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PRODUCTION AND PRE-REQUISITES FOR PRODUCTION OF MACHINE TOOLS IN LATIN AMERICA 1/

by

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CONTENTS

Pre-requisites for Production and Production of Machine Tools in Latin America.

This Paper considers the pre-requisites and manufacture of machine tools in the countries of the region. The human, technical and financial requirements are considered together with an analysis of the demand which is likely to develop by the end of the decade. Particular attention is given to the sources of technology and the ways in which this knowledge can be acquired by the countries of the region. The cyclical nature of the machine tool trade is reviewed and tables showing machine tool population of various industries are included to indicate the pattern of machine tool distribution in industry.

1:1 Machine Tool Production and Trade.

World machine tool production is principally concentrated in ten of the industrial countries while a further fifteen countries are also major machine tool producers. Table 1.1 shows the production and trade for the 31 principal machine tool producing countries. It will be noted from this Table that even the largest machine tool producers are also major importers of machine tools while most of the smaller producers shown in the Table import more machines than they produce. The increasing industrial development of many countries is leading them to consider manufacturing part of their machine tool requirements, which is a logical and desirable development, provided that careful selection is made of the type of machines to be built and that an adequate market, either within any single country or through sales to neighbouring countries, can be established.

In the long term a machine tool industry will bring important benefits to a country as the existence of such an industry demands that the work force reaches a high degree of skill and both production engineering and technology advance more rapidly in countries where there is a flourishing machine tool industry.

Table 1:1

World Machine-Tool Production and Trade
(Millions of U.S. dollars)

1971 (Estimated)

Country	Production			Trade	
	Total	Cutting	Forming	Export	Import
1. West Germany	$1820.0	$1230.0	$590.0	$920.0	$210.0
2. Soviet Union	1160.0	865.0	295.0	* 96.0	*196.0
3. United States	980.0	662.0	318.0	264.0	96.0
4. Japan	912.0	722.0	190.0	100.0	132.0
5. United Kingdom	465.0	367.0	98.0	220.0	122.0
6. Italy	423.0	338.0	85.0	179.0	169.0
7. France	387.0	273.0	114.0	133.0	224.0
8. Czechoslovakia	275.0	230.0	45.0	136.0	68.0
9. Switzerland	266.0	226.0	40.0	218.0	40.0
10. East Germany	260.0	193.0	67.0	202.0	60.0
11. Poland	145.0	132.0	13.0	57.0	90.0
12. Spain	98.0	83.0	15.0	33.0	49.0
13. Sweden	79.0	51.0	28.0	54.0	78.0
14. China	58.0	43.0	15.0	3.0	32.0
15. Hungary	47.3	* 44.3	* 3.0	28.0	28.0
16. India	45.0	42.5	2.5	4.1	24.0
17. Belgium	37.4	17.7	19.7	33.1	40.3
18. Canada	37.0	22.0	15.0	24.0	90.0
19. Yugoslavia	36.3	29.0	7.3	12.0	25.5
20. Brazil	34.4	20.0	14.4	3.0	37.7
21. Argentina	34.3	19.1	15.2	2.1	32.0
22. Netherlands	33.7	21.1	12.6	27.2	51.1
23. Austria	28.1	12.9	15.2	20.7	52.7
24. Bulgaria	26.9	24.6	2.3	18.9	36.3
25. Australia	23.9	6.8	17.1	2.9	39.4
26. Romania	* 22.8	* 20.8	* 2.9	* 6.5	* 34.2
27. Taiwan	16.0	9.5	6.5	4.0	10.0
28. Denmark	15.3	10.1	5.2	12.5	13.0
29. South Africa	7.0	3.0	4.0	0.3	53.6
30. Mexico	* 5.0	-	-	* 0.1	67.0
31. Portugal	3.1	1.7	1.4	1.5	8.5
Total	$7781.5	$5720.1	$2056.4	$2815.9	$2209.3

* Estimate from fragmentary data.

Source - American Machinist.

1:2 Industrial Environment.

A machine tool manufacturing industry can only be successful where there is a suitable industrial environment that will sustain this industry which, even in the countries with the highest machine tool production, accounts for no more than 1% or 2% of their industrial output.

The requirements of this industry are highly exacting in respect of materials, management skills, workforce skills, technology and marketing.

Theoretically almost every country could manufacture machine tools, but whether it would be economically desirable to do so is quite another matter. Machine tools have a long life and are relatively expensive for their weight so that shipping costs are not unreasonable. It is therefore much less expensive to buy from other countries than to manufacture locally, unless there is a good demand for a particular model of machine. When such a situation exists local manufacture can be considered, but a very detailed examination must be made of all the problems before embarking on manufacture, or the operation may prove technically undesirable and totally uneconomic. The machine tools must be satisfactory in performance over a long period of time as well as being competitively priced in the first instance. Reliability is probably the most important aspect as inferior products will reduce the efficiency of the entire metalworking industry of the country. Some of the vital aspects for production are reviewed in the following sections.

1:3 Material Supply.

The cast iron content of the average machine tool represents some 50%-60% of the total weight. It is therefore extremely

important that there should be a good supply source of high quality castings having close grained dense iron to give the necessary wearing qualities on the slideways. It is most desirable that the foundries should be close to the machine tool plant to permit the closest technical collaboration. High quality alloy steels of many different types are required which may have to be imported. Steel forgings will be required for spindle and gear blank manufacture. Many highly specialised machine parts will be required but the volume of any one type is likely to be relatively small which adds to the procurement difficulties. The parts required will include:-

Anti-friction ball and roller bearings. (These bearings are made to much higher standards than the general purpose bearings used in the automotive industry, in order to withstand prolonged periods of usage.)

Sintered bronze bearings;

Oil seals;

Lubrication pumps;

Air and oil pipes and fittings;

Hydraulic and pneumatic valves;

Manual and power operated chucks;

Tracer and other specialist attachments;

Electrical control equipment and cables;

Electric motors;

Electric cooling pumps;

Sheet metal guards;

Dowel pins;

High tensile bolts.

It may not be possible to obtain all these items to the high standards required in which case it will be necessary for the machine

tool plant to set-up specialist sections to produce items such as their own forgings, sheet-metal parts and electrical control panels. Items such as the valves and chucks will have to be imported, if there is no local manufacturer, unless these items are required in very large volume in which case manufacture may be justified.

1:4 Specialist Processes.

In an industrialised country most machine tool companies rely heavily on specialist companies to carry out certain of their processes. One of the most important of these processes is the heat treatment of the steels during the course of component manufacture from a wide variety of different types of steel requiring diversified heat treatment plant. Plating operations such as hard chrome are usually undertaken by specialist contractors as well as the manufacture of name plates and the engraving of panels.

The design and manufacture of jigs, fixtures and tooling will be essential to the commencement of production. The manufacture of these within the new factory would seriously delay the commencement of manufacturing their new product line, so that outside sources of supply must be found. Ultimately it may be desirable to include this within the manufacturing programme so that full tooling facilities can be offered to customers.

1:5 Management.

It is essential for the top level management to have a much more intimate understanding of the product than is necessary in many other industrial operations due to the highly specialised nature of machine tool manufacture.

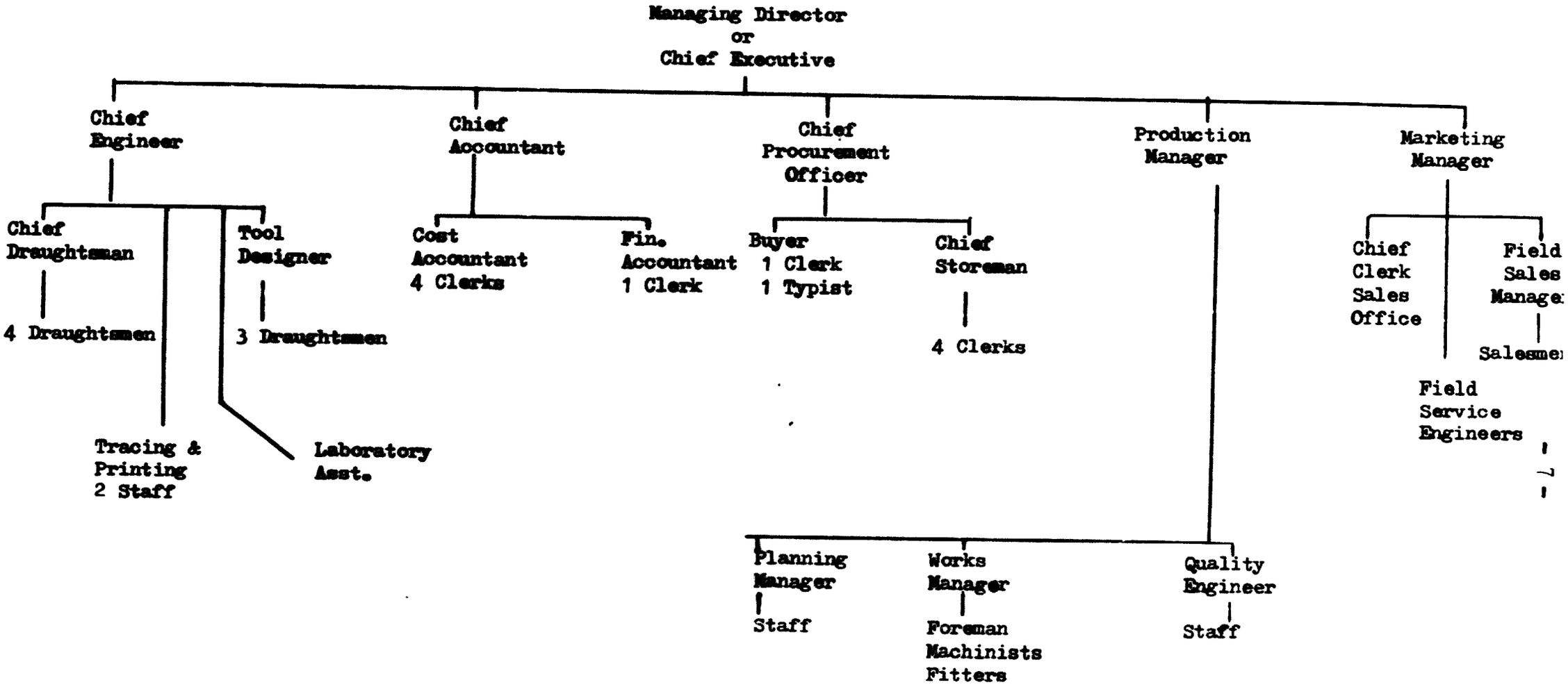
The machine tool company is usually small which means that even the Chief Executive must become closely involved in all aspects of the operations and fully understand the technology.

The management must have considerable experience in the manufacture of high quality engineering products in quite small batch sizes without incurring the high costs which usually appertain when working under such conditions.

A typical organisation chart from a machine tool company employing some two to three hundred people is shown in Table 1.2. Each of the senior executives should have a good knowledge of machine tool manufacturing methods but if men with these qualifications are not available the opportunity should be taken to send them on a Fellowship Course with a machine tool company in an industrialised country for a period of not less than six months.

Organisation Chart for Machine Tool Plant

Table 1.2



1:6 Scale of Operation.

The machine tool industry is essentially a small business industry. Table 1.3 shows the percentage of employment by size distribution for machine tool establishments in the U.K. in 1968. Both in the U.K. and in the U.S.A. establishments with less than 500 employees accounted for roughly half the total national output of machine tools. The average number of employees per establishment was 142. It will therefore be appreciated that the industry is extremely diffuse with many more small firms than large ones making a tremendous variety of different products. Even among the large groups there is often a high degree of product specialisation. The most successful small companies tend to specialise on only one class of product. In West Germany, according to their Machine Tool Catalogue, out of 425 companies 47% specialised on one class of product while a further 28% made only two classes.

It is therefore not necessary to consider setting up a large industry when deciding to embark on machine tool manufacture but it is vital to have an adequately experienced staff to select a suitable product and to have the necessary industrial supporting services available in the country.

Table 1.3

Employment Percentage by Size of Establishment.
U.K. Machine Tool Industry 1968

Average Number Employed by Establishment.	% of Employment.
1 - 24	8
25 - 99	11
100 - 499	39
500 - 999	22
1,000 & Over	20

Source - U.K. Census of Production.

1:7 Type of Machines.

The principal differentiation is between metal cutting and metal forming machines. These two categories are further divided into broad types of machines.

Metal Cutting.	Metal Forming.
Turning.	Bending and Forming.
Boring.	Pressing.
Drilling.	Punching & Shearing.
Milling.	Forging.
Tapping & Threading.	Riveting.
Broaching.	
Planing, Shaping & Slotting.	
Cut-off & Sawing.	
Grinding.	
Honing & Lapping.	
Polishing & Buffing.	
Gear Cutting.	
Gear Finishing.	

These broad categories are further divided into sub-groups which with increasing specialisation are rapidly multiplying to meet the user need for increasingly specialised machines. In addition, there are of course further divisions by size of machine.

The introduction of numerically controlled machines has brought about further sub-division of the previous classification and even the N.C. machines themselves are now divided as to whether their control is the simple 'point to point' or full contouring control. A new range of machines has also been developed as a result of numerical control known as machining centres where a number of machining operations previously undertaken on seperate machines are combined on the one N.C. machine.

It would be quite impractical for a company without previous machine tool manufacturing experience to commence building the more sophisticated types of machines or numerically controlled machines. On the other hand it would be a mistake to automatically commence manufacturing the very simple machines such as engine lathes, drilling machines and simple grinding machines, where sources of supply within the region are already available. A careful market research survey may well indicate that there is a worthwhile potential demand for a slightly more advanced machine which will have an increasing potential as the industrial progress of the country develops. Such a machine may impose more exacting demands on the newly established machine tool manufacturing plant but will offer much greater future potential. It is likely to have less competition, so prices can therefore be more realistic and the same product is likely to be in production for a longer period without the necessity for a costly change-over of one product to another within a limited number of years.

1:8 Development Costs.

The cost of developing a new model to the point at which it can be successfully introduced to the market includes not only the design and development costs but also the cost of patterns, special jigs and tools and the production planning and control procedures. The character of the design and development depends to a large extent on the type of machine tool to be developed. In the case of simple models which are to be sold in significant numbers, concentration will be on making the machine perform reliably while it must be engineered so that it can be produced relatively cheaply. The more sophisticated machine tools are designed for more exacting tasks

concerning quality and dependability under arduous duty, so that design is concentrated on these aspects and cost is of secondary importance.

In all cases the cost of development should rightly include the cost of introducing the new model into production and also the cost of introducing it to the market. It is not unusual for the first production batch of the new model to be made at a loss, partly because design mistakes will have to be corrected but particularly because the workforce are unfamiliar with the manufacture of the machine and therefore each operation is more prolonged.

In an industrialised country the cost of development to the stage of producing the prototype for a machine will vary widely depending entirely on individual circumstances. However, a cost of £250,000 for the design, development and manufacture of the prototype machine would be quite normal. The cost of putting the machine tool into production, once the prototype has been proved, could equally amount to a similar figure and marketing costs would be additional.

The cost of the initial development has to be recovered over the life of the product. A recent study showed that the initial development costs could account for between 5% and 30% of the total production cost of the machine tool. The higher figure applying to a machine produced in small quantity while the lower percentage relates to a machine sold in large volume which may amount to 1,000 units per year.

The growing cost of development has been recognised more and more in recent years and this has lead to many licensing and co-operation agreements and has been a major reason for many of the mergers in the industrialised countries. The ability to spread development costs over a greater number of unit sales clearly offers a significant scope for economy of scale.

Many developing countries do not have staff with adequate experience to successfully design and develop a machine tool other than the simplest models. Even where such staff exist, the supporting facilities for undertaking the necessary research into the various elements of the machine design and for conducting a fully scientific analysis of the prototype machine, are unlikely to be available. For these reasons, some of the most successful manufacturing programmes undertaken in the developing countries have been with products manufactured under licence from a leading manufacturer of the particular class of machine in one of the industrialised countries. When chosing such a design, care must be taken to ensure that the design is completely up to date and will not be outmoded within a few years bearing in mind that the period between entering into the Licence Agreement and commencing production may be anything between one and three years. It is most desirable that once production has commenced a prolonged period of manufacture without any major design changes taking place should ensue.

The manufacturing facilities available in the plant where the machine is to be made must also be taken into account in selecting the design, together with the state of the industrial development of the country and the supporting services which will

be available. The most advanced design may be quite unsuitable for use in a developing country due to limited manufacturing facilities or the non-availability of large numbers of specialised components which would then have to be imported. Furthermore the machine may be so advanced that it would not be suitable to meet the local user requirements, or may be too complicated for the maintenance staff to fully comprehend which would result in the machine being unnecessarily out of commission.

1:9 Cost Analysis.

The cost of each machine built will vary considerably depending on the number of machines manufactured each year to a particular design. There are three principle variants bringing about this change in manufacturing costs, namely - material price reduction for quantity; reduced number of manufacturing hours, due to familiarity with the product, but also due to different manufacturing techniques which are justified with larger scale production and increasing use of special jigs and fixtures which would not be economically warranted for small scale production; and finally perhaps most important, the value of development cost which must be written off against each machine. Table 1:4 presents the cost variance for sales levels between 10 and 800 units per annum. The figures would not be presented in this way by a normal costing system but it is important that the cost variation should be studied in this way when considering manufacturing a machine at various levels of production. The Table particularly demonstrates the importance of spreading initial development costs over a sufficient number of units.

Table 1.4

ANNUAL UNIT SALES AND UNIT EX-FACTORY COSTS

Annual unit sales	10	50	100	800
Initial dev't cost (000)	100	133	167	300
Initial " " per unit (£)	1430	380	240	40
Manufacturing costs (£)	1150	1050	1020	960
Ex-factory cost per unit (£)	2580	1430	1260	1000

Note: (1) The initial development cost per unit sale assumes a 7 year life for the model.

(2) Production costs include direct labour and materials only.

From the above Table it will be clear that production of 10 units per annum will be totally uneconomic unless the model was a highly specialised machine. In the case of general purpose machines, there will always be sources of supply from companies with substantial volumes of production, so that normal economics demand that a machine should be imported rather than manufactured locally where there is insufficient demand to reach a reasonable level of production. It will be noted however that the principal variant is in the development cost so that a production level of 50 units per year could be viable if a suitable design could be obtained from another company on reasonable terms either as an outright purchase or on a royalty basis.

2:1 Financial.

The machine tool industry is not a capital intensive industry such as steel making or chemical industries but requires much heavier buildings and more expensive plant than many consumer goods industries. An analysis of capital equipment used by machine tool companies shows on average that investment per employee varies between £1,250 and £6,000. A new plant set up with all modern machinery will require a figure near the top end of the scale.

A survey made in the U.S.A. shows that an average machine tool plant has 64 machines installed per 100 employees. Details of these machines are given in Table 2.1.

Table 2.1

MACHINE TOOLS INSTALLED PER 100 EMPLOYEES (U.S.A., 1968)

Metalworking Machinery and Equipment (machine tools, dies, tools, jigs, fixtures and accessories)

Machines		Numbers of machine tools per 100 Employees	
Turning	- Bench lathes	1	
	- Standard engine lathes	2	
	- Toolroom " "	2	
	- Turret lathes	2	
	- Automatic bar type	1	
	- Other	2	10
Boring	- Jig borers	1	
	- Others	1	2
Drilling	- Upright	4	
	- Radial	2	
	- Other	2	8
Milling	- Vertical ram type	3	
	- Knee or bed	5	
	- Other	3	11
Shapint & Planing			2
Contour sawing and filing			1
Cut off and Sawing			3
Grinding	- External	3	
	- Internal	1	
	- Surface	5	
	- Tool & Cutter	3	
	- Other	6	18
Lapping & Honing			1
Polishing & Buffing			1
Gear Making			1
Others			2
Presses	Metal forming	3	
Other	Metal forming	1	4
			64

In addition to the capital equipment, a further investment for working capital will be required amounting to between £2,000 and £4,000 per employee or on an alternative basis as 50%-75% of the annual sales value. The working capital will mostly comprise materials in the raw and semi-finished condition, as well as the usual financial requirements for debtors and creditors.

In some developing countries the output per employee has been as low as £2,000 per annum but in these cases the investment has usually been very much lower due to the use of old buildings and inferior plant. Unless an output per employee of £5,000 per annum can be anticipated it is unlikely that manufacture of machine tools would be economically justified by a company in the region. In an industrialised country the expected annual output would be at least £10,000 per employee and a figure of this order should certainly be the aim of any company proposing to enter machine tool manufacture.

2:2 Sources of Technology.

Access to advanced technology wherever it has been developed is important for the economic development of all countries regardless of their economic and social systems and is particularly important in respect of the transfer of technology from the developed to the developing countries. The transfer of technology on reasonable terms constitutes one of the key elements accelerating the pace of economic and social development of the less advanced countries.

The industrialised countries possess a vast store of machine tool technology and much of this can be obtained at purely nominal

cost by purchasing the proceedings of the Machine Tool Conferences which have been held at the Universities at Aachen in Germany and Birmingham and Manchester in England. Various research bodies have also undertaken extensive investigations into machine tool matters and much of this information is also available. Similar information is also held in the United States but this may be less accessible as much of the work has been undertaken by or on behalf of individual companies. Specific machine design information is, of course, also available on immense scale as a result of some form of technological co-operation agreement between companies in the region and machine tool manufacturing companies in the highly industrialised countries.

2:3 Forms of Transfer.

One of the simplest forms of acquiring technology is the purchase of drawings. However, once the drawings have been handed over the vendor has no further obligations and the buyer must rely entirely on his own resources to achieve effective utilisation of the data which may not be possible unless the receiving organisation already has considerable expertise in the manufacture of similar products. The "know-how" type of agreement is therefore more frequently used where the supply of drawings is augmented by full technical information on the manufacture of the product. The information may be in the form of written instructions for the manufacture of every component and may include drawings for all the necessary jigs and fixtures required for production.

Although costs will be further increased if the contract includes the provision of training programmes and the loan of technicians, it is usually more than compensated for by the substantial reduction in the time required to achieve full production levels. In the first instance staff of a developing

country may be sent to the works of the company selling the technology so that they can become fully familiar with all aspects of manufacturing methods and the equipment used. This may be followed by the loan of technicians to assist with the commencement of production. Where an entirely new plant is to be established it may be desirable for a complete management team to be seconded to the operation by the suppliers of the technology who can advise on design of buildings, on the plant requirements and on all matters related to production. Alongside this team the indigenous organisation would have their own permanent personnel working closely with their counterpart advisors to ensure that all phases of the technology are absorbed as rapidly and thoroughly as possible. As production gets under way the advisory technicians will be progressively withdrawn until the entire operation is in the hands of the local staff.

In countries such as Argentina, Brazil and Mexico, where machine tool companies have already been established, another type of specialised joint venture operation may be adopted. The rapid rate of technical evolution makes it impossible for any country to be self sufficient and design themselves all types of machine tools required throughout their industry. It will be desirable for the industry to concentrate on the design and development of a certain range of machine tools but this can be extended and the expenditure involved reduced by entering into co-operation with machine tool firms in other countries which can offer the most advanced machines of a particular type. An established local machine tool company undertakes the manufacture of the machine which may have been adapted to suit special local requirements of the region. The

sale of the machine is undertaken by a selling organisation jointly owned between the manufacturing company and the company supplying the machine design. Foreign currency expenditure is reduced and exports to agreed markets increased by agreements of this type.

A joint venture of this type would be initiated by organisations in a developing country and the industrialised country signing an Outline Agreement. This would be followed by specialists from the industrialised country undertaking a detailed market research survey and then working out forecasts in close collaboration with the local organisation to prove the feasibility of establishing or expanding sales of a particular product within the region, over a reasonable period of years. Provided the forecast proved satisfactory a full Agreement of Co-operation would be signed and the planning of production commenced. The specialists from the industrialised country would supervise the initial production, which in the early stages may rely extensively on the use of imported components and assemblies, but locally manufactured items would be progressively introduced. A joint sales organisation would be established to handle the sales in the local and associated markets, this organisation may initially handle completely imported machines in order to achieve market acceptance of the product before the locally manufactured machines are available, thereby ensuring a good level of demand by the time production commences.

The sales organisation would also have special responsibility for organising after sales service of the machines delivered, the training of servicing staff and the organisation of spare parts supply. It would also provide an advisory service to users on the most effective utilisation of the machine.

The machine tool industry of the region might benefit considerably by the establishment of a specialist centre staffed by suitably trained personnel under an efficient Director providing a service for the effective dissemination of technical information from industrialised countries. Initially it may be desirable that the Director of the Centre should be loaned by the industrialised countries through an International Organisation such as U.N.I.D.O.

It is suggested that initially the Centre should cover -

a) new techniques and related machinery;

b) machine tool designs;

c) standards.

These fields of interest are not necessarily the only ones which should be covered but, in a region where three countries are already important machine tool producers, the industry would benefit considerably from the establishment of such a Centre either on a regional basis or in one of the countries with substantial industry.

The new techniques and related machinery section would continuously monitor trade journals from selected countries and maintain contact with professional institutions and trade associations in these countries in order to keep themselves fully informed of all developments. Staff would be sent at suitable intervals to attend major machine tool and other industrial exhibitions and to visit suitable industrial organisations to keep abreast of the latest application of technology and with the latest types of machines which are being developed for the application of this technology. The machine design section would be responsible for assisting the designers working in the manufacturing companies and where necessary undertaking complete machine design in accordance with the latest techniques employed

in the industrialised countries. There are considerable advantages for the design work to be concentrated in a single centre even where more than one manufacturing unit is being served. The Centre should be provided with adequate laboratory facilities as it is usually found that greater effectiveness is obtained when full development facilities and manufacture and testing of prototypes are associated with the unit. The standards centre would consider all appropriate international standards and decide which could be applied nationally or regionally in their original form, and which ones may require adaptation to meet special local needs. The Centre would also play an important part in the evolution of future standards by ensuring that international standards organisations are kept fully appraised of the special conditions applicable in their region which should be taken into account when drawing up new standards.

2:4 Product Range.

The demand for machine tools grows proportionately to the growth of industrial development. As the ability to manufacture these machines is also related to the level of industrialisation, an appropriate correlation exists between demand and the ability to manufacture. It has been shown elsewhere in this Paper that some of the major machine tool manufacturing countries are also those which import the greatest volume. The countries with a major machine tool industry also have some of the highest rates of industrial growth even though there is an extensive international trade in machine tools.

A number of companies in the region are already manufacturing general purpose machines such as engine lathes, drilling machines

and some grinding machines. The increasing industrial development of the countries will ensure an increasing demand for more advanced types of machines. The introduction of a new machine is an extremely costly operation and it is therefore important that the decision on the type of machine to introduce is made with adequate knowledge of the potential market. This can only be achieved by a full market research investigation undertaken by experienced market research investigators in the capital goods field with special knowledge of machine tools. A detailed analysis of the large volume of imports in Argentina, Brazil and Mexico would provide a useful starting point as to the type of machines which are most likely to be in large demand for the full market research investigation. The advanced and now reliable electric or electronic control systems which have been developed for plug-board or other simple methods of sequential machine control have brought about a revolution in control of machines. Of particular note are the plug-board bar automatics, the electro-hydraulic automatic chucking lathes and the tracer controlled lathes. In the boring field machines with digital read-out and really accurate boring spindles have eliminated most of the need for costly and cumbersome boring fixtures. The simpler types of numerically controlled drilling machines have also brought important changes in drilling operations while the later designs of milling and grinding machines also offer considerable advantages.

Manufacture of any of these types of machines could undoubtedly be undertaken by these three countries who already have established machine tool manufacture with considerable savings in foreign currency. The delays which will be imposed by designing these machines locally, and the cost of building prototypes and eliminating difficulties, would almost certainly justify the cost of acquiring licences for machines of well proved design.

2:5 Advanced Technology.

The most spectacular form of advanced technology recently developed in machine tools is undoubtedly numerical control and these systems have now developed to the stage where a package unit can be safely married to a suitable machine without complicated control system modifications which were necessary in the early stages of development. All that is necessary is for the machine tool to be designed with a suitable interface to accept the chosen control system. Plug-board controls are also readily available which will greatly increase the versatility of a machine. Hydraulic systems are also frequently used for controlling machine tool functions. The demand for higher production rates and greater accuracies created a demand for a radial or lineal bearing system capable of meeting these more exacting demands and this has been achieved through the development of hydrostatic bearings.

These advances in technology are not solely the prerogative of the industrialised nations and should be incorporated into their machine tool design by the more advanced developing countries.

3:1 Machine Tool Consumption.

The increasing industrial activity in many of the countries of the region has led to a steadily increasing demand for machine tools. While some of the demand has been met from local production, both Argentina and Brazil, who are the major machine tool producing countries in the region, import approximately 50% of the machine tools used in their country. Table 3.1 shows the consumption of machine tools by countries of the region for the years from 1964 to 1968.

Past consumption figures may be of interest when considering the desirability or practicability of establishing or expanding machine tool production but due to many extraneous factors they may be totally misleading as a straightforward prediction for future requirements.

Table 3.1

CONSUMPTION OF MACHINE TOOLS IN COUNTRIES OF THE REGION.

Units 000$

Country	1964	1965	1966	1967	1968
Central America					
Mexico	33869	35959	35911	37633	45413
Guatemala	619	627	699	839	615
Dominican Republic	326	124	167	489	862
E. Salvador	740	1058	912	332	557
Honduras	93	148	195	261	258
Jamaica	386	388	669	782	869
Nicaragua	222	707	655	392	213
Costa Rica	326	853	312	409	343
Panama	212	256	509	427	338
Trinidad & Tobago	173	337	341	374	454
South America					
Brazil	-	19000	29690	40120	63280
Argentina	19198	18123	22588	24010	20176
Colombia	-	10619	4205	3167	4871
Peru	1516	2866	3399	3338	2361
Venezuela	6481	7026	6946	5742	8347
Chile	3216	4106	3469	4900	9436
Ecuador	550	389	703	632	719
Bolivia	158	239	189	307	1297
Uruguay	361	291	200	169	182

3:2 Future Machine Tool Demand.

As one of the most vital prerequisites for embarking on a machine tool production programme is an adequate, expanding and if possible, stable market, forecasts from the U.N.I.D.O. machine tool study are included in this Paper. The study sought to establish the relationship between machine tool demand and the commonly available macro-economic factors such as gross national product (G.N.P), population, power consumption or vehicles in use. While it was found that there was a strong relationship between machine tool consumption and each of these factors, it was established that the strongest relationship existed with G.N.P. per capita. Statistics for 1968 showing population, G.N.P. per capita and machine tool and industrial machinery consumption for countries of the region are shown in Table 3.2, while in Table 3.3 predictions for 1980 have been prepared using the U.N. estimates for population and G.N.P. for that year.

It will be seen from these predictions for 1980 that machine tool demand in Latin America is expected to increase substantially above the previous levels and to justify further expansion of the machine tool industry which has already been established in certain of these countries.

Table 3.2

Country	1968 SUMMARY STATISTICS			
	Data for 1968		Data for 1965/8 Average	
	Population in 000's	GNP per Capita, US $	Machine Tools, 000 $	Industrial Machinery 000 $
CENTRAL AMERICA				
Mexico	47,267	566	38,729	458,962
Guatemala	4,864	315	695	25,961
Dominican Republic	4,029	290	411	20,048
El Salvador	3,266	277	715	20,898
Honduras	2,413	256	214	18,517
Jamaica	1,913	496	677	39,045
Nicaragua	1,842	373	492	25,185
Costa Rica	1,634	456	479	18,265
Panama	1,372	609	383	20,696
Trinidad	1,021	395	377	26,357
	68,600 (total)	403 (average)	42,722 (total)	673,934 (total)
SOUTH AMERICA				
Brazil	88,209	316	38,020	287,835
Argentina	23,617	739	21,224	365,225
Colombia	19,825	359	5,702	124,685
Peru	12,772	291	2,991	128,993
Venezuela	9,686	944	7,015	261,072
Chile	9,351	569	5,478	141,101
Ecuador	5,695	229	611	30,631
Bolivia	4,680	173	508	20,756
Uruguay	2,818	650	211	15,407
	176,653 (total)	474 (average)	81,760 (total)	1,375,705 (total)

Table 3.3

Country	FORECASTS FOR 1980			
	Basic Forecasts 1980		Forecasts for 1980	
	Population in 000's	GNP per Capita, US $ 1968 prices	Machine Tools 000 $ 1968 prices	
CENTRAL AMERICA				
Mexico	70,664	751	83,310	A
Guatemala	7,016	418	1,450	A
Dominian Republic	6,199	385	930	A
El Salvador	4,883	363	1,490	A
Honduras	3,562	286	390	A
Jamaica	2,398	672	1,110	A
Nicaragua	2,688	495	1,030	A
Costa Rica	2,673	508	1,040	A
Panama	2,002	958	930	A
Trinidad	1,455	1,190	880	A
	102,065 (total)	486 (average)	92,560 (total)	
SOUTH AMERICA				
Brazil	125,742	389	66,590	A
Argentina	28,569	852	33,000	A
Colombia	28,933	418	9,100	U
Peru	18,206	425	5,830	U
Venezuela	14,467	1,053	11,900	U
Chile	12,286	731	9,080	A
Ecuador	8,408	261	1,080	A
Bolivia	5,530	234	930	U
Uruguay	3,330	725	290	A
	242,141 (total	565 (average)	137,800 (total)	

A: Adjusted Forecast

U: Unadjusted Forecast

The countries have been grouped under two main locational headings.

Central America:

For most of the forecasts prepared for the countries in this group, it has been assumed that 1968 consumption levels relative to the value predicted by the equation are likely to be maintained up until 1980 and so the forecasts have been adjusted accordingly. For most of these countries, high rates of growth for both population and G.N.P. have been estimated and this results in significantly high increases in consumption over the period 1968 to 1980. In several cases consumption of both machine tools and industrial machinery is forecast to increase by at least 100 per cent.

South America:

It is by no means obvious that the levels of consumption for the countries in this group will maintain their relative positions as observed in 1968, and adjustments have been selectively applied to take account of trends in time series. The forecasts arrived at for Brazil and Argentina, the two major consumers, may be too low in view of the fact that both are now significant producers of machine tools and a large range of industrial machinery. It could well be that the statistics computed for historical consumption (especially production) understate the true level and hence bias the forecasts downwards. In the case of Uruguay the forecasts levels need revising upwards as the calculated figure is almost certainly too low. The remaining forecasts appear quite acceptable in the light of the 1968 summary statistics and the estimated levels for population and G.N.P.

3:3 Trade Cycles.

The causes responsible for the fluctuating machine tool consumption economy are complex and have not been satisfactorily explained in detail. In general terms, however, the range of capital investment in machine tools is a direct reflection of the state of the economy at large. Machine tools are bought for one of three reasons:

1. Because they are needed for manufacture, where no capacity already exists;
2. To replace an obsolete or inadequate unit by a more efficient machine serving more or less the same purpose, for time and cost savings;
3. Because an existing machine tool has broken down beyond repair and needs to be replaced.

In the great majority of cases, machine tools have to be bought at a particular time only when there is immediate need for additional machining capacity. Replacing existing machines for the purpose of cost improvement can always be deferred, and it is rare for a machine tool to break down irreparably without ample prior warning. In any case, the life of most machine tools is long: - in 1968, somewhere approaching one-quarter of all metal cutting and forming machines installed in the U.S.A. were over 20 years old. The 1970 age distribution of metal cutting machine tools in Great Britain was as follows:

5 years or less	19%
6-9 years	23%
10-20 years	37%
Over 20 years	21%

Table 3.4

MACHINE TOOL CONSUMPTION:-
GROWTH AND INSTABILITY

Annual Growth Rates, 1955 to 1970

	Highest % p.a.	Lowest % p.a.	Average % p.a.	Mean Deviation %
Italy	+ 109	- 65	13	39
Japan	+ 195	- 23	30	38
Germany	+ 65	- 26	9	22
U.S.A.	+ 36	- 52	3	18
Belgium	+ 50	- 18	7	16
Netherlands	+ 52	- 24	4	13
U.K.	+ 28	- 19	6	13
France	+ 46	- 9	12	12

Note:
Mean Deviation is the mean deviation of annual growth percentages from the average over the 15 year period.

Table 3.4 shows the highest and lowest growth rate obtained by each country from any one year to the next in the 15 year period up to 1970. It is evident that the severe fluctuations make it difficult to establish any time trends in machine tool consumption of an individual country. The general pattern seems to be one in which an investment boom lasting anywhere between one and six years is followed by an equally variable period during which investment remains steady or more probably declines.

3:4 Distribution of Machine Tool Population and Users.

It may be useful to consider the distribution of machine tools by type of machine in an industrialised country to gain an indication of demand within broad classifications. A much more intimate and detailed survey would need to be made before considering embarking

on a particular product line but the broad classification may be a useful guide and for this reason machine tool population statistics have been given in Table 3.5 for the U.S.A. and U.K.

Table 3.5

TYPES OF MACHINE TOOLS
POPULATION DISTRIBUTION, U.S.A. AND U.K.

Type of Machine	U.S.A. 1968	U.K. 1970
METAL CUTTING:		
Turning.	21	28
Boring.	2	3
Drilling.	19	22
Milling.	12	12
Tapping & Threading	2	3
Broaching.	1	1
Planing, Shaping, Slotting.	2	3
Cut-off & Sawing.	8	6
Grinding.	22	16
Honing & Lapping.	1	1
Polishing & Buffing.	4	-
Gear Cutting & Finishing	2	3
Other.	4	2
	100 (76%)	100 (85%)
METAL FORMING:		
Bending & Forming.	14	15
Hydraulic & Mechanical Presses.	57	64
Punching & Shearing.	12	14
Forging.	4	7
Rivetting.	8	-
Other.	6	-
	100 (24%)	100 (15%)

Sources:-

American Machinist, Tenth Inventory.
Metalworking Production, Third Survey.

The two populations differ in detail, but show the same general pattern. The main difference lies in the greater use of metal forming machines in the U.S.A. : these machines are used mainly in the mass production of consumer durables.

In both countries, about three-quarters of all metal cutting machine tools are in the groups of Turning, Drilling, Milling and Grinding machines. These basic types of machine tools form part of the equipment for almost any kind of machine shop. Other types of machine are used less universally, depending on the need of the particular industry.

The use of different types of machine tools in different industries is shown in Table 3.6 which relates to the U.K. (1970).

The motor vehicle industry - with which is included manufacture of components and accessories - is the biggest individual user of machine tools.

The next biggest is the "Other Machinery" group which includes all kinds of machines ranging from mining machinery to food and drink processing, and including also pumps, valves and compressors. The "Other Mechanical Engineering" category includes component manufacture, including ball and roller bearings, and general engineering subcontract work. In the third general category, "Other Metal Industries", are building fixtures and domestic hardware.

These three general categories account for almost a third of all machine tools installed; motor vehicles and tractors have about half that number; and aerospace have in turn about half the number installed in the motor vehicle category. Other industries are all lesser users of machine tools.

Table 3.6

MACHINE TOOLS IN DIFFERENT INDUSTRIES.

Population distribution in Great Britain, 1970.

(From Metalworking Production, third survey).

USER INDUSTRY.	% of all Machine Tools	Example of a Specific Product: % of Internal Grinders.
Agricultural Machinery	1	0
Metalworking Machine Tools	3	5
Industrial Engines	1	1
Textile Machinery	2	0
Construction Machines	1	1
Mechanical Handling Equipment	2	0
Office Machinery	1	0
Other Machinery	11	13
Industrial & Process Plant	4	2
Other Mechanical Engineering	10	19
Photographic & Instruments	4	3
Electrical Machinery	4	1
Electronics & Communications	5	1
Electric Domestic Appliances	2	0
Other Electrical Goods	2	0
Shipbuilding & Marine Engineering	3	3
Motor Vehicles & Tractors	16	31
Motor and Pedal Cycles	1	1
Aerospace	7	10
Locomotives & Railway	1	0
Engineers Tools & Gauges	4	7
Hand Tools	1	1
Bolts, Nuts, Screws, Rivets, Etc.	2	1
Cans & Metal Boxes	1	0
Other Metal Industries	11	0
	100	100

The number of machines installed per hundred employees for different industries in the U.S.A. is given in Table 3.7.

It shows examples of industries using relatively high and low numbers of machine tools per employee. These figures relate to the U.S.A. with its well known high investment per employee, so the numbers would be lower in most other countries.

Table 3.7

MACHINE TOOL DENSITIES IN DIFFERENT INDUSTRIES

(From American Machinist. 10th Inventory; U.S.A. 1968)

	INDUSTRY	Number of Machine Tools Installed Per 100 Employees		
		Metal Cutting	Metal Forming	Total
1	Screw Machine Products	70	21	91
2	Metalworking Machinery	60	4	64
3	Hand Tools & Hardware	30	17	47
4	Machinery (not electrical)	37	5	42
5	Automotive Parts & Accessories	28	6	34
6	Farm Machinery	24	9	33
7	Oil Field Equipment	24	4	28
8	Electrical Machinery	15	6	21
9	Household Appliances	10	7	17
10	Ships, Boats, Railroads	11	3	14
11	Motor Vehicles (not components)	6	3	9

CONCLUSIONS.

4:1 The Prerequisites.

The essential prerequisites for the manufacture of machine tools in a developing country of the region are:-

a) An adequate local supply of materials, particularly of high quality grey iron castings, as it is usually not practical to import these for machine tool use.

b) A supporting industry which can supply many of the semi-finished products required, and also carry out a number of the specialist processes.

c) Adequate availability of highly skilled machinists and fitters.

d) Highly qualified management who either already have experience in machine tool building or who can be sent to other countries for a period of six or twelve months to gain this experience.

e) Sufficient regional demand for a particular model of machine to justify the cost of commencing production, and to allow economic manufacture.

4:2 Financial Considerations.

The capital investment for commencing machine tool production is not excessive and the operation is relatively labour intensive so that a good ratio of employment to capital invested will result. Efficient manufacture will however only be achieved where good building facilities are provided together with first class plant, therefore adequate investment on the scales given in the Paper are essential for success.

The design and development costs of a new machine are high and, especially where volume of production is low, these costs form a major part of the ultimate machine costs. Careful consideration should therefore be given to buying designs for machines of proved quality suitable to the local requirements.

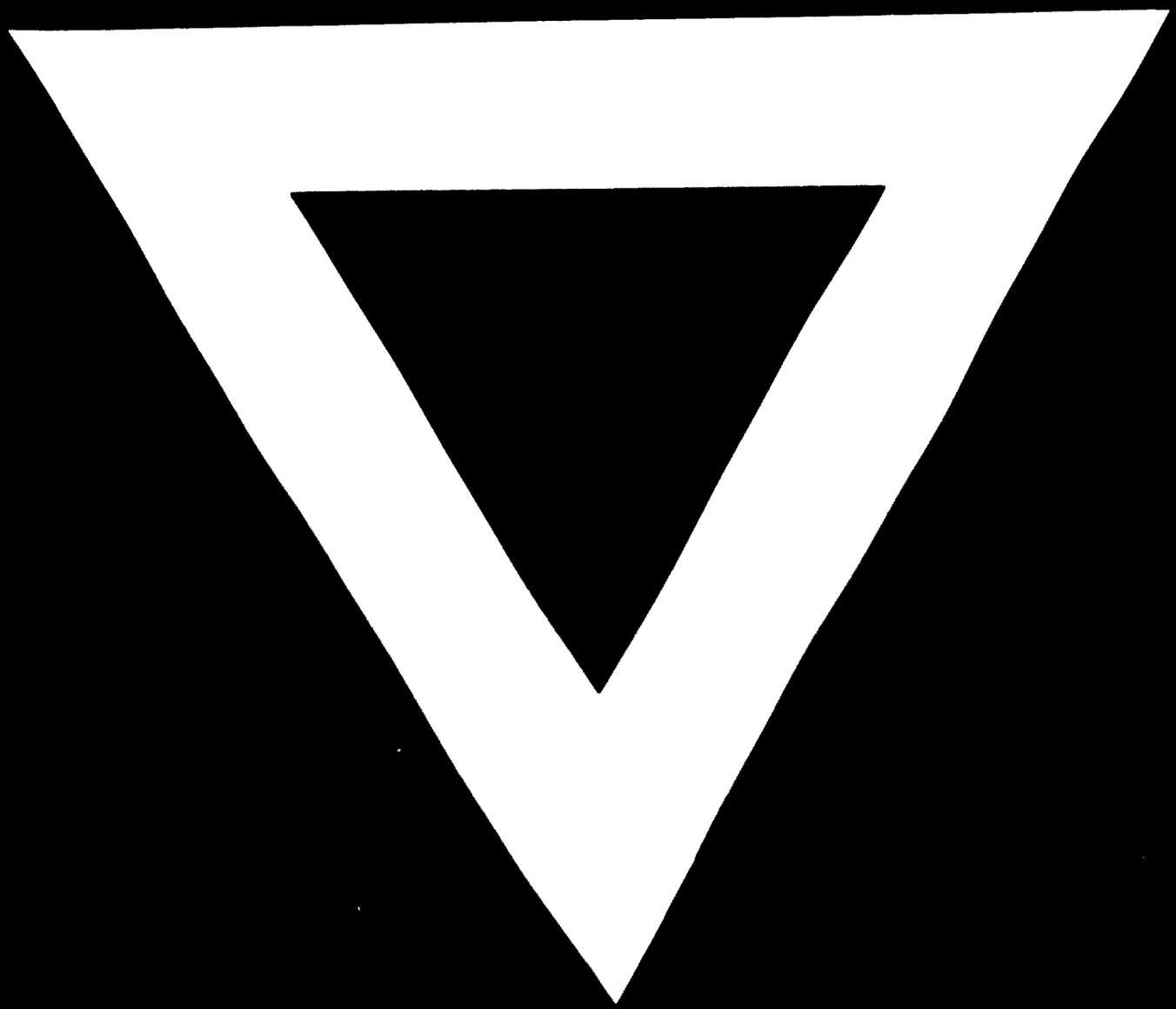
4:3 Technology.

It is necessary to consider not only the technology of machine tool manufacture but also the technology adopted by the machine tool user industry. Technology is changing rapidly so that it is essential that when putting a machine into production it is designed for manufacture by the latest methods and that the design incorporates technology which will be required by the customers for a reasonably long period of years ahead. In the early stages of starting a machine tool industry it will almost certainly be desirable to obtain this technology from the industrialised countries, either under Licence Agreements or through some form of joint venture operation.

4:4 Future Demand.

There is already established in the region a substantial machine tool industry manufacturing general purpose machine tools. Demand for machine tools is rising and this trend is expected to continue as shown on the forecasts for 1980. An automotive industry is also well established in the region which creates a demand for advanced types of high production machine tools. It is therefore desirable that the machine tool industry should undertake an extensive market research investigation into the type and quantity of machine tools which will be required over the next decade with a view to introducing into their production

programme the more advanced types of machine tools which the survey indicates will be required. There would be considerable advantage if the survey were conducted on a regional basis with assistance from an international organisation such as U.N.I.D.O.



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