very low income (especially Central Africa) and with little or no industrialization, by considering the simple agricultural, rural equipment that meets their priority requirements for the mechanization of rural zones.

4.1 The Technological Manufacturing Channels.

The manufacture of agricultural equipment calls for various means of manufacture, from the production of certain base pieces to assembling and finishing the completed equipment. It therefore involves making base parts in steel, machining them using various machine tools, mechanical welding workshops and boiler and plate workshops, constructing frames and bodies to protect the mechanical units when in operation, and finally finishing the equipment (assembly, paintwork).

As part of a study dealing with capital equipment in general, UNIDO has identified the various manufacturing processes and the level of technical complexity necessary for the manufacture of approximately 400 capital goods, of which about 60 are agricultural equipment, using the technology existing in developed countries.[2/] A detailed list of these items of equipment is given in the appendices to this document. Attention will be drawn to the importance of the role of the traditional industrial infrastructure (heavy industry, foundry), the complexity of the necessary machining operations such as pneumatic tyres or the need for recourse to foreign components.

2/ First global study on the capital goods industry: strategies for development ID/WG 342/3

The existence of mastery of these manufacturing means is often either unattainable or undesirable due to the cost and the small scale of potential markets. For example, smelting and heavy forging with heavy, expensive equipment (fuel oil stove, drop-forging presses, etc.) are inflexible techniques which are only of value when you have large series which permit the amortization of the wooden foundry templates or foundry dies. The hand forge with a bending mould is very rigid in use and needs large stoves because the bellows forge is not sufficient.

Thus the foundry and heavy forging should generally be avoided for the preparation of base mechanical parts Instead techniques of cutting and welding to make chassis, frames and blanks for mechanical parts should be selected.

A second important aspect consists of reducing machining which requires costly equipment and a long apprenticeship for the work force. To allow for this, special techniques have been developed for the production of "as welded" ball races. still directly usable for bearings and bushings, the simplification of the production of axle sleeves, bearings, etc.

4.2 Choice of techniques as an instrument for training of users

The choice of the level of complexity of production lines which must form the first phase in the motorization of agriculture is not a merely technical choice: It should permit the peasants to become acquainted with the use of agricultural machinery and must raise the basic level of their technical knowledge. From this viewpoint, animal-draught cultivation, whenever practical, e.g., where there is no sleeping sickness, constitutes a very interesting educational phase.

At the first level of complexity, should it be possible to easily observe the kinematic chain involved in the automation, e.g., the transmission of movement from the engine to the wheels, etc. Tractors with an enclosed chassis are particularly unenlightening: nothing is seen of what is contained in the main body; only the shafts of the control levers are visible (even the hydraulic jacks are incorporated in the housing of the tractor. Therefore simplified tractors should be designed preferably on the basis of a chassis plate carrying the mechanical parts on the outside and connected by visible belts, chains and shafts to permit immediate identification of the level at which a malfunction occurs. In the same vein, transmission by friction discs and belts which do not need a hermetic oil sump will be more easy to study than chain transmission with gears.

Eliminating electrical and hydraulic circuits (e.g., lifting) and replacing them with mechanical systems (e.g. a lifting winch and manual starting) would also aid understanding of machines. It is easy to change a cable or a broken winch, whereas work on hydraulic circuits is difficult. Fully hydraulic machinery of the TINKABI type could also be offered. The ideal would be to arrive at equipment which is so simple that it can be maintained and built by the peasant community.

A modular, non-integrated design is preferable for the first stage of mechanization. Each sub-unit is separate and could be made visible on the chassis by a separate block; in the event of break-down each module could be rapidly interchanged to reduce the time during which it is out of service.

4.3 Self-sufficiency for the user

A breakdown occurs when a part is worn out or broken. In either case it must be changed or a similar one must be made locally.

Therefore as far as possible the use of parts whose after sales service is not assured locally must be avoided. If this is not possible, more reliable types should be used to reduce the risk of damage or the risk must be transferred to weaker parts which are easier to find or make.

Automobile firms are among those which have the best after sales service in developing countries. Therefore sub-units (progonal recovered parts, which are much less expensive) from private cars could be used.

Another suggestion would be to voluntary limit the batch of tools required to maintain the machinery. For example, at the design stage bolts can be kept to one or two sizes (e.g. 12 mm or 14 mm diameter). A console attached by 6 8 mm screws will hold just as well with 4 12 mm screws. It is advantageous to limit the set of taps, spanners, dies, drills and stocks of bolts required by the artisan repairer, e.g., hexagonal socket heads or split head screws should be eliminated because Allen keys and other screwdrivers in good condition are very rare in rural workshops. A large tool box could be attached to the chassis of equipment and be delivered equipped with the necessary tools, including a grease pump and can. If possible, flat belts, sold by the meter in any good ironmongery, should be used, rather than trapezoidal belts. All these proposals are designed to allow the peasant or local artisan to take care of all running maintenance.

The dispute between advocates of petrol engines and those of robust but complex diesel engines is not over. The diesel solution has the advantage of being cheaper to operate.

Naturally the machines will be designed to be adaptable to local conditions, bearing in mind the variety of work to be performed, its specificity, the local climate, the state of the tracks, etc. It is therefore necessary to study carefully the work to be undertaken and then to run on-site tests and carry out successive modifications on the proposed equipment; perfecting prototypes is unavoidable, lengthy and difficult.

4.4 Concrete examples

To illustrate the preceding analysis, a brief description follows of the tests conducted by CINAM on the Ivory Coast and in France on simplified tractors for mountain agriculture. It is obvious that this limited experience must not be generalized too widely. However, it offers some background to the preceding discussion.

a. The Pangolin tractor (Ivory Coast)

The Pangolin tractor is a caterpillar, 1.4 m wide, 2 m long, weighing 1,200 kg. It is intended for plantation work, principally for the transport of coffee or cocoa from the field to the village. It can tow a load of 800 to 1000 kg. Its design after seven or eight intermediary prototypes is such that no locally turned or milled part is used. It can be built in a level 4 workshop. The engine, gearbox and wheels are imported. All the rest is manufactured locally and represents approximately half the value of the machine.

A small-scale manufacturing system with three or four rural craftsmen and a central workshop now being built at Guiberoua, near Gagnoa, is being studied within the framework of the large Ivory Coast rural mechanization project. One of the aims of this project is to ensure that a manufacturing system can be self-financed and to resolve problems of day-to-day maintenance of the agricultural equipment of the region, as a result of the more lucrative manufacturing activities which complete its plan of action.

It is too early to draw conclusions from this case because the central workshop has not yet been completed. The Pangolin project started in 1982 but this delay is due to the lack of fixed institutional protection: three different ministries have followed the development of the machine over the course of the years. The problems encountered are the lack of confidence in endogenous solutions and the financial impossibility of piloting the project by groups of the peasants concerned. Those interested have no money, and the managers of state resources are not directly involved in the promotion of this equipment.

b. The Yeti tractor (France)

During an enquiry conducted by CINAM during the spring of 1981 in the mountainous regions of France, the gaps in the equipment ranges covered by industrial companies (German, Austrian and Swiss) rapidly became apparent. These companies offered complex equipment which was very expensive and not suitable for multi-purpose application.

This enquiry resulted in an assembly of a group of people including mountain peasants, university researchers, and local artisans, all of whom were extremely interested in the idea of a more simple item of equipment which would be less expensive but would still meet the needs of the wide range of activities involved (e.g. artisan work, agriculture, independent construction of buildings, transporting of firewood). Financing was provided by a state research agency. In less than 18 months, after three generations of prototypes, the Yeti mountain tractor is practically ready, and production of the pilot series has commenced.

The Yeti is a caterpillar, 1.6 m wide and 2 m long, weighing 1,200 kg, with 0.5 m wide rubber clamp bands, ground clearance of 24 m space and an overall height of 1.7 m. The ground pressure of 100 g/2 cm (one third of a human pace) allows it to travel over packed snow. The Yeti is capable of moving up slopes with an angle of up to 60 percent, in all directions and continuously.

The kinematic chain of the Yeti is similar to that of the Pangolin: a friction roller is sandwiched between three sets of wheels placed around it. The roller is thus self-centred. It turns in a direction opposite to that of the chain-pulleys, which are thus all drive parts. At the rear, two sets of wheels keep the semi-crawlers in contact by a friction effect against the chain-pulleys. The engine-gear box unit activates the two friction rollers - right and left - which can be braked individually to steer the caterpillar (this blocks the right crawler on the left, so that the differential makes the unlocked track turn at twice the speed).

The power package may be a 18 hp or 27 hp unit similar to the one used in passenger cars. But it is better to adapt a 17 to 26 hp diesel engine to the gearbox of 27 hp unit. Spare parts for the gearbox can be found everywhere for these. The rollers are manufactured on the spot. The cab of the Yeti is reversible. In the reversed position, the power take-off hitch becomes frontal to start up a 2 m cutting unit, a windrower, a manure-fork (150 kg power), a small lumber conveying winch, a snow plough attachment, a minibull plate, etc.

In its normal position the Yeti tows an 800 kg trailer, a 400 kg "landes-type" trailer, 1 m wide, a 10-inch plough and all-tined implements and a ski-track tracer (1 trace). The three-point raising and the power take-off hitch are of the standard category 1.

The turn-key price of the (1982) Yeti diesel version is FF 42,000 ($US 6000). This is half the price of a small imported mountain tractor.

A network in Chartreuse massif in the Northern Alps is the most advanced. Two craftsmen who already have a level 4 workshop have specialized: one in the manufacture of the crawler the other in the production of the chassis. At present, there is a definite tendency for peasant clients to manufacture the rest of the units and fit out and paint their own tractors. Some artisans wish to install completed Yetis for clients who would like to acquire turn-key machines. No commercial agent is foreseen. CINAM supplies a kit including an assembled engine-box, wheels and some accessories such as bronze bushes and master brake cylinders. The client pays a royalty which allows repayment of the ANVAR loans and covers further expenses. This entitles him to the plans and the loan of a batch of assembly jigs. Training sessions are organized for clients wishing to build their own Yetis. A smaller tractor, the Mouflon, is being studied by CEEMAT for a mechanization project in the mountains of l'Ile de la Reunion. Local self-building is planned.

The Yeti project seems to confirm that proposals for the chosen modified technology and the possibilities of the level 4 workshop making use of technical short-cuts are well-founded. The project would appear to be completely transferable to the Third World.

5. A proposal for action

A stock of manufacturing plans for agricultural equipment which can be manufactured in rural parts of Africa should be accumulated. Our objective in this document is to link the problems of design directly to the characteristics of local manufacturing structures and the equipment used, in particular those of a type of level 4 manufacturing workshop, described above. Often, for small and medium-sized manufacturing enterprises, the first problem posed is simply "knowing what to do", that is, choosing equipment suitable for the priority requirements of the rural world.

Further to this objective, files could be maintained of manufacturing drawings, with sufficient details, of useful rural equipment not by industrial manufactures in order to avoid competition already produced.

These drawings would be workshops/manufacturing systems which either exist already in the country or which could be set up in areas where they do not exist.

The main features of the programme for action are:

(1) A preliminary enquiry

An enquiry would be conducted in a country, sub-region and/or homogenous ecological zone (forest zone) in order to identify various gaps in specific equipment not catered for, or poorly catered for, by the industrialised countries, which could be manufactured locally to meet several priority requirements of the rural populations

(2) A study of the identified equipment with prototypes and tests

(3) An elaboration of complete manufacturing files (detailed drawings) after the final modifications

(4) Necessary patents and protection of the invention

(5) Distribution of files, with or without collection of royalties

It is anticipated that this programme of action will remove the obstacle of "not knowing what to do and how to do it" and enable States without the manpower or the capital to develop new equipment and thereby enter a development phase permitting them to produce their own agricultural or rural tools and equipment. The ideal would be to have teams of local engineers working together on the prototype. They could later continue to diversify the research.

Technical Annex

The nature and complexity of technical operations for the manufacturing of capital goods, in particular agricultural machinery

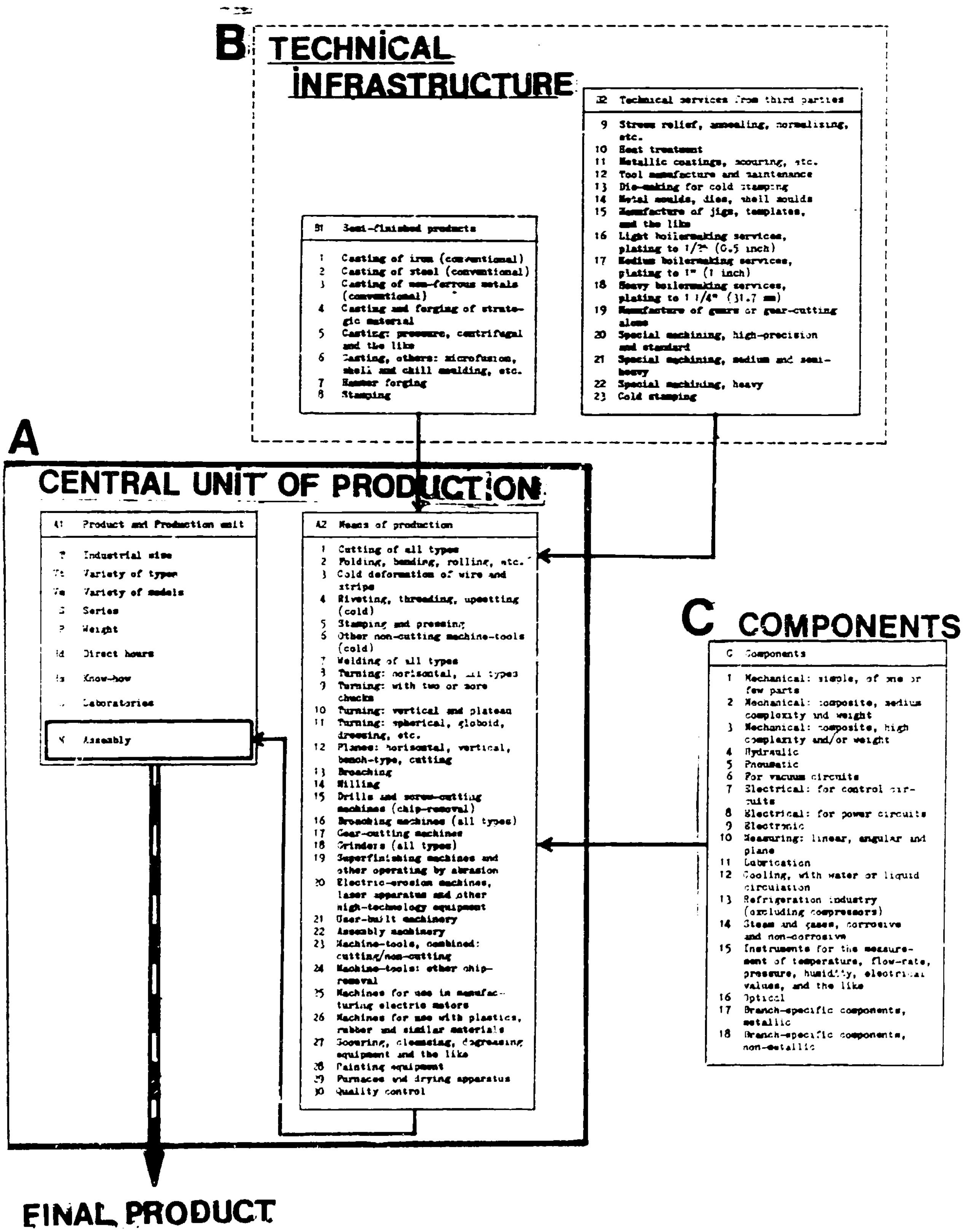
UNIDO has been developing since 1979 a method for analysing technological complexity in the manufacturing of capital goods. Within a global sample of about 400 products, more than 60 agricultural machines have been identified and analysed. One immediate interest of this work is to characterize the manufacturing process for each of these equipment on the basis of 88 parameters, each of them having 6 possible levels of complexity.

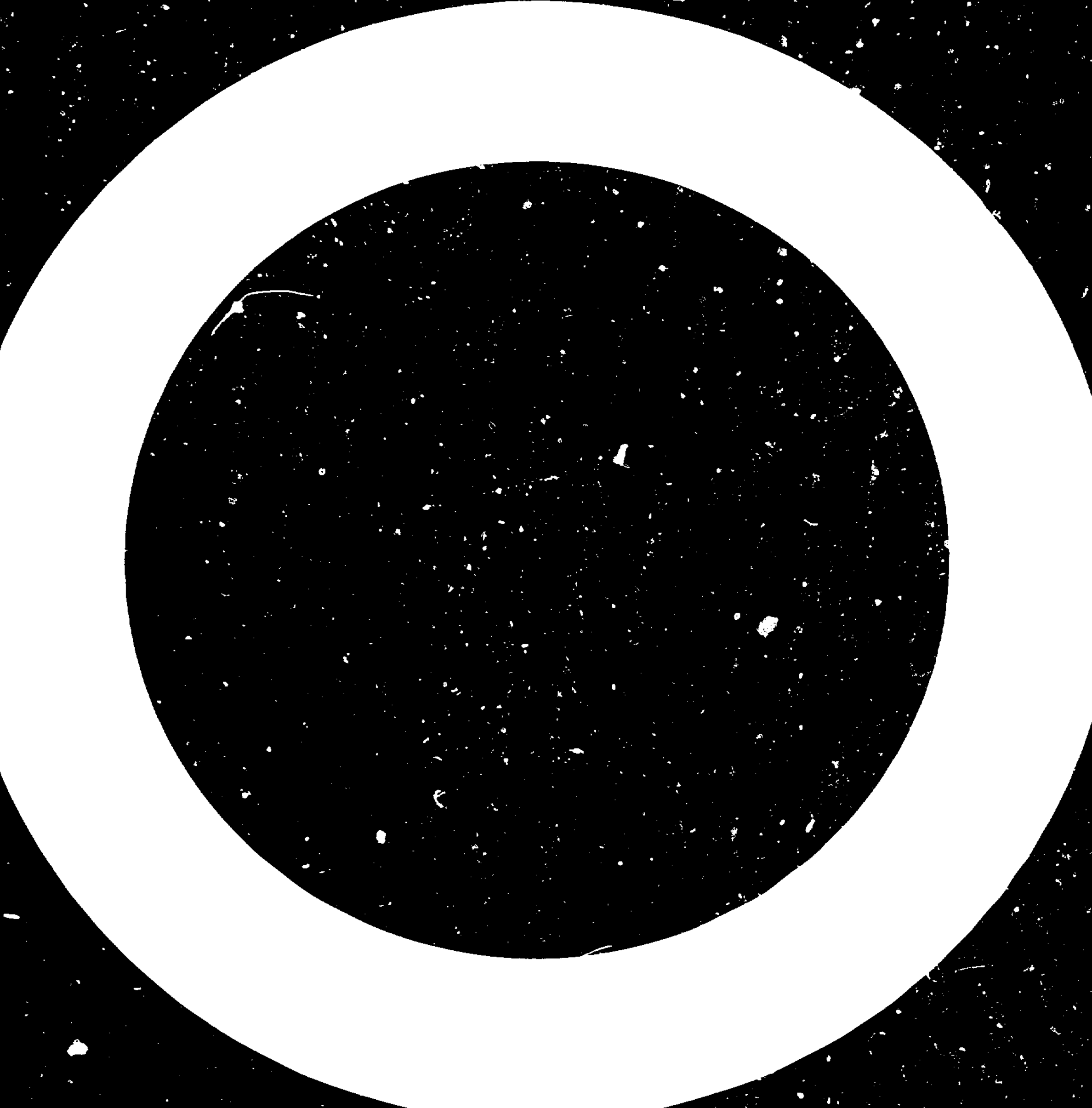
Diagram No. 1(A) indicates the nature of these parameters which either belong to the central unit of production, or to the basic industrial facilities (e.g. foundry) or are components purchased from external suppliers. The following pages (B) provide the definitions of the levels of complexity for each of these parameters.

Lastly, part C of this annex provides the "Technological manufacturing profile" for each agricultural machinery belonging to the sample, a so-called "classical" profile since the process(es) described are those currently used in industrialized countries. One may notice that some choices are open in the technological complexity level (symbol 2/3 for example), while symbol (23) means that both levels are required.

Diagram No. 1

Assemblies and Sub-Assemblies of the Techno-economic Factors in the Structure of the Production of Capital Goods





3A$_1$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 9 FACTORS OF THE BLOCK "PRODUCTS AND PRODUCTION UNIT"

1. Product weight and manufacture

I - Light to medium industry

II - Medium-sized industry

III - Medium-sized heavy industry

IV - Heavy industry

V - Ultra-heavy industry

VI - Highest precision industry for micromechanics, fine optometry, microelectro-mechanics, etc.

2. Hours of know-how

I - Up to 1 hour of KH/1,000 dollars of CG

II - From 1.1 to 2 hours of KH/1,000 dollars of CG

III - From 2.1 to 4 hours of KH/1,000 dollars of CG

IV - From 4.1 to 7 hours of KH/1,000 dollars of CG

V - From 7.1 to 10 hours of KH/1,000 dollars of CG

VI - Over 10 hours of KH/1,000 dollars of CG

3. Laboratory

I - Metrology, weights, electrics, materials resistance, simple static and dynamic testing (e.g. fatigue testing) of parts, chemical analysis of materials, and the like

II - Dynamic testing of mechanical, fluid-dynamic, thermodynamic, electrical and other forms of performance for machinery, equipment and their components of up to intermediate size and complexity; failure and deformation testing of finished products under static and dynamic load

III - As under II, but for catalogue-listed machinery and equipment of intermediate weight and/or complexity

IV - Hydraulics laboratories: hydrodynamic basins, models of dams, channels, hydraulic machinery, etc.; conventional subsonic aerodynamic laboratories

V - Electrical laboratories for work with high and very high voltage, and the like; other advanced testing, as under II and III, for heavy machinery and equipment, both catalogue-listed and specially produced

VI - Supersonic wind tunnels; advanced simulators; testing of high technology aeronautical, marine, space, civil-engineering and military equipment

4. Direct hours per ton

I - Less than 200 direct hours/ton of product
II - Between 200 and 400
III - Between 400 and 800
IV - Between 800 and 1,600
V - Between 1,600 and 3,200
VI - Over 3,200

5. Number of types

I - Up to 3
II - From 4 to 15
III - From 16 to 50
IV - From 51 to 250
V - From 251 to 500
VI - More than 500

6. Variety of models

I - Up to 3
II - From 4 to 7
III - From 8 to 15
IV - From 16 to 31
V - From 32 to 63
VI - More than 64

7. Manufacturing series

I - Continuous very high series
II - From 1,000 to 500
III - From 500 to 100
IV - Up to 1-3 per month
V - Repetitive unit manufacture
VI - Special (non-repetitive) unit manufacture

8. Assembly

I - CG of very limited complexity and weight, delivered to the user or seller ready for use, all that is required being to read the manufacturer's instructions, which usually accompany the product; includes all cases of storable capital goods

II - CG requiring a highly mechanized assembly line fed by auxiliary assembly lines for groups and subsystems; applies to sophisticated products of medium and semi-heavy weight produced in a continuous series, such as trucks, road-building machines, etc.

III - CG delivered partially assembled to the user, with final assembly and geometric, dynamic and performance testing conducted at the customer's plan with the assistance of assembly personnel provided by the CG manufacturer; examples are machinery incorporating large and/or complex basic structures, for whose installation the know-how and guidance are made available by the manufacturer

IV - Cases where an assembly mason is needed to mount the capital goods, the labour being provided by the maker (these being specialists). This complication becomes more difficult when:

V - The capital goods require specialists from the constructing firm as well as other workers for the assembly and construction of the appropriate infrastructure and/or additional personnel. This arises in cases of large-scale operations or installations

VI - The ultimate degree of difficulty is reached in cases of highly complex and very special capital goods for which the maker needs a whole organization capable of transferring a great deal of know-how by means of courses, simulated operations, practical work under instructors, etc. (For instance, for aircraft, ships, etc.).

9. Size of enterprise

I - From 50 to 100 persons employed

II - From 101 to 250

III - From 251 to 500

IV - From 501 to 1,000

V - From 1,000 to 3,000

VI - Over 3,000 persons employed

3A$_2$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 30 FACTORS OF THE BLOCK "MEANS OF PRODUCTION"

1. For all the factors of block A2, except the quality control, the six levels of complexity are characterized by the following general definitions:

I - Machinery, equipment or installations with universal operating cycles and fully manual or almost fully manual operation; common, conventional technology of limited precision

II - Machinery, equipment or installations of advanced universal design and/or high precision

III - Machinery, equipment or installations with semi-automatic performance cycles

IV - Catalogue-listed machinery, equipment or installations with automatic performance cycles and fixed, rigid working programmes

V - Automatic cycles with flexible programming of every type: numerical control, computerized numerical control and the like; machining centers

VI - Special custom-designed machinery or installations (not listed in the catalogues) for one or more special operations, such as stationary transfer machines and the like

2. For the quality control the definition of the six levels of complexity are the following:

I - Pressure, static load, dynamic equilibrium, welding, etc.

II - Geometric testing according to standards

III - Dynamic operational testing, with or without standards, not involving the use of a special test stand

IV - Use of special test stands for series-produced products

V - Use of test stands for non-series-produced and/or heavy products

VI - Highly specialized testing (usually performed to order) of complex equipment

3B₁. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 8 FACTORS OF THE BLOCK "SEMI-FINISHED PRODUCTS"

1. Iron castings, conventional processes

I – Elementary, primary, craft activity, without standards. Mainly manual operations. Cupola furnaces

II – To standards. Ordinary grey and white iron. Limited weights. Mechanical moulding for smaller parts. Value of r always less than 30 kg/mm2. Electric furnaces occasionally used

III – Malleable, nodular cast iron alloyed with Mn, Cr, Ni and other elements. Complex parts. Semi-mechanized casting. Control of earth and sands. Very thin walls, microporosity, etc.

IV – Special alloys. Rather unusual cases. Very large parts. Very strict quality control. Automatic installations

2. Steel casting, conventional processes

I – Elementary, no standards. Manual operations

II – To standards. Carbon steels. Up to parts of medium weight and complexity

III – Special steels with Cr, Ni, Mo, Mn and other alloying additions. Semi-mechanized casting. Complex parts, heavy

IV – Special alloys. Large parts. Automatic installations. High level of quality control

V – Highly complex or large and very large parts for military applications, highly specialized. Special alloys

3. Casting of non-ferrous metals, conventional processes

I – Ordinary aluminium, bronze and brass castings, no standards. Manual operation

II – Small and medium-sized parts. To standards. Bronze, brass and Al, Mg, Zn alloys with low and medium-level mechanical properties. Semi-mechanized operation. Partial quality control

III – Bronze, brass and Al, Mg, Zn and other alloys with high-grade mechanical properties. Up to heavy parts. Systematic quality control

IV – Very heavy parts (for example, large propellers). Special non-strategic alloys. Automatic installations

4. Casting and forging of strategic materials: all processes

V - Small parts for aeronautical engineering, turbines, piston engines for aeronautics, space travel, satellites. Special mechanical properties. Very strict quality control. Military, naval, land and air applications, including rockets

VI - As V with medium-sized pieces as maximum. Very special mechanical properties

5. Pressure and centrifugal casting, etc.

I - Zamak, aluminium and other non-ferrous metals. No standards. Simple and manual equipment

II - For ferrous and non-ferrous metals, to standards. Small and medium-sized parts. Semi-automatic equipment. Normal quality and complexity. Semi-automatic equipment

III - For ferrous and non-ferrous metals. To standards. Up to large and complex parts. High-level quality control. Good mechanical properties

IV - For ferrous and non-ferrous metals. Special cases with regard to shape, resistance of materials and size. Strict quality control. Highly automated installations

6. Other casting processes: microfusion, shell moulding, chill moulding, vacuum casting, etc.

II - Simple cases for shell moulding and chill moulding. To standards. Simple equipment. Ferrous and non-ferrous metals. Limited level of mechanical properties

III - Almost all processes for ferrous and non-ferrous metals. Medium-sized parts. Strict quality control. Semi-automatic installations or equipment. High degree of complexity. Thin walls

IV - Special cases. Very complex or heavy parts or parts with high mechanical resistance. Maximum quality. Automatic equipment. For ferrous and non-ferrous metals

7. Hammer forging

I - Light parts. Manual operations. Simple shapes. No standards

II - To standards. Up to medium-weight parts. Limited guarantees

III - Semi-heavy and heavy parts. Guarantees and standards

IV - Special cases. Ultra-heavy parts. Strict quality control. High mechanical resistance

V - Incorporated in 4-V

$3B_2$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 15 FACTORS OF THE BLOCK "TECHNICAL SERVICES PROVIDED BY THIRD PARTIES"

1. Stress relief and annealing

I - With simple installations and limited quality control. Parts of limited size. Partial guarantees

II - To standards. Guarantees. Up to semi-heavy parts, medium thick walls. Controlled atmosphere. Conventional installations

III - Up to semi-heavy and heavy parts. Strict quality control. Thick walls. Automatic installations. Laboratory

IV - Ultra-heavy parts. Special cases. Complex automatic installations. Special processes. Research and development laboratory

2. Heat treatment

I - Elementary installations. Limited weight and quality control. Normal materials. No standards

II - To standards. Hardening, case hardening, tempering and normalizing. Moderate complexity. Conventional installation

III - The foregoing processes for an extended range of steels. Larger parts and heavier weights, up to medium. Nitriding, carbo-nitriding and similar processes. Semi-automatic equipment. Correct quality controls. Guarantees. Laboratory

IV - Special requirements and advanced technology. Strict quality control. Complex automatic installations. Heavy parts. Research and development laboratory

3. Surface metal deposits, etc.

I - Semi-craft-type installations. No quality control

II - To standards. Irregular quality control. Nickel-plating, chromium-plating, cadmium-plating, zinc-plating, phosphating, tin-plating, etc. Small and standard parts. Non-automatic installations

III - Medium-sized parts. Normal quality controls. Laboratory. Surface deposits by powder metallurgy methods. Hard porous chromium. Other processes. Semi-automatic installations

IV - Special requirements. Automatic and programmable installations, etc. Large parts. All advanced technological processes. Strict quality control. Research and development

4. Manufacture and maintenance of tools

I – Maintenance of simple tools. Manufacture of simple tools. Irregular quality. Limited know-how

II – Maintenance of tools of medium complexity. Precision expressed in 1/100 mm. Medium size. Manufacture of cutting and shaping tools and simple dies for extrusion, etc. Irregular quality. Conventional equipment. Limited guarantees. Some standards

III – Maintenance of complex tools including broaches, gear-cutters, milling cutters, etc. for tolerances up to ISO 6 and 7. Manufacture of multiple or compound tools and special tools of medium complexity. Guarantees. Standards. Metrology laboratory. Not including series production of tools

IV – Maintenance of highly complex and/or special tools for metal and woodcutting etc. Large size. In small dimensions for tolerances up to ISO 5 and 6. Simple drills for wells, etc.; maintenance. Manufacture only of special tools of medium complexity (excluding large-scale series production). Standards, guarantees, metrology laboratory. Small-scale R and D

V – All complex special cases for all applications in maintenance and manufacture. Maintenance of tools for well-drilling, including oil wells, and mining. R and D

5. Construction of dies for cold stamping

I – Crafts-type construction with simple equipment. Limited quality. Small parts

II – Moderately equipped workshops. Parts of standard dimensions and medium complexity. Limited durability. Irregular guarantee and quality

III – Workshops with good but incomplete equipment. Up to parts of medium size. High complexity in small parts. Precision. Guarantee. Durability. Simple progressive dies. Includes own know-how

IV – Workshops with complete and high-quality equipment. Precision, guarantee, productivity, durability. High complexity, progressive and multiple dies, etc. Micro-stamping. Large parts. Special cases. Relevant own know-how. Laboratory

6. Construction of moulds, stamping dies, chill moulds, etc., for metals

I – Low quality. Wide tolerances. Small workshops with standard equipment. Simple parts of limited weight. No guarantee

II – Medium-size workshops with varied standard equipment. Irregular guarantees and quality. Up to parts of medium size. Semi-complex shapes (depth, walls, ridges, etc.)

III - Well equipped workshops for parts of up to semi-heavy weight. Considerable degree of own know-how. Normal guarantees, precision and durability. Systematic quality control. Complex shapes

IV - Very well equipped workshops. Up to large and complex parts. Special requirements. Relevant know-how. High level of guarantee, durability and precision. Solutions for large series. Quality control and other laboratories

V - Specific solutions for naval, land and air armaments. Civil aviation, turbines, piston engines. R and D laboratories

7. Construction of jigs, templates, etc.

II - Limited own know-how. Design by third parties. Workshops with standard and incomplete equipment. Moderate complexity. Precision expressed in 1/100 mm. Partial guarantees

III - Highly developed own know-how. Design by third parties. Workshops with good but incomplete equipment. Air conditioning. Precision expressed in 1/1,000 mm. for small parts. Guarantees. Quality. Highly developed metrology. Up to medium-sized parts

IV - Workshops with complete and advanced equipment. Large scale parts. Special and complete solutions for large series. Advanced know-how. Guarantees. Laboratory. Very high precision

8. Light boilermaking services, plate up to 1/2"

I - Semi-crafts-type workshops. Standard equipment. Limited precision. Design work by third parties. Low complexity. Conventional welding

II - Well equipped workshops. Partial guarantees. Standards. Own designs and design work by third parties. Normal precision. Profiles and structures up to complex level. Manual or semi-automatic operation. Various types of welding

III - Workshops with complete and advanced equipment. Guarantee, standards, quality controls. Own designs and design work by third parties. Complex and precision operations. Machines automated and/or with programming. Stainless steel. Special welding for various materials. Complex cases with strict quality control including pressure and similar tests

9. Semi-heavy and medium boiler-making services, plate up to 1"

I - Small workshops with simple, incomplete equipment. Elementary quality control. Limited complexity. Design work by third parties. Conventional welding. No standards

II - Medium-sized workshops with good but incomplete equipment. Conical, spherical and complex structures. Design work by third parties. Standards. Partial guarantees. Some simple mechanization. Adequate quality and precision

III - Workshops with complete equipment. Technological advanced operating stations. High degree of complexity. Strict quality control including welds. Guarantees. Standards. Design work by third parties

10. <u>Heavy boiler-making services, plate up to 1 1/4"</u>

II - Medium-sized workshops with incomplete, conventional equipment. Partial general quality control, including welding. Adequate hoisting gear. Manual welding and semi-automatic welding sets. Medium complexity. Plate up to 2" and related sections. Some standards. Design work by third parties

III - Well equipped workshops with some advanced machines. Standards. Correct quality control, including welding. Guarantees. High degree of complexity. Conical, spherical parts, etc. Design work by third parties and own know-how. Plate up to 4" and related sections. Adequate hoisting and materials handling gear. Machining limited to flanges, drilling and tapping

IV - Very well equipped workshops. High quality. Standards. Guarantees. High degree of complexity. Pressure and other tests. Conical and spherical parts. Various materials. Design work by third parties and own know-how. Machining limited to flanges, some flat work, drilling and tapping

11. <u>Manufacture of gear-wheels or gear-cutting alone</u>

I - Workshops with conventional, universal equipment. Parts up to medium size. Quality class IV. Standard shapes. No guarantees

II - Medium-sized workshops. Quality class III. Parts up to medium size. Cylindrical, conical, straight and helicoidal. Simple corrections

III - Well equipped workshops. Quality classes II and I. Great variety of tooth shapes and corrections. Excluding more complex shapes. Guarantees. Up to medium size. Strict control. For large sizes up to 5 m in diameter. Classes IV and III

IV - Very well equipped workshop. Advanced metrology. All the most complex shapes, corrections and sizes (excluding super-heavy gear wheels). Special surface treatment and materials of highest resistance

12. Special machining, fine and standard

I - Automatic turning of standard complexity, precision and size. Grinding, flaring, milling services etc.

II - Screw cutting. Deep hole drilling. Broaching. Splined shafts. Internal and external super-finishing. Jig boring service. Maximum quality ISO 7 and 6

IV - The same services as in II but with maximum quality ISO 4 and 5. Well equipped workshops, air conditioning, advanced metrology. Machining centre services

13. Medium and semi-heavy special machining

II - Complex automatic turning. Deep hole drilling. Honing, grinding, milling, broaching, jig boring. Large flat surfaces, slotting, etc. Standard quality. Adequate metrology. Incomplete guarantees

III - Jig boring services etc. (as II) at a level of greater precision up to classes ISO 6 and 7. Complex shapes. Materials of good mechanical resistance. Adequate metrology. Guarantees

IV - Special cases, very complex shapes. Materials of high mechanical resistance. Up to precision of class ISO 5. Construction of special tools for the operation of the service. Grinding of threads, racks, spherical parts, etc. Guarantees. High grade metrology. Air conditioning

14. Special heavy machining

III - Vertical and horizontal turning, grinding and super-finishing. Standard and precision flaring machines. Large flat parts. Up to 25 tonnes. Cast iron, steel and boiler-making. Standard quality. Adequate guarantees. Appropriate metrology

IV - Same as III but workshop better equipped in variety and capacity of machines (up to 50 tonnes) and precision. Single parts for sub-assemblies. Simple test benches. Advanced metrology. Good quality. Guarantees. Standards

V - Very well equipped workshop with capacity above 50 tonnes. Special and complex cases, with test bench. Strict quality control. Stainless steel and other special materials. Guarantees. Standards

15. Cold stamping

I - Crafts-type workshops. Primitive quality control. Small and simple parts. Small series. Conventional machinery

II - Medium and small workshops. Standard and medium-sized parts. Limited complexity. For non-ferrous metals and normal steels. Medium precision. Adequate quality control

III - Well equipped workshops. Good quality. Complex progressive stamping. Deep drawing. Conventional or automatic machines. For non-ferrous metals, normal steels, stainless and other. Possibly joining of stamped pieces. Guarantees. Tests

IV - High precision micro-stamping. Very large parts (for example, lorry chassis). Precision line stamping. Deep drawing of large parts. High degree of complexity. Some assembly. Tests, guarantees.

8. Stamping, etc.

I - Light parts of simple form. No standards

II - To standards. Normal complexity of parts. Irregular quality. Simple, conventional equipment

III - Multi-stage forging. Upsetting. Extrusion, etc. Medium-weight parts. Semi-automatic and automatic equipment for smaller parts. Quality. Guarantee. Materials of moderate resistance

IV - Special requirements as to shape, alloys and complexity. Large parts. Strict quality control. Automatic equipment, automated installations. Other hot-farming technologies

V - Incorporated in 4-V

3C. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 18 FACTORS OF THE BLOCK "COMPONENTS"

1. Mechanical: simple machine components consisting of one or very few parts

I - Screws, washers, nuts, pins, rivets, flywhells, pulleys, levers, knobs, springs, etc. Ferrous and non-ferrous. According to geometrical standards but without the corresponding quality

II - Great variety of shapes and sizes, more complete than I. According to geometric and quality standards. Ferrous and non-ferrous. Tempered and ground parts

III - Special cases with regard to shape, materials and resistance. Tempered. High precision. Guarantees. Laboratory. Own know-how in some cases

V - Components for aeronautics, aircraft engines, satellites, rockets, etc. Strict quality control. Maximum guarantee. Research laboratory. Special materials. Creative capacity

2. Mechanical: compound machine components up to medium complexity and weight

I - Couplings, de-couplers, power limiters, gaskets, clutches, universal joints, cams, drums, brakes, levelling devices, supports, etc. With and without standards. Limited size, power, variety, performance and quality

II - Medium and small workshops. According to geometrical and quality standards. List I expanded as to variety, power, size, etc. up to normal performance. Add to the list: small variators, simple reducers of up to 25 metric horsepower, shock absorbers, etc.

III - Medium sized and larger workshops. High performance, standards, guarantees, quality control laboratories, testing stations. Variety of models and power. Complex variators, reducers, multipliers, safety devices, simple ball-bearings up to 17 mm diameter, etc. Reference power about 50 metric horsepower

IV - The same as III, but with a greater variety of types, models, performance, power, capacity and complexity. High quality. Testing stations. Creative capacity. Ball-bearings up to medium size and for appropriate applications. R and D

V - Added to IV: greater variety of series manufactured ball-bearings. Special ball-bearings. Components for aeronautics and the land, naval and air arms industry. Advanced R and D

3. Mechanical: compound machine component up to heavy, complex and special

III - The same list as 2.III in greater size, power, performance, etc. Small series. Add: reducers, gear boxes, angular take-off devices, etc. Medium-sized workshops with conventional and advanced machines. Standard quality. Normal metrology. Partial guarantees. Some standards. Power only for reference of the order of 75-100 metric horsepower

IV - Same list as above, with greater guarantees, power, load, size and quality. Excluding ball-bearings. Power greater than 100 metric horsepower. Testing stations. Advanced metrology. Inspection stations

V - Includes high-power equipment. One-off heavy manufacture. Special. Special ball-bearings. Solutions for land and sea military equipment. Advanced R and D

4. Hydraulics

II - Components for low-pressure circuits up to 70 kg/cm^2. Pumps, motors, distributors, valves, cylinders, filters, tanks, etc. Simple equipment. Little variety of types and models. Normal quality and guarantees

III - Components for moderate pressure and power. Variety of types, models, and power, though limited. Performance tests. Guarantees. High quality

IV - Components for high pressure up to 200 kg/cm^2. Large cylinders. Further mechanisms, fluid drive and variators, testing units, dynamometers, brakes and servo-brakes, shock absorbers, accumulators, motors, etc. Medium and high power. High degree of complexity. Quality. Guarantees. Testing laboratory. R and D

V - Special components. One-off or small series. Normal military applications. Piston aircraft engines. Public works. High degree of complexity, large dimensions. Testing stations. Developed R and D service

VI - Very special applications for civil and military aviation, land and sea armaments, large public works and high-power machinery. Very considerable level of testing stations and R and D

5. Pneumatics

II - Simple components, pistons, valves, distributors. Little variety as to power, flow and characteristics. Limited guarantees

III - Quality, guarantees, operating tests. Add: humidifiers, dosing appliances, automatic valves, brakes, clutches, accumulators, filters, large pistons, engines, etc. Greater power and variety than in II

IV - Servo-mechanisms, automatic mechanisms. Special cases for micro-mechanics. Large-scale or high-power equipment. Laboratories. R and D

V - Very complex and large-scale applications. Components for civil and military aviation and land and sea armaments

6. <u>For vacuum circuits</u>

III - Simple pumps, preparatory. Low power. Accessories for vacuum circuits. Vacuum up to 10^{-3} mm Hg. Quality. Tests. Guarantees

V - Medium and high capacity pumps. High vacuum of less than 10^{-3} mm Hg. Complex accessories. For special industrial applications. High quality. Guarantee. Tests. Laboratory

7. <u>Electrics: control and monitoring</u>

In this speciality, more than in others, the same description covers products with very different degrees of reliability and/or performance. Therefore, to make it possible to subdivide the equipment into I to VI, there is no other option to continue by applying the general criteria already stated. That is to say that we begin at level I with very elementary products like buttons, keys, switches, alarms, etc., without strict or clearly defined standards, passing to material for the aeronautic and space travel industries for environment that demands high reliability of operation (for example, tests against explosions) for the armaments industry, etc., all the latter being divided between V and VI.

8. <u>Electrics: for power circuits</u>

The same general approach is adopted as in point 7. Here also the categories go from I to VI.

9. <u>Electronics</u>

IV - Vacuum and gas tubes, simple series. Semi-conductors (resistances and capacitors). Printed circuits. R and D

V - Vacuum and gas-filled tubes. Semi-conductors (resistances, capacitors, active parts, etc.). Advanced R and D

VI - Special material. Military applications. Micro-miniaturization. Very advanced R and D

10. <u>Linear and angular measurement</u>

III - Mechanical appliances that can be incorporated in machines with precision of 1/10 and 1/20 mm. Circular and linear division services

IV - Appliances and instruments for mechanical measuring, precision 1/50 and 1/100 mm, capable of being incorporated in machines. Solex and similar appliances. Automatic gauges. Pneumatic measuring devices. Laboratory

V - All types with visual read-out. Automatic positioners. NC and CNC. Optical and optical-electric measurement devices. Mar-Poss and similar appliances. R and D

11. Lubrication

I - Static elements for greasing and oiling points. Pressure or gravity types. Simple seals, axial and rotary. Grease guns. Sprayers. Medium quality. Some standards

II - To standards. Quality. Great variety of components, distributors, dosing appliances, manual and mechanized pumps, gauges, safety, etc. Guarantees

III - Automatic lubrication circuits, small and medium power. Hydrostatic and hydrodynamic versions. Constant temperature. Filters. Laboratory and testing station. High quality. Guarantees

V - For high-power automatic circuits. Special cases. Programmed pumps. Applications for aviation, aero-turbines, gas and steam turbines, nuclear energy, etc. High quality. Strict controls, tests, guarantees. R and D

12. Cooling by means of circulating water or liquids

II - Pumps, low-power electric pumps for water; distribution devices, batchers, filters, levels, valves, radiators, cooling and settling tanks; simple, manually-operated, average quality; some standards and partial guarantees

III - For water, cooling liquid in metal-cutting applications, and other liquids for machinery and equipment cooling systems; semi-automatic systems with up to average flow capacity; safety features, testing, guarantees and standards

IV - As under III, but for automatic applications; corrosive liquids; any flow-rate; magnetic cleaning devices; refrigeration plants; quality, standards, guarantees; R and D

V - Special cases with ou without contamination; laboratories; nuclear-energy, military, aeronautical and similar applications; advanced R and D

13. For the refrigeration industry (excluding compressors)

III - Basic components of low power and/or flow-rate; semi-automatic applications; thermostats, valves, distribution devices, radiators, etc.; quality, guarantees, basic standards

IV - Automatic components; high complexity, precision, qu. lity; sophisticated industrial applications; guarantees and laboratory; R and D

V - High power and special cases for civil applications; low and ultra-low temperatures; military applications; advanced R and D

14. For steam and gases, whether or not corrosive; any temperature

II - Simple cases, low temperatures and pressures, non-corrosive media; limited guarantees, no standards

III - Average temperatures, pressures and flow-rates; semi-automatic applications; non-corrosive media; guarantees and standards

IV - Automatic applications; high pressures, temperatures and flow-rates; corrosive media; guarantees, safety features, standards, laboratory

V - Very high pressures and/or temperatures; corrosive media; R and D

VI - Applications in atomic power plants, military applications and the like; advanced E and D

15. Temperature, flow, pressure, humidity, electrical metering, etc.

III - Elementary instruments for liquids, gases and electricity. Little variety. Limited precision of reading. To standards. Guarantees. Tests

IV - Increase in variety and precision - situation intermediate between elementary and advanced. Complex instruments. Standards. Guarantees. Tests. Laboratories

V - High precision of readings. Compound and complex recording instruments. Very large and small power. Special cases for industry. Laboratory. Considerable R and D

VI - Application for aeronautics, space travel, satellites, rocketry. Military industry in general. Advanced R and D

16. Optics

III - Manufacture of simple apparatus. Normal lenses. Combination with normal mechanical appliances

IV - Optics combined with micro-electro-mechanics. Precision reading apparatus. Coated lenses. Optical assemblies. Guarantees. High quality. Laboratories

V - Optical equipment for invisible radiation (Hertzian, infra-red, ultra-violet, etc.). Most usual applications. Advanced R and D. Optics for visible radiation with micro-mechanics. High-precision and complex optics for cine cameras, still cameras, etc. Considerable R and D

VI - Complex and specialized military application. Advanced R and D

17. Other very specialized branch-specific components

These are found at all levels except level I. The heading includes only those components which, although they may entail the use of disciplines or techniques already mentioned under C (from 1 to 16), are intended exclusively for particular branches or families of products. Examples: A hydraulic copying machine designed by a firm specializing in hydraulic equipment (C.4) will be classified under C.17 because of the specific nature of the component. Combs and other components for textile machinery, ploughshares, etc., are single-element components which are not classified under C.1 but under C.17 because they are used exclusively in a specific capital goods branch.

18. Other, non-metallic, branch-specific components

These are found at all levels except level I. The list of materials does not cover the entire spectrum, but only those materials which are of greatest significance for the calculation of I_c; namely:

- Components of natural and synthetic rubber; tires; components of plastic, composite materials, bakelite and the like
- Components of glass, crystal, plexiglass and the like
- Components produced using ceramics, rare earths, graphite, insulating mica and the like.

Technological Profiles

for key agricultural machinery and equipment

Source : UNIDO

Agricultural machinery and equipment	CENTRAL UNIT OF PRODUCTION: General characteristics									Technological means of production: Cutting and all type of cold forming						W	Turning				Other machining									Special machining						Final operations			
	T	Vs	Wm	S	P	Hd	Hs	L	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Category 1 SOIL PREPARATION EQUIPMENT																																							
Mounted frontal rakes	1	1/3	1/3	23	23	1	1		1	23	2			2	3	23								2													1	1	3
Rotary hedge and stubble clearers	1/2	1/2	2	12	2	1	1	1	1	23	2			2	3	2	3						23	23		2	2										1		3
Mounted hole diggers	2	2	1/2	24	2	2	1/2		1	2/3	1/2			3	3	2	3/4					3	3/4	3/4	5		2/3					3	2			1	2		1/3
Category 2 HAND TOOLS AND EQUIPMENT FOR SOIL CULTIV.																																							
Discs for ploughs (lathed [illegible] process)	1	1	3	12	2	1	1			2				3			1		3								3									3	1	1	1
Rigid arm cultivators	1	1	1/2	2/3	12	1	1		1	23				13	3	1					1		1	3													1	1	
Animal-drawn ploughs	1	1	1	1/2	12	1	1		1	1/3	1	1		1/3		2					1		1	1/3													1/3	1	1
Hand tools	1/2	3/4	1	1/2	1	1	1		1	1/3	1/3	1/3	1	1/3	1/3	1								1/3			1						1				1		1
Flexible arm- and spring-t. cultivators (simple + multiple)	1	1	1/2	2/3	12	1	1		1	23				13	3	1					1		1	3													1	1	1
Flexible arm- and spring-t. cultivators	2	2	2	2/3	12	1	1	1	1	24			3	23	35	2	3						2	23													1	1	1
Discs for ploughs	2/3	2	3/4	1	2	1	1	1		3/4				3/4	6				1/6								3/6				3/4						1/2	3/4	1
Discs ploughs with 2-3 discs	2	2	1/2	1/2	12	1	1		1	3/4	2/3	2/3		2/3	2/3	2/3	3/4						3/4	2/3	3												1/3	1/3	1/3
Chisel ploughs	2/3	3	1/2	2/3	2	1	2	1	1	24	2/3	2/3	2	23	35	2	3				2		23		3		2										1/3	1/3	1
Category 3 CROP PROTECTION EQUIPMENT																																							
Cart sprayers (mounted or portable)	1/2	1/2	1/2	2/3	1	1	1		1	2	2			2/3	3	2	3/4						3	2/3			3								3		2		3
Tractor-drawn sprayers (incl. pumps)	3	3	2/3	2/3	12	2/3	2/3	4	1	2/3		2/3	3	2/3		2	3/4			3/4		3	35	3	3		3	3					3		3		2		1/4
Other sprayers	3/4	3	2	24	2	2/3	3	3	1	24	2/3	2/3	2/3	2/3	3	2/3	3/4			3		3	35	35	35	2/3	2/3					3	3		3		2/3		1/3
Category 4 HARVESTING EQUIPMENT																																							
Tractor-drawn forage harvesters	1	2	1	3	2	12	1		1	23	2	1	1	2	25	2	23				2		2	23		2	2										1		3
Spare parts for harvesters	1/2	3	1/2	1/2	1	1	1	1	1	34		3/4	3/4	34	36												46						3/4				3/4	3/4	1/3
Rotary-head tedders	1/2	2/3	1/2	24	2	1/2	1		1	2/3	2	2		2/3	3	2/3	3					3	3/4	3/4	3	2/3	2/3					3					2		1/3
Hay balers, presses (powered by tractor or mechan. tractor)	2	1/2	1/2	24	2	2	2		1	2/3	2/3	2		2/3	5	2/3	3/4			3		3	24	25	25	2/3	2/3					3	3				2/3		1/3
Tractor-drawn mowers mower-loaders	2/3	2/3	2	2/3	2		2/3	3	1	23	2/3	2/3		3/4	3	2	3/4					3	3/4	35	35	2/3	2/3					3	3/4				2/3		1/2
Motors of self-propell. cane harvesters	2/3	1	1/2	3/4	3	3	3	3	1	23	2/3	2	2	2/3	35	2	23				2	3	2/3	25	23	2	2/3						2				2		1/3
Motor-tracted self-propelled cereal harvesters	3	2	1/2	3/4	3	3	3	3	1	23	2/3	2/3	2	2/3	35	2	3				2	3	25	25	25	2/3	2/3					3	3			2	2		1/3
Corn harvesters	3	2/3	1/2	34	23	2/3	2/3	3	1	23	2/3	2/3		2/4	35	2/3	3/4					3	34	25	35	2/3	2/3						3/4			2/3	2/3		1/3
Category 5 TRANSPORT EQUIPMENT																																							
Harvest trailers (for fruit)	1	1/2	1	3/4	1	1	1		1	2/3	1/3	1		1/2	1/3	1/2	3							1/3													1/2		
Front loaders	2/3	2/3	1/2	2/3	2	1	2		1	23	2		2	2/3	2/3	2	3/4						2/3	25	3		2/3					3					2/3		3
Single-axle carts and trailers	1/2	2/3	1/2	2/3	1	1	1		1	2/3	2/3	2/3		24	3	2/3	3						2/3	25	35	3	3						2/3				2/3		3
Automatic loading wagons and carts	2/3	2	1/2	2/3	2	1/2	2	2	1	23	2/3	2		2/3	35	2/3	3/4						3	35	3	2	2/3					3					2		2/3
Two-axle standard metal trailers	2/3	1/2	1/2	2/3	23	1	1/2		1	2/3	2/3	2		24	3	2/3	3/4						3/4	25	3	2	2/3					3	2/3			2	2/3		1/2

Technical infrastructure (basic facilities)																							Components																		Total complexity without components
Supply of semi-finished products								Technical Services															Mechanical														Specific				
Casting, forging and stamping								Heat treatment		Supply of moulds, dies, jigs, etc.					Boiler making			Special machining				ST																			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
							2		2		12		1						12																						25.1
2											2	12											12	2															2		28.1
3							3	3	3		3	2	3					3					2/3	2/3									2/3								51.2
								2	2		1	1																													22.5
							1		1		12	1							1				12																		23.3
	2					2	2		2		2	2/3	2										2																		28.4
						1/2	1/2	1/2	1/2		1/2	1/2	1/2										1/2																		28.5
						2	2	2	2		12	2							1				2																2		27.0
						2	2	2	2		12	2	2						2				2																2		34.4
								3	3		2/3	2/3																													34.6
	2/3						2/3	2/3	2/3		2	2/3	2/3	2									2/3																2/3		39.5
						2	2	2	2		2	2/3	2/3						2				2/3			3							2						2/3	2	44.4
										2	2	2											2																	2/3	32.4
				3/4	4		3		3		3	3	3						2			2	23														3		3	3	60.2
3	2			3	3				3		3/4	3	3					3	2				2/3	3			3/4						2				3		3/4	3/4	67.3
2									2		23	2							2				2										1						3	2	34.8
							2/3	2/3	2/3		23	3/4	3										2																		38.4
	2					2			2/3		2/3		2						2				2/3										2						2/3	2/3	41.7
2/3	2/3						2/3		2/3		24	2/3	2/3							3			2/3	2/3		3/4							2/3				3		2/3	2/3	53.9
3	3						3	3	3		3/4	3	3					3	2				2/3	3		3							3				3		3/4	3/4	60.8
3	2/3						2		23		3	23	23	2				3	2	3			23	23		4			23	23			3				3		34	34	65.3
23	2					23	23		2/3		23	3	2/3					2/3	2	3			23	2/3		3/4			3	3			3				3		34	34	69.6
3					3		3	3	3		34	3	3	3				3	2	3		2	23	3		3/4							3				3		45	45	72.3
											1	2											1/2																	2/3	21.0
									2/3	2	2/3	2/3							2				2	2		3							2						2/3	3	37.7
2/3	2/3								2/3		2/3	2/3							2			2	1/2	2/3		3/4							2						2/4	2/3	38.3
2/3	2								2/3		2/3							3		3			2/3	3		3							2						2/3	2/3	43.5
3	3								2/3		2/3	2/3							2			2/3	2/3			3/4							2						2/3	2/3	45.4

Agricultural machinery and equipment	T	Vs	Vm	S	P	Hd	Hs	L	M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	CENTRAL UNIT OF PRODUCTION																																						
	General characteristics									Technological means of production																													
										Cutting and all type of cold forming						W	Turning				Other machining									Special machining						Final operations			
Category 6 PRIMARY PROCESSING AND GENERAL FARM EQUIPMENT																																							
Manual forage cutters	1	2	1	23	12	1	1		1	1	1	1		1	2	1	13						13	13													1		
Pneumatic conveyors, aspirators	1/2	2	1/2	24	12	1	1	1	1	23	23		2	23	3	23	23							23			2						3				1		3
Bucket elevators	1/2	2	1/2	24	1	1	1		1/3	3	3	2		3	3	2	3						23	3		2	2										1		3
Sizing machinery	1/2	2/3	1	34	12	1/2	1		1	2	2	2		2	25	2	23				2		2	23			2										1		3
Elevators and belt-type conveyors	1	2	1/2	24	1/2	1	1		1/3	24	2	2	3/4	3/4	26	2	3/4						3	3/5	3	2	2										2/3		3
Grinders (straight and curved blades)	1	1	1	34	12	2	2		1	2							23				2		2	25	25	2	2						2				1		2
Grinders and crushers	1/2	2	1/2	2/3	2	1/2	1/2	2	1	2/3	2	2		2/3	25	2	3/4				2/3		2/3	25	25	2	2/3						3				1/2		3
Machinery for cereal grain processing	1/2	2	1/2	34	2	2	2	2	1/3	23	2		2	2	25	2	23						2	25	23	2	2										1		3
Seed and grain sorters	2	2	1/2	24	2	2	23	1/2	1	23	2	2		2	25	2/3	23				2		23	25	3	2	2						2				1/2		1/3
Metal cereal grain sorters	2/3	2/3	2/3	34	2/3	1	2	3	3/4	3	26	2		23	36	2	23						23	23		2	2									3	2		1/3
Simple manual, low-powered cream separators	1/2	1/2	1/2	2/3	1	1	2	1	1	23	2	2		2	2	2	23						23	23	25	2	2	3					2			2	2		1/3
Grinders, combined crushers, mixers	2/3	2/3	2	24	2/3	2	2	1	1/3	23	23	2		2/3	25	2	3/4				2/3		2/3	25	25	2	2						3				2		3
Coolers and milk tanks	1/2	2	1/2	24	2	2	23	2	1/3	2	2	2		2	2	2	23						23	23	25	2	2	3					2			2	2		1/3
Fixed and mobile cereal dryers	3/4	3	2/4	35	23	2	2/3	3	34	24	2/3	2	2/3	2/4	25	2/3	2/3		2		2		23	25	2/3	2	2					3	2			2	2		1/3
Category 7 IRRIGATION EQUIPMENT																																							
Reciprocal pump units	1/2	2/3	1/2	23	2	2	1	4	1	23	2				2	2	23						23	25	23		2										1		1/3
Rotary centrifugal pumps	2	2	2	12	1	1	1		1	23	3												3/4	3/4	3/4		2/3					3					1		3
Oscillating irrigation equipment	1	2	2/3	24	1	1	1		1	23		3		1	3		3/4						3	23			3						3/4						3
Category 8 HUSBANDRY EQUIPMENT																																							
Mounted frontal rakes	1	2/3	1/3	23	23	1	1		1	23	2			2	3	23								2													1	1	3
Rotary hedge and stubble clearers	1/2	1/2	2	23	2	1	1	1	1	23	2			2	3	2	3						23	23		2	2										1		3
Mounted hole diggers	2	2	1/2	24	2	2	1/2		1	2/3	1/2			3	3	2	3/4					3	3/4	3/4	5		2/3					3	2			1	2		1/3
Category 9 TRACTORS* AND MOTORS																																							
Single-axle, hand-guided tractors (<15 HP)	2/3	1	2	1/2	1	1	1		2	34	34	3	3	34		3	34					3	34	3/6	3/6	3	34						3			3	3	3	1/3
Small 1 cyl. air-cooled motors (< 10 HP)	2/3	2	1/2	1	1	1	1	3	1	4			4				4			4		3	3/4	4/6	4/6	3	3/4	3/4				6	4			3		3	1/4
Wheeled tractors (< 25 HP)	3/4	1/2	1/2	1	1/2	1/2	3	3	2	3/4	3	3	3	3/4	3/4	3	3/4	3/4				3	36	36	36	3/4	3/4					4/6	3/6			3	3		1/4
Gasoline motors (<100 HP) (excl. automotive use)	4/5	1	2	12	12	1	1/2	1/2	2	4			4				45	4		4		3/4	36	36	36	3/4	36	4					36			3/6	3/4		1/4
Wheeled tractors (25-100 HP)	1/3	1/2	1/2	1	2/3	1/2	3	3	2	3/4	3	3	3/6	3/4	3/6	3/4	3/4	1/4		4		3/4	36	36	36	3/4	3/4					46	36			3/4	3		1/4
Track-laying tractors	4/5	1/2	1/2	1/2	2/3	2	3	3	2	3/4	3	3	3/6	3/4	3/6	3/4	3/4	3/4		4		3/4	36	36	36	3/4	3/4					46	36			3/4	3		1/4
Movable, tripod and/or oscill. tractors (25-100 HP)	4/5	1/2	1/2	2/3	3	23	34	3	2	24	3	3	3/4	3/4	3/4	3/4	3/4	3/4	3/4	3/4		3	36	34	36	3	3/4					4/6	3/6			3	3		1/4

* tractors without motor

TECHNICAL INFRASTRUCTURE (BASIC FACILITIES) – [illegible] semi-[illegible] products: [illegible]ing, forging and stamping								Technical Services: Heat treatment		Supply of moulds, dies, jigs, etc.					Boiler making			Special machining				ST	COMPONENTS – Mechanical														Specific				Total complexity without components
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1/2											2	2											12																2		23.1
1/2											2	1/2											12	2					2	2			2							2	28.0
1/2											1/2	2/3						2					1	2																	31.7
[illegible]		2								1	1/2	1/2						2	2				2	2					2	2										2	32.3
[illegible]											2/3	2/3											2	2					2	2			2						2	2/3	34.9
[illegible]		2							23	2	23								2/4				2	3		3			2/3	2/3			2	2			3		2/3	2/3	35.2
2/3									2/3		2	2/3											2	2					2	2			2							2	38.2
[illegible]										1	1/2	1/2							2			2/3	1/2	2			3		2	2			2							2	39.3
[illegible]										2	1/2	1/2										2/3	2	2/3			2/3		2	2			2							2	42.4
1/2		1/2								2	2	2						2	2	2			2	2/3			3		2/3	2/3			2				3/4		2	2/3	43.8
	3					3				2	3	3/4	3										2						2											2/3	48.8
2/3	2										2/3	2/3						2	2	3			2	2/3					2/3	2/3			2/3				3/4		2/3	2/3	50.4
	3					3				2	3	3/4	3										2						1	1				3	3		3/4		3/4	3/4	55.0
[illegible]										2	2	2						2	2			2	1/2	2/3			2/3		2/3	2/3			2				3		2	2	6111
2/3		2/3						2		2/3													2	2																2/3	35.3
2/3										2													1/2	1									2	2						2	25.2
1		2			2						2		2										2											2					2	2	2643
							2		2		12		1						12																						25.1
2											2	12											12	2															2		28.1
3							3	3	3		3	2	3					3					2/3	2/3									2/3								51.2
2				2/3			2/3	3	3	2	3	3	2/3	2				3					2	2					2	2			2						2/3	2/3	55.4
3				3	3		3	3	3		3/4	3	3	3									2/3																3/4	3	59.0
3	3	3		3	3		3	3	3/4		3/4	3	3	3						2		3	2/3	3					3	3			3				3		3/4	3/4	80.0
3/4				4	3/4		3/4	3/4	3/4		3/4	3/4	4	4				3				2/3	3							3/4			3	3					3/4	3	81.6
2/4	3	3		3/4	4		3/4	3/4	3/4		3/4	3/4	4	4								3	2/3	3		4			3/4	3/4			3				3		3/4	3/4	91.7
4	4			4	4		4	3/4	3/4		3/4	4	4	4					2	3		3	3	3/4		4			3/4	3/4			3				3		3/4	3	95.5
4	4			4	4		4	3/4	3/4	3	4	4	4	4				4	2	3		3	3	3/4		4			3/4	3/4			3				3		3/4	3/4	106.6