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A STUDY ON RENEWAL, REPAIR AND MAINTENANCE [1]

by

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A STUDY ON RENEWAL, REPAIR AND MAINTENANCE

I. INTRODUCTION

The specific aim of this study is to provide planners in developing countries with a set of methodological instruments for assessing the nature and volume of needs for replacement, repair and maintenance and for identifying the material resources - labour, materials and machinery - required to meet these needs. At the same time, the study gives a review of the main technical and organizational procedures used in this important area of economic activity. The main emphasis is, of course, being laid upon methodological instruments for analysis and projections.

An attempt is being made in this study at analysing the problems at various levels, i.e. the plant, sectoral, national and international levels. Admittedly, the bulk of technical and organisational problems must be solved at the level of enterprise; on one hand, as an integral part of current utilisation of installed capital, on the other hand, through the specialized activities of maintenance and repair units.

Considerations are also taken to analyse the problem at sectoral level. By applying a sectoral approach it is possible to assess the demand for replacement and repair and, consequently, the needs for specific economic resources in various sectors. In the process, important conclusions usually emerge which are relevant to the formulation of the over-all economic strategy and economic policies. At the same time, the sectoral approach can also contribute to the bridging of the existing gap between micro- and macro-economic levels of analysis and of solving the problems of industrial development. Some aspects of the problem area under discussion are undoubtedly of macroeconomic nature as e.g. the balance of payments impact of different replacement and repair policies. Certain problems can be successfully solved by coordinative and indicative measures of the Government.

Problems connected with replacement, repair and maintenance assume a great importance from the very start of the industrialisation process. Sound policy in this field is a necessary condition for rational investment outlays and capital utilization. The more so in developing countries where scarcity of investment resources is often being considered as the main limitation of economic growth. Efficient and safe operation of build-up capacities requires highly qualified personnel, various material supplies, and an appropriate organizational framework which in the conditions of industrially developed countries are taken for granted, however, in developing countries are often lacking.

The aim of this study is not to put forward uniform or normative solutions to problems dealt with. Instead, by suggesting alternative solutions we will aim to create preconditions for a choice of an optimum approach in the given specific conditions of individual countries and/or sectors. In fact, even the basic concepts of renewal, repair and maintenance have to be defined in an alternative way.

This study will deal with replacement, repair and maintenance of fixed capital stock in industrial sector. Main attention will be devoted to plant equipment.

II. BASIC CONCEPTS

A. Wear and Obsolescence

The aim of this chapter is to review the causes of depreciation of individual plants and equipment and to outline the factors determining the various requirements for their renewal and repair.

At the same time as buildings, machinery and other equipment are being worn out physically, they also loose their value due to the continuous economic and technical progress. Thus, there are two types of depreciation with entirely different causes. The classification of causes of depreciation is given in a schematic way in Table 1.

Table 1

Classification of Causes of Depreciation

1. Causes of deterioration
   - 1.1. By gradual wear
     - 1.1.1. Through operation
     - 1.1.2. Due to environment
   - 1.2. Break-down

2. Causes of depreciation in economic terms
   - 2.1. Obsolescence
     - 2.1.1. Due to the development of new, more efficient types of capital means
     - 2.1.2. Due to changes in production technology
     - 2.1.3. Due to changes in market conditions
   - 2.2. Reduction in the actual purchase cost.

1. Physical wear

Physical wear is a process which changes the original qualities - physical, chemical, mechanical, etc. - of plants and equipment.

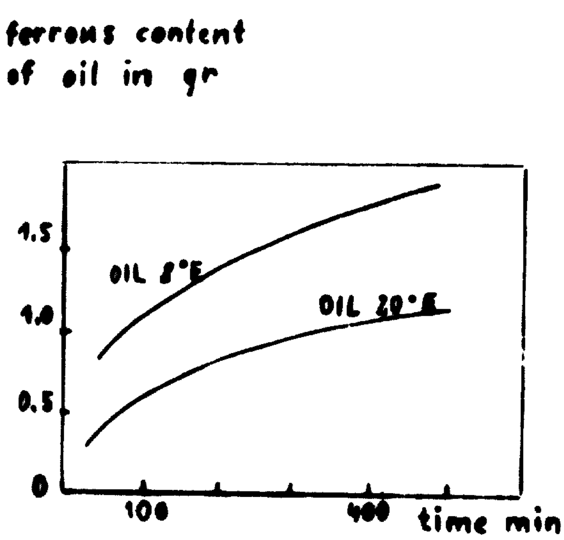
The rate of physical wear of plants and equipment is determined by the following factors:

- rate of utilization and load characteristics of the equipment
- environment in which the plants and equipment are utilized
- care extended in operation and maintenance.

In contrast to the wear connected with operation, the wear caused by adverse effects of environment is not positively related to the degree of equipment utilization. On the contrary, the adverse effects of environment are often greater in case of less utilised or completely unutilized equipment.

To illustrate possible factors which determine the degree of physical wear two examples are presented in Figure A (dependence of wear on usage of oil) and Figure B (dependence of changes of dimensions of a part on temperature and the aggressivity of the environment.

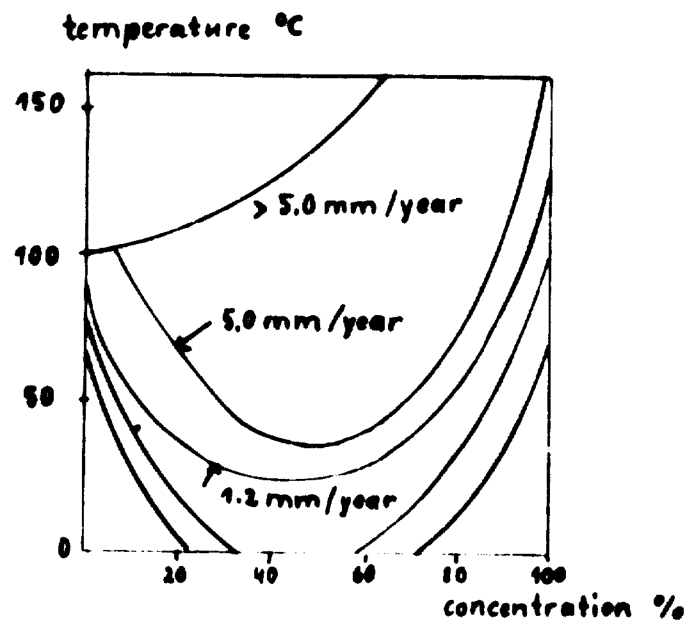
FIG. A



Dependence of engine wear on usage of oil

Source: Voinov H.R., Issledovanie obkladki dvigateley trenija, Sbornik IV, Moscow, 1949

FIG. B



Dependence of loss of material on temperature and concentration of environment

Source: Fontana M.G., Ind.Eng.Chem. vol. 44, No. 4, 1952, p.89a

Two basic apparent forms of physical wear can be distinguished:

Mechanical wear, resulting in

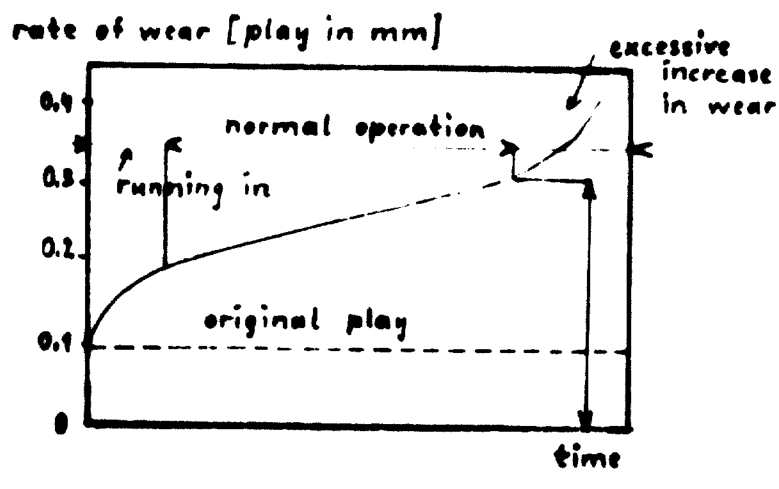
- surface damage of the parts (components) of plants and equipment
- changes of original dimensions and shape
- reduction of their functions (precision and performance), etc.

Chemical wear, resulting in

- material is eaten away (corrosion)
- mechanical qualities of parts deteriorate
- functional failure.

An illustrative example of the mechanical wear of simple elements of a machine (e.g. bearing, pin) is given in Figure C. In the first, rather short period after the equipment is been put into operation, wear increases very markedly. This period is the running-in period. In the subsequent, long period wear does not increase substantially. Finally, in the last period, wear increases very steeply.

FIG. C

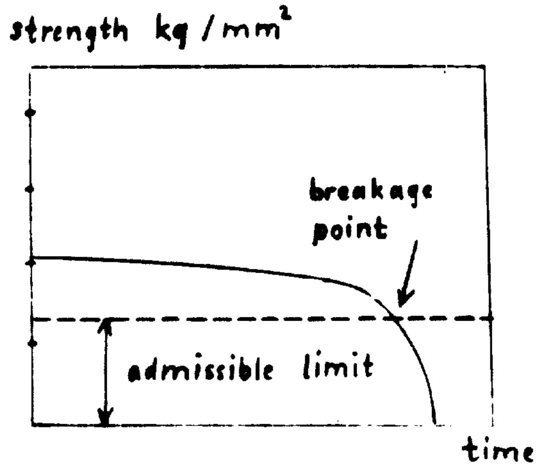


Course of wear of a simple element

Source: Zelenkov G.I., Technologija remonta doroshnyhk mashin, Dorisdat 1951, Moscow

An illustrative example of chemical wear is a case of a pipe-line wear due to gradual decarburization, see Figure D.

FIG. D



Course of pipe-line wear due to gradual decarburization

Some elements of plants and equipment loose their functional qualities suddenly (e.g. bulb, certain elements of measuring devices). It is of course not possible to make a reliable and exact prediction of such a functional failure.

Two specific cases of the physical wear are to be introduced:

So called infant illnesses, caused usually by unexpected defects (deficiencies) in production, assembly, methods of installation, etc.

Accidental depreciation or break-down: the wear does not proceed gradually but suddenly, caused either by external or internal factors.

As a typical example of accidental depreciation can be mentioned fire, explosion, flood, typhoon and other disasters.

2. Economic depreciation

In a dynamic economic system the bulk of the plants and equipment is depreciated and scrapped due to the process of economic, rather than due to its physical wear.

Economic depreciation is a process in which plants and equipment lose their value due to the introduction of technical innovations and to changes in the economic conditions.

Generally, three different cases of economic depreciation can be distinguished:

(i) Appearance of a "challenger", e.g. a new, more efficient machine, which can replace the installed machine. This is the case of obsolescence due to technical progress in newly manufactured capital goods. The use of the new, more efficient machine usually causes a reduction of production cost, an improvement in quality of the product, and/or an increment of safety and improvements of labour conditions, etc.

The rate and the pace of depreciation of installed machines is above all determined by economic parameters of those new machines, which can replace the installed machines in their functions. The pace of technical progress and, consequently, the pace of depreciation of the installed equipment vary substantially from one branch of industry to a other and differ also for various kinds of equipment. In general, it can be said that the fastest changes in design are observed in equipment used in most progressive lines of production - most progressive from the point of view of technology and requirements of the market.

(ii) Changes in the technology and organization of production. These changes can be caused by:

- innovations resulting in substantial changes in material inputs;
- changes in product design;
- transition from small to large-scale production.

In engineering industry, for instance, a shift from metal-cutting to metal-forming tends to accelerate the depreciation of currently used metal-cutting machine tools. Transition to large scale production leads to accelerated scrapping of universal machine tools and to their replacement by specialized equipment.

(iii) Changes in market conditions. This can cause a decline in demand for products produced on the given equipment.

Thus extensive replacement of classical electron tubes by transistors accelerated the depreciation and scrapping of many types of vacuum technique equipment.

A specific case of "economic" depreciation - exceptionally appreciation - of installed capital means is a decline (increase) in reproduction purchase cost of these means.

It is thus necessary to consider the changes of value of the given plants and equipment both from the point of view of their physical state and their efficiency of operation, in the context of over-all economic conditions.

3. Service life

Depreciation of the individual capital means usually proceeds gradually. The final stage of this process is scrapping. The time period, during which a given piece of equipment fulfills its technical and economic functions is the period of service life. A quantitative analysis of the service life usually is a starting point for an estimation of renewal needs.

The following different concepts of service life are of a special practical significance:

- "Total"service life which is the age at which a machine is being scrapped;
- "Primary" service life. This can be defined as that part of the total service life, in which a machine brings the highest effects;
- "Economically useful" or "optimal" service life.

Normally, the service life of plants and equipment can physically be extended almost without limits through repair and careful maintenance.

However, capital means are usually scrapped as soon as their operation does not meet certain economic requirements.

Estimates of the length of service life can for the same machine vary between 10 to 30 years. The same machine can really reach a completely different "active" age depending on the way and conditions of utilization both from the view point of the process of physical wear and from the view point of different conditions of "economic depreciation". Therefore, the illustrative example of service life given in Table 2 serves only as a very rough orientation.

Table 2

Estimates of Service Life and Cost of Over-hauls of Various Kinds of Plants and Equipment [1]

- examples -

	Service Life (years)	Average Yearly Cost of Over-haul (% of the purchase cost)
Buildings		
industrial	60 - 80	0.6 - 1.7
office and residential	100	0.5
Structures		
bridges - reinforced concrete -	200	0.3
railway roadbeds and super-structures	120	1.5
dams	80 - 120	0.5 - 1.0
melioration systems	30 - 50	1.6 - 1.0
sewer pipes - cement -	20	1.4
concrete cooling towers	50	2.0
steel drilling derricks	12	8.7
Machinery and Equipment		
Power and driving equipment		
mobile compressors	10	8.0
mine ventilators	40	2.0
transformers	30	1.0
steam turbines with generator	30	2.0
hydraulic turbines with generator	40	1.8
mobile combustion engines	15	4.0
distribution mains 200 kV and 100 kv	40	0.5
switchgear cubicles 200 kv and 100 kv	30	1.0
Mining industry equipment		
mining equipment	35 - 40	1.5 - 3.2
stripping shovels	10 - 25	2.4 - 30.0
drilling sets	4 - 12	4.0 - 20.0
mills and crushers	15 - 20	5.0 - 20.0
Food industry equipment		
masticating mills	15 - 30	1.2 - 5.0
sifting/screening machines	15 - 40	1.5 - 5.0
oven/bakery	20	2.5
bottle washing machines	10	3.0
milk and canning evaporators	20	2.2 - 4.0

	Service Life (years)	Average Yearly Cost of Over-haul (% of the purchase cost)
Wood-working industry equipment		
wood drilling machine	15	0
knot borers	15	3.2
wood-working lathes	15	6.6
sanders	15	3.8
Paper industry equipment		
diffusers	20	5.0
paper machines	30	5.0
cutting machines	20	5.0
Printing industry equipment		
composing machines	20	4.0
rotary printing machines	20	2.0
gravure printing presses	8	3.2
cutting machines	30	0
Chemical and rubber industry equipment		
homogenizators	20	4.0
absorbing towers/sulphuric acid production	15	5.3
storage tanks for gasolin, oil	40	2.0
reactors/sulphuric acid production	12	5.5
roasting furnaces for pyrites	30	6.7
Non-metallic minerals industry		
building materials equipment	10	7.0
cementation furnaces	25	2.8
baking ovens/ceramics	40	2.5
drying and annealing kilns	20	7.0
Basic metals industries		
blast furnaces	30	5.3
coke ovens	18	2.0
steel melting furnaces	24	10.0
moulding machines	12	3.3
casting machines and equipment	20	3.3
rolling mills	20 - 30	2.5 - 3.3
Metal-working industry		
reheating furnace	20	4.0
power presses	20	5.6
centre lathes	12 - 25	3.3 - 7.1
automatic lathes	12	5.2
horizontal boring machines	15 - 20	3.5
planing machines	20 - 25	3.1 - 4.0
grinders	12 - 15	5.8 - 9.0
welding equipment	12 - 15	5.5 - 7.1
coil winding machines	15	4.5
Construction industry		
concrete and mortar mixers	10	8.0
dozers, scrapers, graders	5 - 6	10 - 35
building cranes	8 - 12	9 - 12

	Service Life (years)	Average Yearly Cost of Over-haul (% of the purchase cost)
Transport and communication		
trunk cables	30 - 35	0.7
main gas lines	30	0.5
telephone exchanges	25	1.0
diesel-electric locomotives	10	8.0
covered wagons	45	0.7
cargo boats	40	1.8
airplanes	5 - 12	2.7 - 16.2

1/ Experts' estimates for the sake of depreciation charges.

Source: Ministry of Finance (USSR), Laws and Orders, 1954.

Estimates of service life are generally quite different from the service life periods actually achieved. For cutting-machine tools and forming machines estimates of service life generally vary around 15 years. But, in all countries where an inventory of installed machine tools according to their age has been made, a large number of machines older than 20 year has been found still in operation.

From the data contained in the inventories of machinery in metal-working industry in USA which were carried out by American Machinists in 1949 and 1958 we can conclude that between the 10th and 20th year of their age only 14.5 per cent of the original number of metal-forming machines and 26 per cent of metal-cutting machine tools were scrapped. A very detailed analysis by the Research Institute for Engineering Technology and Economics in Prague has shown that in the Czechoslovak engineering industry machine tools are kept in operation on average for 25 to 30 years. Even after this period, however, most of them are not scrapped. More than 70 per cent of discarded machines are resold or transferred to plants, shops and schools outside the engineering industry.

Table 3

Age-Composition of Machine Tools in the Industrialized Countries

Country	Year	Percentage of Machine Tools older than 10 years	20 years
USA	1958	60	18
United Kingdom 1/	1955	52	12
	1961	59	22
Western Germany	1953	62	21
	1961	55	20
France	1955	62	43
	1961	59	..
Italy 1/	1958	59	33
	1961	56	..
Canada	1958	58	18
Czechoslovakia	1962	61	23

1/ machine-tools in metal-working industries only

Not all of the causes for depreciation have a direct bearing on the service life. Thus, physical wear may have no impact on the length of service time, if the consequences of physical wear can be made up for by repairs. Physical wear plays a decisive role only in case repair would be more costly than the purchase of a new machine or would not be technically feasible at all. Therefore the bulk of machinery and equipment and also of buildings and structures is being scrapped - discarded - due to "economic" depreciation, caused in turn by the appearance of new, more efficient machines and equipment, the changes in technology of production and by market conditions for the products.

It is being asserted that machines are being scrapped before they are completely physically worn out. In the junk-yards we can, however, see that the machines brought there are usually both physically worn out and technically obsolete. The question - which of the two basic causes of depreciation determines the service life - cannot be answered univocally in most cases. The technical obsolescence generally is the basic cause, whereas the technical condition of a machine,i.e. the degree of its physical wear is often the direct (immediate) cause of scrapping.

It should be mentioned in this context that the technical condition of a machine is to a certain extent dependent on economic factors since to the machines which cannot meet certain economic criteria proper maintenance and repair care is not being extended.

Machines which are "prematurely" scrapped due to their technical obsolescence are considered to cause a loss, amounting to the portion of balance value not written off. However, it is hardly a loss in case of really obsolete machines. The loss actually incurred at the time when the investment was made into an obsolete machine and should therefore be charged on the past period, i.e. during which the machine was purchased. Otherwise there is the danger that obsolescent equipment is kept in operation.

Some of the factors that determine the service life as dependent upon the intensity of physical wear can be quantified or estimated on the basis of past experience. An example of such estimates is presented in Table 4. According to the coefficients contained in this table the physical wear of a lathe utilised in two shifts (coefficient 0.7), operated in dusty environment (coefficient 0.7), exposed to shocks and vibration (coefficient 0.7) and operating under adverse difficult cutting conditions (coefficient 0.8) would be so high that compared to the normal conditions of the lathe utilization in one shift, the service life would be reduced to almost one third. A corrective coefficient of 1.25 corresponds to the use of four partial coefficients, therefore 0.7 x 0.7 x 0.7 x 0.8 x 1.25 = 0.343.

If the same lathe is used as a piece of ancillary equipment in an assembly shop in good conditions, its service life might be extended by 50 per cent over the standard service time.

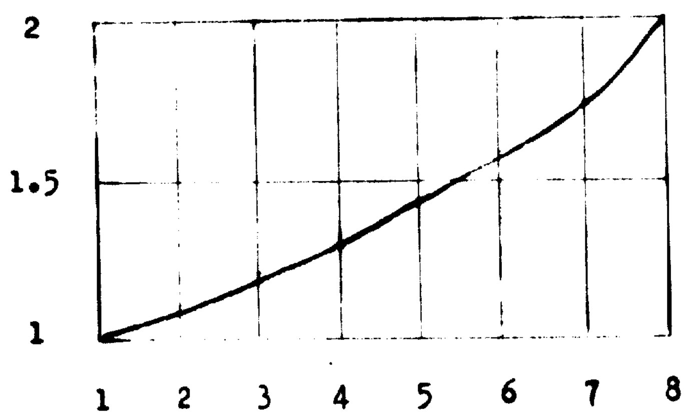
Table 4

Coefficients for Calculating Service Life of Machinery under Different Conditions of Utilization

Conditions of Utilization	Coefficient
Normal operation in two shifts	0.6 - 0.8
in three shifts	0.4 - 0.6
for less than 8 hours a day (x number of hours in operation a day)	$\frac{8}{x}$
When used in laboratories or research units (shops)	1.2 - 1.3
in assembly shops	1.4 - 1.4
Incidental usage	0.6 - 0.8
Usage in humid rooms or outdoors	0.6 - 0.8
in excessively dusty rooms	0.6 - 0.8
Usage in rooms with adverse chemical environment	0.4 - 0.8
in rooms without heating	0.7 - 0.9
in rooms exposed to intensive shocks (vibration)	0.6 - 0.8
Usage without adequate footing (foundation)	0.7 - 0.9
Work in wetness	0.7 - 0.9
Prevailing work with continuous mesh (machining)	0.8 - 0.9
Work under difficult cutting conditions	0.7 - 0.9
Cast iron machining	0.8 - 0.9
Plastic material machining	0.8 - 0.9
Incidental usage of grinding preparations on cutting machine tools	0.7 - 0.8
Deficient operation (vocational training shops)	0.6 - 0.8

Note: A multiple of all the relevant coefficients has to be multiplied by a corrective coefficient which is graphically described on next page.

Corrective coefficient



number of coefficients

Source: Simonis, F.W.: "Die Bewertung von gebrauchten Werkzeugmachinen und machinellen Anlagen", VDI No.13/1956.

The rather complex process of depreciation and scrapping of the plants and equipment allows only exceptionally the establishment of a direct link between the scrapping, the service life of individual pieces of plants and equipment and the renewal of a particular plant or machine. Individual machines are replaced in their economic functions without it being possible to follow and quantify this process. Therefore it is appropriate to set the problems of renewal in the context of the whole system of capital means installed in an industry or in the economy as a whole (see appendix II). Besides, the problem of renewal is not to be reduced to the mere replacement of plants and equipment. Renewal connected with modernisation of equipment, buildings and structures is depending on or conditioned by the development of technology, production, demand, etc.

B. Renewal, Repair and Maintenance

1. Renewal

Renewal is defined here as the volume of investment needed for replacing plants and equipment depreciated in a given period.

> In a broader sense renewal would mean not only actual replacement but also repairs of worn out parts of machinery, equipment, buildings etc. In this case repairs of machinery particularly so called general repairs (over-hauls) fall under the concept of replacement.
>
> Usually, however, only the replacement of the whole machines or eventually of complete lines of productive equipment by new machines is considered as renewal.
>
> In the over-all national economy context also the construction of new capacities can be considered as renewal, even if there is no visible connection with the old capacities being liquidated. In that case the value of renewal is corresponding to the part of the total investment that equals the depreciation of the existing plants and equipment in the given period.
>
> The most common interpretation of renewal is physical replacement of worn out machinery, equipment, buildings etc.within given productive units by new ones. This interpretation is being applied in this study.

The purpose of renewal is not only to replace physically worn out plants and equipment, but also to modernise the whole system of equipment, according to the needs of modern technology and the requirements of the market. Active renewal policy means the adoption of a consistent and economically rational investment policy. Above all it takes into account the aspect of modernisation and transfer of machines. For estimating the investment resources required by the needs for renewal, it is also necessary to consider the timelag between replacement investment and discarding of the obsolete capital means. As a rule, active renewal takes place earlier than the actual scrapping of the replaced items.

> Frequently used machines are transferred within a plant, i.e. the location and/or the function of the machine is changed to better meet the overall requirements of the plant. Trade statistics of industrialised countries show that there also is a considerable transfer of used machines between various plants.

Normally worn out machinery is not replaced by exactly the same type of machinery due to the technical progress. Replacement thus is mostly carried out with the aim to modernize the existing fixed capital stock. Consequently, replacement and modernization cannot be considered as two separate phenomena. Replacement usually expresses quantitative and modernization qualitative aspects of the same process.

Modernization can be carried out in various ways. One way is the modernization of existing machinery with the view of increasing the performance, minimizing losses from failures, lowering the labour cost, improving the safety of operation, etc. Another form of modernization consists in actual replacement of individual obsolete pieces of equipment by new, more efficient ones. The largest effects can be usually achieved by a systematic total modernization of the whole productive unit.

Modernization in a narrower sense is the modernization of individual units of equipment installed in accordance with the requirements of modern production technology. Two basic approaches can be mentioned:

(i) Adaptation of machines, equipment, buildings or construction to the specific way of its utilization, e.g. reconstruction of an older lathe to a machine tool for centrifugal casting;

(ii) Standard modernization aiming to increase the qualities of older models of machines. Impulses for such a modernization are given usually by producers of the machines.

The best occasion for a modernization is usually by a major over-haul. Thus, major over-haul and repair as a whole are to be considered not only as a way of removing the traces of deterioration of a machine, but also of increasing its adaptability to new conditions of its utilization.

Modernization is sometimes connected with reconstruction, i.e. a functional adaptation of machinery, equipment and/or buildings through changes in technical design. Reconstruction and modernization are not identical concepts, but reconstruction is usually undertaken with the aim to modernize the capital assets.

2. Repair

As has been already mentioned, the distinction between renewal and repair is far from being clear-cut. However, renewal normally means total replacement of worn out or obsolete machinery, equipment, buildings, etc. while repairs consist in replacement of only certain parts of machinery, equipment, building, as well as their restoration and renovation.

Two basic categories of repairs can be distinguished:

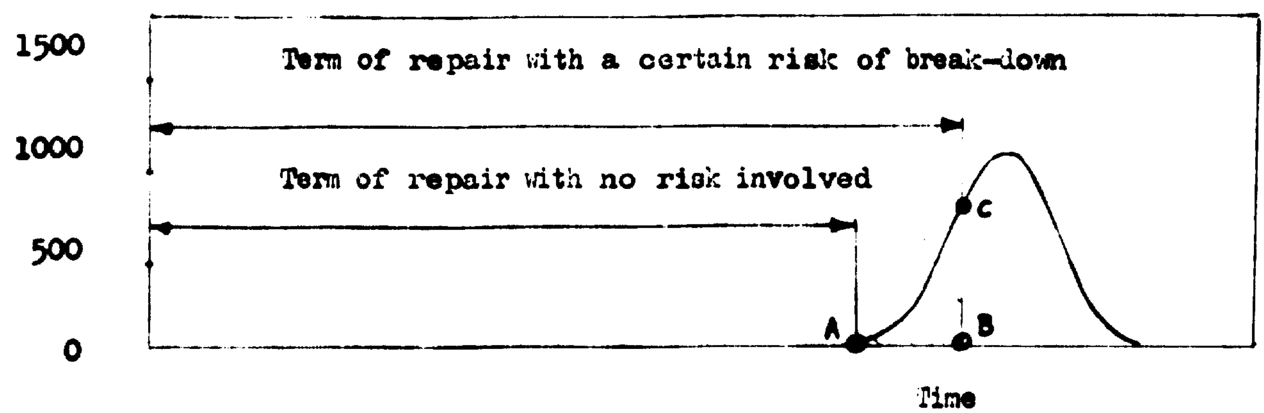
(i) routine (small) repairs, consisting usually in replacement or repair of individual parts and elements of the machine, i.e. those which have a shorter service life.

(ii) over-haul (rather extensive repair of the whole machine, building, etc.) of all worn out and damaged parts, with the purpose to renew the original technical condition and operational efficiency. As a rule, the cycle of major over-hauls is longer than one year.

The causes of physical wear vary for individual parts of plants and equipment. Individual parts therefore have different periods of service life. The different prevailing working conditions determine the wear of individual parts and of the whole machines, equipment, buildings and structures and can give an accidental character to the course of physical wear. The distribution of admissible wear values of individual parts determines the degree of risk of a failure of the whole machine.

From Figure E it can be seen that if the repair is carried out in a point A, the risk of failure is almost nil since all the parts of the machine will not yet have reached the level of admissible wear. However, if the date for repair is fixed into the point B, a risk is being taken that some parts wear out before the repair is undertaken. The curve reflects the spread of physical wear periods of individual parts and their numbers.

FIG. E

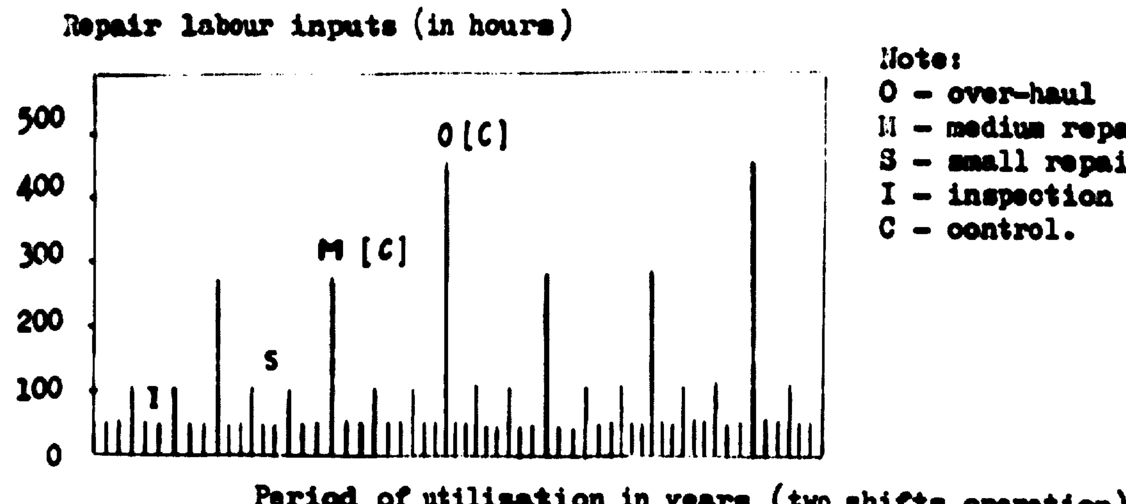


Repair Timing in Regard to the Degree of Risk of Break-down.
Source: Vybrene kapiboly z ekonomiky chemickeho prumyslu slatni pedagogicke nakladatelstri, Prague 1966, p.111 (collective work of several authors)

The course of wear of individual parts and the general cost of their repair or renewal determine the volume and timing of repair, during the repair cycle.

The graph in Figure F has been worked out according to the norms of preventive repair applied in the Czechoslovak engineering industry. In the period between two over-hauls there are to be carried out:
- two "medium" repairs,
- six small repairs,
- a number of inspections,
- precision measuring before and after each "medium" repair and over-haul.

FIG. F



Note:
O - over-haul
M - medium repair
S - small repair
I - inspection
C - control.

Cycle of Repairs according to the Standards for preventive Periodical Repairs of a Lathe

There is no standard repair system which could generally be applied. The obvious reasons for this are the different courses of wear of individual machines, the different requirements in regard to the reliability of operation of equipment, differences in working conditions of the equipment in individual countries and a number of other factors. The repair systems to be used therefore should be based on an objective evaluation of the actual situation in regard to the equipment, plant, industry and country. A classification of repair systems is introduced in Table 5.

The needs for over-hauls and for other repairs are interdependent. Thus, careful and regular carrying out of small repairs can reduce the need for over-hauls.

This interrelationship has been proved by a sample inquiry in the Czechoslovak engineering industry: whereas in individual plants both the cost of over-hauls and the cost of small repairs (in relation to the purchase cost of machinery) widely fluctuate, their aggregate values come much closer to each other. On average, the small repair cost were by 50 per cent higher than the over-haul cost.

Table 5

Classification of Repair Systems

	Complex repair	Standard repair	Planned preventive (periodical) repair	After checking scheduled repair	Break-down repair
Characteristics	Complex repair planned and prepared long time ahead	Rigid repair cycle, replacement of all parts according to the prescribed standards 1/	Repairs planned on the basis of standards 3/, definite decisions about timing taken after checking	Repairs planned on the basis of regular inspections	Repairs carried out in case of imminent danger of a break-down or after actual breakdown
Advisable for	Whole sets of electrical power plants and metallurgy, chemical and food industry equipment 2/	Equipment involving great safety risks or excessive losses in case of break-down; equipment with low cost spare parts	Great number of identical machines; in large-scale production; in production requiring high accuracy	In cases where the service life periods of individual parts differ widely or the course of wear is ambiguous 4/	Auxiliary equipment, equipment with a completely incidental nature of course of wear
Pre-conditions	Co-ordinated repair activities with production programme, synchronization of the process of wear of individual components of equipment	Discipline and regularity of the repair process, scientifically elaborated system of standards	System of scientifically worked out standards of the cycles, the volume, and the duration of repairs	Qualified and experienced personnel checking the equipment; measuring devices and laboratory facilities, advanced operative planning of repair activities, adequate stock of spare parts	Reserves in equipment, great stocks of spare parts, high flexibility of repair capacities
Effects	Minimal losses in output; minimal time needed for repairs	Lower requirements for the qualification and flexibility of repair personnel; possible planning of repair activities	High utilization of repair capacities	Repairs are planned and carried out at most appropriate points of time	Timing of repairs incidental; difficult planning of repair activities

1/ Repairs are timed according to the course of wear of the component with the shortest service life.
2/ Individual components are functionally interdependent.
3/ Repairs planned with certain degree of flexibility as compared to standard repairs.
4/ Equipment exposed to intensive corrosion, buildings and structures.

3. <u>Maintenance</u>

According to generally accepted terminology, maintenance means the whole set of measures for keeping the plant in good operating condition. The concept of maintenance thus would include repairs and sometimes even renewal. In this study, however, a narrower concept will be used, covering only the routine care, such as:

- cleaning
- painting, anticorrosion protection
- lubrication
- inspection control.

Some secondary functions usually are being organised closely together with maintenance, such as:

- stock keeping
- generation and distribution of power and other utilities
- plant protection including fire protection
- pollution and noise abatement, etc.

The treatment of these activities does not fall within the framework of this study.

Special importance should be attached to anticorrosion protection, lubrication and inspection control, since these activities require specific resources and skills.

<u>Anticorrosion</u> protection ensures the surface protection of machinery, equipment, buildings and structures against the aggressivity of environment.

Anticorrosion protection which mainly consists of protective coatings and conservation is quite labour-intensive and requires a wide variety of special materials. Losses caused by corrosion are estimated at $ 6.5 billion p.a. in USA, £ 195 mil. in U.K. and DM 2-3 billion (only steel corrosion) in the Federal Republic of Germany.

In a number of industries corrosion is the main cause of repair. Therefore increasing attention is being paid to coating and painting. The cost of anticorrosion measures in US chemical industry represent 20 per cent of investment cost and 30 per cent of repair and maintenance cost.

Lubrication is to be regulated by exact rules determining the kind of lubricants, their quantity and the timing and method for their use.

Proper lubrication, accordingly, demands specific qualification of personnel (lubrication technicians), materials and organizational measures.

It can be assumed that on average one specialist for lubrication is required for each thousand of employees in an engineering plant.

Different pieces of equipment and their individual components have specific requirements for the quality of lubricants. Therefore a large variety of lubricants is needed, requiring specific purchases and large stocks.

The organization and control of lubrication in a plant is handled by the maintenance chief. The lubrication technicians are usually organized in maintenance crews. A proper organization of lubrication requires

- equipment records,
- lubrication prescriptions, lubrication plans
- indications of lubrication points
- organization of deliveries, stocks and distribution of lubricants
- system of utilization of used lubricants.

Inspection means a check up of the condition and the functioning of plants and equipment. This requires a variety of activities including the removal of minor defects, largely without stopping the operation.

These activities are carried out by both the operating personnel and by special "inspection repair-men". Which of these two categories is to carry out each of the various functions depends on the specific conditions as well as the safety requirements of the plant.

The professional supervision of plants and equipment is usually undertaken by a special group of maintenance workers These workers are to be at permanent disposal, especially in the case of continuous production.

Special problems in regard to the staffing are the under-utilization of the specialized inspection maintenance workers as well as the control of their work.

C. Preconditions for Repair and Maintenance

1. Labour (Maintenance workers)

It is not possible to draw a clear-cut line between maintenance workers and workers who operate machinery and other equipment. In enterprise statistics repair workers usually fall within the category of auxiliary personnel. The broader term "maintenance workers" often includes not only workers carrying out maintenance and repair but also workers producing spare parts and parts or the whole pieces of equipment. In addition, firemen and members of factory guard are sometimes included here as well.

The main factors determining the number of maintenance workers needed (i.e. the ratio of the number of repair workers to the total manpower in a plant) are:

(i) Capital intensity of the production; the manpower requirements tend to be high in capital intensive industries (e.g. power, metalworking and chemical industry) while it is low in textile, garment, tanning, and wood working industries.

(ii) Structure of capital means to be maintained; machinery and equipment naturally have a different demand for repair than buildings and structures.

(iii) Standardization, design and material characteristics of plants and equipment; the manpower requirements thus depend to a great extent on the choice of equipment, on the technology and production of given equipment.

(iv) Factors determining the deterioration of plants and equipment (see Chapter A.1).

(v) Efficiency of the applied system of maintenance.

The data in Table 6 and 7 serve as an illustration of differences in repair intensities of various industries. Equipment requires about 4-5 times more labour per value of installed capital than buildings and structures. Also within the category of "equipment" there are substantial differences between repair work requirements of technological equipment, power plants, and instruments. In more elaborated systems the needs for repair workers are determined on the basis of standards of repair intensity for individual kinds of capital means. The data in Table 7 which is based on standards for Czechoslovak machinery can serve as an illustration for this.

Table 6

Indicators of Repair Activities Intensity in Various Industries

Industry	Number of all personnel	installed HP	Plant area in m2	Area of repair shops in m2	Share of repair workers in total personnel (%)	Area of repair shops as a percentage of the total plant area
		per one repair worker			%	%
Oil refineries	5	41	-	6.6	33.3	-
Chemical industry	8	59	720	13.8	12.5	1.92
Metallurgy	9	153	970	17.3	11.0	1.78
Rubber	13	94	475	7.7	7.8	1.62
Textile	20	68	725	20.3	5.0	2.8
Electro-engineering	27	105	660	12.8	3.7	1.94
Engineering	28	92	740	12.8	3.6	1.73
Precision tools	37	60	495	9.2	2.7	1.86

Source: FACTORY 110/1958/No. 8, pp. 52-63

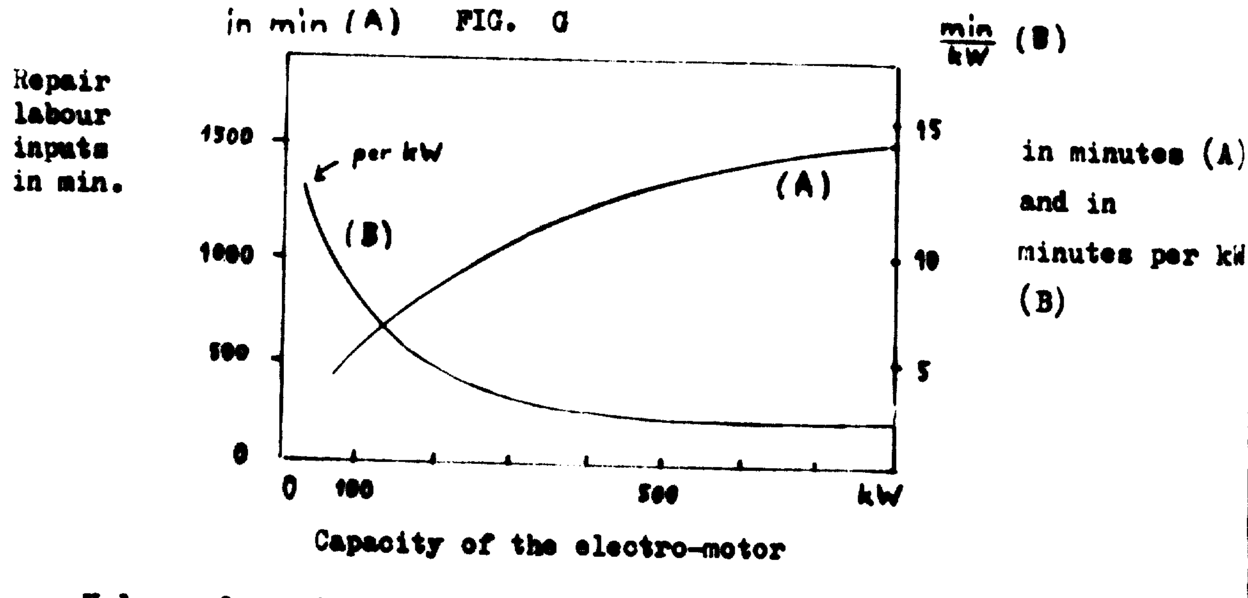
Table 7

Labour Standards for Preventive Repairs of a Bench Drilling Machine

Type of repair	Norm of labour intensity in hours
Inspection	0.75
Control	1.0
Minor Repair	10
Medium Repair	27
Over-haul	54

Figure G shows that the number of maintenance workers depends on the technical capacity of the equipment. The repair of an electro-motor of, for instance, 10 kw, takes about 15 minutes repair per 1 kw, whereas the repair of an 100 kw-motor only takes about 7 minutes per kw.

FIG. G



Volume of repair and the capacity of the equipment (electro-motor).
Source: Zigmund J., Informace o udribe, No. 6050/1966, VUTECHP, Prague

As technical development progresses, the ratio of repair workers to the total number of personnel tends to increase. Particularly, the process of automation increases the complexity of equipment and its repair requirements.

Thus, for instance, in Du Pont de Nemours chemical concern the number of production workers was increased 1940-1955 by 50 per cent while the number of repair workers grew with 250 per cent.

Repair and maintenance place special requirements on the skills of labour. In several types of industries the skill requirements for maintenance workers are higher than for production workers. In case of automatic or programme controlled machines, for instance, the production worker must only have an ability to repeat relatively simple tasks, i.e. manual skills for fixing and handling the finished products and to switch the machine on and off. The maintenance worker on the other hand should not only have the manual skills but also a deep professional knowledge, in particular, regarding the basic mechanical, electric and hydraulic principles. These skill requirements obviously make the specialization and division of labour within a plant necessary.

The opinion on the specialization of maintenance professions is far from uniform. Generally, two basic professions are recommended: maintenance workers for mechanical systems and maintenance workers for electrical systems.

Special training is necessary for maintenance and repair personnel. The training should aim at both the broadening of the general knowledge and the mastering of specific technical problems.

In addition to the formal education at appropriate level (vocational schools, technical high-schools, technical universities), the qualification of technicians requires specialized practical knowledge of maintenance. An example of a basic training programme for repair workers is given in Table 3.

Table 3

Repair-worker Training Programme (Example)

General Millwrights Assignment		hours
1.	Assembling and erecting and general maintenance of machines and shop equipment	2 920
2.	Construction of special equipment	1 000
3.	Installation and maintenance of hydraulic and pneumatic equipment	1 000
4.	Fitting bearing and scraping ways	500
5.	Lubrication of machines	500
6.	Welding and cutting arc and acetylene	1 000
7.	Operation of various machines	500
8.	Related classroom instruction	580
	Total	8 000

Source: Morrow L.C.: Maintenance Engineering Handbook, Mc Graw-Hill, NY.1957 pp. 2-19

2. Spare parts and materials

Spare parts are used to replace the parts of a machine which get worn out faster than the machine as a whole. A spare part can be defined as that part of a machine and/or equipment, which can be used separately as a replacement for the identical, worn out or damaged part of the machine. Also a separate functional unit can be considered as a spare part, e.g. electric motor, pump, etc. On the other hand clamping and cutting implements of lathes for instance are not regarded as spare parts, but instead as material inputs. They are not depreciated as a part of the value of installed equipment.

The need for spare parts and materials for maintenance is determined similarly to the need for maintenance workers. However, there is generally a need for a wide range of different parts. Special importance therefore must be ascribed to the supply and stock keeping of spare parts.

> In various industries the annual consumption of spare parts amounts to 1-4 per cent of the purchase cost of installed machine and equipment. Spare parts stocks represent 1 to 2 years' consumption.
>
> In an average sized chemical plant there are about 10,000 items on the list of spare parts and about 15,000 items on the list of repair materials.
>
> The need for spare parts is especially influenced by the degree of standardization of equipment. For 100 machines of the same type it is necessary to keep in stock only about one third of spare parts compared to what is needed for 100 machines of five different types.

3. Equipment in repair shops

Only a certain part of repair and maintenance activities require special floor and equipment capacities. By their nature repair and maintenance mainly are ambulatory. A large part of repairs and the dominant part of maintenance is carried out on the spot of installation without moving the machine or equipment.

Capital requirements of repair and maintenance are given by

- the technical outfit of repair shops (machinery and equipment)
- the working area of repair shops
- mechanical implements (tools) and instruments (e.g. measuring)
- the stock of spare parts and materials (mentioned in preceding chapter).

The technical outfit of repair shops is partly characterized by the large proportion of universal machines (general purpose lathes, drilling, grinding and milling machines of normal sizes) and partly by expensive and complex measuring devices. Data on the technological structure of machine-tools in repair shops in USSR are contained in Table 9.

Table 9

Composition of Machine-tools in Repair shops in Engineering Industry

Kind of the machine	Share (per cent) in the total number of machines in repair shops
Centre and turret lathes	40 - 50
Vertical and chucking lathes	2 - 3
Boring machines	3 - 4
Vertical drilling machines	7 - 8
Radial drilling machines	2 - 3
Milling machines	7 - 9
Planing machines	7 - 8
Shaping (slotting) machine	2 - 3
Grinders	10 - 12
Gear milling machines	6 - 7
Other machines	3 - 4

Source: Jakobson M.C.: Jedinaja sistema planovopredupreditelnovo remonta masinostreitelnych predprijatij, Masinostrojenije, Moskva 1967

The outfit of repair shops in big plants outside the engineering industry (e.g. metallurgical, chemical works) is generally more complex and costly. There are special anticorrosion shops usually linked to the material testing department, boiler shops, pipe shops, stainless steel welding shops, etc. Relatively more equipped and bigger are also electroshops and particularly shops for the repair of measuring and regulation devices.

The working area of repair shops is, as a rule, relatively larger than the area devoted to basic activities in machine-tool works. In repair shops there is a working area of about 30-35 m2 per worker, which is three times more than the average area in processing shops in the machine-tool industry. It must be stressed that this estimate concerns the relation between the number of workers and the extent of the area of repair shops and not the - different - relation between the total number of maintenance and repair workers and the area of repair shops (see table 6).

The investment cost of building up and equipping repair shops is determined by the technical outfit of the shops, the working area needed, the costs connected with the initial outfitting with tools, and the necessary spare parts and repair materials. The fixed investment costs into repair shops generally represent about 1 - 3 per cent of the total fixed investment into a plant. For smaller plants higher values are valid.

The value of the stock of spare parts is approximately at the same level, i.e. 1-3 per cent of the investment.

4. Down-time of equipment

One of the specific implications of repair activities is the down-time during which the machinery partly or entirely is taken out of production and which accordingly causes losses of production.

In order to keep these production losses at their minimum the plant manager can undertake specific organisational and technical measures for shortening the down-time during the given repair work. Furthermore, losses can be reduced by utilising normal idle periods of equipment for the repair or utilising reserve capacities. Finally, all mentioned activities reducing the deterioration of equipment and the risks for break-downs naturally play an important role in this context. The choice of repair system is largely determined by the estimated risk for down-time of the machines.

The length of time during which the machine is put out of operation due to repairs depends on the magnitude of the repair. The down-time of equipment in repair can accordingly be reduced by rationalizing the repairs and planning them well in advance. Technically repairs can be prepared beforehand, mainly by:

- preparing the necessary technical documentation
- securing the availability of spare parts needed
- calculating the repair time and scheduling the repair work sequence.

In many cases it is possible to prepare the scheduled repair by dismounting the equipment for a short time and make a diagnosis of the repair and spare part needs.

Finally, the risk of losses due to down-time of machinery caused by failures and repairs can be minimized by means of reserve equipment. These reserves can be kept either in installed equipment of productive units or in the repair shops (system of repair through exchange).

The feasibility of keeping such reserves is shown by the ratio between the investment cost of such a solution and the volume of probable losses that could be avoided. Hence it is usually not feasible to keep reserves of costly and complex machinery. One can also regard the possibility to more intensively use other machines of the same kind in the case of breakdown and down-time as one kind of spare capacity. In the engineering industry a universal machine tool could be used for this purpose.

5. Specialized repair and maintenance shops

In order to rationalize repair services at the sectoral and national levels specialized repair shops can be established. Generally three types of such repair shops can be distinguished:

- sectoral shops,
- repair shops for specific kinds and brands of machines,
- regional repair shops.

In addition, it should be mentioned that the most common external specialized repair and maintenance service is the one carried out by producers of the equipment.

Sectoral repair shops are usually established for repair and maintenance of special equipment of a certain industry such as oil refineries, electro energy and construction industries.

A sectoral repair shop can be organized as a separate plant or as a repair shop attached to some plant within the specific industrial sector. Either the personnel of such a specialized repair shop is sent out to carry out service in the plants, or the machines and equipment are sent to the repair shop.

Repair shops dealing with specific kind and brands of machines represent a progressive form of specialized repair shops. They mainly perform over-hauls.

This kind of specialization makes it feasible to introduce methods of large-scale production into repair activities. In this way, over-hauls can be carried out at much lower cost than if they are done individually by the plants themselves. As a result of specialization of over-hauls in the Czechoslovak engineering industry the time needed for over-hauls of certain types of machines was reduced by 75 per cent and the labour costs by 50 per cent. The experience shows that in order to achieve such substantial savings, the number of machines of a certain type to be repaired must reach 35 pieces annually.

Some experiments in USSR and in Czechoslovakia show a possibility to reduce the down-time of equipment through the "system of repairs through exchange". In this system the specialized repair shop concurrently with demounting the machine for over-haul delivers another machine of the same type in good working conditions as permanent replacement. This system can only function if the repairs are of high quality and if the repaired machines have the same technical parameters as a new machine. Another precondition for the rational use of this system is the existence of a sufficiently large industrial sector and of a sufficient number of machines.

Regional repair shops can be used in regions which have a great concentration of industrial - mainly small-sized - establishments with the same repair requirements. The main items to be repaired are in this case buildings, electro-motors, coatings, pipes, electro-distribution systems and climatisation equipment.

III. RENEWAL, REPAIR AND MAINTENANCE POLICY AND STRATEGY

This chapter deals with the economic and organizational aspects of renewal, repair and maintenance on the plant and the aggregate levels. Emphasis is placed on the plant level and mainly on explaining the organization, the management and control, the book-keeping and recording system as well as the analysis of renewal, repair and maintenance. The aggregation of these problems will then be discussed, i.e. the national planning of renewal, repair and maintenance, and the strategy in the context of industrial development.

A. Plant Level

1. Organization and management

The specific problems of the organization and management of repair and maintenance are to decide upon:

(i) the degree of specialization of repair shops and repair teams in the plant; 1/

(ii) the centralization or decentralization of repair capacities; and

(iii) the organization of management for the repair and maintenance activities.

The choice of the appropriate degree of specialization depends mainly on the size of the enterprise. The larger the plant is, the more can the repair facilities be specialized. In smaller enterprises all the maintenance and repair activities are concentrated in one maintenance department, while over-hauls and special services are carried out by external shops. In large plants the specialization can lead to the establishment of a system of internal maintenance units. Such a system could include:

a) maintenance of machines and equipment
   (i) mechanical shops (machine tool shops)
   (ii) welding shops (pipe shops, tinsmith shops, boiler shops, etc.)

1/ The problems of specialized repair and maintenance shops functioning at the sectoral or regional basis have been dealt with in Part II.

b) transportation equipment maintenance

c) electrical maintenance (shops for electro-motors, etc.)

d) maintenance of radio-technique, measuring and regulation devices

e) joiner's maintenance

f) construction maintenance (bricklayer crews, scaffolding crews, etc.).

The specialization of maintenance capacities depends, however, not only on the size of the plant, but also on the technology and organization of the main production activity. Thus, in the chemical industry, in the production of electrical energy, and in such metallurgy or engineering industries which require a high precision of machine-tools, the specialization generally is rather far reaching.

The second mentioned problem to be solved by the management is the choice between centralized and decentralized maintenance capacities. The following alternatives are possible:

a) Centralized maintenance capacities, organized either as
   (i) an independent repair plant of an enterprise (or a trust),
   (ii) a central workshop within the plant, or as
   (iii) several workshops, one for each major section of the plant.

b) Decentralized workshops within the productive sections

c) A combination of a) and b) based on several smaller detached shops which are combined with the central workshop. This can be organized either as:
   (i) decentralized workshops, with the planning, the spare parts stocking and the inspection being centralized in the chief maintenance department; or
   (ii) decentralized workshops in the large productive sections and centralized maintenance for smaller departments, and also centralized maintenance for certain kinds of equipment which have special requirements for maintenance.

The choice of the appropriate degree of specialization depends on the actual costs, the quality and the quantity of activities as well as the actual down-time of machines in repair.

Finally, there is a basic organizational problem in regard to management of repair and maintenance activities. A decision must be taken on the degree of centralization of management and on the incorporation of maintenance and repair activities within the organisational set-up of the enterprise. Two alternative solutions are possible for the latter problem:

(i) all personnel is subordinated to the chief of the whole repair section (usually for electro-maintenance, maintenance of measuring devices and maintenance of buildings);

(ii) the personnel is partly subordinated to the chiefs of various production sections, and to the maintenance chief only in regard to methodology and professional aspects of maintenance and repair.

The maintenance chief is alternatively subordinated

(i) to the production manager,
(ii) to the technical manager or
(iii) to the director.

The subordination to the production director is often problematic, since maintenance in the short term may conflict with the aim to maximize the output. There may be a tendency to postpone or neglect repairs. This risk can be avoided or reduced, if the technical manager is in charge. The direct subordination of the maintenance manager to the director, finally, is particularly suitable for large plants with complex equipment and a great number of repair and maintenance workers.

As can be seen, there are no fixed criteria for choosing one of these alternatives. The choice depends on the actual conditions in the enterprise and its experiences from the past.

2. The recording system

The analysis and planning of repair and renewal necessarily requires a systematic collection of information on the existing capital stock and its development. This information usually serves as a basis not only for the actual managing of repair and maintenance activities, but also for tax calculation, capacity planning, etc.

The two basic kinds of records are the financial book-keeping and the operational technical recording.

The financial book-keeping deals with money-value of installed plants and equipment, of depreciation, of maintenance and repair costs,etc.

It requires a stock-taking of plants and equipment which is a problem in itself, since it depends on the method of evaluation. In general, there are three ways of evaluating the existing capital stock:

- in terms of the original purchase cost,
- in terms of contemporary purchase cost,
- in terms of balance value (net, after depreciation).

Generally, however, the method to be used for evaluating installed plants and equipment is determined by governmental regulations.

The value of installed plants and equipment includes the purchase cost, transportation cost and the cost of putting them into operation, i.e. the assembling, mounting and installation.

The operational technical recording is the source of primary information for the control of renewal, repair and maintenance activities. Basic elements are the inventory list and the inventory card.

The inventory list summarizes the installation of plants and equipment in a chronological order, while the inventory card gives the detailed basic information on plants and equipment. The inventory card usually serves both the financial accounting and technical decisions. The contents and form of such a card naturally depend upon the kind of plant and equipment and the maintenance system. An illustrative example is given in Table 10.

Usually, the necessary details and records concerning maintenance, lubrication and spare parts are noted on the card. Records on the costs of individual pieces of equipment on the other hand are only kept for valuable equipment and if highly developed systems of accounting are used. These records serve as a basis for a systematic evaluation of renewal alternatives.

Table 10

EQUIPMENT RECORD

ITEM — INVENTORY NO — W-

PURCHASED FROM

MANUFACTURER

HORSE POWER	AMPS.	SERIAL NO.	TYPE
SPEED (RPM)	OUPUT SPEED	MODEL NO.	SIZE
VOLTS	RATIO	STYLE NO.	CAPACITY
PHASE	FRAME	CAT NO.	DIMENSIONS
CYCLES	JOB NO.	DRAWING NO	SHIPPING WEIGHT

ADDITIONAL DESCRIPTIVE DATA AND COMMENTS

DRIVES W. — ITEM — THROUGH TRANSMISSION/SPEED REDUCER AND INV. NO.

DRIVEN BY — H.P.

USED IN CONNECTION WITH W. — ITEM

DATE OF PURCHASE TRANSFER OR SALVAGE	REG. NO.	BRANCH	LOCATION		REMARKS

PACKING SPECIFICATION

BEARING DATA

LUBRICATION DATA

DRIVE SPECIFICATIONS

FREQUENCY OF P.M. INSPECTION

ITEM FOR P.M. INSPECTION

INVENTORY NO'S OF AUXILIARY EQUIPMENT

DAILY | WEEKLY | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC

SPARE PARTS STOCK LIST

SYMBOL NO.	DESCRIPTION	MFGS. PART NUMBER	MAX	MIN	UNIT COST

SOURCE: L.C. MORROW: MAINTENANCE ENGINEERING HANDBOOK
Mc Graw-Hill Book Company, Inc., 1957

To enable a rational decision on renewal, repair and maintenance it is important to have a constant flow of up-to-date information on innovations, i.e. new technologies and new machines, which offer possible alternatives to those currently in use.

The introduction of a rational information system on installed plants and equipment requires various methodological and organizational pre-conditions, such as:

(i) the definition of an "inventory item"

(ii) the determination of its code number

(iii) the classification of plants and equipment

(iv) introduction of the new plants and equipment in the control records

(v) regulations concerning periodical inventories.

An "inventory item" is the smallest separate unit of plants and equipment. The concept "inventory item" is usually determined in tax laws which define the minimum value of an "inventory item" or the minimum period of its service life. In this way a dividing line is drawn between investment items and other, minor or short-lived items. In the case of buildings, each separate building is an inventory item, irrespective of whether it actually stands alone or is located within a block of buildings. In the case of structures, each separate part which fulfills a certain technical or economic function and has all accessories of the whole complex forms an inventory item. More complicated is the definition of an inventory item in those kinds of equipment which have a large number of components and various accessories. The telephone system of a plant, for instance, can be considered as one item including connecting lines and telephone sets. In the case of a boiler house it is, however, opportune to use the boiler with the supporting frame, gallery and foundation as a separate inventory item, and the economizer, the ventilator, pipes, stock, fly ash handling equipment, etc. each as separate inventory items.

Code numbering of inventory items enables a permanent, uniform and univocal identification of plants and equipment by a symbol, usually a number. Code numbering is the best solution also for mechanized recording. Since the number of inventory items generally arrives at thousands, it is in such cases not possible to make a separate coding for the technical characteristics of each item.

As a rule, the items are numbered chronologically. Sometimes it is useful to combine the identification number with the classification number, as shown in Table 11.

Table 11

An example of a system of code-numbering of plants and equipment

Classification number	Group of plants and equipment	Inventory number	Number of possible items
1	Buildings	101 - 199	99
2	Structures	201 - 299	99
3	Power equipment	3001 - 3999	999
4	Production machinery and equipment	40001 - 49999	9999
5	Power distribution equipment	5001 - 5999	999
6	Transportation equipment	6001 - 6999	999
7	Instruments etc.	7001 - 7999	999
8	Animals	801 - 899	99
9	Land, land improvements	901 - 999	99

The further basic step for introducing an information system is the classification of plants and equipment. The simplest and most general way of classifying capital means is to divide them into two groups: buildings and machinery. These two groups can be divided further in a more detailed classification. The machinery component, for instance, can be broken down into: production machinery and equipment, power equipment, driving and transmission equipment, transportation means, instruments, etc. However, even this type of classification is usually too rough to serve as an operational technical information system. An example of a more detailed classification is given in Table 12, which shows the decimal classification system used in the Czechoslovak engineering industry. In this case a classification number stands for a rather detailed technical characteristic.

Table 12

Decimal classification system (example)

Classification code	Description
4	Machines
402	Machines in engineering industry
4024	Metal-cutting machines
40241	Centre lathes
402412	Centre lathes with 250-315 mm turning diameter
4024122	Centre lathes with 250-315 mm turning diameter and 750-1000 mm bed length

The introduction of the new plants and equipment in the control records is an important measure for the information system. Obviously, the starting point for the record-keeping of plants and equipment is the installation during which the following actions are to be taken:

(i) the item is given an "inventory number";
(ii) the item is registered in an inventory list;
(iii) a permanent equipment record (inventory card) is established;
(iv) the technical documentation is registered.

The periodical inventories are the revisions of the records which from time to time are necessary. They are based on a comparison of the records with the real state of plants and equipment.

An inventory of plants and equipment is usually combined with the inventories of other items of the capital assets, such as unfinished investments, unfinished production, stocks of material, stocks of products, etc. The inventory of plants and equipment can be carried out in connection with a technical inspection. A special case of inventory is the so-called "general inventory", organized for the whole industry or country.

3. Analysis of the economic efficiency

The analysis of "needs and resources" of renewal, repair, etc. is explicitly or implicitly an optimization analysis. Repair requirements of a machine are not determined exclusively by the technical circumstances, i.e. by its physical wear and technical functions. Ultimately, also criteria of economic efficiency play a decisive role, since a decision to carry out a repair also means an extension of the "life" of the existing part of installed capacities. Such a decision therefore necessarily is an outcome of economic rather than purely technological considerations.

The methodology of assessing the economic efficiency for decisions on new investment as well as on repair and renewal is subject to profound theoretical discussions in the literature. In the following some of the basic methodological concepts will be introduced. It should be noted that the problem of evaluation cannot be solved by a mere application of simple or even complex formulas based on a system of indicators. It must also include the utilization of relevant broader experiences and qualified prognoses.

The logical structure of the efficiency evaluation is the confrontation of the aimed utility function with the given restrictions. The first methodological precondition for such an evaluation therefore is the establishing of an utility function. Usually, the maximization of profit is considered to be the main utility function. In the case of repair vis-à-vis renewal the maximization of profit is identical with the minimization of production costs. Thus, the first step of efficiency evaluation is the calculation of the operation costs.

The calculation of the operation costs of a repaired machine as compared with the costs of a new machine is usually rather complicated. Such a calculation therefore both can and should be limited to consider those items which are specifically subject to changes due to renewal, such as:

- basic wages
- depreciation charges
- materials cost

- instruments cost
- repair and maintenance cost
- energy
- technical preparation of production.

The main restriction for achieving the given utility function are the investment funds or the investment costs respectivtly. These consist not only of the actual investment outlays (purchasing or repair costs, respectively), but also of the costs of introducing the new technology, the costs of installation, the costs connected with the demontage, etc.

An illustrative example of a calculation of operation costs and investment costs is given in Table 13. In the example we assume that two universal centre lathes are in operation. One of the lathes is now due for an over-haul, and the other will be due for an over-haul in two years time.

The two alternatives to be evaluated are:

(A) the carrying out of these over-hauls

(B) the replacement of the two lathes by one semi-automatic lathe.

Table 13

Evaluation of the Economic Efficiency of a Repair and/or Replacement of a Machine

I. CHARACTERISTICS

Subject of analysis:	Replacement of two universal lathes by a semi-automatic profiling lathe.	
Product-mix and volume of output:	No changes.	
Description of alternative solutions:	Alternative A:	Maintaining the old technology; production on two universal lathes utilized for more than two shifts a day; lathes require major over-haul.
	Alternative B:	Introduction of a new technology; usage of one new semi-automatic lathe.

Table 13 (con.)

II. OPERATIONAL COST (in $)

	Alternative A	Alternative B	Differences between alternatives (A - B)
Wages	3030	1310	1720
Materials (basic)			
Materials (overhead)			
Energy	1030	1200	-170
Instruments	330	350	- 20
Routine repairs and maintenance	500	400	100
Depreciation charges	690	1300	-610
Rejects	200	30	170
Technical preparation of production		80	- 80
Total savings in case of alternative B			1110

III. RESOURCE REQUIREMENTS (in $)

	Alternative A	Alternative B	Differences between alternatives (B - A)
Investment outlays	-	8750	3750
Over-haul cost	5430		-5430
Balance (resale) value of discarded lathes		-2000	-2000
Start-up costs associated with new machine		250	250
Difference in outlays			1570

IV. RESULTS

a) Annual savings in production cost 1110 US$

b) Difference in investment (once for all) outlays 1570 US$

If the replacement is carried out instead of the two over-hauls, the wage costs will be reduced. On the other hand, the costs of electro-energy, maintenance and routine repairs, of instruments and of the technical preparation of production will increase. The costs of an over-haul of an universal lathe are estimated at US$ 3,000. The present value of the second machine-tool over-haul is naturally less, since it occurs first in two years' time. The cost of a new semi-automatic lathe is estimated at US$ 10,000. The costs for introducing the new technology represent about US$ 300. The replacement of two universal lathes by one semi-automatic lathe will reduce the floor area by 10 m2. It is appropriate to include the reduction in floor area (expressed in investment outlays per 10 m2 of floor area) in the calculations, since all rationalization measures within the given plant also should economize on floor area, thereby reducing the requirements for extensions.

There are different methods for evaluating the efficiency of renewal and repair. The simplest methods are based on the following criteria:

- the length of the pay-off time (minimizing)
- the rate of return (maximizing)
- the average cost (minimizing).

Each of these methods can be applied in a variety of forms. Here, however, we will only deal with the simplest forms of application.

The method based on the length of pay-off is applied in the following procedure: The annual cost savings resulting from the use of the new machine vis-à-vis the utilization of the old machine, are compared with the amount of investment according to the formula:

$$k = \frac{I_2 - I_1}{C_1 - C_2}$$

where k is the coefficient of economic efficiency of the renewal (2) as compared with the over-haul (1);

I_1, I_2 are the purchasing costs involved in the over-haul (I_1) or renewal (I_2); and

C_1, C_2 are the annual costs of production of the old repaired machine (C_1) or the new machine (C_2).

The results of the calculation are then confronted with a "normative" pay-off period, which plays the decisive role in evaluating the results of an efficiency analysis of this kind.

In the case mentioned in table 13, the coefficient representing the pay-off time is

$$k = \frac{1570}{1110} = 1.4$$

This result is usually interpreted in that way that the new machine pays for itself in 1.4 years. If the minimum pay-off period has been determined to, for instance, 2 years 1/, the alternative of renewal is acceptable.

The rate of return method is in its simplest version very similar to the above pay-off method. Its basic component is a coefficient representing the inverted value of the above mentioned formula, viz.:

$$k = \frac{C_1 - C_2}{I_2 - I_1}$$

$C_1 - C_2$ is reduced by the depreciation charges caused by the installation of the new machine. The empirical value of the calculation is then compared with the required rate of return. In the case presented in Table 13, the value of the coefficient is

$$k = \frac{1110}{1570} = 0.71$$

This value is - explicitly or implicitly - compared with an internal rate of return. If this internal rate is set at for instance 20 %, the renewal (which has a rate of return of 71 %) would in this case be recommended.

The minimum average cost method basically means that an item is to be replaced when the sum of the lowest combined annual average of operating costs and capital costs of a new machine is smaller than the corresponding average of costs caused hereafter by the old machine.

1/ According to the Journal Manufacturing Industries, Vol.XV, No.1, p.27, about 60 % of US companies require the pay-off period in the range of between 1.5 and 3 years.

This method can be illustrated by a hypothetical example. According to the figures given in Table 14, the minimum average cost of a new machine with seven years service life is $ 4336. The replacement is carried out when the old, repaired machine causes a minimum average cost which is higher than this figure. As a rule, the present annual operating costs of an old machine are considered to be at their minimum, since it is assumed that the costs are rising from year to year.

A problem common to each form of efficiency analysis is the time adjustment of capital costs and operating costs. This adjustment is carried out to discount receipts and expenditures spread unevenly over time. Theoretically, the internal rate of return for replacement should be higher than (or equal to) the rate of return obtainable from alternative investments with comparable risk and tax status; and lower than (or equal to) the costs for obtaining outside financing.

In Table 14 an example is given also of a calculation with time adjustment. The interest rate used is 10 per cent. In this case the renewal is efficient if the annual average costs of the old machine are higher than $ 4173, compared with time-adjusted total cost.

Table 14

Calculation of minimum average cost of a new machine ($)

Years of service	Annual average for period ending with year indicated					
	Without time-adjustment			With time-adjustment		
	Operating cost	Capital cost	Total cost	Operating cost	Capital cost	Total Cost
1	3000	5500	8500	3000	5500	8500
2	3100	2750	5850	3048	2881	5929
3	3200	1833	5033	3094	2011	5104
4	3300	1375	4675	3138	1577	4716
5	3400	1100	4500	3181	1319	4500
6	3500	917	4417	3222	1148	4371
7	3600	786	4386	3262	1027	4289
8	3700	688	4388	3300	937	4238
9	3800	611	4411	3337	868	4205
10	3900	550	4450	3373	814	4186
11	4000	500	4500	3406	770	4176
12	4100	458	4558	3439	734	4173
13	4200	423	4623	3470	704	4174
14	4300	393	4693	3500	679	4178
15	4400	367	4767	3528	657	4185

(Figures do not always add, because of rounding.)

Source: G. Terborgh, Dynamic Equipment Policy, Mc.Graw Hill, New York, 1949

4. Planning

Planning of renewal and repair can be defined as the explicit coordination of future requirements and supplies. Thus, it is the establishing of a material balance of the requirements for renewal, repair and maintenance in physical and/or value terms against available repair and maintenance capacities, including allowance for external services and supplies. Two different kinds of plans can be distinguished, i.e. general plans and operational plans.

General plans mainly aim at balancing on a long-term basis the requirements of renewal, repair and maintenance against available resources within the framework of the system of plans of the enterprises. In the case of long and medium-term plans, ranging from about 4 - 10 years, great attention has to be paid to the choice between renewal and over-hauls as alternatives of the equipment strategy. Another crucial point of long-term planning is the assessment of future capacity resources for repair and maintenance.

While the long-term plan consists of a system of rather aggregated indicators, the annual plan for renewal, repair and maintenance is more detailed. The example given in Appendix I of this chapter can be regarded as an illustration of a system of indicators suitable for annual planning of repair.

The concrete programming of repair and maintenance activities is a matter of operational plans. Their character and form depend on the choice of maintenance system (see table 5). Two basic kinds of operational plans for maintenance can be distinguished: (i) plans based on inspection regulations, viz. "after-checking planning", and (ii) plans based on fixed maintenance and repair standards.

After-checking operatinnal planning of repair requires qualified and experienced personnel (inspectors), advanced operative planning in repair shops and a relatively large stock of spare parts. It is primarily suitable for buildings and structures and for equipment with an ambiguous course of wear. An illustrative example of planning on the basis of inspection regulations is given in Table 15.

TABLE. 15.

DAILY INSPECTION SHEET

DEP'T ______ DATE ______

INSPECTOR
TORN 2

MECH ELECT LUBR. HYDR. PNEU MISC.

NO.	EQUIPMENT	SYM. SCH.	REMARKS	REASON FOR REPAIRS	NO.
1	STIFF LEG	A		1. Lub lines broken	
2	PIT COVERS	A			
3	INGOT BUGGY	B		2. Lub lines off	
4	P.C. CRANES	E	1	on 4 lead rollers	
5	CHARGE CRANE	A			
6	F B TABLES	E	2		

One sheet each turn for type of inspection

MAINTENANCE INSPECTION LOG SHEET

NO.	EQUIPMENT	T.C.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	STIFF LEG																						
	MECHANICAL	3							A							A							A
	ELECTRICAL	3							A							A							C
	LUBRICATION	3							A							A							E
2	PIT COVERS																						
	MECHANICAL	3							C							C							A
	ELECTRICAL	3							A							A							A
	LUBRICATION	2	A	A	A	A	A	A	A	A	A	B	A	C	B	B	C	A	B	A	A	A	B
3	INGOT BUGGY																						
	MECHANICAL	2	A	A	B	B	A	B	C	B	A	A	A	A	C	B	A	A	A	C	B	B	B B
	ELECTRICAL	2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	LUBRICATION	2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

T.C. = TIME CYCLE : 1 - EVERY 8 HOURS
2 - EVERY 24 HOURS
3 - EVERY 7 DAYS
4 - EVERY 28 DAYS

SYMBOL SCHEDULE : A - NO REPAIRS
B - MINOR REPAIRS
C - ROUTINE REPAIRS
E - EMERGENCY REPAIRS

SOURCE : Morrow L.C. : Maintenance Engineering Handbook
Mc. Graw - Hill Book Comp. Inc; New York 1957

<u>Operational planning based on fixed repair standards</u> is the basic characteristic of standard repair and planned preventive (periodioal) repair. Its basic precondition is an elaborated system of standards. It is suitable for equipment involving a great safety risk and for a great number of identical machines of equipment in large-scale production. An example of standards for this kind of operational planning is shown in Figure F and in Tables 16 and 17.

The basic distinction between the mentioned systems of operation planning is the different degree of the flexibility of plans. Taking into consideration that in reality the needs for renewal and repair are to a certain degree influenced by factors of accidental nature, it is realized that operation planning must always be flexible to some extent. Even in the most developed systems of maintenance, certain decisions remain to be made from day to day.

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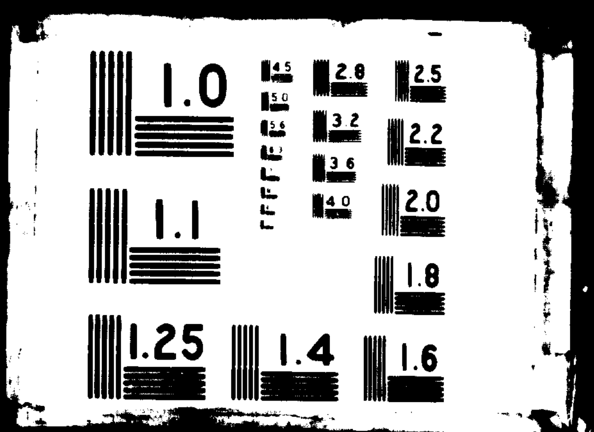

TABLE 16

REPAIR STANDARDS

EQUIPMENT: COMPRESSOR

KIND OF REPAIR	REPAIR CYCLE (HOURS)	REPAIR TIME (HOURS)	REPAIR LABOUR INPUT (HOURS)	AVERAGE NUMBER OF REPAIRS PER YEAR	COST OF ONE REPAIR IN 1000 Kcs				
					MATERIALS	WAGES	OVERHEAD	EXTERNAL SERVICES	TOTAL
O	17 520	300	1600	1/2	30	16	20	5	71
M	4 380	60	250	3/2	4	2,5	2,5	-	9
R	1 460	15	50	2	1	0,5	0,5	-	2
YEARLY AVERAGE		270	1 265	x	23	12,7	14,7	2,5	53,0

NOTE: O - OVER-HAUL
M - MEDIUM REPAIR
R - ROUTINE REPAIR

R R M R R M R R M R R O

MONTHS → 6 12

STRUCTURE OF A REPAIR CYCLE

PRODUCTION UNIT: ANNUAL PLAN OF REPAIRS FOR 19...

EQUIPMENT NUMBER	MONTH 1	2	3	4	5	6	7	8	9	10	11	12
1	15/50 R 1)	R	60/250 M	R	R	M	R	R	M	R	R	300/1600 O
2		M			70/300 M			M			M	
3		10/80 R		R			200/3000 O		R		R	
REPAIR TIME (DURATION OF R.S.) (HOURS)	15	70	60	15	70	60	200	70	60	15	70	300
REPAIR LABOUR INPUT (HOURS)	50	420	250	120	350	250	3050	350	330	50	420	1600
REPAIR COST: M PLUS R PLUS OTHER MINOR REPAIRS												
REPAIR OUTLAYS	x	x	x	x	x	x	120	x	x	x	x	71

ANNUAL DATA FOR FINANCIAL PLAN .... 240 PLUS 191 THOUSAND Kcs

ANNUAL DATA FOR PLANNING REPAIR LABOUR .... 7270 HOURS OF LABOUR INPUTS

ANNUAL DATA FOR PRODUCTION (OUTPUT) PLANNING (EQUIPMENT UTILIZATION) .... 1035 HOURS - 11,8 PER CENT OUT OF 8 760 HOURS

1) NOTE: 15 .... DURATION OF REPAIR IN HOURS
50 .... REPAIR LABOUR INPUTS IN HOURS

Table 17

Standards for Repair in the Chemical Industry (USSR)

Equipment: Centrifugal vertical pump, 10–25 m3/hr, 70 m, 2900 r.p.m. 8kw
Type of repair cycle: 7 B-25-60

R = routine repair
M = medium repair
O = over-haul.

Kind of repair	Cycle of the first over-haul (hours)	Repair cycles (hours)	Duration of one repair (hours)	Number of repairs in one cycle	Volume of one repair (hours)		Costs (Roubles)	
					total	machinery	materials	spare parts
O	8640	8200	168	1	68	27	200	300
M		2880	48	2	34	13	100	150
R		720	8	7	10	4	50	80
Total in one cycle	x	x	x	10	206	81	750	1160

B. The aggregate level

There is a number of problems of rational maintenance, repair and renewal policy which exceeds both the technical and economic capacities of a plant and must be solved at the multi-plant, sectoral and/or national levels.

The setting of these problems and their methodological solution depend on the over-all context of economic policy. Thus, the formulation of the problems and the proposed solutions will obviously be different in a market economy and in a centrally planned economy.

1. Analysis and planning

The aggregate analysis and planning of repair and renewal of plants and equipment, aiming at coordinating future requirements and supplies, differ from the methods and the objectives used at the plant level.

In sectoral and macro-economic considerations regarding the process of industrialization, the assessment of requirements and resources for renewal, repair and maintenance is obviously based on highly aggregated indicators.

a) Demand

The preceding paragraphs dealt with repair and maintenance of individual machines, pieces of equipment, buildings and structures. The analysis of a system of e.g. a machine park must describe the process of depreciation, renewal, modernization, etc. with quite different methods. The model of the development of machine-tools shown in Appendix II gives a relevant illustration of the content and methodology of planning and analysis at that level.

As will be explained below, the aggregate demand for renewal, repair and maintenance depends on the characteristics of the installed capital, i.e. the volume and the age characteristic and the structure from the point of view of service life.

It is self-explanatory that with the increase in the volume of capital means in a given sector or country, the demand for renewal, repair and maintenance services increases as well. It is, however, difficult to make generalizations of the ratio of this demand to the value of capital stock. On the one hand, the importance of the demand tends to increase not only in absolute terms, but also in relative terms due to the continuing process of mechanization and automation. On the other hand, the demand can be reduced through the pursuance of a rational policy of renewal, by means of rationalizing designs of machinery and, last but not least, by rationalization of the repair and maintenance activities.

Table 18

Capital Output Ratios of Manufacturing Industries in the United States

Industry branches	Total	Machinery (including electrical and transportation equipment)	
	US$1/	US$	per cent of total
Food, beverages and tobacco	0.81	0.41	51
Textiles	0.91	0.51	45
Wood and wood products	0.78	0.39	50
Pulp and paper	1.13	0.65	58
Printing and publishing	0.66	0.42	64
Rubber	0.70	0.44	63
Leather	0.43	0.19	44
Clothing	0.38	0.18	53
Non-metallic minerals	1.18	0.67	43
Chemicals	0.89	0.35	61
Petroleum	5.64	0.94	17
Basic metals	2.34	0.92	39
Metal products	0.83	0.51	62

1/ Dollar of purchasing cost of capital per dollar value added in 1953 prices.

Source: Compiled on the basis of unpublished materials supplied by Harvard Economic Research Project.

In general, it can be assumed that the extent of wear and the requirements for renewal, repair and maintenance are a function of the age of the stock of plants and equipment. With increasing age the maintenance and repair requirements are growing, mostly with an accelerated rate. The age characteristics of plants and equipment therefore play an important role in time scheduling the requirements. But the rule is not without exceptions. Old equipment (and buildings as well) is often used for auxiliary purposes only, their precision and performance requirements are usually less strict. This can reduce their needs for renewal, repair and maintenance.

The various categories of capital means differ in regard to their needs for repair. The simplest example for this can be found in the differences between the volume of renewal, repair and maintenance requirements for buildings and that for machines. Thus, depending on these structural characteristics the same volume of capital can be associated with entirely different volumes of repair needs. A larger share of machinery and equipment results obviously in relatively bigger requirements.

In Table 18 data are given of the share of machinery and equipment in the total value of fixed capital assets in various manufacturing industries in the USA. From these data conclusions can be drawn about the relatively higher requirements for renewal, repair and maintenance of the installed capital in metal-working industries, printing and publishing, chemicals and rubber, as compared with e.g. the petroleum industry.

The data contained in Table 2 show very different requirements for renewal and repair for different kinds of buildings, structures and equipment. Equipment in the construction industry, for instance, has much greater repair requirements (the costs of an over-haul represent in average more than 10 per cent of the purchase costs per year) than machine tools in the machinery (in average about 5 per cent) 1/.

1/ These estimates of service life and cost of over-hauls were originally designed for financing renewal and over-hauls out of a special fund. Mainly the following data were used: estimates of average service life, standards for a cycle of major over-hauls (according to the system of planned preventive repairs), and the relationship between the over-haul costs and purchase costs of a machine.

There is a special relationship between the cost of madhines and the cost of their over-haul. As a rule, over-hauls of costly machines have relatively lower costs of repair as related to their purchasing cost than cheaper machines. This applies, for instance, for machine tools. There are several causes for this relationship. The most important cause is probably the fact that low-cost machines mainly are produced in large series, whereas their over-hauls are carried out individually. The difference in labour productivity of repair shops and of production units of new machines is in this case more pronounced than in case of larger and complex machines, which are often produced as unique pieces.

Repair and renewal requirements are, generally, interdependent: Machinery and equipment with higher renewal requirements also demand more repair. However, in some cases the accelerated renewal of equipment (shortening of service life) can result in the reduction of needs for repair. In such a situation, the renewal requirements and repair requirements exclude each other.

b) Supply

From the national or sectoral point of view the resources required for renewal, repair and maintenance consist of specialized labour, capital, material supplies and stocks and specific imports of goods (equipments and spare parts).

Repair activities are characterized by large labour inputs both in regard to the quantity and the quality of the labour required. This is partly due to the fact that manual work prevails in the actual productive time and partly to the relatively low share of actual productive time (35 % - 50 %) of the total working time of repair personnel. Even with a good organization, the bulk of the working time of repair workers is spent on preparatory activities.

In the framework of the whole economy large resources of labour usually are engaged in repair activities. Out of the population of 14 million of Czechoslovakia for instance there are about 500,000 repair workers.

Compared to the labour input in repair activities the capital inputs are generally not large. Thus, in Czechoslovak repair shops there is only 28,000 Kcs worth of fixed capital stock per worker, whereas in the chemical industry the figure is 220,000 Kcs.

Material inputs are also not large in volume. The variety of materials required in repair shops on the other hand is generally large. Keeping an adequate level of stocks of spare parts and materials therefore requires relatively large amounts of working capital.

A country's requirements for maintenance can normally be met only partially by domestic resources. The degree of self-sufficiency in maintenance services, in supplies of spare parts, etc. depends primarily on the size of the economy and on the level of the economic, particularly the industrial development achieved. Developing countries are to a large extent dependent on imports of capital goods, especially machinery. This is reflected in the high import rates of maintenance services and deliveries of spare parts and components for renewal.

c) Techniques of planning

A country's plans for renewal, repair and maintenance at the aggregate level are generally not prepared in details, and they only exceptionally have the form of material balance sheets. This also is true for centralistic planning systems, where in most cases only partial analysis and plans are made with a view to applying specific policy measures.

Such a partial analysis can for instance aim at assessing the needs for renewal. Sectoral studies would then be the most suitable method of analysis. The sectoral studies are generally examining the existing state of installed capital means and the overall investment climate and will include the evaluation of installed machines from the viewpoint of their replacement by new machines. For the latter purpose the technological level of machines has to be reviewed and be compared with the technological innovations.

The analysis of the needs for renewal, based on the examination of the economic efficiency of replacement investment, usually requires plenty of data and large inputs of highly qualified labour. When these prerequisites are not available, a different, less demanding method of comparative analysis is being used. The technological level and structure, the age and composition of machinery and equipment in a certain sector of the country in question are then compared with the situation in another country in which this specific sector is more developed. The volume of resources needed can subsequently be calculated by using approximative methods.

2. Policy measures

Governmental action in solving renewal, repair and maintenance problems mostly takes the form of technical, organizational as well as financial policy measures. The technical measures include the promotion or eventually the actual establishing of:

- specialized repair shops and servicing facilities
- central stocks of spare parts
- design and technical bureaus, research institutes and organs of state inspection
- educational and training facilities, etc.

These actions must be based on a systematic analysis of the economic and technical feasibility from the national point of view. Thus, the question of the establishment and the size of specialized repair shops, stocks, and the various institutions must be thoroughly investigated.

Specialized repair shops as the technical basis for rational supplies and services have been discussed in Chapter II.B. In regard to the organization of specialized repair shops it is necessary to consider on one hand the savings, resulting from higher productivity of the shops and the improved quality and shorter time of the repair services and on the other hand the losses. These are mainly increased transport costs, the reduced flexibility and speed in coping with breakdowns and the lack of knowledge of concrete conditions of equipment operation.

To determine a general, appropriate ratio between (a) the volume of repair and maintenance to be carried out by workshops of plants and (b) the volume performed by external suppliers is not possible. The ratios of different industries vary substantially. They also depend on the type of capital means in use. Large differences exist even between different countries. These differences cannot be explained merely by the different levels of industrial development, but also by actual habits, traditions and the institutional set-up. In USA, for instance, about 30 per cent of all plants use external repair services, but the external suppliers perform on average only 7.6 per cent of the total volume of repair work. In the Federal Republic of Germany and in Eastern Germany, on the other hand, chemical plants use external services to a very little extent. In Japan, finally, repairs are usually performed by external firms, particularly by the suppliers of the equipment.

Decisions regarding central stocks of spare parts at the national, sectoral or regional levels are based on similar considerations. Specialized repair shops also form a natural basis for storing and distributing the spare parts.

The design and technical bureaus, research institutes and organs of state inspections have the following functions:

- to provide consultative services in regard to the rational repair and maintenance of equipment;
- to develop the "type" project of the organization and the techniques of repair and maintenance;
- to adapt the design of imported machinery and equipment to local conditions;
- to develop a system of technical standards, which would promote the unification and standardization of the equipment;
- to establish a system of state inspection for crucial parts of plants and equipment (electro energy, hydropower plants, etc.), especially in cases where major safety risks are involved.

The government plays an important role in promoting or establishing these institutions. Many developing countries lack this necessary institutional set-up.

In the field of education and training the governmental policy comprises the following measures:

- promotion of the education of skilled labour by establishing training centres and vocational schools;
- encouragement of closer contacts between industries and educational institutions;
- inclusion of the problems of maintenance, repair and proper operation of equipment into the curricula of vocational schools;
- the organization of exchanging experience among repair and maintenance personnel.

In addition to these various direc actions, the government can apply indirect measures. In order to promote proper maintenance, repair and renewal, the government can specifically impose some of the following policies:

(i) a rational depreciation policy aiming to create conditions for efficient modernization of installed plants and equipment;

(ii) tax and credit policy measures, or subsidies and/or state capital participation to promote the establishing of specialized repair shops, stores of spare parts, and specialized plants producing spare parts;

(iii) foreign exchange and tariff regulations to create conditions for adequate imports of spare parts and technical services as well as for the rational policy of renewal of machines which are not produced domestically.

Taking into account the adverse balance of payments and scarcity of foreign exchange, generally prevailing in developing countries, the policy decisions related to foreign exchange outlays on imports of replacement parts and maintenance services require a special attention. In short, it can be said that the policy maker in a developing country has a two-fold task. Firstly, he must minimize foreign exchange outlays on imports of spare parts and maintenance services. Secondly, he has to assure the continuous and adequate supply of these items to all public and private enterprises.

To achieve these aims, the government could adopt several measures. First of all the government should endeavour to increase the efficiency of maintenance and the economy in spare parts utilization. In this connexion it is important to improve the skills of maintenance and repair personnel assigned to identify the causes of break-down and to specify the ordering of spare parts and services. In regard to administrative restrictions and tariffs on imports of spare parts a flexible policy is needed which could allow to speed up the delivery of spare parts. Imports of spare parts should be given a special treatment from the point of view of both customs procedures and tariff policies. Finally, the government could take measures aiming at rigorous import substitution policy with a view to building up domestic repair shops and workshops producing spare parts.

In promoting the domestic production and services the government should not restrict itself to levying high tariffs on imports of spare parts to protect the local producers from foreign competition. Temporary tariff barriers have to be accompanied by additional, positive measures from the part of the government. Thus, local production could be stimulated by technical services, credits, training facilities, etc. A mere introduction of administrative or tariff restrictions on imports of spare parts and maintenance services may bring certain foreign exchange savings in the short run, but will inevitably lead to underutilization of equipment. Since generally large amounts of foreign exchange had been spent on the equipment, there will then be no saving in the long run.

If, in the case of export industries, the foreign exchange savings achieved through reducing the imports of spare parts and maintenance services have adverse effects on the output, the savings could be easily compared with the eventual losses in export proceeds. In domestic market oriented industries the corresponding cost-benefit calculation involves a comparison of losses in output against the foreign exchange savings. Here a shadow price will be used for the foreign exchange in order to evaluate the losses in supplies for the domestic market. In addition it must be taken into account that the demand for other imported goods may increase. This could be due to the fact that certain domestic industries are forced to operate at a lower capacity because of lack of spare parts, etc. and that the demand therefore cannot be fully met by the domestic production.

3. Data requirements

For the above mentioned measures the governmental bodies and other relevant institutions require information on existing plants and their equipment.

The system for collecting the data as well as the type of data asked for are obviously related to the given economic system. In a market economy capital means are only exceptionally subject to centralized stock-taking, whereas in centrally planned economies usually very detailed information on capital stock in the whole national economy are collected and used in ministries, planning agencies, etc.

For the first group of countries usually indirect methods of estimates are applied. The necessary data is arrived at from:

- balance sheets of individual companies;
- retrospective data on investment;
- data on output, imports and exports of capital goods; and
- inquiries, mainly by sampling method[1/].

In a centrally planned economy the fixed capital stock and its development is normally subject to a very detailed system of information. In Czechoslovakia, for instance, a centralised system was introduced to

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1/ As an example can be mentioned that the US journal American Machinist sent out questionnaires to ascertain the state of machinery in the metalworking industry.

obtain information on the state and the annual changes of all machinery in engineering industry, of railway wagons, important machines in coal mining, etc.

The data collected are not only in terms of value but also of technical nature. The whole system is based on a rational computing technique (punch cards). The contents of the system can be seen from the illustrative example of a punch card on Table 19.

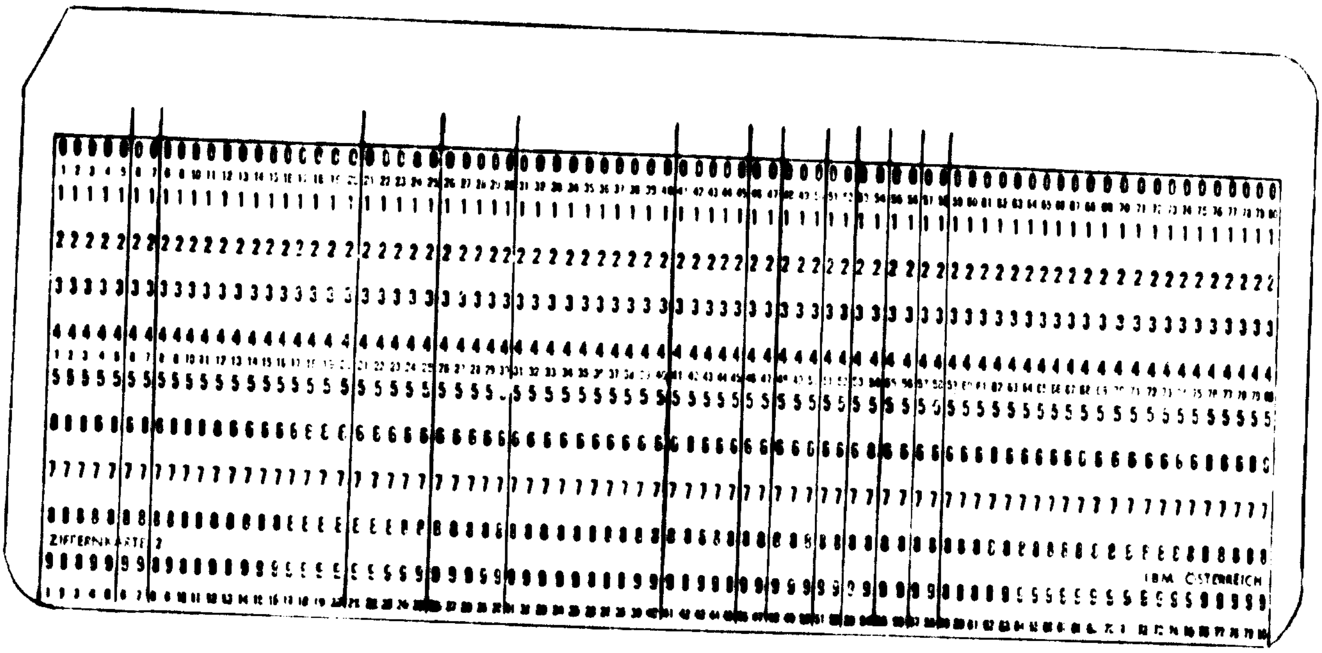
Such a detailed system of centralized information requires a whole complex of organizational prescriptions, normative definitions, classification and code numbers. This is necessary to enable the identification of a given machine and to get information about the extent and composition of machine park in different enterprises, industries, regions, etc. The system is based on primary records provided in plants according to a standard form. It becomes an efficient means for the rationalization of the information system within individual enterprises.

In all economic systems governmental tax policy requires some basic unification of recording on installed capital. Special regulations usually define the methods of the book-keeping on plants and equipment and their definition and evaluation as well as the periodical inventories.

Most problems connected with these regulations were already discussed from the point of view of plant level. A specific problem is the re-evaluation of installed plants and equipment in such cases, when the nominal values differ widely from the present real values. The process of re-evaluation of installed plants and equipment is a very expensive and complicated one. The aim of such a unified way of evaluation is to create a more reliable basis for the calculation of amortisation charges. The evaluation is based alternatively on price indices or on price lists. A new evaluation can be combined with the so-called "general inventory" (inventory of existing plants, equipment in the country, region, industry). Such measure was undertaken in 1954 in Czechoslovakia, in 1960 in the USSR.

Table 19

Description of a Punch Card for the Statistics of Installed Machines



Column	Data
0 - 5	Classification Code
6 - 7	Country of origin
8 - 20	Producer, model
21 - 25	Purchasing value
26 - 30	Weight in kgs.
31 - 40	Technical characteristics
41 - 45	Maintenance characteristics
46 - 47	Year of production
48 - 50	Central organ (industry)
51 - 52	Trust
53 - 54	Enterprise
55 - 56	Plant
57 - 58	Shop
59 -	Free columns

4. Recommendations for development strategy

Developing countries execute their industrialization programmes in the conditions of much higher investment intensity of the industrialization process than it used to be in the nineteenth century in now industrialized countries. In addition, a rather pronounced division of labour has developed between the actual operation and the maintenance of plants and equipment. That is the reason why the problems of repair and maintenance have gained such importance and consequently have become an inherent part of a sound development policy.

The lack of capacity to assure adequate maintenance and repairs is one of the reasons why some developing countries often are not capable to adopt new technologies. In such a situation even equipment provided through grants can become a burden for the receiving country.

The problem area of renewal, repair and maintenance has a number of aspects relevant for the formulation of fundamental principles which underly the setting of long-term aims of economic development:

(i) The renewal, repair and maintenance of the existing plants and equipment is one of the essential conditions for the economic development;

(ii) renewal and to a certain extent repairs represent an alternative to the building up of new capacities.

Renewal, repair and maintenance place specific demands on economic resources and they, consequently, represent an important limitation to economic development in an optimalization exercise.

The needs for renewal, repair and maintenance also determine to a certain extent a substantial part of the demand structure for commodities. We can therefore speak about a structural limitation of the process of economic development.

A certain similarity can be found between the supplies of services, spare parts and machines for renewal on the one hand and the supplies of intermediates on the other hand. Problems of repair and renewal are treated accordingly. All supplies mentioned are described in the matrix of inter-industry relationship (technical coefficients). Furthermore, renewal, repair and maintenance place specific demands on qualified labour and material supplies. In this context we can speak about a limitation of economic development from the viewpoint of available resources.

Maintenance, repair and renewal require productive factors of the same technological nature as those required by the supplies for the new investments. Essentially, the factors of engineering industries and construction are involved. Maintenance, repair and renewal thus create a competing demand in relation to the building up of new productive plants. They, in particular, need a great number of skilled personnel at intermediate levels which is the very scarce factor in developing countries.

In the conditions of severe scarcity of investment resources - both financial and material - renewal can be considered as an alternative to development. In order to concentrate investment resources on important development projects it is possible to delay the renewal of existing plants and equipment, i.e. to prolong their service life. Developing countries usually do not need to economize labour costs through innovations and modernisation of equipment in the same degree as industrialised countries. On the contrary, investment is often motivated by the aim to create additional employment opportunities. Thus abundance of labour stimulates a rational extension of the service life of the installed capital.

In developing countries the share of machinery older than 10 or even 20 years of the total equipment is rather large. This is a natural reflection of the delayed renewal of equipment in favour of extensive new investment and the increase in industrial employment.

To a certain extent it is possible to delay also major overhauls. Technical possibilities of postponing renewal and/or repair have, of course, certain technological and economic limits the trespassing of which results in the misallocation of resources.

As an example of such misallocation inefficient or too costly repairs may be mentioned. Introduction of measures limiting investment outlays on renewal may lead to the situation when the cost of overhauls become higher than the cost of purchase of new equipment.

In the persuing of an industrialization programme the modernisation and rational utilization of older machinery acquire strategic importance, since in this way the existing equipment of several industries can be adapted to the requirements of modern technology. Modernization is usually less costly (in terms of investment funds) than renewal and it facilitates the adapting of machinery to the concrete conditions of production.

Another important way of reducing investment outlays for the industrial development is the purchase and use of second-hand machines and equipment. Such a utilization of older machines can obviously be considered rational, only if the cost of their repair and modernisation is less than the cost of new machines. The application of the efficiency analysis is therefore absolutely necessary. Installation of second-hand equipment can on one hand reduce the purchasing cost, but on the other hand, it usually increases the repair and maintenance costs. Furthermore, the use of second-hand equipment generally is a hindrance to the unification of installed equipment. Efficiency considerations are therefore necessary even in cases of very favourable purchasing conditions.

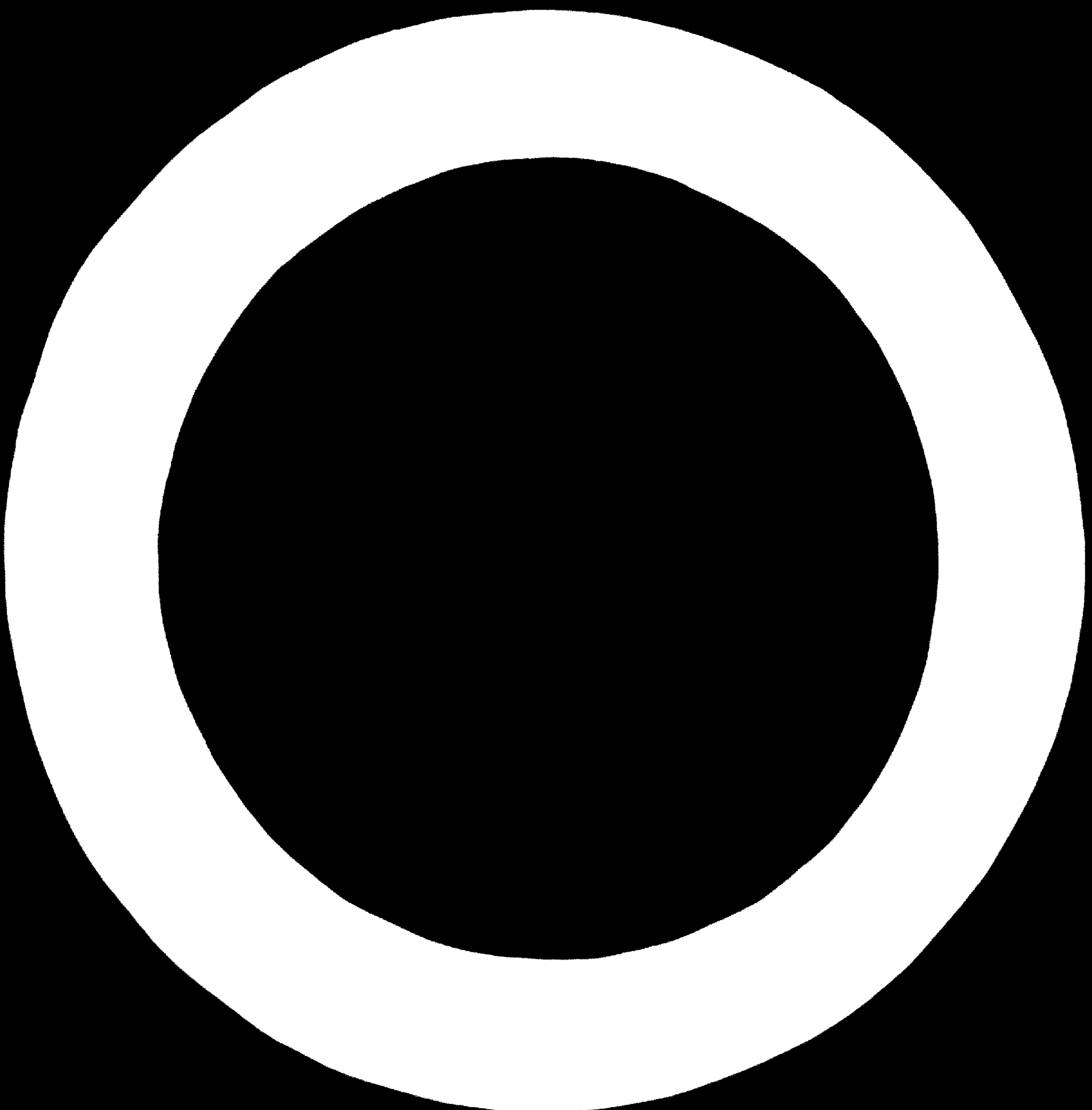
Various material and organisational preconditions are required to assure adequate maintenance, repair and renewal. These preconditions form an important part of the industrial infrastructure. A large part of this infrastructure is represented by maintenance and repair capacities of enterprises. As was discussed already in connexion with the policy measures, the building up of specialised repair shops, plants for production of spare parts and their stocks form a specific problem for the policy maker. Among the institutional conditions for facilitating a smooth operation of plants and equipment an important role is played by the whole set-up of training, consulting and research institutions.

The problem of maintenance, repair and renewal also has an impact on the time-scheduling in economic programming. The demand for renewal and/or overhaul usually arises several years after the plant and equipment had been put into operation. However, from the very beginning of the operation, an adequate maintenance and repair work is required. The conditions for assuring these services must be created from the very outset of the execution of the investment programme.

The rules governing the needs for repair (mainly overhauls) and renewal are of stochastic character. Most of the requirements appear after a period corresponding approximately to the average service life of given equipment and its parts. The necessity to have maintenance and repair capacities installed from the beginning is enhanced by the frequent incidence of the so-called infant-illnesses of the equipment.

The time-scheduling must include the advance training of an adequate number of repair and maintenance workers and lubrication specialists. Approximately half of the number of these workers must be available during the running-in periods of equipment. Analogically, the primary stock of spare parts and maintenance materials must be available from the very beginning.

Finally, it can be mentioned that maintenance and repair activities can be viewed upon as the natural basis for the development of domestic engineering industries.



Appendix I

A SYSTEM OF INDICATORS FOR PLANNING REPAIR

The simplified example of a repair plan represents a system of the most important indicators reflecting the interrelationships between needs and resources of repair activities. The data are obtained from empirical studies 1/.

The repair needs are here calculated for various types of plants and equipment, which differ in the intensity of repair or in the labour or material requirements. The following example classifies four groups of plants and equipment:

(i) machinery

(ii) electro equipment

(iii) measuring devices

(iv) buildings and constructions.

The necessary resources are classified as follows:

(i) labour inputs:
- repair workers
- technical and administrative personnel

(ii) material inputs:
- spare parts (flows and stocks)
  - produced in own workshops
  - external deliveries
- other materials (flows and stocks)

(iii) external repairs (services delivered from outside)

1/ The studies were undertaken in the Czechoslovak chemical industry.

The final balance of the requirements for repair against resources is obtained on the basis of cost calculation.

Under "preconditions" we understand here a system of standards which form the basis of a repair plan and which define:

(i) the relative needs of repairs for the different categories of fixed assets

(ii) the relative inputs of labour and material

(iii) the relative volume of stocks of spare parts and materials, and

(iv) the degree of self-sufficiency of the enterprise or industry in repair services and production of spare parts.

The determination of these standards is based on thorough analyses which preceed the actual planning process.

The example is meant to cover a period of up to 5 years. It can be applied both for an individual enterprise and for more aggregated units. According to the length of the plan period and the level of planning, the needs and resources for repair can be disaggregated. Thus, the needs can be divided according to different kinds of machines, different kinds of repairs, etc. The classification of spare parts and material inputs can be done according to technological, organisational or other criteria.

A PLAN OF REPAIR

Table I/1

Item	Indicator	Unit	Total	Machinery	Electro equipment	Apparatus	Construction
	I. PRECONDITIONS						
A	Value of fixed assets	1000 $	50000	24500	5000	3000	17500
B	Cost of repairs related to the value of fixed assets	%	x	8.0	7.0	12.0	1.3
C	Degree of repair self-sufficiency	%	x	70.0	70.0	60.0	20
D	Degree of self-sufficiency in the production of spare parts	%	x	25.0	20.0	15.0	x
E	Annual volume of repair per repair worker	1000 $	x	8.0	7.0	8.3	5.5
E'	Volume of fixed assets per repair worker	1000 $	x	100.0	100.0	70.0	440.0
F	Annual consumption of spare parts per 1000 $ of fixed assets	$	x	14.3	10.4	16.2	x
G	Annual consumption of materials per 1000 $ of fixed assets	$	x	4.1	5.6	7.0	0.9
H	Stock of spare parts per 1000 $ of the fixed assets	$	x	21.5	18.7	26.0	x
H'	Stock of spare parts in relation to the annual consumption	years	x	1.5	1.8	1.6	x
I	Stock of material per 1000 $ of fixed assets	$	x	4.1	5.6	7.0	0.6
I'	Stock of material in relation to annual consumption	years	x	1.0	1.0	1.0	0.7
J	Average wage of repair workers per year	$	x	2680	2490	3080	2000
K	Overhead costs in relation to wage costs	%	x	100	90	80	70
L	Technical and administrative staff in relation to the number of workers	%	x	18.0	16.0	17.0	12.0
	II. CALCULATION OF THE VOLUME OF REPAIR ACTIVITIES						
a	Total cost of repair per year $(A\cdot\frac{B}{100})$	1000 $	2900	1960	350	360	230
b	Cost of repairs realized with own capacities $(a\cdot\frac{C}{100})$	1000 $	1875	1370	245	215	45
c	External repairs value $(a-b = a\cdot\frac{100-C}{100})$	1000 $	1025	590	105	145	185

Table I/1 (cont.)

Item	Indicator	Unit	Total	Machinery	Electro equipment	Apparatus	Construction
	III. CALCULATION OF THE NUMBER OF REPAIR WORKERS						
d	Number of repair workers $(b.E = \frac{A}{E} \cdot \frac{C}{100})$	Persons	241	172	35	26	8
e	Technical and administrative personnel $(d \cdot \frac{L}{100})$	Persons	42	31	6	4	1
f	Total number of repair personnel (d + e)	Persons	283	203	41	30	9
	IV. CALCULATION OF THE SPARE PARTS AND MATERIALS						
g	Annual needs of spare parts $(A \cdot \frac{F}{1000})$	1000 $	451	350	52	49	x
h	Annual needs of materials $(A \cdot \frac{G}{1000})$	1000 $	164	100	28	21	15
i	Total spare parts and material (g + h)	1000 $	615	450	80	70	15
j	Own production of spare parts $(g \cdot \frac{D}{100})$	1000 $	105	88	10	7	x
k	External purchases of spare parts (g-j)	1000 $	346	262	42	42	x
l	Stock of spare parts $(A \cdot \frac{H}{1000} = g.H')$	1000 $	698	527	93	78	x
m	Stock of materials $(A \cdot \frac{I}{1000} \cdot \frac{C}{100} = h.I')$	1000 $	159	100	28	21	10
n	Stock of spare parts and materials (l + m)	1000 $	857	627	121	99	10
	V. COST CALCULATION						
o	Labour costs per year (d.J)	1000 $	643	460	87	80	16
p	Material and spare parts costs (i)	1000 $	615	450	80	70	15
q	Overhead costs $(o \cdot \frac{K}{100})$	1000 $	614	460	78	65	11
r	Total costs (o + p + q = b)	1000 $	1872	1370	245	215	42

(Differencies because of rounding)

Appendix II

A MODEL FOR THE ANALYSIS AND PLANNING RENEWAL

The analysis of renewal requirement is a specific problem on the over-plant (sectoral, nationwide) level and in the long-term prospects. The following model is introduced here to highlight this problem. The data used for this model result from empirical studies in the metal-working industry [1] and they can therefore serve not only as a methodological instrument, but also as an actual illustration to the described rules governing the development of a system of plants and equipment.

The aim of the model is to enable a quantitative analysis of the volume of renewal of a system of plants and equipment, such as a park of machine tools, looms or a fleet of vehicles. The whole set-up of plants and equipment is usually far from being homogeneous. Therefore, special attention is being paid to the problem of the structure of plants and equipment and its changes as well as to the impact of these changes on the volume and composition of renewal requirements.

The calculation of renewal requirements is based both on the physical terms and on money value terms.

Renewal requirements in physical terms

The volume of requirements for renewal, expressed in physical units (e.g. number of machines) depends on the following factors:

(i) the length of period to be considered

(ii) the size of the plant and its growth

(iii) the age composition of the plant and the equipment

(iv) the service life.

The availability of data on the volume, the rate of growth, the age and the service life is thus the precondition for an analysis of the

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1/ Nesvera, Rozvoj technicke zakladny strojirenstvi, Prag, SNTL, 1963 renewal requirements. The model describes the interrelationships of these data and their utilization for an analysis (see Table II/1).

Special attention must be paid to the characteristics of the service life. For an analysis of the requirements for renewal the information on the average service life is not sufficient. Empirical analyses show that the service life of individual items can substantially differ from the average, since the process of renewal is of a stochastic nature. A precise calculation must therefore be based not only on data of the average service life, but also on data on the survival curve (Fig.II/A).

The survival curve describes the pace of discarding the number of machines installed in a given time. Based on this curve the number of machines of various age groups which are to be discarded during the plan period can be estimated. According to the "rate of discarding" in the Table II/1, about 12 per cent of the initial number of installed machines which at 1.1.1960 reached the age of 11-15 years were discarded during the following five years. There are substantial differences in the intensity of discarding the machines in the individual age groups. About 10 % survive the age of 50 years. In the given case the average service life of the machines - determined as a median to the survival curve (age at which 50 % of the original number has been discarded) - is 27.5 years.

In the given case the requirements for renewal which are considered to be identical with the number of machines discarded, during the years 1961-1965 is 1378.

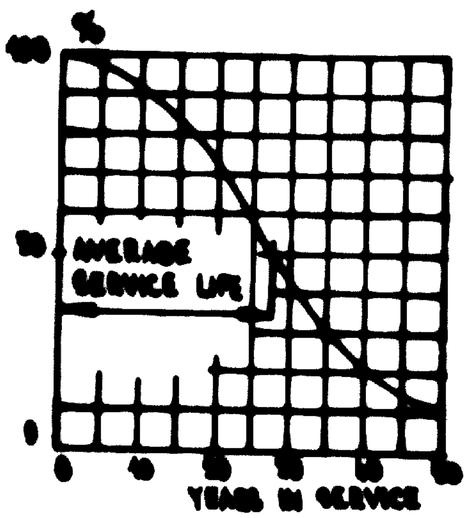
This illustrates how far from reality the results of the planning of future needs can be if it is based on the age composition and estimates of a "normal" service life.

In this scheme the analysis and projection of the survival curve is the basis on which the number of discarded machines and the volume of necessary renewal is being determined (the number of machines and their age composition being given).

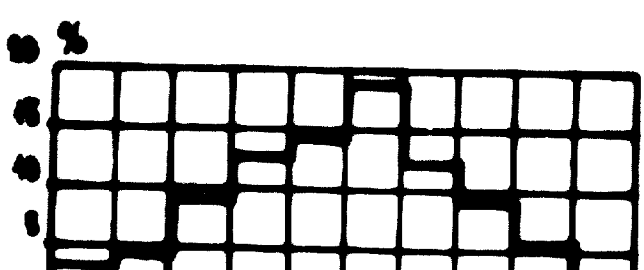
The model enables a follow-up of structural changes. These changes can then be taken into consideration for analysing the needs of renewal.

Renewal, as a part of rational investment policy, plays an important role in the process of technical innovations.

In the example an important trend of changes in the structure of machines is shown in the case of grinding machines. These machines are characterised firstly by their increasing number within the total installed machine tools (from 20.0 % in 1961 to 22.8 % in 1965) and, secondly, by their relatively short service life (cf. the higher rates of discarding). The share of these machines in the number of new machine tools was about twice as high as their share in the total number of installed machines (see Table II/1).



Gradual decrease in the number of installed machines and their average service life (survival. curve)



Number of discarded machines in individual periods of utilisation (expressed as a percentage of the number of originally installed machines)

Renewal requirements in the money value terms

The requirements for renewal of plants and equipment are more often calculated on the basis of value terms, derived from investment outlays. Two alternative concepts are possible:

- gross values (purchase cost); and
- net values (purchase cost reduced by the amortization charges).

If the calculations are based on the gross value of installed plants and equipment, the length of the plan period, the volume of fixed assets and the age and service life must be considered. In addition, the changes in purchase cost of the physical items must be included in the calculations. Empirical analyses show that generally the money value of plants and equipment increases in a higher rate than their physical volume (expressed in the number of machines, extent of floor space, etc.). This is due to the improvements of the technical parameters, to changes in the composition, etc. Thus, in Table II/2 the average purchase cost of new machine tools was trebled during 1930-1965 (in terms of constant prices). The number of installed machine tools increased in a 5 year period by about 9 per cent, whereas their value increased by 25-30 per cent.

Under these circumstances, the requirements for renewal which are identical with the volume of discarded machines are low. The average value of discarded machines amounts roughly to the cost of machines which were purchased before the period corresponding to their average service life.

In the case of machine tools park, the number of yearly discarded machines represented 2.5 - 3 per cent of installed machines, in terms of value it was about 2 per cent only. This example shows a further rule: the service life of machine tools is positively correlated with their average value, the service life of more expensive machines is in average longer.

If the requirements for renewal are calculated on the basis of the net value of plants and equipment, they are identified through the depreciation charges. The renewal requirements thus depend on the value of plants and equipment (amortisation basis), on the method of depreciating and - of course - on the length of the plan period. The money value of depreciation charges usually exceeds the real value of renewal requirements. The reason for this is that the depreciation charges are calculated from the very beginning of the functioning of plants and equipment, while the real requirements for renewal follow with a considerable time-lag. This lag thus plays a big role, especially in the case of a high rate of growth of the fixed assets. It must also be mentioned that tax considerations generally dominate the depreciation rate and that it is very problematic to use the depreciation charges or net value of fixed assets as the basis for calculating the service life and the requirements for renewal.

The different concepts of calculating the requirements for renewal lead to different results. For establishing a realistic renewal policy it is recommended to use the system based on physical terms. This system of indicators makes it possible to confront the state of plants and equipment with the technical innovations and changes on the market. Innovations are after all to be considered as the primary motives and impulses for renewal.

Table II/1

AN ILLUSTRATIVE MODEL FOR THE ANALYSIS OF RENEWAL IN PHYSICAL TERMS

	Total	Age of capital means in years: to 5	6–10	11–15	16–20	21–25	26–30	over 30
Total number of MACHINE TOOLS (1.1.1961)	10000	2200	1900	1300	2300	1200	500	600
Rate of discarding (5 years)	x	3.8	6.4	11.6	17.0	25.8	31.4	27.7
Number of discarded machines (1961–1965)	1378	83	122	151	390	309	157	166
Gross increments - new machines (1961–1965)	2248							
Total number of machine tools (31.12.1965)	10870	2248	2117	1778	1149	1910	891	777
Number of GRINDING MACHINES (1.1.1961)	2000	770	510	310	210	110	50	40
Rate of discarding (5 years)	x	13.0	28.0	27.9	27.1	27.3	28.0	27.5
Discarded machines (1961–1965)	450	100	143	95	57	30	14	11
Gross increments (1961–1965)	930							
Number of grinding machines (31.12.1965)	2480	930	670	367	215	153	80	65

Percentage of grinding machines

- in total number of machine tools (1.1.1961) 20.0
- in total number of machine tools (31.12.1965) 22.8
- in gross increment (1961–1965) 41.4

Table II/2

ILLUSTRATIVE MODEL FOR THE ANALYSIS OF RENEWAL IN TERMS OF VALUE

	Total	Age of capital means in years						
		to 5	6–10	11–15	16–20	21–25	26–30	over 30
Number of machine tools INSTALLED (1.1.1961)	10000	2200	1900	1300	2300	1200	500	600
Their purchasing value ($ million)	42.61	13.20	9.12	5.55	3.95	3.25	1.15	1.39
Average purchasing value of a machine (1000 $)	4.26	6.00	4.80	4.27	3.89	2.71	2.30	2.32
Number of machine tools DISCARDED	1378	83	122	151	390	309	157	166
Their purchasing value ($ million)	4.36	0.25	0.47	0.60	1.48	0.82	0.36	0.38
Average purchasing value of machine (1000 $)	4.00	2.97	3.83	3.97	3.80	2.66	2.27	2.30
Number of machine tools NEW	2248							
Their purchasing value ($ million)	16.03							
Average purchasing value (1000 $)	7.13							
Number of machine tools INSTALLED (31.12.1965)	10870	2248	2117	1778	1149	1910	891	777
Their purchasing value ($ million)	54.29	16.03	12.95	8.65	4.95	7.47	2.44	1.80
Average purchasing value (1000 $)	4.99	7.13	6.09	4.86	4.31	3.91	2.74	2.32
PERCENTAGE AGE STRUCTURE								
– of the number of machines (1961)	100,0	22.0	19.0	13.0	23.0	12.0	5.0	6.0
– of the value of machines (1961)	100.0	31.0	21.4	13.0	21.0	7.6	2.7	3.3
– of the number of machines (1965)	100.0	20.7	19.5	16.4	10.6	17.6	8.2	7.1
– of the value of machines (1965)	100.0	29.5	23.9	15.9	9.1	13.7	4.5	3.3

74.10.18