ECONOMIC MACHINE TOOL INVESTMENT

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When planning an investment in machine tools the most important point is to use the best means at our disposal. The tools which are the most suitable for a particular technology should be selected, to meet not only momentary demands, but also to find solutions for problems that may arise in the future. Increased production gives rise to higher demands also as regards tools used in technological processes.

Tools, appliances, and even gauges are generally considered as transitory items, whereas machine tools usually belong to fixed funds. Within the total amount of capital investments in machine industry, machinery participates by 25 to 50 per cent., and, in some special cases, even by considerably higher percentages.

As regards the composition of capital investment in machine industry, within the above mentioned percentages, the majority of the machinery purchased consists of machine tools, which are not only expected to be fit for ensuring the production of the required dimensions under perfect conditions, but are regarded as items of capital investment, also to be amortized within a certain period of time.

In the present study, machine tool investments are considered rather from the point of view of the technical man. They are important not only for the whole of the national economy, but also for the individual enterprise. Keeping the principle of economy always in mind, investments must be planned with due regard to the capacity of national economy, and an optimum programme must be worked out to ensure machine tools suitable for use in up-to-date technologies.

The idea to abandon simple, all-purpose machine tools for means of production permitting the execution of several operations at a time (dates) goes back to about thirty years. It has become general principle to herald that universal, all-purpose machines are paraphernalia of piece manufacture, and the specialization of machines has been brought about by long-run production. The versatility of all-purpose machines also means longer operation times. Naturally, the design of the machines has undergone variations depending on the size of the runs, which has resulted in a great variety of machine tools, often of extremely complicated construction.

The latest phase in progress, which was reached in our days, is automation. Following from the differences in the sizes of runs, two definite trends may be marked in automation. The first is the automation of all-purpose machine tools by completing them with various feed and delivery devices for small and medium-series manufacturing, and single-purpose machines or machine lines composed of standardized or typified units, destined for large series production. Lately, the construction of equipments on the principle of bricks for building has been gaining ground. Practice has shown that in this respect a difference must be made between the *principle of building bricks applied in the strict sense of the word*, and *that permitting certain dimensional variations* in the elements to be used. Thus, an important process of differentiation is found even in the application of the brick for building principle.

As the field of application of single purpose machines has considerably been enlarged, their use raises a number of problems of crucial importance which demand special consideration as to their system of construction.

From the nature of the "field of application" of single-purpose machines it follows that they may be built in quite a number of variants. Machines for the handling of a host of workpieces, each differing from the others, and to perform many different operations, may be deviced. This requires a *great amount of work*, because for every technological task there is a number of possible solutions, and the one to be decided on must be *the best.*

When selecting an investment and developing a technology, all possible solutions must be set side by side, also from the points of view of economy, so as to find the optimum. It should be pointed out, that a decision based only on technical points, as, for instance, on shorter production times, cannot be accepted, as the problem needs examination from the point of investment also.

As a rule of thumb we may state that in our machine industry, the equipment of a workplace with conventional machinery costs 80,000 to 120,000 Forints. In our estimation, partly based on data received from foreign countries, the creation of a workplace in a highly automatized machine factory will cost from 150,000 to 250,000 Forints. From this it follows that in machine industry the switching over to automation would imply the doubling of investment costs as a minimum.

The above points must also be kept in mind then, when deciding on the technology to be adopted, technologist and investor in common deliberate on the quality and number of machines to be procured. In the last analysis, economic efficiency has the casting voice as to when well-known classic machinery and when single-purpose or highly specialized machine tools should be purchased. From this the result is that special machines must answer particular manufacturing and planning conditions, developed for these purposes. Special machines might happen to lend themselves to some modifications, permitting the machining of different workpieces of identical type. This is a situation which is much easier to deal with, on the other hand, when building machines to solve more difficult technological problems, particularly when they imply the demand of an improved accuracy, a system leaving a wider margin in the selection of limit sizes in production, should be preferred. In this latter case, the application of the brick for building principle is necessarily restricted to a few special units, and the constructor will be at liberty to use his abilities and imagination in designing the equipment as a whole.

It follows from the above that the present development of technology, and the machine tools required by it are characterized by ever-growing and comprehensive mechanization and automation. The analysis of the international trend testifies to the immense economic advantages derived from mechanization and automation. In the socialist countries, of course, the rate of development, improvement and generalization of new techniques is faster. Social conditions here not only permit, but imperiously expect high-grade mechanization and automation. Socialist production creates the preliminary conditions for the comprehensive application of the novel technique in national economy. Yet a certain caution must be observed as regards the application of machine tools adapted to the new technique, since it cannot be said whether the technical perfection of a machine implies its higher economic efficiency, without any further conditions. A measure must be found for particular conditions, represented by the number of pieces to be manufactured, the raw material, the shape and size of the workpiece to be handled etc. could guarantee optimum economic efficiency. To be able to select the best solution from the point of economy, and implicitely, of technology, the amounts of dead and living work resulting from the variants must be set side by side and compared.

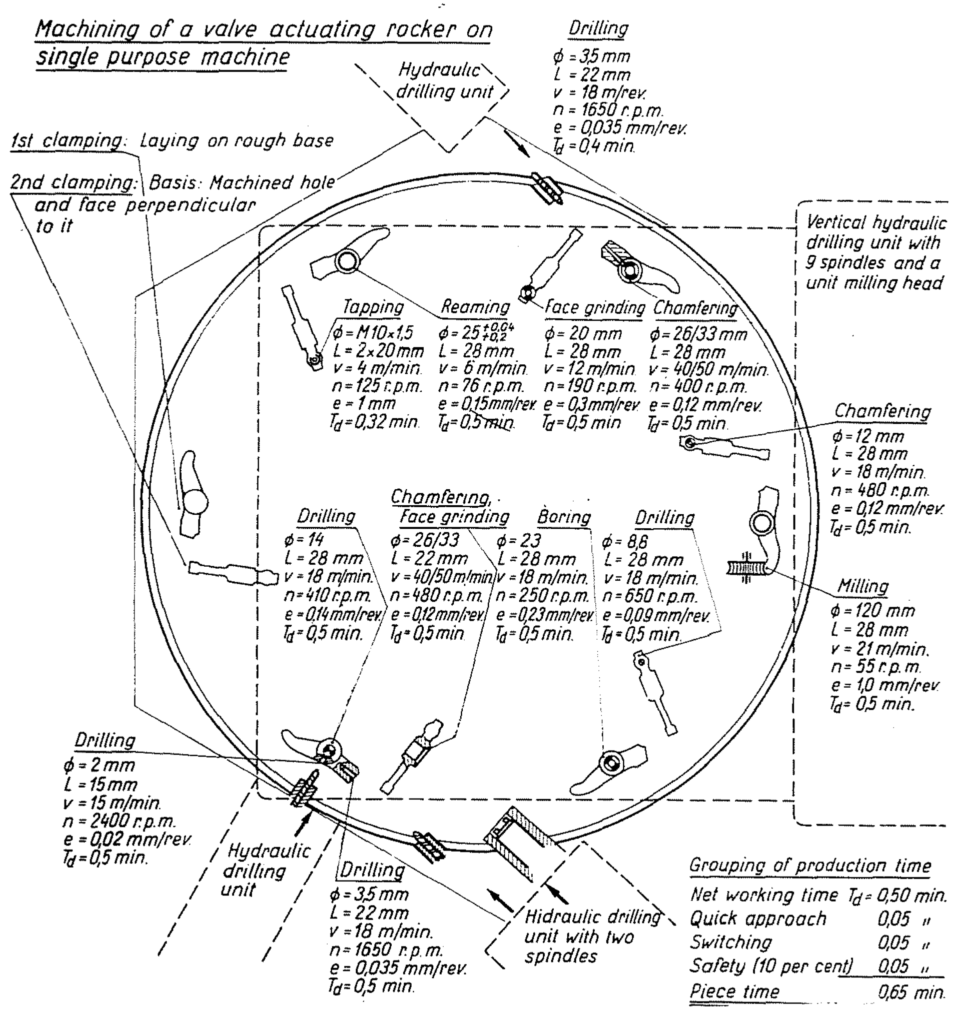
We wish to point out the importance of working out not only one or two variants, as we are sorry to say, often occurs in practice, but quite a number of solutions, to be able to select the most convenient one. The most precise anticipation of the economic results is of particular importance when planning investments, that imply a significant amount of mechanization and automation, considering the greater expenses involved. We have pointed out that automation sends investment costs for a workplace soaring. Should the computation of economy give a deceptively favourable picture because of miscalculation, or raise hopes of economies that would not be realized in practice, serious losses are inevitable. A mistake of no little consequence would be to underestimate the economic advantages that may be obtained with the programme of mechanization and automation, as this might hamper technical progress. As a rule, when planning a technology, technical questions are given much wider consideration than to problems of economy and, owing to this, too little attention is bestowed on the economy of machine tool investments. The underestimation of the computation of economy is illustrated also by the time allotted to it. Technical planning may take long months and even years, whereas the computation of economy is concluded in a few days, or, at best, in a few weeks.

The comparison of the two intervals of time proves that the importance of economical computation has not been fully realized yet. In the majority of cases computation relating to mechanization and automation are far from representing reality, not even by a rough approximation. The origin of this fact is, that the results are worked out by methods partly unsatisfactory and partly quite incorrect. Single-purpose machines and highly complicated machine tools are, in general, designed and put into service to reduce transit times in some manufacturing processes, and possible technological solutions are compared and examined only from the points of view of the time required for the manufacturing of items and of wages to be paid. The solution required the least amount of wages is usually picked out as most economic. Carrying matters to the extreme this would mean that machine tools and equipment of the highest grade of automation are, by this very fact, the most economic ones, as requiring the least expense both in time and in wages. Evidently, no thought is given here to the relative increase in the cost of investment. This point, however, deserves great attention also, because in a workpiece handled on an automatic machine the proportion dead labour to living labour undergoes an essential modification. The participation of dead labour, in general, increases that of living labour decreases. Yet the sum of dead and living labour is smaller in automatized or partly automatized production than in a manufacturing process where manual work has a greater share. When the increase of dead labour is higher than the economy which may be obtained in living labour, automation is not economic. The truer the picture it gives on the changes intervening in consequence of mechanization and automation, the more convincing the computation of economy is.

Instances for the computation of the production cost of vehicle parts have been found where original and modified production costs were worked out by a simple multiplication of the difference in labour cost, leaving the overhead expenses unchanged. The premise of this proceeding was that all components of overhead expenses varied in proportion to the labour cost. Evidently, this is erroneous. It would mean that if, owing to automation cost drops by 60—80 per cent., amortization, maintenance cost, reject, operation and other expenses are automatically reduced at the same rate. In reality, of course, this is not the case. We do not wish to disapprove of the reduction of manufacturing time by higher grade mechanization and automation. This is a primary demand in any production. We only consider it necessary to underline the fact that the efficiency of an investment cannot be solely judged on this basis, by this oversimplified way of comparison.

In the following we shall give a few examples of the production of some machine parts manufactured in Hungary, on conventional machine tools

Table 1



and on special-purpose machines. We have taken our examples from motor cars production, because this is one of the branches of industry in which single-purpose machines have at an extremely rapid pace gained ground.

Let us first consider the technology of a valve actuating rocker, a part of the Csepel Diesel engine, produced at the Csepel Motorcar Factory.

It would be practicable to process this part on a single-purpose machine equipped with an indexing rotary table, and of unit heads located as required by the sequence of operations.

The plan of machining of a valve actuating rocker on a single-purpose machine equipped with an indexing table is shown in Table 1.

As can be seen, the workpiece is chucked into the device on the machine table, first in horizontal position and after a full turn, it is transferred to another device which holds it upright.

Table 2

	Machining on conventional machine tools	Machining on single purpose machine
Number of machines required	6 drilling machines 1 broaching machine 1 centre lathe 1 plain grinder 1 milling machine	1 single purpose machine
Number of workers required	10 skilled and semiskilled workers 3 hands	1 skilled worker 1/2 hand
Piece time	6,04 min.	0,65 min.
Floor space requirement	63 sq.m.	18 sq.m.
Energy consumption	32 kW	25 kW
Weight of machine(s)	16 000 kg	11 500 kg
Cost	1055 000 Ft	1780 000 Ft

Thus, the workpiece completes two full turns with the machine table until it is ready. The unit heads required in the several positions and the operations corresponding to them have also been indicated in Fig. 1.

Table 2 compares the production of the valve actuating rocker on universal machine tools, with that on single-purpose machines, as regards the number of machines, number of workers, production time, floor space requirement, energy consumption, the weight of machines and the investment costs implied.

Naturally, the comparison may show still better results in particular cases, and turn out less favourable ones in others. Collations are given in the following to illustrate the influence of some factors individually taken under various conditions.

Table 3 compares the drilling of holes on the end surfaces of the crankshaft, countersinking, chamfering, threading and fine turning when performed with two different technological processes.

Table 4 relates to the machining of the valve actuating rocker shaft.

Tables 5 compares the machining of the piston in two cases.

Table 3

	Machining on conventional machine tools	Machining on single purpose machine
Number of machines required	3 radial drills 1 column drill 1 centre lathe 1 internal grinder	1 Revolving drum single-purpose machine
Number of workers required	6 skilled workers 2 hands	1 skilled worker 1/2 hand
Piece time	43 min.	1,35 min.
Floor space requirement	45 sq.m.	20 sq.m.
Energy consumption	22 kW	25 kW
Weight of machine(s)	17 000 kg	15 000 kg
Cost	950 000 Ft	2 950 000 Ft

Finally, Table 6 gives a comparison between the machining of a connecting rod on standard machine tools and on single-purpose machines.

The comparative tables contain piece machining times. As can be seen from Table 7, piece time represents only part of a whole time which is taken up by the handling of one piece.

With single-purpose machines, preparation time t_e may usually be neglected. Even if the machines need some readjustment, this is followed by very long runs of production and the fractions of preparation times computed for individual pieces will be very small.

Piece time (t_{db}) is composed of operation time ($t_{müv}$) and transfer time (t_t).

As transfer time is predetermined both for single purpose and universal machines, so we shall not consider it in detail.

Operation time ($t_{müv}$) is composed of main time and down times, which must be investigated for the purpose of computating economy.

By single-purpose machines, piece time is substituted by cycle time.

To determine cycle time the worktime at disposal must be compared to the number of items required for production. The number of items should be taken with a fair amount of safety factor, preferably 0.75 to 0.85 per cent.

Table 4

	Machining on conventional machine tools	Machining on single purpose machines
Number of machines required	3 drilling machines 1 centre lathe 1 centre grinder 1 rotary table plain grinder	Single-purpose machine with indexing table Single-purpose machine with indexing table
Number of workers required	6 skilled workers 2 hands	2 skilled workers 1 hand
Piece time	12,36 min.	1,7 min.
Floor space requirement	58 sq. m.	47 sq. m.
Energy consumption	35,8 kW	38 kW
Weight of machine(s)	12 000 kg	22 000 kg
Cost	754 000 Ft	3 300 000 Ft

As is known, operation expenses are composed of the following items:
Operation expenses = Material + labour cost + production overhead.
The composition of production overhead:
Energy
Means of production (tooling, apparatus)
Other transitory materials
Amortization of machines
Amortization of buildings
Maintenance
Maintenance of buildings
Indirect labour costs.

Now let us examine the items listed in Table 2, when valve actuating rocker is machined on standard machine tools and special-purpose machines, respectively. To simplify matters we have made some generalizations and, taking data from foreign countries into consideration and examining information of Hungarian origin, we have formed quasi-statistic averages.

The factors are listed according to their magnitudes, by considering values resulting from production using classical method (*i.e.* on universal

Table 5

	Machining on conventional machine tools	Machining on single purpose machines
Number of machines required	3 drilling machines Four-spindle fine boring machine	Two-spindle fine boring machine Five-spindle single-purpose machine Five-spindle single-purpose machine
Number of workers required	4 skilled workers 1 hand	3 skilled workers 1 hand
Piece time	4,91 min.	3,3 min.
Floor space requirement	33 sq.m.	42 sq.m.
Energy consumption	14,3 kW	30,5 kW
Weight of machine(s)	5 650 kg	1380 kg
Cost	1 575 000 Ft	2 340 000 Ft

machines) as 100 per cent. and changes because of mechanization and automation considered as percentages of these values.

	Percentages of original costs
Energy (electric, compressed air)	30 to 80
Manufacturing equipment (tooling)	300 to 500
Other transitory materials	about 100

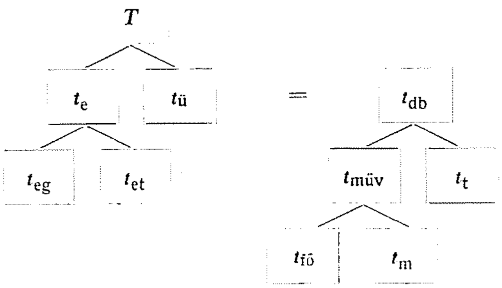
Amortization

a) Amortization of machines (the amortization of universal machines extended over a period of 10 years, that of highly mechanized or automatized machines over 6 years; Table 8).

Table 6

	Machining on conventional machine tools	Machining on single purpose machines
Number of machines required	9 drilling machines; 4 horizontal milling machines; 1 vertical milling machine; 2 centre lathes; 3 fine boring machines; 1 multi-spindle drilling machine	Two-spindle milling machine with rotary table; Single-purpose machine with indexing table; 2 horizontal milling machines; Single-purpose machine with indexing table; 3 fine boring machines
Number of workers required	20 skilled workers; 5 hands	8 skilled workers; 2 hands
Piece time	139 min.	14 min.
Floor space requirement	129 sq.m.	96 sq.m.
Energy consumption	112 kW	112 kW
Weight of machine(s)	49 650 kg	59 400 kg
Cost	4 650 000 Ft	8 700 000 Ft

Table 7



T — Time taken up for the handling one of piece
t_e — Preparation time
t_{eg} — Preparation time of machine tool
t_{et} — Preparation time of conveying equipment
$t_{ü}$ — Cycle time
t_{db} — Piece time
$t_{müv}$ — Operation time
t_t — Transfer time
$t_{fő}$ — Main time
t_m — Down time

Table 8

	Cost of machines	Cost of erection (about 15 per cent)	Investment-immobilization factor (about 4 to 6 per cent)
With conventional machines	1,055.000 +	158.250 +	$52.570 = \frac{1,216.000}{10} = 121.600$ Ft/year
With single-purpose machines	1.780.000 +	267.000 +	$89.000 = \frac{2.136.000}{6} = 356.000$ Ft/year

Table 9

Energy	4460 hours. 32 kW = 140 000 kWhr per 1,80 = 250 · 10³ Ft	4460 hours. 25 kW = 112 000 kWhr per 1,80 = 200 · 10³ Ft
Means of production	$60 \cdot 10^3$ Ft	$300 \cdot 10^3$ Ft
Other transitory materials	$5 \cdot 10^3$ Ft	$5 \cdot 10^3$ Ft
Machine amortization	$122 \cdot 10^3$ Ft	$356 \cdot 10^3$ Ft
Building amortization	$25 \cdot 10^3$ Ft	$14 \cdot 10^3$ Ft
Maintenance	$15 \cdot 10^3$ Ft	$22 \cdot 10^3$ Ft
Building maintenance	$5 \cdot 10^3$ Ft	$8 \cdot 10^3$ Ft
Indirect labour cost	$20 \cdot 10^3$ Ft	$25 \cdot 10^3$ Ft
Production overhead	$502 \cdot 10^3$ Ft	$930 \cdot 10^3$ Ft

b) Amortization of buildings (assuming that 1/3 of the factory buildings represent a constant factor, and only 2/3 are proportional to the floor space taken up by the machines. As mentioned previously, from the structural division of investments in machine industry, it results that buildings participate from 35 to 43 per cent. in the whole sum).

Amortization rate: 2,5 to 3 per cent. per year

For universal machines Ft 810 664, from which

$$1/3 = 270\ 221 \text{ constant,}$$
$$2/3 = 540\ 442 \text{ variable.}$$

This has been obtained by taking the 40 per cent. missing and adding it to the investment in machinery, and the sum thus obtained resulted as total investment.

In the case taken as an example, the floor space needed for single-purpose machines amounted to only 28 per cent. of that taken by universal machines: 63 and 18 square meters, respectively.

540 422 · 0.285	154 000 Ft
+ constant area	270 221 Ft
Total	424 221 Ft

A 3 per cent. yearly amortization of this sum: 424 221 · 0.03 = 13 726 Ft per year, as against the area (floor space) required by conventional equipment whose yearly rate of amortization is

$$810\ 664 \cdot 0.03 = 24\ 320 \text{ Ft per year.}$$

Maintenance

Maintenance of buildings about 150 per cent. of the original sums.

Indirect labour cost (preparation cost, etc.) about 120 per cent.

In addition to the above, the production overhead includes the *overhead expenses of headquarters*, representing 100 per cent. of the original.

Let us consider these data in our further computations by taking the proportions of production times also into consideration. As regards the cost of material, let us assume as first approximation, that mechanization and automation do not greatly differ. At this point our computation slightly favours single-purpose machines, as the demands raised against raw material are generally higher with these than with conventional equipment.

Table 2 shows that the piece time of a valve actuating rocker produced on conventional machines is 6.04 minutes, whereas with single-purpose machines it only takes 0.65 minute.

Yearly production figure: Actual yearly working time/Piece time

Assuming production in two shifts (16 hours) the number of actual workdays in a year:

367—57—other losses = 280 days.
280 days per 16 hours = 4660 hours a year.

Loss factor (empirical), 20 per cent.
Actual yearly worktime = 4660—892 = 3568 hours = 214 080 minutes.
Yearly production figures:
With conventional machine tools:

$$\frac{214\ 080}{6{,}04} = 35\ 680 \text{ pieces per year,}$$

With single-purpose machines:

$$\frac{214{,}080}{0.65} = 330{,}000 \text{ pieces per year,}$$

assuming the number of working hours in a year to be 4460.

This figure, multiplied by the wages per hour of the worker who handles the single-purpose machine and divided it with the yearly production figure gives the direct labour cost of a piece.

The handling of a single-purpose machine is done by a semi-skilled worker. Let his hourly wages be Ft 6.50

$$4460 \cdot 6.50 = 28{,}990$$

Labour cost per piece:

$$\frac{28{,}990}{330{,}000} = 0.09 \text{ Ft}$$

In production with conventional machine tools an average wage per hour must be considered, worked out from the wages per hour of ten skilled and semi-skilled workers, and for time taken by the production of a part. Generally speaking this wage per hour will be higher than the wages of the semi-skilled worker who handles the single-purpose machine. Here is another point for the special machine.

In the case in hand this average wage per hour work out at 7.— Ft.

$$4460 \cdot 7 = 31{,}220 \text{ Ft,}$$

labour cost per piece:

$$\frac{31{,}220}{35{,}680} = 0.88 \text{ Ft.}$$

That is to say, in the case examined, labour cost per piece is nearly ten times the cost of that with single purpose machines (Table 9).

Let us consider the variation of the production overhead.

Overhead per piece with universal machines:

$$\frac{562{,}000}{35{,}680} = 13.6 \text{ Ft per piece,}$$

with single-purpose machines:

$$\frac{930{,}000}{330{,}000} = 2.8 \text{ Ft per piece.}$$

This method permits the checking of the economical use of investment funds allotted to machine tools. In the computations of automatized equipment, investment cost and other cost factors have on purpose slightly been exaggerated: we did not wish to represent everything through rose-tinted glasses. The relatively high amortization rates seem to limit automation; yet the influence of these rates on production overhead dwindles as soon as our machine-tool factories turn out less expensive and more effective automatic machines or equipment, and as soon as they can put the machinery to a better use.

Our considerations do not pretend to be complete. Our intention has been to examine a few crucial points only. Yet, we believe that our method outlined above comes closer to reality than comparisons made only by considering relationships between production times and labour costs.

Summary

The paper deals with the economy of machine tool investments. Some particular examples are shown in connection with the machining of a few Hungarian machine parts, producted on normal and special machine tools, respectively.

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