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THE ROLE OF MAINTENANCE AND REPAIR FOR THE ECONOMIC DEVELOPMENT OF THE MANUFACTURING INDUSTRY[1/]

by

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I. EXAMINATION OF THE PROBLEM

1. The Importance of Maintenance and Repair for Economic Development

A. The situation of maintenance and repair in developing countries

One of the characteristics of developing countries is the great scarcity of capital. It should be expected, therefore, that capital goods in these countries are maintained better than in industrially developed nations which have a relative abundance of capital goods. Besides, the natural conditions in many developing countries call for special care of machinery and structures: tropical climate, extremely high or low humidities pose their own maintenance problems unknown in temperate zones.

Unfortunately, the actual situation is anything but adequate to the conditions prevailing. Since many years, experts have stressed the lack of proper maintenance and repair in developing countries. In 1958, Hirschman wrote in his Strategy of Economic Development:

> "This is perhaps one of the most characteristic failings of underdeveloped countries and one that is spread over the whole economic landscape. Eroding soils, stalled trucks, leaking roofs, prematurely run-down machines, unsafe bridges, clogged-up irrigation ditches - all testify to the same pervasive and paradoxical trait: the inadequate care for existing capital in capital-poor countries." 1

In the same year, the United Nations Secretariat stated:

> "Because of inadequate maintenance, industry in many underdeveloped countries suffers from an unduly high rate of depletion of capital assets and a chronic waste of production

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1 Albert O. Hirschman, The Strategy of Economic Development, Yale University Press, New Haven and London, Tenth Printing (Paperbound), 1966, p. 141.

> capacity which even economically stronger countries could hardly afford." 1

The situation has hardly changed since this was written. The same complaints about neglect of maintenance and inadequacy of spare parts supply which were made in a report of United Nations Technical Assistance Experts in 1959 [2] reappear in a case study of the steel industry in a developing country, published in 1966 [3]. So the United Nations Secretariat's suggestion for urgent action made in 1958 has nothing lost of its topicality:

> " The attention of governments and industry is drawn to the urgent need for adopting proper maintenance methods and practices, and to establish proper facilities for training of maintenance personnel." 4

The lack of proper maintenance practices has serious consequences for the economic development. Possible losses in production and growth resulting from, and possible gains forgone by, inadequate maintenance and repair are the subject of the following section.

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1 United Nations, Management of Industrial Enterprises in Under-developed Countries, para. 84, as cited in Industrialisation and Productivity, Bulletin 2, United Nations, Department of Economic and Social Affairs, New York, March 1959, p. 55.

2 "Some Problems of Industrial Management Reported by Technical Assistance Experts", Industrialisation and Productivity, Bulletin 2, United Nations, Department of Economic and Social Affairs, New York, March 1959, pp. 53-57.

3 William A. Johnson, The Steel Industry of India, Harvard University Press, Cambridge, Massachusetts, 1966, pp. 174 ff.

4 United Nations, Management of Industrial Enterprises in Under-developed Countries, op.cit., as cited in Industrialisation and Productivity, Bulletin 2, op.cit., p. 57.

B. Possible losses in production and growth due to poor maintenance and repair

a) Destruction of equipment

The most eye-catching loss caused by poor maintenance or inadequate repair is the premature deterioration or total destruction of productive capital. The already cited report of the United Nations Technical Assistance Experts mentions numerous instances of "equipment being allowed to deteriorate beyond repair and having to be replaced".[1] Negligence in the maintenance of buildings and structures can cause - in addition to direct losses - secondary damages to the machinery that is unadequately protected.

Since capital is scarce in developing countries, the relative importance of capital destructions is much greater than it would be in an industrialised country. Thus, the marginal impact on growth is likewise greater.

b) Production losses

Deterioration or destruction of equipment leads to losses in production. These losses are twofold: a falling-off in product quality and frequent disruptions of the production process (or even a combination of both).

Undetected or unredressed wear and tear of machinery, or lack of care for control devices, typically results in deterioration of product quality. In other cases, inadequate maintenance or incompetent repair causes frequent breakdowns of machinery leading to disruptions in the production process. During downtimes, when the production factors do not render productive services, wages of idled labour and capital cost for idled equipment still

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1 "Some Problems of Industrial Management Reported by Technical Assistance Experts", op. cit., p. 55.

have to be paid. The consequent effects are enhanced if the repair cannot be carried out, or the spare parts cannot be delivered, immediately. The economic penalty for stoppage of operation is highest in continuous process-type industries. The cost of interruption to operations is lower in the case of fabrication or assembly of discrete units.[1]

e) Induced (secondary) losses

Primary production losses caused by poor maintenance and repair have negative effects on those firms which are customers of the firm in question.

Poor quality of intermediate goods deteriorates the quality of the final products as well - or requires additional treatment or processing by the final manufacturer. If the quality is so poor that the material cannot be used at all but is still passed on to the customer, the waste is even greater because of needless haulage by railways or trucks.[2] Again, it should be mentioned that the losses through waste impair economic growth and development relatively more in a developing country, where resources are particularly limited and the industrial sector is only small.

Frequent breakdowns of machinery which reduce the output of a firm or industry, or lead to irregular deliveries, also affect the industry that is supplied by these products. Here, too, disruptions in production may become unavoidable. In order to reduce their dependency on unreliable suppliers and, thus, to keep their production flow more constant, it has become common practice with many firms to keep - normally unnecessary - high stocks of intermediate products. This, of course, is an uneconomical tying up of scarce capital and hence a waste of resources, too.

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1 Cf. "Better Way to Compare Your Plant's Maintenance Practices", Factory, Management and Maintenance, August 1958, p. 140.

2 Cf. W.A. Johnson, op. cit., p. 163.

The construction industries illustrate particularly well the case of induced losses. Negligence in the maintenance of construction equipment brings about delays in the completion of buildings and structures. If important industrial projects are concerned, this delay will cause new delays and inconveniences in the "interrelated" industries; the set-back in programmed industrial performance, i.e. in the implementation of the nation's economic plan, will alltogether be multiplied.

Other induced losses occur because of bottlenecks in the supply of spare parts, be it that their import is restricted or that their shipment is just impossible without lengthy delays.[1] The consequence is that many firms try to hold an abnormally large stock of spare parts. From the individual firm's point of view, this is an absolutely rational policy, but for the overall national economy this is a waste of resources detrimental to growth; it might be overcome by a revision of the country's spare part supply policy.

d) Disguised losses

It is well-known today that in many developing countries installed capacities are under-utilized.[2] It is less known that excess capacity quite often disguises inadequate maintenance, at least temporarily. The breakdown of an ill-kept machine need not disrupt the firm's production process: a switch-over to idle equipment is an often used device. Only if the practice of poor maintenance and incompetent repair is continued over a longer period of time, deterioration and frequent breakdowns of the whole set of equipment will become apparent.

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1 Cf. e.g. "Some Problems of Industrial Management Reported by Technical Assistance Experts", op. cit., pp. 55-56.

2 Cf. eg. Under-utilization of Industrial Capacity, National Council of Applied Economic Research, New Delhi, 1966, esp. pp. 44-49.

The cannibalisation of machines also belongs to the category of disguised losses due to excess capacity: parts are stripped from idle machines in order to obtain the spares needed for broken machinery. Again, this can only be a short-lived practice averting from the real problem: shortcomings in the country's development policy to provide for an adequate supply of spare parts, and, as a consequence, uneconomic investment decisions on the part of the single firm.

Deterioration and delays in delivery can be disguised in a situation generally described as a seller's market. Producers are able to dispose of poor-quality products - at any time - where there is a serious shortage of supply. The situation is not unfamiliar to developing countries where tariffs or quotas bar the import of competing goods. Poor performance is particularly well disguised if the product allocation is no longer left to the market forces of supply and demand, but is replaced by an administrative distribution system which forces consumers to purchase from firms not necessarily of their own choosing.[1] Here, consumers will have to accept whatever quality is made available at whatever time.

e) Foreign exchange losses and damage to good will

The developing countries generally have to import most of their industrial equipment for investment and most of the spare parts to maintain this equipment. Inadequacy of maintenance makes it necessary to replace parts excessively often, sometimes even to exchange the whole machine before it reaches its normal service life. This implies an unnecessary loss in foreign exchange; it is an absurd situation in countries which suffer notoriously from severe shortages in hard currencies.

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1 Cf. W.A. Johnson, op. cit., pp. 158, 162.

Possible losses on the export side should not be overlooked, either. The supply of poor quality products and lengthy times of delivery are badly suited to gain export markets. Once the deterioration of quality has been realized, future exports might become jeopardized. The "MADE IN ..." mark of origin may lose its attraction, and the loss of confidence need not remain confined to the actual low-quality product; it may just as well affect other export products of the country. The loss of prestige might become so serious that not even expensive marketing campaigns abroad or participation in international trade-fairs will fully restore it.

2. Optimal Maintenance and Repair Activities of a Country: A Theoretical Analysis*

A. The effects of differences in the interest rate

a) Longevity, durability outlays and maintenance outlays

Maintenance and repair costs can be conceived as outlays aimed at extending the service life of the equipment which occur only after the equipment has been installed and began to operate. Spending on maintenance is only one way to extend the service life, the "longevity" of capital goods. The other way is spending on higher quality at the time of purchase of the capital good, so that it is less prone to wear and tear. Longevity outlays can thus be broken down, as suggested by Blitz[1], into durability outlays and maintenance outlays. Both are interrelated and are to be considered together.

Durability outlays are made for the built-in enduring quality of a capital good. The price of higher durability can be compared with the cost of maintenance of initially less durable equipment which can only reach the same longevity if it receives better care and if parts are changed more often.

It should be pointed out that the variations in durability are assumed for equipment having the same operating characteristics.[2] Whereas greater durability could be reached by dispensing with accuracy of operation, speed, versatility, complicated control devices of a machine - in short: by simpler construction and hence at a cheaper price - the operating characteristics of the machine would thus be altered. On the other hand, greater durability

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1 Rudolph C. Blitz, "Capital Longevity and Economic Development", The American Economic Review, Vol. 48, No. 3, June 1958, pp. 313 ff. - Rudolph C. Blitz, "Maintenance Costs and Economic Development", The Journal of Political Economy, Vol. 67, 1959, pp. 560 ff. (In the following cited as: AER, 1958, resp. JPE, 1959.) - The discussion in this paragraph has benefited particularly from this author.

2 Cf. W. Paul Strassmann, Technological Change and Economic Development, Cornell University Press, Ithaca, N.Y., 1968, pp. 195 ff.

* A graphical presentation is given in the Appendix.

for equipment of the same kind is only possible by making it more expensive: by choosing better materials, a costlier construction, by assembling the parts more carefully and inspecting the work more often and more thoroughly. Thus, greater durability has its price.

To get a certain desired longevity of equipment, a firm can spend more on durability and less on maintenance, or vice versa. Generally a mix of both, durability and maintenance outlays, is needed. In an extreme case, longevity can be obtained by spending only on durability, without any maintenance.[1] On the other hand, it is not possible to get longevity only by maintenance; some durability outlay is always required.

Blitz draws an analogy to the factors determining the lifespan of a human being: "This initial durable endowment is to be conceived as similar to the innate physical endowment of a human being; on the other hand, maintenance expenditures are analogous to subsequent efforts of doctors to extend longevity." 2

Within the a.m. limits which are imposed by technical constraints, a substitution of maintenance outlays for durability outlays is possible. For every investment the optimal combination of both kinds of outlays is to be defined. The optimal combination is that which, for any assumed longevity, minimizes the total cost of longevity.

b) The influence of the interest rate on the combination of durability and maintenance outlays

Durability outlays occur immediately at the time of the initial investment. Maintenance outlays are to be made only in the future. To compare both, the future costs of maintenance have to be discounted to the present, using the given rate of interest. The level

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1 This is possible in the case of capital goods such as buildings, etc. For example: more expensive construction material is used which need not be painted, instead of a cheaper material which has to be painted periodically to reach the same longevity.

2 R.G. Blitz, JPE, 1959, p. 561.

of the interest rate will influence the present value of the maintenance costs occurring in the future: Discounted at a higher (lower) interest rate the present value of future costs will be less (higher). In other words: The amount of money to be put out at interest now, can be lower if the interest rate is high; it has to be higher if the interest rate is low.

Assume two countries, one having a relatively low, the other one having a relatively high, interest rate. The equipment invested and the maintenance techniques are supposed to be identical in both countries, and it is also assumed that the future price of a "maintenance unit" (labour plus materials) is the same in both countries. The same technical combination of durability and maintenance contains, in the high interest country, a lower present value of future maintenance outlays. That is, the present sum of money that is necessary for maintenance outlays in the future is lower because the interest rate is high. The same longevity can be reached , in the high interest country, at a lower present cost.

A technical combination of durability and maintenance which results in minimal total outlays for a given longevity in a low-interest country is, however, not the optimal policy under the different conditions of a high-interest country. Since in the latter country the factor "maintenance" is relatively cheaper than the factor "durability", economic rationality requires to buy relatively more maintenance and relatively less durability than is optimal in the former country. The minimal-cost combination of durability and maintenance for any given longevity is thus, in the high-interest country, not only at a lower level of total (present) costs than in the low-interest country (price effect); it reflects also another combination of the two cost ingredients: relatively more will be spent on maintenance and relatively less on durability, compared to the low-interest country (substitution effect).

Hence follows the first recommendation for an optimal policy: Provided that all other things are equal, the country with a higher

interest rate should spend more on maintenance and less on built-in durability to obtain a given longevity, than the country where capital is available at a cheaper rate.

c) The influence of the interest rate on the longevity chosen

So far our analysis started from the assumption that the longevity of the equipment was given, and the question was which mix of durability and maintenance would be optimal to obtain this longevity. Now we ask which longevity will be chosen. The decision, again, is influenced by the prevailing interest rate.

In determining the optimal longevity of equipment at the moment when the investment decision is made, two factors have to be taken into consideration. One is the cost of additional longevity, the other are the "savings" which result from postponing the capital replacements in the future.[1]

Suppose that a machine of higher longevity is chosen for initial investment. It follows that we have an increment in cost, but the next and all successive replacements can be postponed by the increment in lifetime. Postponing all future replacements brings about a stream of "savings". These savings may be considered as a capital gain or a marginal revenue of increased longevity. The present value of this stream of future savings can be determined by discounting it at the prevailing interest rate.

The capitalized value of the savings has to be compared with the increment in cost caused by the greater longevity. It is economical to choose a higher longevity - and thus to increase the total cost of longevity - as long as the marginal revenue of longevity is greater than the marginal cost of longevity. The optimum is reached when the capitalized value of the stream of savings equals the increment in cost for higher longevity. At this point the sum of the

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1 Cf. R.C. Blitz, AER, 1958, pp. 314 ff. - W.P. Strassmann, op. cit., pp. 195 ff.

cost of the initial investment and the discounted values of all future replacements is a minimum.[1]

The interest rate has a decisive influence on this computation. The present value of the stream of future savings will be less if it is discounted at a higher interest rate. If the savings are smaller, the increment in cost of longevity has to be smaller. It follows that the optimal longevity will be shorter if the interest rate is higher.

All other things being equal, the optimal choice of capital longevity in the country with a relatively higher interest rate would thus be a lower capital longevity compared to the country where the interest rate is relatively low.

d) The combined effect of the interest rate: level and structure of longevity

In section b) and c), the effects of differences in the interest rates were analysed separately. Now the combination of the effects is examined.

The longevity impact of a higher interest rate is a combination of two effects on the level and on the structure of the longevity of equipment. The effect on the structure of longevity (the mix of durability and maintenance) always has an unequivocal direction, towards more maintenance (cf. section b). The effect on the level of longevity (i.e. the longevity chosen) consists of a direct tendency towards shorter lifetimes of capital goods (cf. section c), combined with an indirect effect via the substitution of maintenance for durability. The indirect effect goes into the opposite direction: it lowers total cost of longevity (cf. section b) and therefore curbs the tendency towards shorter lifetime. The change

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1 For a mathematical treatment see: Fred M. Westfield, "A Mathematical Note on Optimum Longevity," The American Economic Review, Vol. 48, No. 2, June 1958, pp. 329-332.

in direction of the level of longevity is, therefore, not determinable on a priori grounds. It is likely that the direct incentive to shorten longevity will not be counteracted entirely by the a.m. indirect effect.

This is assumed because of the following consideration: All savings occur in the future, and therefore the interest rate affects the savings in toto. As to the cost aspect, only part of the longevity mix, viz. expenditure on maintenance, will occur in the future. So, the fact that the interest rate is higher will affect only part of the cost side. Thus, the impact on the savings side should be greater. The higher the share of maintenance costs in total longevity costs, the less the longevity will be reduced by impact of a high interest rate.

All other things being equal, the country with a relatively high interest rate should tend to reduce the longevity of its capital goods. However, if the country can rely heavily on maintenance (and less on built-in durability) in order to obtain a desired longevity, the optimal policy would be to realize this substitution as far as possible; then longevity will not be reduced very much - in the extreme case, it may remain almost unaltered.

B. The effects of differences in the wage rate

Up to this point, the analysis was concerned with the isolated effect of differences in the interest rate, resulting in differences in the present (discounted) value of future costs and revenues. It was assumed that the technical composition of a "maintenance unit" as well as the future price of such a unit were identical in either country, regardless of whether the countries had high or low interest rates. This assumption is now dropped.

Differences in the interest rate between two countries - if we disregard distortions of the market forces by political interventions - reflect differences in the factor endowments in these countries. A high interest rate indicates a relative scarcity, a low interest rate, a relative abundance, of capital. A relative scarcity of capital corresponds to a relative abundance of labour, and vice versa. That is why a country with a relatively high interest rate will have a relatively low wage rate, and a country with a relatively low interest rate will have a relatively high wage rate.

Differences in the wage rate influence the (future) value of maintenance costs. Suppose that the same techniques for maintenance and repair are applied in either country, the maintenance wage per hour, and therefore the total cost of maintenance, will be less in the low-wage country.

Now, maintenance and repair costs are not composed only of wage outlays but also of outlays for spare parts, tools, materials, mechanical aids. To a certain degree a substitution between labour and capital is possible: maintenance work can be done with more or less mechanical aid; repair may be more or less labour-intensive depending upon whether a broken part, or a whole aggregate, is replaced by a new one or fixed again.

If the price of maintenance capital is the same in both countries, economic rationality should induce the low-wage country to substitute labour for capital in maintenance and repair activities; and all the more so if the price of maintenance capital in the low-wage country is relatively higher. In the ideal case, this substitution would take place until the marginal costs of labour and capital were equal to one another and to their marginal products. The substitution of relatively cheaper maintenance labour for maintenance capital will result in an even greater reduction of total (future) maintenance costs.

The same longevity can be obtained at a considerably lower (discounted) cost; or by spending the same amount, the low-wage/high-interest country can obtain a higher longevity than the other country. In other words, a reduction in total cost of longevity, induced by the high interest rate, is possible without reducing longevity, perhaps even extending it.

The conclusion drawn in section A.d ought to be modified now, taking into account the influence of wage differentials: The combined effect of a high interest rate and a low wage rate will make

it economically optimal for a country to choose a greater capital longevity than a low-interest/high-wage country. The higher longevity should be achieved by substituting maintenance for durability and, in addition, by choosing maintenance techniques which are more labour-intensive. On the other hand, the optimal policy for a country with a low interest rate and a high wage rate would be to choose equipment of less longevity, to spend relatively more on built-in durability than on maintenance, and to apply capital-intensive maintenance techniques.

C. The effects of differences in the price of capital goods

If the capital goods which two countries invest, and some of the "maintenance capital" (e.g. spare parts) which is used in both, are produced only in one of the countries, viz. the low-interest/high-wage country, it is most likely that the price of these capital goods will be higher in the other country which has to import these goods: Transportation cost and customs duties will raise the price.

It has already been pointed out in section B that a higher price of maintenance capital will reinforce the, already existing, tendency in the high-interest/low-wage country to substitute maintenance labour for maintenance capital. A higher price for investment will also make the (initial) capital expenditure on built-in durability less attractive.

D. The combined impact of differences in interest rates, wages, and prices of capital goods.

a) Conclusions

The combined impact of differences in interest rates, wages, and prices of capital goods between two countries can now be summarized:

Suppose there are two countries: country A has a relatively low interest rate, a high wage rate, and low prices for capital goods; country B has a relatively high interest rate, a low wage rate, and high prices for capital goods. Under these assumptions it is optimal for country A to invest in capital goods of a relatively short lifetime, to obtain the chosen longevity by spending relatively more on built-in durabilit, and less on maintenance, and to carry out the indispensable maintenance and repair work by relatively capital-intensive methods. The optimal policy for country B would be to choose capital goods of a relatively long service life, to obtain this longevity by spending less on built-in durability and more on maintenance, and rely for the maintenance and repair activities on relatively more labour-intensive techniques.

b) A numerical example

The preceding analysis can be illustrated by a numerical example computed by the United Nations Bureau of Economic Affairs. (Cf. table 1.) The example compares the average yearly costs of depreciation and maintenance for a nitrogenous fertilizer plant in the United States and in Central America. Alternative lifetimes of 10 and 15 years are assumed in both regions. The computation does not take into account differences in interest rates but gives due weight to wage and price differences.[1]

It is assumed that the extension of longevity of the fertilizer plants can be achieved by increasing the outlays on maintenance and repair. According to the practice in the United States, maintenance costs are equally divided between labour cost and outlays for spare parts. Plant equipment and spare parts are only produced

1 For another example cf. "Use of Industrial Equipment in Underdeveloped Countries: Problems of Maintenance, Repairs, Replacement and Obsolescence", Industrialisation and Productivity, Bulletin 4, United Nations, Department of Economic and Social Affairs, New York, April 1961, pp. 33-36.

Table 1: Comparative cost data on depreciation and maintenance for a nitrogenous fertiliser plant with alternative lifetimes of 10 and 15 years. United States and Central American
(Thousands of U.S. dollars, per year, per one million dollars of investment in the United States)

	United States		Central America			
			Same techniques in MAR as in the USA		Greater relative use of labour in MAR	
	10 years	15 years	10 years	15 years	10 years	15 years
Depreciation	10[illegible]	67	135	90	[illegible]	90
Maintenance and repair	40	80	35	70	29	58
thereof labour	(20)	(40)	(8)	(16)	(14.5)	(29)
thereof spare Parts	(20)	(40)	(27)	(54)	(14.5)	(29)
Total	14[illegible]	147	170	160	1[illegible]	148

Source: "Problems of Size of Plant in Industry in Under-developed Countries", Industrialisation and Productivity, Bulletin 2, United Nations, Department of Economic and Social Affairs, New York, March 1959. p.22

in the United States and have to be imported to Central America. This raises their costs in Central America to 135 percent of the cost in the United States. On the other hand, labour cost in Central America is estimated at 40 percent of the labour cost in the US.

It appears that the shorter lifetime of 10 years is most economical in the United States, whereas in Central America the extension of longevity to 15 years is the economically rational choice, even if the same techniques in maintenance and repair were applied as in the US. Central America could even gain a higher cost advantage from the extension of longevity to 15 years, if relatively more labour was used in maintenance. According to the example, the optimum is reached in Central America when the substitution hits the point where the costs of labour and spare parts are equal.

It may be added that the cost of longevity, in <u>absolute</u> terms, is lower in the United States even if a lifetime of 15 years is chosen; Central America achieves a <u>relative</u> cost advantage only by extending the service life of the capital good.

E. <u>The applicability of the model</u>

Empirical evidence shows that the theoretical model presented here may fairly well be applied to maintenance and longevity decisions in the United States as compared to industrialised Europe.

There is enough evidence, indeed, that the United States - that has had a relatively high wage rate and a relatively low interest rate during the post-World-War II period - acted according to the principles deducted in the preceding theoretical analysis: it is a well-known tendency in the US economy to make the equipment easy-serviceable, to exchange parts and units rather than to repair them, to design the equipment in a way that repairs and replacements of parts can be executed with a maximum of mechanical aid. All this is done in order to avoid high costs of labour-intensive maintenance and repair.

Unlike the US, wages in industrialised Europe were lower and interests rates higher. Labour-intensive maintenance and repair used to be of much greater importance.

As to the longevity of capital goods, there is not much reliable information. In the US, many "durable" consumer goods as well as less valuable production goods are cheap to buy and disposable after a relatively short service life. There are some indications that the longevity of capital in general is lower in the United States than in Europe and that it is declining over time in all industrialized countries.1 This issue, however, presents too many statistical uncertainties to be decided unambiguously.

The model may be applied particularly well to industrialized countries, on the one hand, and to developing countries on the other. Generally, the developing countries have relatively high interest rates and low wage rates and the prices of capital goods are high, compared to industrialized countries. However, some modifications have to be introduced that take the specific conditions of developing countries full into account.

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1 Cf. R.C. Blitz, AER, 1958, pp. 326-7. - R.C. Blitz, JPE, 1959, pp. 562-4. - L. Rostas, Comparative Productivity in British and American Industry, New York, 1948.

3. The Problem of Maintenance and Repair under the Specific Conditions of Developing Countries

A. The quantity and quality of available labour

So far it has been assumed that the quality of labour available in a country is homogeneous and thus the single "labour units" (man-hours) interchangeable. In reality, however, this is not the case, and we have to consider the impact of this fact on our model.

Generally, there exists a relative abundance of aggregate labour in developing countries, but skilled labour is usually scarce. Consequently, unskilled labour is cheap while the wages of the skilled workers are high, in some instances even extremely high compared with the wage relations in industrialized countries. Since most of the maintenance and repair activities require skilled or even highly skilled (specialized) workers, the cost of labour-intensive maintenance and repair may be extremely high in the developing countries, too.

The real situation in the developing countries requires that we differentiate again and consider short-run and long-run solutions and different kinds of developing countries.

For our purpose here, developing countries can be divided into two groups:[1]

(1) Traditionally purely agrarian countries which are now making first steps towards industrialization, which have only a poor tradition in handicrafts, and are not familiar with even the simpler modern technologies (countries of type I).

(2) Countries which have already a certain industrial tradition, which can dispose of a cadre of industrially trained workers and, in addition, have a considerable number of craftsmen familiar with the basic techniques of working metal and wood (countries of type II).

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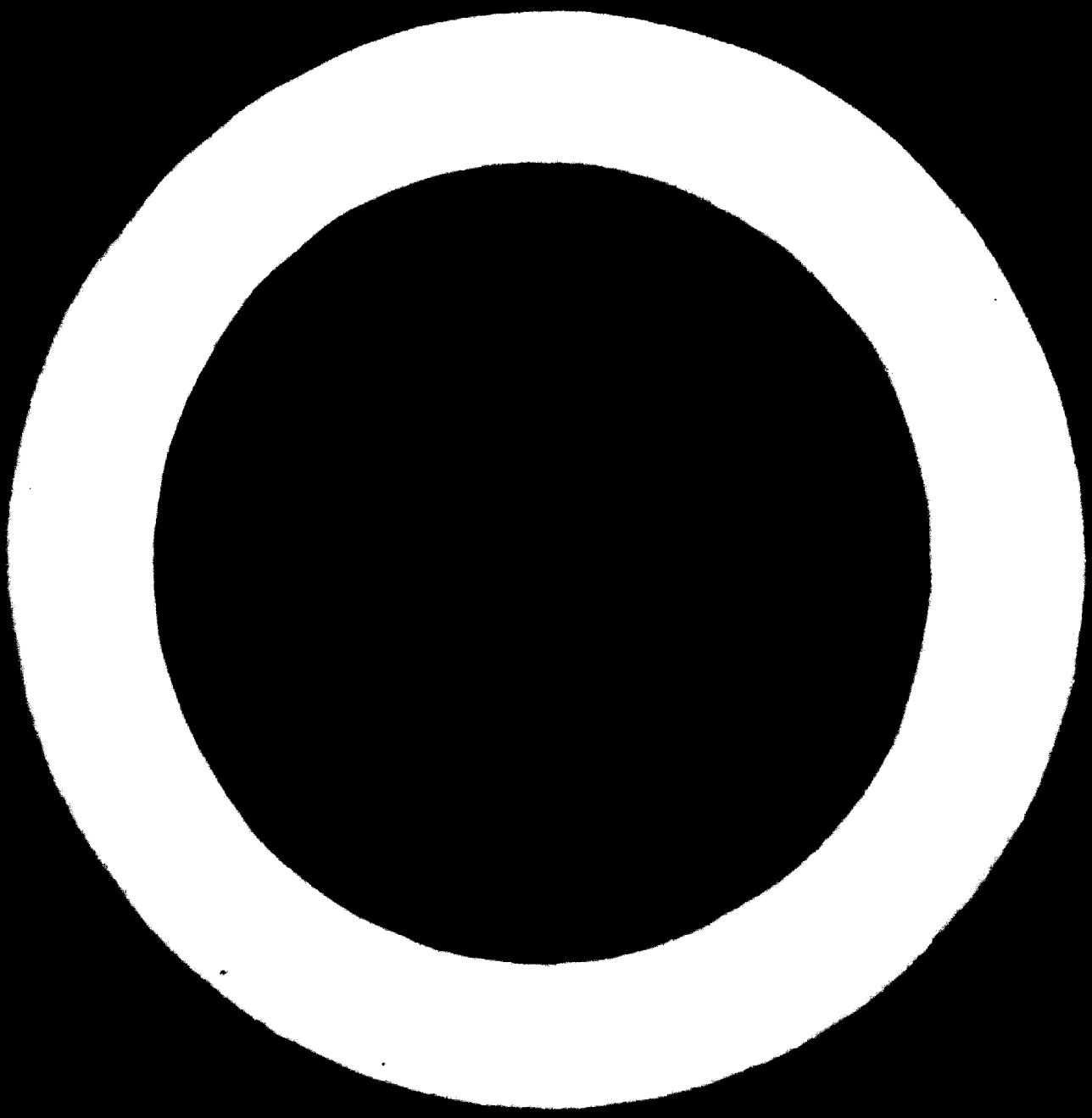
1 Under certain circumstances, this distinction may reflect two stages of development, too.



a) Countries of type I

What is the optimum policy for countries of type I in the short run where skilled maintenance workers are practically not available? The most obvious solution would be to choose those projects which do not require maintenance and repair because they have enough built-in durability to reach a certain longevity. However, this is only possible in very restricted cases: for projects such as buildings, roads, or bridges. All kinds of machinery with moving parts need a certain amount of maintenance.[1] Hence, other solutions have to be looked for.

In the short run, these countries have to employ foreign specialists for practically all maintenance and repair work of complicated industrial devices. These specialists receive an even higher remuneration than in their home countries. On the other hand, investment goods and maintenance equipment, too, have to be imported completely from industrialized countries and hence will be more expensive than in the exporting countries. In this situation the factor-price relations will not induce a substitution of maintenance labour for maintenance capital, nor of maintenance outlays in general for durability outlays. The only influencing factor will be the higher interest rate inducing a substitution of (future) maintenance outlays for (present) durability outlays, and, eventually, a slight shortening of the lifetime of equipment. If however - as is usual in the early stage of industrialization - very favourable credit conditions are offered for the initial investment, the burden of durability outlays will be reduced, and hence the interest rate effect will be moderated or totally equalized.

Under these conditions, the optimum short-run policy for a country of type I would be to choose the same production technique as an industrialized country short of skilled labour: i.e. to rely less on maintenance and more on durability and to extend the lifetime of the equipment only to the point that is optimal in developed countries.

1 Cf. A.O. Hirschman, op. cit., pp. 141-2. - R.C. Blitz, AER, 1958, p. 324.

If there is a choice between two types of equipment, one requiring highly specialised production workers but less skill in maintenance and repair (simple machinery), the other doing with semi-skilled workers in production but requiring highly skilled maintenance workers (sophisticated equipment), the decision should be in favour of the second type of equipment (what, by the way, would also be the optimal choice in the industrialised country). This is so because maintenance workers have to be "imported" anyway - for both types of equipment. The differences in wage pay for these more or less specialized foreign workers are only "marginal"; so it is economically rational to employ them in maintenance activities where professional skill requirements are highest. Semiskilled production workers, on the other hand, can be trained in a relatively short time, hence foreign assistance is needed here only in the very beginning of industrialisation.

The long-run aspect adds a new angle to this policy. Here, the dynamic effects of economic development come into play. Within the context of our theoretical model, the most important effect of economic development is the development of manpower skills. We have seen that countries in the early stages of industrialisation do not command over a labour force whose skills are comparable to those of workers in industrialized countries, and optimal policy in the short run has to follow the pattern of investment as if there was no abundance of labour. Optimal policy in the long run has to develop a highly skilled labour force because this is the only way for a country in early stages of development to reach eventually the point of substituting scarce capital by abundant - skilled - labour, i.e. profiting from its natural comparative advantage by using its cheaper (abundant) factor of production.

The training of workers, the type of training offered, is closely related to the type of industry chosen. Whether it is easier to train people for production rather than for maintenance is controversial; experts have expressed both opinions. Hirschman, for example, considers preventive maintenance (not repair!) as an

administrative process which is "intrinsically harder to master than production jobs".[1] Consequently it presents a particular problem in early stages of industrialization. Hirschman states:

> "Any production activity has these three assets: the target is clear-cut, we know it can be reached, and success in doing so is subject to an objective test...
> The basic difficulty about maintenance of capital - as opposed to operation on the one hand and repair on the other - is that it is preventive activity which must be performed at fairly long intervals that are neither known with precision nor signaled by the capital itself... For maintenance to be effective, people must be similarly made to act as though it had to be undertaken at precise intervals, suppressing their better knowledge that deferment by a day, a week, or a month may not matter; they must organize this fiction, submit to it, and set up a signaling system to enforce it. In other words, maintenance is predominantly an administrative process if we so define an activity whose performance is not directly invited or compelled by the production process or the product itself, and as such it requires an especially high degree of organizational ability." 2

The opposite opinion is expressed by an American steel engineer:

> "Lack of experienced and technically skilled workers can best be offset by using methods and processes in which the operations requiring skill are entrusted to machinery to the greatest possible extent. Skill in maintenance, mechanical and electrical work seems to be more easily found or developed than that required for complicated manual operations such, for example, as in sheet or tinplate rolling." 3

Perhaps it is not possible to make a generally valid statement deciding a priori that maintenance skills or production skills are easier to transmit. Different cultural backgrounds of the developing countries may partly induce the different attitudes of labour towards a certain job. The general under-evaluation of maintenance activities is most likely, however, to affect the professional status of the repair-and-maintenance man negatively.

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1 A.O. Hirschman, op. cit., p. 154.

2 A.O. Hirschman, op. cit., pp. 154 and 141.

3 William A. Haven, "Selection of Steelmaking Processes and of Locations for Integrated Iron and Steel Works", A Study of the Iron and Steel Industry in Latin America, United Nations, New York, 1954, Vol.II, p.354. Cited by W.P. Strassmann, op. cit., p. 201.

hence the psychological obstacles for maintenance training may be substantial.

The type of industry that is best fitted for vocational training in maintenance skills in developing countries depends to some extent on the "weakest" point in skill deficiencies which again is a matter of the degree of industrialization already obtained: in the very early stages of development manual abilities as well as a "maintenance habit" are lacking.

The generally accepted expert opinion seems to be that maintenance habits are the most difficult to promote. Some experts therefore give preference to those industries which have the highest "educational" effect. Hirschman, for example, recommends that developing countries should concentrate on new ventures with a complicated technology (preferably machine-paced, process-centered) which presents a compulsion to maintain[1]:

> "industries and processes where lack of maintenance carries stiff penalties in the form of serious breakdowns and accidents instead of simply leading to a slow deterioration in the quality and quantity of output or to brief outages of single machines that do not disrupt the whole production schedule."

According to Hirschman, "simple" industries present too many "Latitudes", too much tolerance for poor performance in maintenance.

Hirschman's propositions imply that the capital- and maintenance-intensive productions chosen at the early stages of industrialization should not only be continued but even be expanded during the progressing stages of industrialization. This however raises the question of the availability of capital. The United Nations Department of Economic and Social Affairs, for example, pointed out that the proposition is "generally too expensive in terms of capital and skilled labour to be introduced on a mass scale".[2]

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1 A.O. Hirschman, op. cit., p. 142.

2 "Use of Industrial Equipment in Under-developed Countries", op. cit., p. 31.

The cost argument is indeed fundamental. The limited access to foreign capital has actually induced most developing countries to pursue more modest industrial projects as well. This may allow another way of training professional skills and advancing the development of maintenance habits: "breakdown maintenance", in case of simpler technical devices.

Repair after breakdown is said to have the same psychological assets as production activity: success or failure in performance are immediately apparent.[1] Moreover, "breakdown maintenance" or "replacement at failure" is by no means an inferior way of maintaining equipment: (1) It may be cost-saving - in case the cost of downtimes is smaller than the cost of preventive maintenance. (2) It is the optimal policy for all equipment with a failure rate that is independent of age or decreases with age - whether or not replacement cost is higher after failure than before. Investigations have shown that a wide variety of devices falls into this category.[2]

Examples cited are: Power hand tools, ball bearings, electric motor centrifugal switches, linotype machines, automatic calculating machines, bus motors (subsequent to the second major overhaul), most electronic components, etc.

The training of repairmen for "breakdown maintenance" of simpler industrial equipment has the advantage of familiarizing the workers with relatively simple techniques but avoiding the discouraging "latitudes" and the high organizational requirements of preventive maintenance.[3] This form of training appears to be particularly suitable for developing countries with a poor stock of skilled maintenance workers. By comparison, the training of experienced repairmen for preventive maintenance would be the "second" step. The country would eventually reach the stage which is typical for countries of type II.

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1 A.O. Hirschman, op. cit., p. 154.

2 D.W. Jorgenson, J.J. McCall, R. Radner, Optimal Replacement Policy, North-Holland Publishing Company, Amsterdam, 1967, esp. pp. 45 ff., 70-71, 132 ff., 146 ff., 156 ff.

3 "Use of Industrial Equipment in Under-developed Countries", op.cit., p. 43.

b) Countries of type II

In countries of type II the situation of labour supply is "better" if compared with the situation in predominantly agrarian countries: countries of type II can count already on a cadre of workers familiar with maintaining and repairing simpler, conventional devices. In the short run, these countries may have to rely on foreign specialists for the servicing of some complicated modern industrial equipment. But their main task is that of advisers training people rather than doing the job themselves for a longer period of time.

The problem of training in manual skills might satisfactorily be solved within relatively short periods of time, but the problem of developing a maintenance habit remains the pivotal point of long-term development efforts. As pointed out before, maintenance and repair do not enjoy high evaluation in almost any developing country where the mentality of negligence is not confined to the labour force; equal indifference, even strong aversion, is found on the part of the management to engage in maintenance activities.

A change in the mentality of management is therefore as important as the acquisition of maintenance and repair skills by the worker. The training of supervisory skills ("to organize, to instruct, and to motivate subordinates") and the instruction of foremen ("a necessary social stratum lacking in preindustrial societies"),[1] may be added to the catalogue of preconditions which are necessary to raise the "production factor" labour to a level comparable to industrialized countries.

Once this problem of developing a maintenance habit is however solved, the developing countries in the long run should gain an advantage in maintenance and repair costs compared to the

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1 W. P. Strassmann, op. cit., p. 273.

industrialised countries.[1] Although training and upgrading of maintenance workers as well as greater awareness of the maintenance problem will eventually cause a rise in wages, it is most likely that maintenance labour will remain cheaper than in industrialised countries. On the other hand, capital - which is not only needed in real assets but also for education and training - will continue to be scarce; therefore, the interest rate will tend to be higher than in already industrialized countries.

Regarding our theoretical two-country model, we may conclude that developing countries of type II, especially in the long run, are adequately presented in the low wage/high interest-country model, whereas paradoxically the model of the high wage/low interest-country (normally the industrialised country) is applicable for the short-run conditions of countries of type I..

B. Alternative choices of capital and techniques in developing countries

After having discussed the production factor labour in developing countries the choice of capital will now be taken into consideration. Except for the case of a country of type I under short-run conditions, the factor relations in developing countries suggested, as optimal policy, a "two-stage" substitution of labour for capital: (1) by spending less on durability than in industrialised economies, but extending the lifetime of equipment by more intensive maintenance and repair; and (2) by relying on more labour-intensive methods of maintenance and repair than is customary in developed countries.

How far can those propositions be followed under present-day conditions?

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1 Cf. also R.C. Blitz, JPE, 1959, pp. 560 and 564 ff.

a) Degree of durability of equipment

Let us first consider the decision for more or less built-in durability at the time the initial investment is made. Enterprises in a developing country have to buy most of the investment goods from producers in industrialized countries. Naturally, this equipment is generally designed to the needs and requirements of firms in industrialized countries that make up the bulk of the customers. In these cases, the developing countries will have no choice between more or less durable capital goods. They will have to put up with the equipment that is more properly suitable in industrially advanced countries. The only means to approach the desired optimum is to extend the longevity of equipment over a longer period than is customary in industrialized economies, in other words: to repair installed plants and equipment when they would have been replaced in developed countries.

The choice of capital is, however, not always restricted to such an extent. In particular, there are three possibilities of which developing countries could take advantage to get less built-in durability of equipment and hence to lower present cost of investment:

(1) Some of the equipment which developed countries supply has different degrees of built-in durability and repairability, that is, require more or less maintenance. Firms in industrialised countries make use of this choice, and so could the industrially less developed countries. Sometimes changes in maintenance requirements entail changes in operating characteristics, too.[1] As long as these changes do not impair the quality of the final product, they are unobjectionable. They may sometimes suit the typical needs of developing economies even better (smaller scale production, lower speeds of output, etc.).

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[1] E.g. machines may be run at different speeds etc.

(ii) In the more advanced developing countries (countries of type II) where machinery is already produced locally, foreign prototype machines may be redesigned to fit local materials, standards, or skills of operators. Maintenance and repair requirements may also be subjected to redesigning.[1] Initial costs for durability can be reduced (at the expense of higher maintenance and repair costs) by using cheaper materials, a simpler construction, or by permitting less accuracy in assembling.

(iii) A third way to purchase less durability is the import of second-hand equipment from industrialised countries. High-wage/low-interest countries replace their equipment when the cost of maintenance and repair rises with the growing age of the equipment. At this point, it can still be economically used in developing countries (of type II) which have cheaper skilled labour available for maintenance. Provided that the cost of transportation and mounting is not excessive and that spare parts will be available, it pays for a low-wage/high-interest country to use second-hand machinery.

Second-hand equipment may be all the more advantageous if the equipment was replaced in the industrialized country only because more modern equipment needing less maintenance had become available. In other words: labour-displacing inventions can make replacement of old machinery profitable in the high-wage countries without doing so in the low-wage countries; the latter may make a bargain by buying these machines. The problems involved in the use of second-hand machinery will be analysed more thoroughly in chapter II of this study.

b) <u>The capital-intensity of maintenance and repair</u>

Compelled by rising wage rates firms in industrialised countries try to substitute capital for labour in production and maintenance

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1 Cf. Gerard Karel Boon, Economic Choice of Human and Physical Factors in Production, North-Holland Publishing Company, Amsterdam, 1964, pp. 55 ff.

as far as possible. But the possibilities of labour-saving operations in maintenance are more limited than in the manufacturing processes where capital intensity can be pursued up to the point of automation. Most maintenance and repair work can never be done on a large scale; it is more in the nature of "made-to-order" work and, therefore, more labour-intensive.

Capital/labour substitution in maintenance and repair is achieved in three ways:

(i) Auxiliary work may be mechanized by introducing mechanical aids for mounting and demounting of machines, handling of machine parts and in transportation work.[1]

(ii) The labour content of repairs may be lowered by a policy of "unrepairability and expendability" of components: not the single broken part is identified, removed, repaired and replaced, but a "package" of parts, a "functional unit" is replaced by a new one; the old unit is not disassembled and repaired any more.[2] By this method (1) the time and manpower involved in fault identification is reduced, and (2) handicraft repair (regrinding, reconditioning, soldering, etc.) is made unnecessary.

(iii) Economies of scale can be realized by specialized shops for overhauls in case of mass-produced goods (e.g. truck engines).

These relatively limited technological possibilities of reducing the labour content in maintenance and repair work demonstrate that the odds are in favour of developing countries of type II, where wages of skilled workers are comparatively low. These countries may realize their comparative advantage by:

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1 Cf. Productivity Report: Plant Maintenance, Report of a Visit to the U.S.A. in 1952 of a Specialist Team on Plant Maintenance, British Productivity Council, London, December 1952, pp. 46-49.

2 Cf. "Maintainability of equipment" in: McGraw-Hill Encyclopedia of Science and Technology, Vol. 8, McGraw-Hill, New York etc., 1960, p. 75.

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(i) avoiding all capital-intensive forms of maintenance and repair,

(ii) relying on more conventional practices for auxiliary work as well as repair work proper,

(iii) aiming at additional capital-saving methods of maintaining and restoring the proper functioning of the equipment.

This includes the identification and exact localization of the broken component so that the number of machine parts that have to be exchanged is minimal. Also, the reconditioning of parts would be preferable to replacing them by new ones.

It should also be pointed out that it may pay for a low-wage country to produce at least some of the spare parts itself instead of importing them. There is a definite advantage if local production of spares is labour-intensive; the substitution of labour for capital would make the price of the spare parts attractive.[1] Production of spare parts in industrialised countries may, however, have reached a point of capital-intensity and large-scale output where their price is lower than any price at which a low-wage country is able to produce without economic losses. Import substitution for economic reasons should then be avoided.

C. The balance-of-payments aspect

Shortages of foreign exchange have become a common criterion for all but a fortunate few of the developing countries regardless of the degree of industrialization they may have reached already. The foreign exchange aspect, therefore, is a limiting factor imposing itself on all economic plans for industrial development. Import substitution and export promotion have been popular recommendations, whereas the maintenance and repair aspect has enjoyed much less attention. Its influence on the balance of payments, however, is anything but negligible.

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1 Cf. also: "Use of Industrial Equipment in Under-developed Countries", op. cit., pp. 32, 46.

It is evident that the premature destruction of equipment due to poor - or lack of any - maintenance causes premature import needs for replacement and thus an unnecessary burden on the balance of payments. But there is more to maintenance and repair policy than this general aspect might suggest. The decision on the type of equipment and the kind of maintenance applied will affect the amount and timing of imports, as well.

If the choice of machinery follows the pattern of industrialised countries, i.e. if machines are chosen with high built-in durability requiring relatively little but capital-intensive maintenance, the burden on the balance of payments will be heaviest: it means choosing a high import value at the time the initial investment is made, high expenditure on spare parts and other "maintenance capital", finally high replacement outlays after a relatively short time.

A foreign-exchange conscious, cost-saving investment, taking the developing country's factor endowments into account, would be determined by the following considerations:

(i) Expenditure on the initial investment as well as on later replacements can be cut down by choosing equipment of less built-in durability, be it new or second-hand.

(ii) The period between the necessary replacements can be prolonged by attaching more importance to maintenance and repair, thereby increasing the longevity of equipment. The number of replacements within a certain period of time is reduced, and so is the total amount of requisite foreign exchange.

(iii) The foreign exchange content of maintenance and repair outlays can be reduced by relying more on labour-intensive maintenance and repair methods and by a policy of import substitution for spare parts.

At first sight the highest savings in foreign exchange seem to follow from an import-substituting production of the equipment itself. In this case, however, raw materials and components must often be imported all the same, and this makes for smaller overall-savings. (Of course, the development of a domestic machinery industry may still be economically advantageous for other reasons.)

It appears that a policy which is directed towards saving a maximum of foreign exchange is a policy which, in the long run, promotes the most economic use of the production factors available in a developing country.

II. SPECIFIC ASPECTS OF THE PROBLEM OF MAINTENANCE AND REPAIR WHICH SHOULD BE FOCUSED AT THE NATIONAL LEVEL

1. Basic Considerations with Regard to the Import of New versus Second-Hand Equipment

A. The role of second-hand equipment in industrialized and developing countries

The import of second-hand machinery by developing countries has been mentioned on various occasions as one of the ways to choose investment goods of less built-in durability. This problem deserves some further considerations here.

In market economies, investment decisions are made by the individual firms; but most market economies today are mixed economies. Especially in developing countries the "planning ingredient" is considerable. Many of the industrial ventures are promoted or owned by the government. Hence, the question of importing used or new equipment has its bearings also on the public authorities. Moreover, the system of import licensing and foreign exchange control practiced in most developing countries makes decisions of the government relating to this problem necessary.

It may be useful to point out that the utilization of second-hand machinery in developing countries by no means relegates these countries to a second-class status, nor perpetuates the technological gap between industrialized and developing countries. In fact, most of the second-hand equipment that is available in industrialized countries is installed again in these countries: In the mid-1960's, almost 95 percent of the second-hand machinery that was offered on the US market was purchased by US firms.[1] At least two second-hand machine-tools were sold in the United States for

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1 Report of the Group of Experts on Second-hand Industrial Equipment for Developing Countries, United Nations, Economic and Social Council, E/C.5/104, 28 January 1966, (mimeographed), para. 15.

every new one.[1] In Japan, too, the use of second-hand equipment is widespread, particularly among small and medium-size firms, as may be seen from table 2.

Table 2: Second-hand equipment as percentage of total fixed assets in Japanese industry, by size of firms

Number of employees	Percentage of second-hand equipment				
	1954	1955	1956	1957	1958
4 - 9	48.8	40.2	34.3	n.a.	n.a.
10 - 19	44.1	40.8	29.9	n.a.	n.a.
20 - 29	39.5	34.3	28.7	n.a.	n.a.
30 - 49	35.0	28.9	26.1	26.8	26.5
50 - 99	31.5	22.0	22.3	21.9	20.9
100 - 199	23.0	16.3	16.8	14.5	13.8
200 - 299	15.2	9.1	9.9	9.3	10.0
300 - 499	13.9	10.1	9.1	7.4	7.6
500 - 999	11.2	5.2	4.2	4.6	6.3
over 1000	4.6	4.1	4.9	3.3	3.1

Source: M. Shinohara, Sangyokozo (Industrial Structure), 1959, p. 120, as reproduced by Amartya Kumar Sen, "On the Usefulness of Used Machines", The Review of Economics and Statistics, Vol. 44, Nr. 3, August 1962, p. 346.

There has been a certain tendency among developing nations to refuse the import of second-hand equipment. The situation in industrialised countries like the USA or Japan suggests that the arguments against using second-hand equipment need some rethinking. No one, of course, should advise a developing country to acquire only used machinery, no more than a developed country should be advised not to use it at all.

The causes for the generation of second-hand equipment are many, and so are the motives for using it. Main factors that have obviously influenced the employment of second-hand equipment are the size of the firm, type of ownership, the physical characteris-

1 Albert Waterston, "Good Enough for Developing Countries?" The Fund and Bank Review: Finance and Development, Vol. I, No. 2, September 1964, p. 91.

ties of processes (metal working versus chemical industry) and their rate of obsolescence.[1]

Preference for second-hand equipment has been relatively strong in metal working, in the production of lower precision items, for equipment with an average rate of technical obsolescence, and as a means to obtain equipment relatively cheap initially, therefore popular with smaller firms which have scarce financial resources. As to ownership, foreign firms establishing subsidiaries in a developing country have been found to employ more used equipment than local entrepreneurs, partly because of their greater familiarity with the market of second-hand equipment.

To illustrate the use of second-hand equipment in developing countries, the results of an investigation covering 70 Central-American manufacturing firms are partly reproduced in table 3.

The most general prerequisite for the use of second-hand machinery is satisfactory performance. In the words of a Group of Experts of the United Nations: "Second-hand equipment which only produces goods which are not competitive in price and quality at least domestically is not a bargain at any price and should be rejected outright."[2] If a machine does not produce goods of the absolutely best quality, these goods can still be competitive provided the consumers accept their quality - possibly at a lower price. Under these conditions it can be advisable to acquire older equipment that was replaced because new machines had been available which produce improved goods. Yet in most cases lucrative acquisitions of second-hand equipment pertain to machinery which produces goods of the same quality as the new one, but does it under the conditions of a developed country at a higher cost - under the conditions of a developing country, however, at a lower cost, than new equipment. In the following discussion we have only this latter case in mind, the analysis being limited to the maintenance aspect.[3]

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1 Cf. W.P. Strassmann, op. cit., pp. 201-205.

2 Report of the Group of Experts..., op. cit., para. 62.

3 For a more comprehensive discussion cf. Report of the Group of Experts..., op.cit.; A.K. Son, op.cit.; W.P. Strassmann, op.cit. As to second-hand transportation equipment cf. John R. Meyer, "Transport Technologies for Developing Countries", The American Economic Review, Vol.56, Nr.2, May 1966, pp. 83-90.

Table 3: Second-hand equipment policy in major processes of 70 Mexican and Puerto Rican manufacturing firms

Type of firm	Began and replaces or expands with used equipment	Began and replaces or expands with new equipment	Began with used equipment but replaces or expands with new equipment	Began with new equipment but replaces or expands with used equipment	no response or undecided
Small	10	6	1	-	-
Medium	11	7	2	1	5
Large	7	16	3	1	-
U.S.subsidiaries	17	10	-	-	1
European subsidiaries	1	1	-	-	-
Immigrant	1	6	1	-	1
Private national	9	8	5	1	3
Public national	-	4	-	1	-
Nondurables producers	9	20	4	1	1
Durables producers	19	9	2	1	4
Total	28	29	6	2	5

Source: W. Paul Strassmann, Technological Change and Economic Development, Cornell University Press, Ithaca, New York, 1968, p. 208.

B. The isolated effect of differences in maintenance costs

Under the absence of technological progress, the operating characteristics of a new machine will be the same as those of the replaced machine, that is, the new machine is not superior to the used one. The only reason for installing a new machine is the increase in maintenance costs of the machine in use. Theoretically, this would be the case for a low-wage country to buy the old machine if its maintenance costs are below the costs incurred in the country of origin of the machine.

In reality, however, this may not be a sufficiently strong incentive to buy used equipment. If no improved models are on the market to induce an earlier ("premature") replacement of the old machines, the potential buyer may fear - and his apprehension may actually be justified - that the old equipment is replaced only when physically worn out and that satisfactory performance may no longer be expected from such equipment. Even if the said equipment still works rather well, the difference in maintenance cost may not exceed the "threshold of perceptibility"; whether it does or not, depends largely on the extent of the wage differentials.

While in reality differences in maintenance costs are likely to affect the decision in favour of second-hand equipment only in connection with other factors (which are discussed in section C), the influence of differences in maintenance costs is isolated in the following discussion so that their proper effects become more distinct.

The rising maintenance costs of older equipment are largely due to a higher probability of unexpected breakdowns. Their impact varies, depending upon different sets of conditions. For the individual firm, the cost of breakdowns consists of the fixed cost of idled equipment and of the wages of idled operators. Part of the variable costs are down during disruption of production: especially the consumption of materials and power is reduced. So

the cost of breakdowns for the individual firm is not identical with the production loss during downtimes.[1]

(a) In case of highly capital-intensive production of process type or continuous production lines, a breakdown at one point of the production line affects other stages, and sometimes the whole, of the manufacturing process.[2] In these cases the fixed cost of idled equipment will be rather high and will outweigh the cost of idled labour. If breakdowns are frequent and have adverse effects even on those industries which are supplied by the afflicted industry, a temporal setback in economic growth might result.

A developing country should, therefore, refrain from buying used equipment of the a.m. kind with a high probability of breakdowns.

A sample study of two Central-American countries demonstrates very convincingly an awareness of the risks involved: among the firms that did not use second-hand equipment, about half did so in apprehension of production losses in their integrated plants. 3

(b) The situation is different in case of industries of fabrication-and-assembly type or benchwork type that use light equipment and are less capital-intensive. Here, the breakdown of one machine will affect the operation at other production stages very little, or not at all. The cost of breakdowns consists mostly of the wages of idled operators of the machine in question; and these are low in developing countries. Under these conditions, a low-wage/capital-scarce country could still make a "bargain" buying second-hand machinery even if the machines were liable to more frequent breakdowns.

The considerable advantage which developing countries may gain by using second-hand equipment in productions of type (b) can be illustrated in an arithmetical example (cf. table 4).

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1 Cf. M.C. Blitz, JPE, 1959, op. cit., p. 568. - W.P. Strassmann, op. cit., p. 203.

2 Cf. "Better Way to Compare Your Plant's Maintenance Practices", op. cit., pp. 139-140.

3 W.P. Strassmann, op. cit., p. 213.

Table 4: Arithmetical example: "Net savings" for industrialised and developing country on new and used machine, respectively.

	Industrialised country		Developing country	
	New machine	Used machine	New machine	Used machine
(1) Price of machine	$10.000	$5.000	$10.000	$5.000
(2) Interest rate prevailing(percent)	3.65	3.65	7.30	7.30
(3) Opportunity cost of outlay on machine	$365per year $1 per day	$182.50 per year $0.50 per day	$730 p.y. $2 p.d.	$365 p.y. $1 p.d.
(4) Labour cost per day per machine	$25	$25	$2	$2
(5) Expected number of breakdowns per year	1	9	1	9
(6) Expected cost of annual breakdowns in terms of idled labour and idled capital	$26 1x(25+1)	$229.50 9x(25+50)	$4 1x(2+2)	$27 9x(2+1)
(7) Expected yearly interest and breakdown cost per machine	$365.00 26.00 $391.00	$182.50 229.50 $412.00	$730.00 4.00 $734.00	$365.00 27.00 $392.00
(8) Expected "Net savings" (£) of new over used machine	+$21	.....	-$342	.....

Source: Rudolph C. Blitz. "Maintenance Costs and Economic Development". The Journal of Political Economy, Vol.67. 1959. p.569.

3. The Problem of Maintenance and Repair under the Specific Conditions of Developing Countries

A. The quantity and quality of available labour

a) Countries of type I

b) Countries of type II

B. Alternative choices of capital and techniques in developing countries

a) Degree of durability of equipment

b) The capital-intensity of maintenance and repair

C. The balance-of-payments aspect

II. SPECIFIC ASPECTS OF THE PROBLEM OF MAINTENANCE AND REPAIR WHICH SHOULD BE FOCUSED AT THE NATIONAL LEVEL

1. Basic Considerations with Regard to the Import of New versus Second-Hand Equipment

A. The role of second-hand equipment in industrialized and developing countries

B. The isolated effect of differences in maintenance costs

C. The effect of premature obsolescence

D. Special problems of maintenance and spare-part supply for second-hand equipment

2. Availability of Spare Parts

A. The importance of a regular spare parts supply

B. Decentralized large stocks of spare parts at the individual plant

C. The establishing and keeping of central stocks of spare parts at the national, regional, and branch level

D. Possibilities for import substitution of spare parts

3. The Establishing of Specialized Repair and Maintenance Shops in the Context of Industrial Estates

4. Quantitative Aspects of Maintenance and Repair

In this example, yearly interest and breakdown costs of a new versus a used machine are compared in an industrially advanced and a developing country respectively. The wage-cost relation between the two countries is assumed to be $ 25 : $ 2. As expected, the high cost of idled labour makes the utilization of the second-hand machine with its higher frequency of breakdowns unattractive in the high-wage country despite of the low capital cost of the used machine versus a new one. But the low-wage country is able to make "net savings" totalling $ 342 by prefering the second-hand machine to a new one (line 8). In other words: as long as net maintenance and repair cost of the used machine is below this amount, it is economically advantageous to prefer a used machine to a new one. In the arithmetical example presented here, the cost of each repairing may even be ten times as high as daily operating costs, i.e. $ 20 per repair executed, the advantage of using an old machine instead of a new one would still be substantial: $ 342 - $ 160 = $ 182.

This is an extremely favourable result regarding the use of second-hand equipment, which is due, of course, to the assumed high wage differentials between an industrially advanced and a developing country. But even if we assume a higher daily labour cost in the developing country, e.g. $ 8 instead of $ 2, all other things being equal, the case for second-hand equipment would still be impressive: the annual interest and breakdown cost of the new machine (line 7) would be $ 740; that of the used machine $ 446. The "net savings" of the used machine (line 8) would thus be $ 294. The used machine is preferable to a new one as long as repair costs for each breakdown are less than four times the daily operating costs, i.e. less than $ 32 per repair. The cost advantage afforded by the used machine would still be: $ 294 - $ 256 = $ 38.

It should be noted that the price assumptions in the example even understate somewhat the advantage of the used machine.

C. The effect of premature obsolescence

So far our analysis was based on the simplifying assumption of unchanged technological standards. In the absence of technological progress, machines will be replaced when they become physically worn out, and can no longer be economically maintained. They will be replaced by the same type of machine.

For a developing country which plans to import second-hand equipment, the physical condition of this equipment is, of course, very important. The physical condition is primarily influenced by the factors which have caused the generation of second-hand machinery.

The principal causes for the generation of second-hand equipment in an industrialized country - besides mergers of firms and liquidations of plants - are:

(i) the switch-over to a larger scale of operations, caused by increased market demand;

(ii) modernization of plants and equipment up to the point of automation, caused by labour shortage and high wages.

In both cases, the equipment is replaced by technically improved machinery which will suit the changed market demands or factor-supply conditions better than the old machines. We may say, the technical progress has caused premature obsolescence, in the industrialized country, of machinery which actually is working still well, but the conditions in that country do not permit an economic use of these machines.[1]

The very reasons that caused premature obsolescence of equipment in an industrialized country make these machines particularly suitable for a developing country: smaller markets call for smaller outputs, and production on a smaller scale may be more economical than under-utilization of large-scale capacities; and, as pointed out before, the factor-price relations in developing countries

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1 Regarding the optimum replacement policy cf.: George Terborgh, Dynamic Equipment Policy, McGraw-Hill, New York-Toronto-London, 1949. - Vernon L. Smith, Investment and Production, Harvard University Press, Cambridge, Mass., 1961. - Ingrid and Per Wolin, The impact of Technological Progress on the Economic Life of Industrial Equipment, Handelshögskolan i Göteborg, Skrifter 1967-2, Akademiförlaget, Göteborg, 1967.

suggest the use of machinery which needs relatively more labour than capital, both in operation and in maintenance. Premature technical obsolescence (in industrialised countries) will, therefore, become a special incentive, in addition to the maintenance aspect, to prefer second-hand to new equipment in developing countries.

D. Special problems of maintenance and spare-part supply for second-hand equipment

As a United Nations Group of Experts on Second-hand Machinery already pointed out some years ago, "there is no clear-cut difference in the magnitude and nature of maintenance problems between new and second-hand equipment".[1] Much depends, however, on the existence or absence of technological improvements of the equipment in use.

Under the assumptions made in section B, the nature of maintenance is the same for new and used equipment, but the magnitude of required work is greater for used equipment. In the case discussed in section C, the magnitude of the maintenance work may be the same for old and new equipment, whereas the nature of this work is different.

It is often assumed that the maintenance of equipment of older design requires less skills than that of modern machinery, whereas the skill requirements for the operation of old machines are higher than for new ones.[2] But there is no simple solution to this question; it may also be true that modern machines are made easy-serviceable, with unrepairable and expendable units, in order to save on highly paid, skilled maintenance workers. The situation differs from industry to industry.

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1 Report of the Group of Experts..., op. cit., para. 45.

2 Ibid., para. 69.

The special problems of maintaining second-hand machinery are mainly of a practical nature. Sometimes, maintenance manuals and schedules, or part catalogues, are missing, or even blueprints of a machine are not available. Service arrangements are generally not made for a single machine, but may be obtainable for a number of integrated machine units or complete plants. In the latter case, management in developing countries has often shown reluctance to rely on outside repair services. Strassmann, for example, observed that:

> "Willingness to buy used equipment was determined largely by confidence in one's own maintenance and repair abilities. A metalworking plant can grind a bearing or shaft for its own machines; an electrical manufacturer is as good at rewiring circuits for his own as at rewiring those for sale." [1]

The purchase of second-hand equipment is only recommendable if the supply of spare parts can be secured. But the difficulties of getting spare parts should not be over-estimated. No doubt, spare parts are more easily available for new machines than for old ones, in particular if they are supplied by the machine-producing firm. However, machine manufacturers generally do produce spare parts for some years after the particular type of machine has gone out of production. When production of these spares is discontinued as well, manufacturers are wont to hold a certain stock for some more years. It has been reported that some manufacturers of textile machinery continue to make spare parts for machines they produced forty years ago.[2]

There will be a time, of course, when the availability of spares becomes a real problem: when stocks are depleted, or when the manufacturer of the machinery is no longer in business. Missing catalogues or blueprints that are needed to identify the spare part exactly will add to the difficulties.

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1 W.P. Strassmann, op. cit., p. 213.

2 Report of the Group of Experts..., op. cit., para. 48.

Before deciding upon the import of second-hand machinery, a country would do well to explore the availability of spare parts thoroughly, including the possibilities to produce spare parts in local machine shops. Frequently, second-hand machines are less complicated than newer models, are made from simpler materials and have parts of less sophisticated design. In this case, the local production of spares in developing countries (of type II) should not encounter insurmountable difficulties, provided the necessary steps are taken in time. Local production of spare parts for very complicated modern machinery is apt to face many more difficulties.

The preference of second-hand equipment versus new equipment combines several advantages: saving in foreign exchange because the price of used machines is substantially lower than of new equipment; more labour-intensive production and maintenance and hence lower production cost; inducement of local production of spare parts which means adding a labour-intensive spare parts supply to a labour-intensive production.

2. Availability of Spare Parts

A. The importance of a regular spare parts supply

Availability of spare parts is an integral part of a good maintenance policy. In developing countries the lack of spares is often one of the most serious bottlenecks in uninterrupted production. The supply of spare parts, therefore, deserves all the attention of the policy makers concerned.

In a mixed economy a good spare parts policy on the part of the individual firm is not possible without the cooperation of the public authorities. Problems of priority allocation arise between public and private enterprises if spare parts are generally scarce or not easily obtainable on other grounds. The public authority may exercise its influence on the allocation of spare parts by way of a whole set of instruments of commercial policy such as import licensing, foreign exchange control, multiple exchange rates, etc.

An essential aspect of the spare parts problem is stock-piling. There should be no question today regarding the general importance of keeping adequate stocks of spares, although time and again experts' reports disclose a lack of recognition of this fact, especially during the first phase of new industrial ventures.[1] The effects on production are always detrimental.

One of the solutions which have been recommended is that individual enterprises keep large stocks of parts, in particular when poor transportation facilities, rigid foreign exchange controls, and coincidences of all kinds impede their quick supply.

Other solutions that have been proposed are to establish central stocks of spare parts at the national, regional, and branch level, and to envisage their domestic production.

The advantages and shortcomings of these propositions will be given special attention in the following sections.

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1 See e.g. "Solveen Report on Rourkela Steel Plant", The Eastern Economist, Vol. 34, No. 7, August 17, 1962, pp. 304, 307. - "Some Problems of Industrial Management Reported by Technical Assistance Experts", op. cit., pp. 55-56.

B. Decentralised large stocks of spare parts at the individual plant

The advantage of large stocks of spare parts at the plant level is that spares are quickly and easily available if needed. Down-times of equipment can be kept as short as possible. This is especially important in case of heavy process-type production or continuous lines, where the economic penalty for any stoppage of operations is highest.

The most serious handicap of decentralised large stocks is that considerable amounts of capital are tied up. It has been observed that many firms initially tend to keep spare parts inventories at a very low level but after their bad experiences they fall into the other extreme of hoarding whatever spare parts they are able to get.

The particular conditions in developing countries induce firms to keep greater stocks of parts than is customary and necessary in similar industries in developed countries.[1] The reasons are:

(i) Specific climatic conditions in many developing countries make for deterioration of parts that usually have not to be replaced in countries of temperate zones. Wrong treatment and overloading of machines by operators who are not sufficiently trained as well as incompetent maintenance - both more frequent in developing countries - also contribute to higher degrees of deterioration.

(ii) The poor communication and distribution systems in many developing countries make it often impossible to place emergency orders for spare parts and have them delivered within a short time.

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1 The Indian National Council of Applied Economic Research has estimated that in a large number of industries spare parts constitute almost 15 percent of the total inventories, which is considered as a rather high proportion. Cf. Maintenance Imports, National Council of Applied Economic Research, New Delhi, 1967, p. 74.

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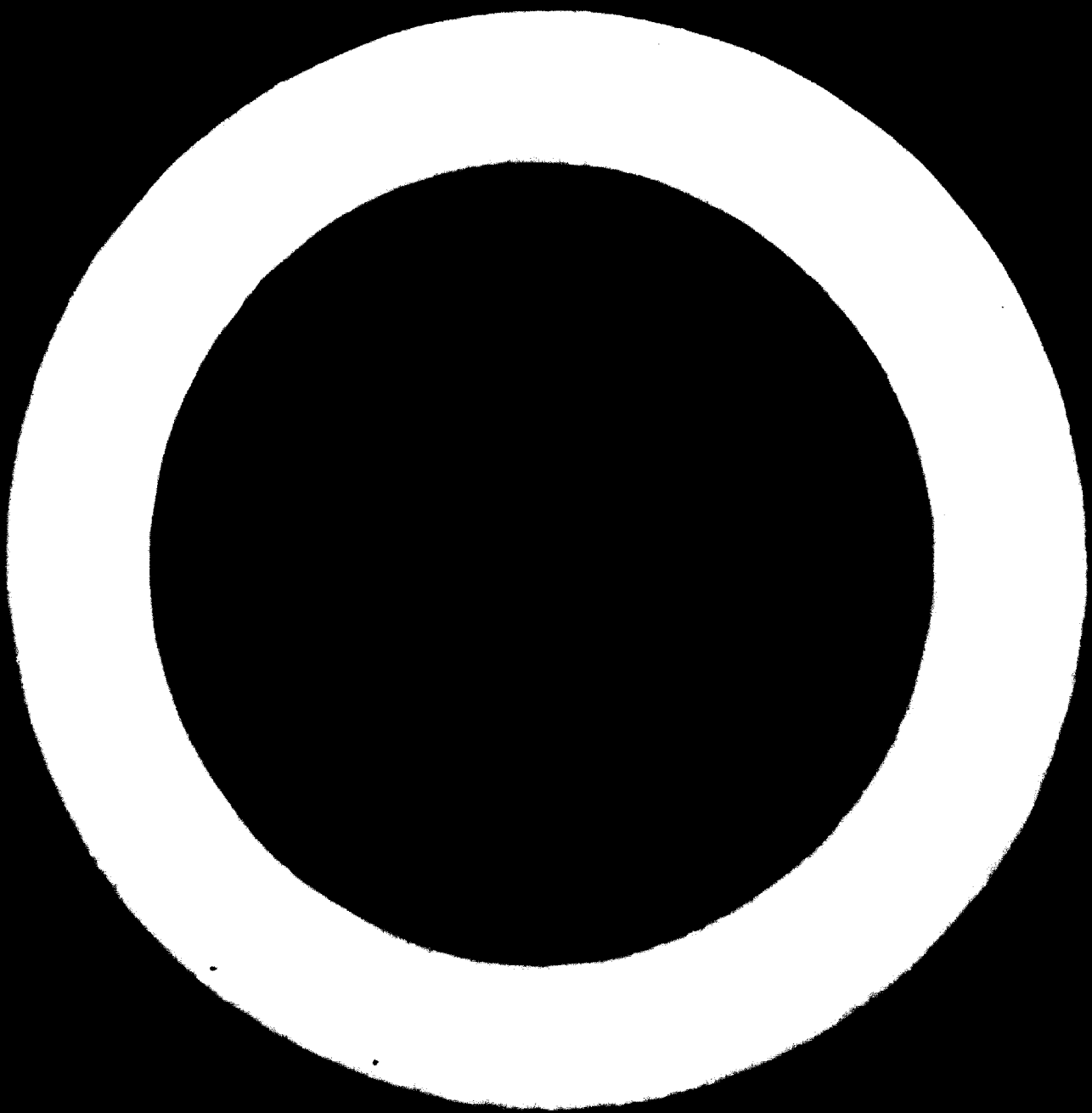

INTRODUCTION

The subject of the present study is maintenance and repair and spare part supply in manufacturing industry with reference to the problems of developing countries. The subject is treated within the framework of a market economy with planning ingredients which is the prevalent economic system in developing countries.

It is the purpose of this study

- to describe the role of maintenance and repair for economic development,
- to review the situation in developing countries,
- to highlight specific aspects of maintenance and repair activities which should be focused at the national level, and
- to outline some possible ways and means for improving or rationalising maintenance and repair in developing countries, taking into consideration their specific porblems.

Chapter I portrays the general present state in developing countries. The importance of maintenance policy is emphasised by sketching out the losses in production and growth which typically result from poor maintenance and repair. A theoretical analysis of optimal maintenance and repair activities of a country under different sets of conditions provides the basis for a thourough discussion of the problem of maintenance and repair with a view to the specific situation of developing countries. The quantity and quality of available labour as well as alternative choices of capital goods and maintenance techniques are taken into consideration. Special attention is drawn to the balance-of-payments aspect of maintenance policy.

Specific problems of maintenance and repair which should be dealt with at the national level are described extensively in Chapter II. The pros and cons regarding the import of new versus second-hand equipment are discussed under the aspect of maintenance and repair. The availability of spare parts is treated at some length; particular attention is paid to the establishment of central stocks of spare parts, and the possibilities for import substitution of spares and other maintenance materials are reviewed. Some considerations concerning the setting-up of repair shops in the context of industrial estates follow. The last paragraph gives a statistical survey of maintenance and repair activities in an industrialized country with a view to find clues for estimating present and future needs for maintenance and repair in developing countries.

The problems of maintenance and repair are analysed with regard to their relevance for economic policy. Conclusions and recommendations are made in the context of the theoretical dicussion. Chapter III reviews some additional ways and means of improving the maintenance and repair performance in developing countries. Recommendations include plannings activities, policy measures, standardization of machinery, creation of technical supervisory agencies, and the training of special repair workers.

For the sake of simplifying the terminology, the concept of "maintenance" is often used in this study in a broader sense including also "repair", especially in such standard terms as "maintenance cost", "maintenance workers", etc., instead of "maintenance and repair costs", etc. If, however, the context required a clear distinction between "repair" as replacing or mending of parts after breakdown of equipment, and "maintenance" as the set of measures to keep plant and equipment in good operating condition and to prevent breakdowns as far as possible, the term "maintenance" has been used with explanatory additions such as "preventive maintenance" or "maintenance proper".

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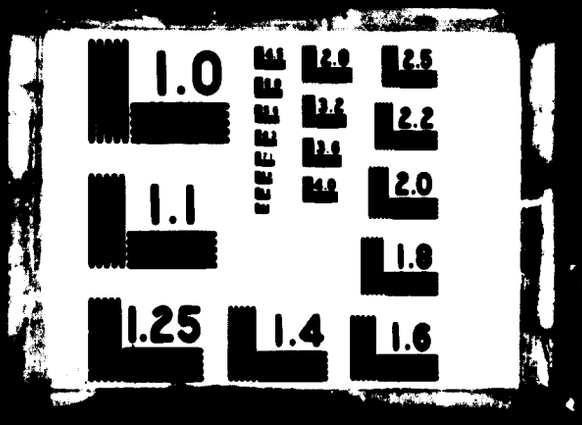

If parts have to be ordered from abroad, the customs clearing retards delivery substantially; delays of ten days and more caused only by customs clearing of spare parts flown in to a developing country are not unusual.

(iii) Import licensing and foreign exchange controls which are practiced in most developing countries get many firms to stock up more spares than are needed. Uncertainty of future quotas makes it appear safer to utilise import opportunities fully when they are offered rather than to trust future allocation of import licences or foreign exchange when spares would be needed. Under import control systems anticipated replacement needs, as reflected in import licence applications, tend to be overstated. Fear of sudden changes in import regulations (e.g. introduction of new controls, higher import duties, etc.) also accounts for excessive stock keeping. It may be pointed out that it is the economic system rather than disability on the side of the managers which leads here to the wasteful use of scarce capital resources, to a discrepancy between a single firm's gains and losses and the overall economic gains and losses of a country.

Where conditions in manufacturing processes require prompt availability of spare parts, the system of decentralised stock keeping of spares has many advantages no other system offers. If this system is chosen, it is necessary, however, to do everything to realise optimum stocking levels, that is to say:

(i) Operators and maintenance workers should be well trained to work with the equipment so that breakdowns are minimised.

(ii) Communication and distribution systems for spare parts should be improved. Much could be gained by facilitating and accelerating the customs clearing of spares imports.

(iii) Controls of spares imports should become less arbitrary and should be freed from lengthy administrative procedures.

3. The Establishing of Specialized Repair and Maintenance Shops in the Context of Industrial Estates

Medium and small-scale firms face particular difficulties in maintenance and repair. They are often too small to make the hiring of full-time specialists for maintenance and repair economical: these men cannot be employed to their full capacity. And what is more, the repair shop of a firm has to be supplied with a certain minimum of machines and tools. These, too, cannot be adequately utilized in a small-scale enterprise. The smaller firms, therefore, have to rely generally on outside contractors which are not easily found in developing countries. If maintenance is assigned to own employees who have not undergone appropriate training, the performance is most likely not of the desirable quality.

The maintenance problem of small-scale and medium-sized industries could be solved to the best advantage by establishing nearby specialised repair and maintenance shops. The creation of such repair shops might be promoted by the government or a special public agency, or they may be established by joint action of the industrialists themselves, possibly on a cooperative basis. In some cases, where several firms pool their demand for maintenance and repair services and hence constitute a regular clientele, private industry may be induced to set up repair shops. In the earlier stages of economic development, however, repair services should be regarded as promotional rather than commercial; initial steps for their provision should be taken by public authorities.

A pre-condition for setting up specialised repair shops is, of course, a certain regional concentration of firms demanding these services. The condition is particularly well met in so-called industrial estates.

Industrial estates have been founded, within the last decade, in almost all developing countries, with the general purpose to promote the development of small-scale industries. Industrial estates have been defined as "a planned clustering of industrial enterprises, offering developed sites, pre-built factory accomodation and pro-

vision of services and facilities to the occupants".[1] Whereas in industrialized countries only general services - such as power, water, sewerage, roads and railroads, etc. - are usually provided, the services and facilities offered in developing countries are of a broader scope: the special services (which differ, of course, from country to country, or even from estate to estate) include e.g. training facilities, technical counseling, marketing assistance, tool rooms, and machine shops. In some countries, maintenance and repair shops have already been added to this program of subsidizing small-scale industries.

Industrial estates must be large enough to guarantee the sufficient utilisation of capacity of the equipment which is installed in the repair shops. When planning the shops, the number of firms outside the industrial estate proper which may share in the services of these shops could be taken into consideration, but special allowance must be made for the regional factor: longer distances impair fast servicing. The transportation conditions in developing countries make this factor relatively more restrictive than would be the case in developed economies.

Repair shops in industrial estates could be established in connection with regional spare parts stocks. It would permit the production of some of the spares in the repair shops, or where existing, in the machine shops of the estate. It might also be envisaged using repair shops as training centres where employees of the customers firms are trained in routine maintenance work so that specialised craftsmen at the repair shops are free for the more complicated maintenance jobs, check-ups and repairs.

Most of the industrial estates which are promoted in developing countries are non-specialized, general-purpose estates accomodating all categories of small-scale industries. Servicing of firms which belong to a variety of branches makes higher demands on the skills of the craftsmen and the outfit of the shop: different specialists

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1 United Nations, Department of Economic and Social Affairs, Industrial Estates: Policies, Plans and Progress, A Comparative Analysis of International Experience, United Nations, New York, 1966, p. 4.

for several branches and a variety of machines and tools are needed. On the other hand, better utilisation of capacity may be guaranteed by a multi-branch clientele: electric motors, for instance, are used in almost every industry.

In single-trade estates which provide accomodation only to firms belonging to the same trade, repair shops can be smaller since narrowly specialized. Special advantages could ensue from connecting such shops with regional spare parts stocks at the branch level.

If well equipped and manned, maintenance and repair shops that are already operating in industrial estates might provide good opportunities for on-the-job training of craftsmen who may later be placed in newly established estates.

4. Quantitative Aspects of Maintenance and Repair

It is of particular interest for the individual firm facing an investment decision as well as for the public authorities engaged in national economic planning to have estimates on present and future maintenance requirements: the total cost, import content, and the manpower needed. In this paragraph, maintenance and repair costs in an industrialized country are analysed on the basis of the statistics available. Some of the findings are used to estimate present and future needs for maintenance and repair in developing countries.

A. Maintenance and repair in industrialised countries: The case of the USA

a) The cost of maintenance and repair in manufactures

Surprisingly there exists very little statistical information on maintenance and repair activities in the manufacturing industry of developed countries. Only one comprehensive report has been published by the U.S. Bureau of the Census as part of the 1958 Census of Manufactures program. The data on maintenance and repair cost, together with other data on selected costs and asset values, were collected in a special sample survey. The investigation covers the year 1957; neither in the half century before, nor in the decade after, this date have maintenance and repair costs been included in the Census of Manufactures.

The results of this survey are reproduced in table 5. The data show that, in 1957, over 9 billion dollars were spent in the USA for maintenance and repair on structures, grounds, and equipment of all operating manufacturing establishments. This sum is rather remarkable. In the same year, expenditures of the manufacturing industry for <u>new</u> plant and equipment totalled 12.145 billion dollars, expenditures for new machinery and equipment coming to 8.281 billion dollars thereof, a sum that is lower than the total spent on maintenance and repair.[1]

Table 5: Cost of maintenance and repair in U.S. manufactures: 1957

Industry group	Gross book value of depreciable assets, end Dec. 31, 1957	Expenditures for M&R on structures, grounds and equipment, in 1957			M&R expenditure as % of gross book value	M&R wages as % of total M&R expenditure
		Total	Salaries and wages paid to own employees	Other M&R costs		
	Mil. dol.	Mil. dol.	Mil. dol.	Mil. dol.	Percent	Percent
All industries	110,489	9,011	4,539	4,472	8	50
Food	11,731	777	357	421	7	46
Tobacco	400	24	11	13	6	45
Textile	4,984	354	148	206	7	42
Apparel	1,006	98	43	55	10	44
Lumber	2,917	292	111	181	10	38
Furniture	1,041	69	32	36	7	47
Pulp, Paper	7,165	514	239	276	7	46
Printing	3,697	172	78	94	5	45
Chemicals	13,105	909	459	451	7	50
Petroleum, Coal	7,936	501	263	238	6	53
Rubber	1,782	149	78	71	8	52
Leather	467	55	23	32	12	42
Stone, Glass	5,153	391	174	216	8	45
Primary Metals	17,329	2,000	1,064	936	12	53
Fabricated Metal	5,713	450	234	216	8	52
Machinery	9,421	624	326	298	7	52
Electr. Machinery	4,089	360	186	174	9	52
Transport Equip.	9,303	986	563	423	11	57
Instruments	1,263	97	54	44	8	55
Miscellaneous	1,987	188	96	92	9	51

Source: See page 64.

Source to Table 5:

U.S. Bureau of the Census, U.S. Census of Manufactures: 1958. Vol.I: Summary Statistics. U.S. Goverment Printing Office, Washington, D.C., 1961, pp.9-8 and 9-9. Percentages: own computation.

Source to Table 6:

U.S. Bureau of the Census, U.S. Corsus of Manufactures: 1958. Vol.I: Summary Statistics. U.S. Government Printing Office, Washington, D.C., 1961, pp.9-8 and 9-9.

U.S. Bureau of the Census, Statistical Abstract of the United States: 1959, (Eightiest edition), Washington, D.C., 1959, Table no.1054, pp.782ff.

Percentages: own computation.

Source to Table 8:

U.S. Bureau of the Census, Statistical Abstract of the United States:1959, (Eightiest edition), Washington, D.C., 1959, Table no.1054, pp.782ff.

Columns 3 and 4: own computation on basis of data published in: U.S. Bureau of the Census,U.S.Census of Manufactures:1958.Vol.I: Summary Statistics. U.S.Goverment Printing Office, Washington,D.C., 1961, pp.9-8 and 9-9.

The outlays for maintenance and repair amount to 8 percent of the gross book value of the fixed assets (that is the actual cost of the assets at the time of the purchase, including transportation and installation costs). The data for the individual industry groups show a very even and narrow distribution around this mark of 8 percent (which is the same as the median): 16 out of 20 industry groups spent between 6 and 10 percent of the value of their fixed assets for maintenance and repair; for 12 out of these 16, the percentages range from 7 to 9.

Total maintenance and repair expenditure is broken down into "salaries and wages paid to own employees" and "other maintenance and repair costs". On the average, within all manufacturing industries of the United States, half the sum of the 9 billion dollars spent on maintenance and repair was in the form of salaries and wages paid to own employees. Again the data for the different industry groups show only small deviations from this average; 15 out of 20 industry groups spent between 45 and 55 percent. Here again, the median proves to be equal to the average. There is no correlation between the deviations from the average observed here and the deviations from the average of total outlay figures.

The so-called "other maintenance and repair costs" include materials and supplies used for maintenance and repair activities as well as maintenance and repair services purchased from other companies. Hence, the breakdown does not distinguish between labour cost and cost of material of total maintenance and repair. It is not reported which part of the "other costs" is spent for outside services, that is on the salaries and wages of employees of other firms. In all probability, this share varies between different industry groups; not only technical reasons but also the cost aspect will influence the expenditure pattern: due to economies of scale, maintenance and repair work may be performed at lower costs by outside specialists than by own employees. There has been a vague indication cited by Morrow that expenditure on maintenance materials, equipment, and supplies make up 90 percent of the amount paid for maintenance wages and salaries.1 This implies a relationship between labour cost and cost of material in the order of 53 percent to 47 percent. Modern Manufacturing, an American review which is mainly concerned with management and maintenance problems, uses for its Maintenance Cost Index the relation of 60 percent labour to 40 percent materials charges. This breakdown seems to be realistic, and it is used in the later computations. 2

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1 L.C. Morrow, "Introduction" to Techniques of Plant Maintenance and Engineering 1955, 1956 Plant Maintenance Show, Inc., New York, 1955, p. 7.

2 Cf. "Maintenance Cost Index - Retooled for the 1970's", Modern Manufacturing, February 1970, p. 86.

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1 (from page 62:) U.S. Bureau of the Census, Statistical Abstract of the United States: 1959. Washington, D.C., 1959, table 1061, p.796.

Several conclusions may be drawn from the statistics of table 5 that are relevant for the purpose of the present study.

(i) First, the average manufacturing firm in the United States spends about 8 percent per annum of the gross book value of its fixed assets on maintenance and repair. Since the different industry groups show very little deviations from the average in this one year for which figures are available, it can be assumed that for the total manufacturing industry the percentage will not vary too much over time either. Thus, a percentage from 7 to 9 percent should be representative for a number of years around 1957.

(ii) About 50 percent of maintenance and repair outlays are in the form of wages and salaries paid to own employees of the manufacturing establishment. Again, there is very little deviation from this average in the different industry groups; so it can be regarded as a typical situation over some time, too. The share of total labour cost in maintenance and repair expenditure will be around 60 percent.

(iii) Since the aggregate "U.S. manufacturing industry" covers an exceptionally wide range of establishments it can be assumed that the total capital stock recorded on December 31, 1957, was composed of plants and machinery of every age (the only exception being equipment using very recently developed techniques). To say that a sum of about 8 percent of the total gross book value is spent, in one year, on maintenance and repair of all fixed assets of every age, is the same as to say that over the whole lifetime of every unit of equipment an average yearly expenditure of approximately 8 percent of its purchase price is made. Because of the uncertainties involved, a margin of at least ±10 percent should be allowed here, too, so that a percentage range of 7 to 9 percent would be realistic.

It should be emphasized that this is an average which is true only of the total manufacturing industry. The individual industry groups will show deviations from the average; the deviations will be greater the more the statistical total is split up. By no means

should this percentage be regarded as an average that is applicable for the individual machine. It is even less true that this average amount is to be spent actually every year in the course of the lifetime of a machine; the expenses will rather be lower for new pieces of equipment and then increase with its age. Since we are concerned with the macroeconomic aspects of maintenance and repair, we can disregard the deviations from the average.

(iv) If the average annual expenditure for maintenance and repair is multiplied by the average lifetime of fixed assets, we get the average total cost of maintenance and repair incurred during the lifetime of plants and equipment.

The concept of average service life of all fixed assets is rather artificial: there are great differences in the economic lives of capital goods, not only between buildings and machines, but also between different kinds of machinery, etc. Estimates of the average service life of capital goods - if available at all - vary substantially. Nevertheless, the concept is useful for obtaining a global figure that indicates the order of magnitudes involved. If, for example, we assume an average lifetime of 15 years, a figure which can be considered conservative,[1] then a total amount equivalent to 120 percent of the purchase price of the fixed assets has to be spent on maintenance and repair during this period. In other words: every dollar invested in manufactures entails on average at least another dollar in expenses for maintenance and repair.

b) Salaries and wages of maintenance employees

Table 6 illustrates another aspect of the cost of maintenance and repair: The amount of salaries and wages paid to own employees occupied in maintenance and repair is compared to the total payroll as well as to the sum of production workers' wages.

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1 Cf. Vaclav Nesvera, Study on Renewal, Repair and Maintenance, Manuscript, p. 13.

Table 6: Salaries and wages paid to own maintenance and repair workers in U.S. manufacturing industry: 1957

Industry group	Total payroll	Wages of production workers Share in total payroll	Salaries and wages of M&R workers	
			Share in total payroll	As percentage of the sums of production workers wages
	Mil.dol.	Percent	Percent	Percent
All industries	76,379	69	6	9
Food	7,143	59	5	9
Tobacco	234	83	4	5
Textile	3,183	78	5	6
Apparel	3,664	82	1	2
Lumber	2,110		5	7
Furniture	1,432	73	2	3
Pulp, Paper	2,734	74	9	12
Printing	4,301	57	2	3
Chemicals	4,090	57	11	20
Petroleum, Coal	1,150	67	23	34
Rubber	1,310	73	6	8
Leather	1,157	81	2	2
Stone, Glass	2,354	77	7	10
Primary Metal	7,019	78	15	20
Fabricated Metal	5,383	71	4	6
Machinery	9,050	67	4	5
Electr.Machinery	5,133	64	5	6
Transport Equip.	10,486	68	3	8
Instruments	1,571	60	3	6
Miscellaneous	2,826	65		5

Source: See page 64.

C. The establishing and keeping of central stocks of spare parts at the national, regional, and branch level

Less capital will be tied up if stock-keeping of spare parts is centralized. The higher the centralization, the smaller the inventories needed for every kind of spares, because a sort of "insurance principle" comes into effect. From this point of view, the highest degree of centralization, i.e. central stock keeping at the national level, would be most preferable. Other arguments in favour of centralizing stocks are:

(i) A central agency has better information of possible suppliers of spare parts both at home and abroad.

(ii) Orders for the domestic fabrication of spare parts can be pooled and production thus be rationalized.

(iii) Spare parts for older models that are no longer produced are better identified; central stock-keeping makes their availability much easier.

(iv) Administration of import licences and customs clearing is facilitated and accelerated.

The smooth functioning of central stock-keeping is, however, dependent on a number of conditions which have to be met in order to avoid damages to the economy which are more serious than any possible gains:

(i) The communication system must be well developed; it must permit the prompt placement of orders.

(ii) Management of the central stocks must have excellent professional standards. Accurate bookkeeping and inventory control should be a matter of course. Moreover, the men in charge of planning the inventories and purchasing the parts must be qualified technicians, familiar with the technologies in the various industries.

On average, 6 percent of the payroll costs in manufactures is spent on maintenance and repair activities. A somewhat higher percentage results if maintenance workers' wages are related to production workers' wages only; for the total manufacturing industry it is 9 percent.

Here, in both relations, the individual industry groups show greater deviations from the average than in table 5. The actual values range from 1 to 23 percent for the share of maintenance workers' wages in total payroll, and from 2 to 34 percent if maintenance workers' wages are related to production workers wages. The highest percentages are shown by the industry groups "Petroleum and coal products", "Primary metal industries", "Chemicals and Products", and "Pulp, paper and products". All of them are highly capital-intensive industries. On the other hand, in the industry groups with the lowest percentage of maintenance workers' wages in total payroll and in production workers wages - "Apparel and related products" and "Leather and leather products" - the capital intensity is very low. This suggests that the share of maintenance workers wages in total payroll is related to the degree of capital intensity.

Table 7 gives closer attention to this relationship. Here, the capital/labour ratios of the individual industry groups (that is: the ratios of fixed assets to total payroll) are compared with the share of maintenance workers' wages in total payroll; the industries are grouped in order of their capital/labour ratio. Figure 1 is a graphical presentation of this table. There proves to be a strong positive correlation between these two sets of values. [1]

It can therefore be concluded that the share of maintenance workers' wages in the total payroll of the US manufactures varies with the ratio of the gross book value of fixed assets to total payroll. Since the correlation of the respective values for 1957 proves to be very strong, there is good reason to assume that this dependency will also be true for other years, and perhaps indicate a general regularity.[2]

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1 Analogous results are obtained if, instead of the capital/labour ratio used in table 7, the ratio of fixed assets to number of employees ("capital per employee") is used, or if both ratios are applied only to production workers, not to all employees. - Only one industry group, "Primary metal industries", does not fit into this correlation. The data available do not present enough clues to explain sufficiently this deviation.

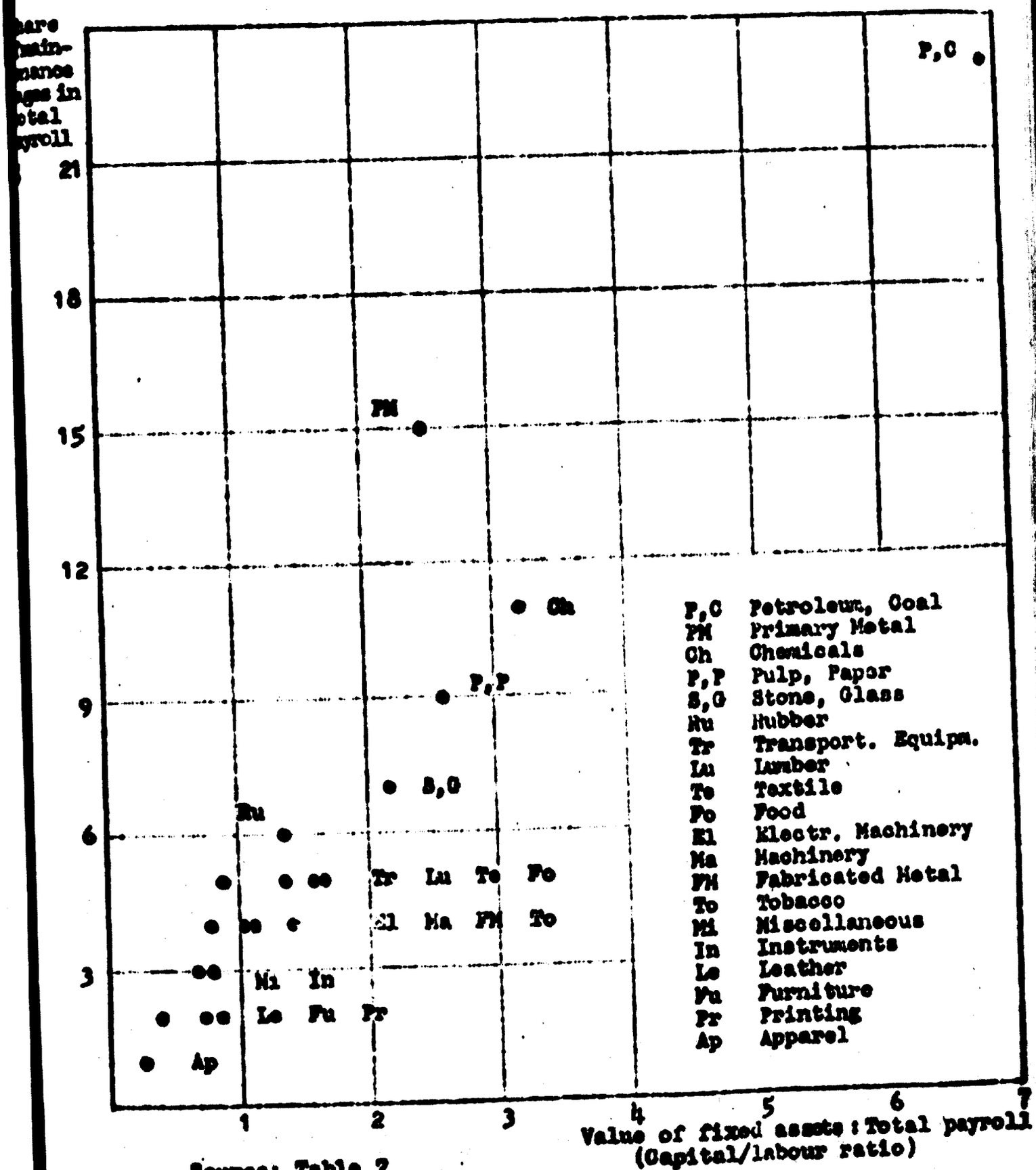
2 Cf. also V. Nesvera, op. cit., p. 25.

Table 7: Capital/labour ratio and share of maintenance workers' wages in total payroll in U.S. manufactures: 1957

Industry Group	Gross book value of fixed assets: Total payroll ("Capital/Labour Ratio")		Share of maintenance workers' wages in total payroll	
	Value	Ranking	Percent	Ranking
Petroleum, Coal	6.90	1	23	1
Chemicals	3.20	2	11	3
Pulp, Paper	2.62	3	9	4
Primary Metal	2.47	4	15	2
Stone, Glass	2.19	5	7	5
Food	1.64	6	5	7
Textile	1.57	7	5	8
All industries, average	1.45		6	
Tobacco	1.41	8	4	11
Lumber	1.38	9	5	9
Rubber	1.36	10	6	6
Fabricated Metal	1.06	11	4	12
Machinery	1.04	12	4	13
Transportation Equip.	0.89	13	5	10
Printing	0.86	14	2	17
Electr. Machinery	0.80	15	4	14
Instruments	0.80	16	3	15
Furniture	0.73	17	2	18
Miscellaneous	0.70	18	3	16
Leather	0.40	19	2	19
Apparel	0.27	20	1	20

Source: Own computation from data presented in Table 5 and Table 6.

Figure 1 : The share of maintenance workers' wages in total payroll compared with the capital/labour ratio in different industry groups of the United States: 1957



Source: Table 7.

e) The number of maintenance and repair employees

Table 8 presents an estimate of the number of maintenance and repair workers in the United States manufacturing industries. The estimate is based on the data on maintenance and repair cost in manufactures in 1957 and on statistics on the number of employees in manufactures in 1957.

The number of employees occupied in in-plant maintenance could be calculated by dividing the sum of the salaries and wages paid to maintenance workers (as given in table 5) by the average wage of these workers. However, on the basis of the statistics obtainable, the average wage of maintenance and repair workers cannot be computed exactly. The statistical sources allow only to calculate the average earnings of all employees, of production workers, and of all non-production employees. The average wage of production workers in every industry group proves to be lower than the general average wage, the average earnings of non-production workers and employees being, logically, above the general average.

Several considerations which cannot be further expounded in this study lead us to assume a maintenance workers wage which is below the non-production workers wage but above the production workers wage, the non-production and the production workers wages being the upper and lower limit. The values that are computed for the number of maintenance workers are therefore margins determined by these limits.

The results of our computation are listed in column 3 of table 8: the minimum figure is 722,000 and the maximum figure 1,109,000 employees occupied in maintenance and repair activities in total US manufactures, in 1957. This corresponds to 4 to 7 percent of the total working force in manufactures (column 4). Again, the highest, or respectively the lowest, percentages are shown by the same industry groups as in table 6.[1]

These results obtained from the statistical survey of 1957 are surprisingly in line with an earlier survey and with the latest figures available.

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1 This is not surprising since simple arithmetics prove that the values listed in column 4 of table 8 are only margins around the figures listed in column 3 of table 6.

Table 8: Number of maintenance and repair workers in the U.S. manufacturing industry: 1957

Industry group	All employees Number 1,000	Production workers Number 1,000	MAR workers (min.-max.) 1,000	Number of MAR workers as % of total number of employees (min.-max.) Percent
All industries	16,630	12,842	722-1,109	4 - 7
Food	1,688	1,134	71 - 95	4-6
Tobacco	88	81	2 - 4	2-4
Textile	989	893	26 - 57	3-6
Apparel	1,264	1,123	8 - 17	1-2
Lumber	646	579	19 - 37	3-6
Furniture	375	311	5 - 10	1-3
Pulp, Paper	565	458	36 - 54	6-10
Printing	867	534	14 - 17	1-2
Chemicals	767	508	67 -100	9-13
Petroleum, Coal	186	135	36 - 46	19-24
Rubber	260	205	12 - 17	5-7
Leather	362	323	4 - 8	1-2
Stone, Glass	526	437	28 - 43	5-8
Primary Metal	1,272	1,053	148 -205	12-16
Fabricated Metal	1,114	880	34 - 54	3-5
Machinery	1,707	1,266	59 - 68	3-4
Electric. Machinery	1,084	795	29 - 45	3-4
Transport. Equip.	1,900	1,401	85 -110	4-6
Instruments	307	212	8 - 12	3-4
Miscellaneous	665	514	15 - 27	2-4

Source: See page 64.

According to data collected for 1935 which cover a "cross section of plants engaged in manufacturing many kinds of products", the average proportion of maintenance to total plant employees was 6 percent, the proportion actually varying between 4 and 10 percent. 1 Exact comparison between these data and those given in table 8 is, however, not feasible because the industry groups covered in the 1935 investigation are not indicated.

The latest figures available are listed in table 9. They are part of a sample survey, published in March 1970, which covers 502 firms, mostly of medium to large size (59 percent of the sample firms had over 500 employees, 40 percent over 1,000). The data are probably of 1969.

Table 9: Share of maintenance employees in total plant employees in US manufactures, in percent

Industry classification	Share in percent
Heavy equipment, fabrication-and-assembly type	2.5
Light equipment, fabr.-and-assembly type	4.0
Services	5.5
Heavy equipment, process-type	8.3
Light equipment, process-type	8.3
Miscellaneous	11.1
Average, all industries	6.6

Source: Computed from data in "Survey mirrors today's maintenance Management", Modern Manufacturing, March 1970, p. 77.

In this survey, industries are grouped according to Modern Manufacturing's industry classification system. "Heavy equipment, fabrication-and-assembly type" or "Heavy fabricating" covers

1 L.C. Morrow, "Maintenance Organization and Management", Factory Management and Maintenance, Vol. 93, Nr. 12, December 1935, Supplement: Plant Operation Library, p. 3-163. Reprinted in: Factory Management and Maintenance Plant Operation Library, Massachusetts Institute of Technology, Cambridge, Mass., 1941.

electrical equipment, non-electric machinery, aircraft and spacecraft, etc. "Light fabricating" refers to fabricated metal products, electronics, instruments, etc. "Heavy process" covers petroleum refining, chemicals, rubber, primary metal, stone, clay and glass, pulp and papers. "Light process" includes foods, textiles, apparel, tobacco, part of chemicals, etc. 1

The new classification makes comparison of percentages with the 1957 survey rather difficult because the 1957 survey followed the Standard Industrial Classification system. In both statistics, however, the higher share of maintenance workers in process-type industries than in fabrication-and-assembly type industries is a common feature. The more comprehensive data of the Census of Manufactures show that maintenance labour and maintenance wage costs are relatively most important in heavy process-type industries (cf. table 7 and 8). Comparing the average figures between the two surveys, a slight increase in the share of maintenance workers in total plant force, from 1957 to 1969, cannot be excluded. 2

B. Conclusions for the planning of maintenance and repair in developing countries.

The results of this study of the quantitative aspects of maintenance and repair in the United States present valuable clues for estimating the needs in developing countries. They can be particularly helpful for estimating aggregate manpower requirements, overall capital needs, and foreign exchange demands regarding future maintenance of new investment projects in manufactures.

a) Maintenance and repair costs

As we have seen, average annual cost of maintenance and repair in US manufacturing industry amounts to about 8 percent of the capital invested; labour costs account for 60 percent and cost of

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1 Cf. "Better Way to Compare Your Plant's Maintenance Practices", Factory, Management and Maintenance, August 1958, pp. 138 ff.

2 Two other sample surveys giving, i.a., information on the importance of maintenance workers in total plant force, are even less comparable: "Maintenance Management Practices in Industry Today", Factory, Management and Maintenance, September 1958, pp. 90 ff., and "The Pulsebeat of Maintenance Today", Factory, June 1966, pp. 98 ff.

material for 40 percent of total maintenance and repair expenses. The amount of maintenance cost ist, of course, determined by the existing wage rates, prices for spares, and maintenance techniques. These may be different in a developing country, and any estimate of aggregate maintenance costs in a developing country on the basis of the American experiences must take these differences into consideration. In the following, three numerical examples have been computed in order to illustrate what the average cost of maintenance will be in the manufacturing industry of a developing country where conditions differ from the American example. The import content of maintenance costs, i.e. necessary foreign exchange outlays, is also computed.

In case 1, it is assumed that the developing country uses the same maintenance and repair techniques as the USA, and that all maintenance materials have to be imported. In case 2, it is assumed that the same maintenance techniques as in the USA are used but that only 50 percent of the spare parts and other maintenance equipment is imported. In case 3, the same import content of 50 percent of maintenance materials is assumed, but maintenance techniques are assumed to be more labour- intensive.

In all three cases, wages in the developing country make up only 40 percent of the wage rate in the USA, and the equipment used in production is always imported. This latter assumption entails that transportation cost and import duties have to be added to the price of the production equipment as well as to the price of the spares. In other words, the value of the fixed assets - to which the maintenance costs are related - is higher in the developing country by the amount of these additional charges. In our examples, they are assumed to be 40 percent of the value of the fixed assets. The same additional charge is imposed on the import price of spare parts and other maintenance materials.

United States:

	$
Investment	1,000
M&R costs per annum: 8 % of investment[1]	80
Wages thereof: 60 %	48
Materials " 40 %	32

Developing country:

	$
Investment, f.o.b. US port	1,000
Transportation and import duties: 40 %	400
Total cost of investment	1,400

Cost of maintenance and repair in a developing country:

Case 1

(Same maintenance techniques as in the US, all spares imported)

	$
Wage rate: 40 % of US wage rate	
M&R wages per annum	19.2
Import content of M&R materials: 100 %	
Cost of imported materials: 140 % of US cost	
M&R materials per annum	44.8
Total M&R costs per annum	64.0
Foreign exchange outlays thereof	44.8

Case 2

(Same maintenance techniques as in the US, 50 % of spares imported)

	$	$
Wage rate: 40 % of US wage rate		
M&R wages per annum		19.2
Import content of M&R materials: 50 %		
Cost of imported materials: 140 % of US cost	22.4	
Cost of locally produced materials: 80 % of US	12.8	
Total cost of materials per annum		35.2
Total M&R cost per annum		54.4
Foreign exchange outlays thereof		22.4

1 M&R = Maintenance and repair.

Case 3

(More labour-intensive maintenance techniques than in the US, 50 % of spares imported)

	$	$
Relation of M&R wages to materials: 70:30		
Wage rate: 40 % of US wage rate		22.4
M&R wages per annum		
Import content of M&R materials: 50 %		
Cost of imported materials: 140 % of US cost	16.8	
Cost of locally produced materials: 80 % of US	9.6	
Total cost of materials per annum		26.4
Total M&R cost per annum		48.8
Whereof foreign exchange outlays		16.8

b) Number of maintenance workers and wage cost of maintenance and repair

National industrial development plans generally contain some estimates on the employment effects of industrial projects. Here, too, the results of the US statistical survey may be useful economic guides for developing countries. It will be remembered that the share of maintenance and repair workers within the total labour force of US manufactures averages 4 to 7 percent, depending on the kind of computation used. Planning authorities in developing countries should regard these percentages as minimum figures which should be reached at least, but in most cases rather be surpassed. The reason is that while developing countries may have little possibility to adapt production techniques to their factor endowments, this is not the case with maintenance techniques. Developing countries realize their comparative advantage by using labour intensive methods and should therefore employ a higher maintenance force than industrialized countries.

As to the percentage of maintenance workers and the share of maintenance wages in total payroll in individual industry groups, the figures of table 7 and 8 may be helpful for more detailed manpower

(iii) Sufficient facilities for rapid transportation of ordered parts must exist both from the suppliers of these parts to the central stock and from there to the manufacturers who demand them - and these facilities must be available irrespective of monsoons, droughts, and other seasonal impacts.

The actual situation in most developing countries is still far from complying with these conditions: their communication and transportation systems have bottlenecks of one kind or the other; besides, the distances within many developing countries are enormous by European standards. Yet, the most crucial point seems to be to master the administrative task of such a central agency securing the supply for so many and different firms. Even in a country with a small industrial sector the centralization of stocks will require a highly sophisticated management.

The best way to run a central agency for spare parts efficiently might be in the form of a commercial enterprise, e.g. as a purchasing and storing cooperative or agency. The individual firms must have confidence in this agency as a prompt supplier. Quick supply, in turn, is only possible for the agency if it has secured access to spare parts, be it by imports or local production. The main role of the central agency would be to rationalize the storage of spare parts, and thus to save scarce capital.

The central agency if conceived as a public authority and endowed with the power to control and approve the individual firms' orders for spare parts, would be in danger to turn into a super-bureaucratic institution that is an obstacle rather than a promoter of economic investment, maintenance, and replacement of capital. The experiences of European countries under the regime of rationing and controlled supply (Bewirtschaftung) during World War II and the early post-war years may be worth-while taking into consideration. The experiences made in a large steel mill of the public

planning. Here, the relation between capital intensity and the number of maintenance workers required deserves due regard: the higher the capital/labour ratio of an industry, the higher the manpower needed in maintenance. Again, the percentages given for the single industry groups in the US ought to be considered as minimum figures, provided more labour-intensive maintenance techniques are applicable.

III. WAYS AND MEANS OF IMPROVING THE MAINTENANCE AND REPAIR PERFORMANCE IN DEVELOPING COUNTRIES

Generally speaking, maintenance and repair can be looked upon as a means to activate unutilised production capacities. By employing labour which is relatively cheap in activities which can be made relatively labour-intensive, developing countries will be able to realise their specific comparative advantages of production. Maintenance is a way to save capital by applying labour skills.

The problems of maintenance and repair have been analysed in this study with regard to their relevance for economic policy. Conclusions and recommendations resulting from the analysis have always been made in the context of the theoretical discussion. There remain some reflections on the practical implications for policy making which will be outlined in the following chapter.

1. Planning Activities

The planning of industrialisation cannot confine itself to the simple installation of new plant and equipment. The amount of costs to be spent on maintenance and repair and the manpower needed in these activities are so considerable, they cannot be neglected when planning investments. On the average of all manufacturing industries in the United States, the same amount that is spent initially on investment is spent again in less than 15 years on the maintenance and repair of this plant and equipment. In developing countries this amount will be somewhat lower if optimal maintenance policies are chosen, but it will still be remarkable.

Investment plans should, therefore, always include estimates on the future needs for maintenance and repair and the possibilities to

meet these requirements. The import needs deserve special attention in countries which are short of hard currencies. Some examples of global computations for total manufactures are given in this study. Similar but more detailed computations should be made for individual industries.

Where studies of the actual situation disclose lack of proper maintenance and repair, the public authorities could improve the performance by establishing regional repair shops, or by promoting private initiative to set up such shops perhaps on a cooperative basis. Plans for the creation of industrial estates should always include the establishment of a common repair shop.

Special steps should be taken to secure the supply of spare parts. The setting-up of regional stocks of spares will often contribute to solve the problem. Spare parts stocks should preferably be linked with a regional repair shop. Possibilities for a domestic production of spare parts should be explored thoroughly. The production of spares may be the appropriate first step towards an own machinery production.

In public sector enterprises, plan targets should not be set in a way that allows or even provokes negligence in the maintenance of equipment. If the plan targets are fixed in terms of quantity of output (instead of the value of the salable products, or profitability of the enterprise), and if this is the only criterion used to judge the performance of the firms, sacrifice of other important objectives which may conflict with production is encouraged. Instances are cited where preoccupation with maximising output in the short run resulted in total neglect of product quality as well as maintenance and inplant training programs. Not only was the management interested in achieving high levels of output, even at the cost of destroying capital, because output was the only criterion by which management was judged, but the workers, too, were similar-

ly motivated since bonuses were related only to physical output.[1] Plan targets as well as wage policy should avoid such encouragement to neglect maintenance. On the contrary, maintaining the capital in good condition should be a declared target, for which incentives are provided.

2. Other Policy Measures

The scarcity of capital in developing countries suggests that even greater attention is paid to maintenance and repair than in industrially developed countries, and it suggests that it is done in a labour-intensive way. Policy measures should be directed towards encouraging optimal maintenance activities. At least, they should not penalize them. Actually, negligence of maintenance on the side of the management, or a bias against labour-intensive methods of maintaining capital, has often be encouraged by public policy.

Payroll taxes discriminate against labour-intensive techniques in production as well as maintenance. Instead of relying on payroll taxes public revenues should be secured by other tax forms which do not penalize the hiring of workers in a situation of relative abundance of labour. A bias against employing more labour may also originate from minimum wage regulations which do not take the actual situation in a country into consideration.

A discrimination in favour of capital-intensive methods of production likewise results from tax incentives to reinvest profits. Part of the income or corporation tax, e.g. a dividends tax, is forgiven if the profits are reinvested.[2] The hiring of additional workers, however, does not give rise to tax benefits.

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[1] Cf. W.A. Johnson, op.cit., pp. 156-7, 163-4, 180-1. Economic history of the USSR and other centrally planned economies provide similar examples which induced these countries to change their original emphasis on tons of output.

[2] For details of a concrete case, see W.P. Strassmann, op.cit., p.127

The incentive towards greater capital intensity is highest if -in addition to the deduction of investment costs from income, even from the tax due- the taxable income in later years can again be lowered by normal depreciation of the assets bought with the tax credit. It is less if later deduction of depreciation is not allowed. In this case, the investment incentive consists not in a tax abatement but only in a deferral, an interest-free loan.

One way to correct this bias towards greater capital intensity would be to discontinue the system of tax incentives for investment. But since the objective of the tax incentive is to promote industrial expansion and economic growth, this solution would be inappropriate. A better way to end the discrimination of labour-using techniques would be to grant the re-investment allowance also for the employment of additional workers.[1] Such incentives would be particularly suitable for hiring trained maintenance workers and thus for improving maintenance performance.

The use of second-hand equipment should be decided on grounds of economic efficiency. It may have decisive advantages in a developing country. Policy measures should therefore not discriminate a priori against using second-hand equipment. Instances of discrimination that were reported are: difficulties in getting credits for the purchase of second-hand equipment and the imposition of high excise taxes on used vehicles.

3. Import Regulations

As long as equipment and spare parts have to be imported by a developing country, the import regulations remain a crucial point of maintenance policy. Under-estimation of the importance of maintenance and repair on the part of the public authorities is reflected by refusing e.g. import licences or delaying imports by cumbersome administrative procedures.

A quick and unimpaired import of spare parts is of the utmost

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[1] An interesting recommendation to promote labour-intensive methods of production by way of a tax deferral has been made by Strassmann. Cf.W.P. Strassmann, op.cit.,p. 126

importance for the full utilization of installed capacity, a problem with which most of the developing countries have to cope. Refusal to grant foreign exchange for one missing spare part may put a unit out of operation for a long time, a unit the installation of which may have cost a multiple of the price of the missing spare in foreign exchange outlays. This is "saving" in the wrong place.

The undelayed supply of spares imported, furthermore, prevents their unnecessary and wasteful hoarding ~~of parts~~ and the tying-up of capital. National import quotas should be "balanced": the import regulations must avoid discrimination against either, machinery or spares. The import of second-hand equipment, too, should be regulated purely on the basis of economic considerations. In many instances this will mean removal of restrictive practices.

4. Standardization of Machinery and Equipment

In many of the developing countries the great variety of types of installed machinery is confusing - and posing maintenance problems of their own. Especially the procurement and stocking of spare parts is complicated. As to the domestic production of machines, the adoption of a standardization system on the national, or preferably international level could help to reduce the inconveniences substantially. Foreign prototype machinery might also be redesigned partially to fit the national standardization system. The supply of spares for older, non-standardized equipment must remain secured, nevertheless, to prevent that capital is prematurely inactivated in a capital-scarce economy.

Regarding the equipment which has to be purchased from abroad, the simplest solution to get largely standardised products would be to concentrate on a single foreign country, even on the most limited number of firms. This would ensure a minimum of different types

of machinery but reliance on a single supplier country or even one firm may create undesirable secondary problems, political or economic dependencies which are unacceptible for the country. Higher prices of the products possibly offset the advantages of standardized machinery. While these extreme limitations should be avoided, a certain concentration on a group of supplier countries whose standards are compatible will bring advantages.

5. Technical Information

Lack of information makes for a great deal of difficulties in maintenance and repair. The indigenous maintenance staff quite frequently lacks proper information on the maintenance and repair of complicated foreign machine devices. Directions for the handling of these machines may be incomplete, or may pose "language" problems.

Apart from this, management as well as workers are often not aware of the maintenance problem since the adverse effects of inadequate maintenance cannot be seen immediately. Fragmentary information on buying and selling possibilities often causes difficulties in the supply of spare parts, and sometimes induces firms not to choose optimal production techniques.

Governments can promote cooperation of firms on the branch level to furnish better information on maintenance problems that are specific to that branch. Where this is not a feasible solution they could set up an organisation which will collect and forward technical informations. The organization may be a technical supervisory agency - as outlined in the following paragraph.

Governments should request the assistance of international organisations to improve information on maintenance requirements and to rationalise actual performance. Information on second-hand equipment could also be propagated by international cooperation.

6. Creation of Technical Supervisory Agencies and Statutory Check-ups

Technical information alone is not sufficient to improve the actual performance of maintenance. In many industrialized countries maintenance of machinery and vehicles is enforced by statutory periodical check-ups which are aimed primarily at promoting occupational safety. These check-ups may, however, also be considered under the aspect of enforcing maintenance standards. In industrialized countries special supervisory agencies are sometimes entrusted with these check-ups, e.g. the Technischer Überwachungsverein (TÜV) in the Federal Republic of Germany.

Developing countries might follow these examples and set up similar agencies. Their formal legal status may be that of a private institution commissioned by the government with the public function of supervision and endowed with statutory power of enforcement, such as the TÜV in the Federal Republic of Germany, or they may be a public institution which is directly responsible to a government. The establishment of such an agency should in both cases be considered as a public task.

Checking safety devices and the safe operation of equipment should be the main functions of this supervisory agency. This would already cover a wide field of activity and would include controling most of the important maintenance operations. Beyond this, the periodical check-ups could be given a broader scope: additional technical counseling on appropriate maintenance and repair could be provided on these occasions, especially for small-scale and medium-sized firms. Another task could be to draw up maintenance manuals and standards designed especially for developing countries, e.g. to give guiding lines for the use of anti-corrosion material under special climatic conditions.

7. Training of Maintenance Personnel

In the now industrialized countries a cadre of maintenance workers has developed step by step simultaneously with - and induced by - the gradual development of the capital goods production. Developing countries, on the other hand, skip most of these stages. They import modern equipment at a time when their own capital goods production if it exists at all, is still in its infancy and a "spontaneous" formation of maintenance labour has not yet taken place.[1] Therefore, governments should take deliberate action to ensure the training of maintenance personnel within their manpower planning programs.

Training for maintenance has a double aspect. One is the training of technical skills, the other the creation of a maintenance habit. Experts agree on the point that lack of appreciation of good maintenance and inadequate organization have more detrimental effects than deficiencies in skills. It is consequently of vital importance that management is made aware of the role of maintenance and repair in modern industry. Education programs should include executives as well as foremen and supervisors. They should cover subjects such as staffing, supervision methods, and organizational and clerical work pertinent to efficient maintenance.

Since the present state of maintenance and repair in most developing countries calls for urgent action, methods of <u>accelerated training</u> which have proved successful in industrialized countries would be recommendable for developing countries, too. Accelerated training has been defined as "a form of systematic concentrated training of a limited character, in order to transfer specific knowledge in a short period."[2] The description of experiences made in the Netherlands may be interesting in this connection.

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[1] Cf. R.C. Blitz, <u>JPE</u>, 1959, p. 570.

[2] G.K. Boon, <u>op.cit.</u>, p. 69-70.

"Several systems are followed, the main feature is to analyse a specific operation or group of operations, which will be qualified as a skill. The people are trained in the different aspects of the skill in a very systematic and clear way, theoretically as well as practically. Beforehand, the workers are tested in a simple way in order to ascertain such things as work-experience, intelligence, talents for the specific skill, character, physical qualities and so on.

In the Netherlands amazing results with this accelerated training have been achieved in the post-war rapid industrialization period. All kinds of metal-workers were trained, including maintenance and repair personnel; and also spinners and weavers, operators for mechanized agricultural equipment, lower and middle management- and administrative personnel." [1]

Avalanche effects are obtained by training first a group of instructors in accelerated training courses. These instructors could then be assigned to regional repair shops or technical supervisory agencies to organize accelerated training in maintenance and repair for the firms settled in the region.

To prevent government-sponsored training centres from becoming overcrowded, a compulsory set-up of maintenance training shops in big business firms could be envisaged, e.g. by tax exemptions. The training in regional repair shops or by technical supervisory agencies could be concentrated on the needs of small-scale and medium-sized firms.

In industrialized countries advanced specialized training is sometimes offered by so-called mobile repair shops or maintenance trucks. The German railways, e.g., employ mobile training shops for practical training in welding. Training in these shops is particularly economical; since they can be moved to different towns, a maximum amount of people may be trained by the same equipment, and by the same instructors. The use of mobile training shops seems to be particularly suitable for developing countries.

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1 G.K.Boon, op.cit., p. 70

sector in a rather advanced developing country may also illustrate our point:

> "The handling of the orders placed by the individual plants with the purchasing department in respect to urgently required spare parts and accessories threatens seriously the production operations. In some cases urgent requisitions of the plants were not forward d by offices which are not in a position to judge the necessity or urgency of the purchases. Repeated requests of the plants were unsuccessful." 1

The difficulties at the level of a national central agency for spare part supply would multiply compared to those arising at the level of a single firm.

From the preceding discussion it appears that a central stocking of spare parts at the national level is likely to be rational policy only in a very small country with a fairly well developed communication and transportation system and serving an industry which is not too diversified. Even then, complete centralization should not be aimed at: inexpensive parts that are needed frequently are better stored at the individual plant as are the important spares for continuous production. The central stock would assume the role of a "wholesaler", a general purchasing agency; it could be run privately or by a public authority whichever would be more appropriate within the context of the economy; it should, however, be run on a commercial basis.

In all other cases the odds seem to be more in favour of a modified solution: to establish central stocks of spare parts <u>at the regional level</u>. This solution would be similar to the central stocking at the national level in a small country. The distances between the various firms and the regional spare parts stock are shorter, transport problems are reduced, the difficulties for management decrease. The qualifications and limitations that were

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1 "Solveen Report on Rourkela Steel Plant", <u>op. cit.</u>, p. 304.

Appendix

A graphical presentation of optimal maintenance and repair activities of a country

A. The effects of differences in the interest rate

The formal relationship between (present) durability outlays and (discounted future) maintenance outlays is shown in Figure 2a and 2b. (1) In both graphs the 45-degree lines - in Figure 2a marked 1, 2, 3, 4, 5 (thousands) - are constant-outlay curves. They indicate combinations of durability outlays and discounted maintenance outlays which together make up 1, 2, etc. thousand dollars: For every point on the same constant outlay curve the sum of the coordinates is the same, namely the value given by the intersections with the axes.

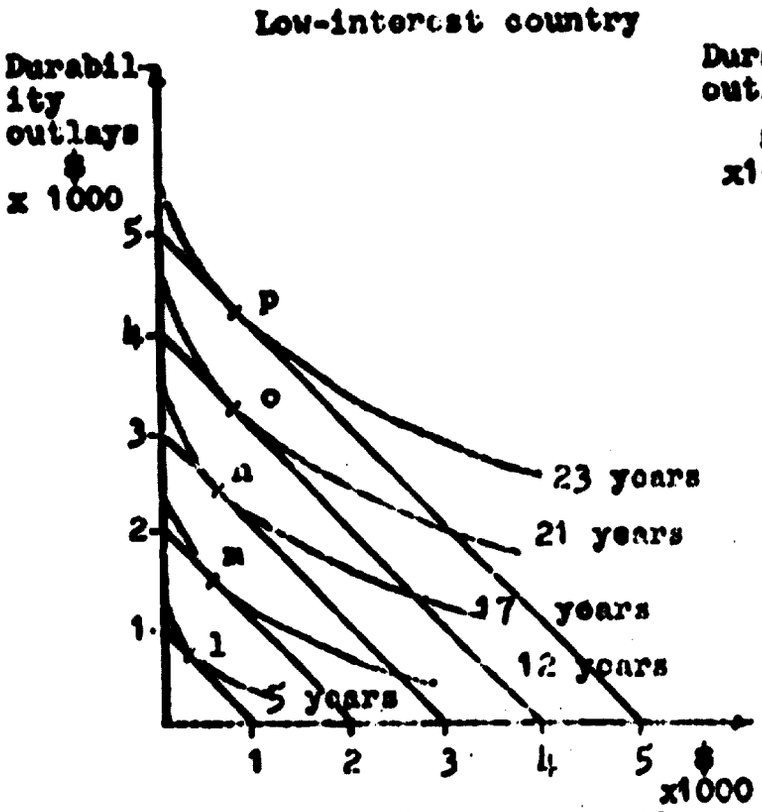
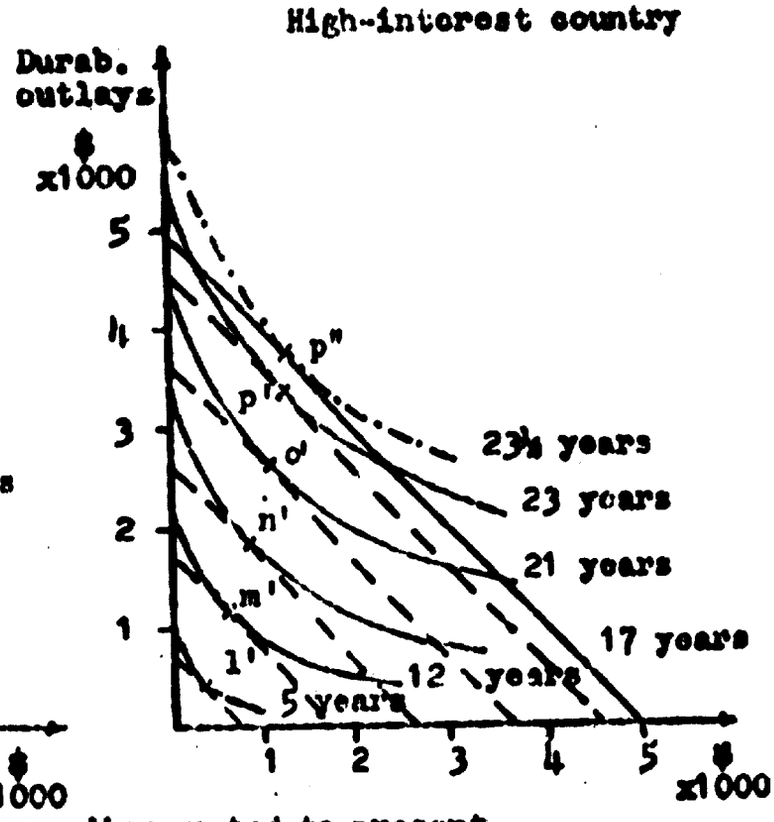


Figure 2 a



Maintenance outlays, discounted to present

Figure 2 b

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1 Figure 2 a is a slight modification of a graph used by R.C. Blitz, AER, 1950, p. 322.

The isoquants marked 5 years, 12 years, etc. show which combinations of durability outlays and discounted maintenance outlays are technically possible for obtaining a longevity of 5 years, 12 years, etc. They start from the durability-outlay axis to indicate that, in the extreme case, a certain desired longevity can be obtained by spending on durability alone without adding any maintenance. Since it is not possible to obtain a desired longevity with outlays on maintenance only and no outlay on durability at all, the isoquants do not intersect with the maintenance-outlay axis. The downward convex shape of the isoquants demonstrates that the rate of substitution decreases with rising share of either component of the cost combination.

The optimal combination of (present) durability outlays and (discounted future) maintenance outlays which minimizes the total cost of a chosen longevity is given by the tangential point of the isoquant of that longevity and a constant-outlay curve. For example: for a longevity of 21 years the point o in figure 2 a indicates the optimal combination of maintenance and durability costs which together amount to 4,000 dollars. Every other combination of maintenance and durability outlays procuring a longevity of 21 years - that is: every other point on the 21-years isoquant - will result in a higher total cost than 4,000 dollars.

The assumptions underlying Figures 2 a and 2 b differ in only one point, all other things being equal: Figure 2a represents a country where the interest rate is relatively low, Figure 2 b represents a country where the interest rate is higher. The purely technical relations remain unchanged, and it is also assumed that the future price of a "maintenance unit" is the same in both countries. The same technical combination of durability and maintenance contains, in the high-interest country, a lower present value of future maintenance outlays. That is, the present sum of money which is necessary for maintenance outlays in the future is lower because the interest rate is high. Therefore, the isoquants in Figure 2 b - as compared to those in Figure 2a - are shifted to the left in all points but one: the intersection with the durability-outlay axis. (The curves swing around the intersection points.) In the high-interest country, the same longevity.

of 5, 12, etc. years can be reached at a lower present cost, except for the extreme case in which the longevity is obtained by durability outlays alone.

The shifted isoquants in Figure 2 b do not touch the same constant-outlay curves as in Figure 2 a. Other optimal combinations of durability and maintenance costs for every chosen longevity are shown by the tangential points of the shifted isoquants and lower constant-outlay curves (dotted lines). In the high-interest country, the minimal cost combinations l', m', etc., for the same longevities are not only at a lower level of total (present) costs than in the low-interest country (price effect), but reflect also other combinations of the two cost ingredients: when the interest rate is higher, relatively more will be spent on maintenance and relatively less on durability (substitution effect). A comparison of the coordinates of the points o and o' shows this very clearly.

If the interest rate is higher, the same longevity of equipment can be obtained at a lower total cost than in the low-interest country because of the shift from a relatively higher spending on durability to a relatively higher spending on maintenance. If, however, the same total outlay as before is made, a higher longevity can be reached. The corresponding isoquant for the constant-outlay curve 5 is drawn in Figure 2 b (dotted isoquant). The optimal combination in this case also contains relatively more maintenance outlays and less durability outlays (cf. point p" in Figure 2b and point p in Figure 2 a).

The combined effect of differences in the interest rates on level and structure of longevity can be demonstrated as follows. In a high-interest country, the effect described in section c of the text will tend to shorten the chosen longevity of the capital goods (in order to reduce the cost of longevity). This can be demonstrated graphically by the shift from one isoquant, e.g. "23 years", to another isoquant, e.g. "21 years", in Figure 2 a.

But not only the present value of future savings is reduced in case of a higher interest rate. At the same time, the effect of the higher interest rate discussed in section b of the text will come into play: future maintenance costs, too, will have a lower present value and, by substituting maintenance for durability

outlays, the "longevity mix" will be changed towards a greater share of maintenance outlays. The substitution will lower total cost for the same longevity: the isoquants themselves are shifted towards the left (Figure 2b). For a total outlay of, e.g. 4,000 dollars a longevity of 22 years instead of 21 years (as in the low-interest country, Figure 2 a) may now be purchased. The optimum point on this shifted isoquant is situated more towards the maintenance-outlay axis.

B. The effects of differences in the wage rate

The combination of a high interest rate with a low wage rate causes a substantially larger shift of the isoquants to the left (turning around the intersection points with the durability-outlay axis) than is shown in Figure 2 b. The shifted isoquants are tangent to lower constant-outlay curves: The same longevity can be obtained at a considerably lower (discounted) cost; or by spending the same amount as in a high-wage/low-interest country, the low-wage/high-interest country can obtain a higher longevity. A reduction in total cost of longevity, induced by the high interest rate, is possible without reducing longevity, perhaps even extending it.

C. The effects of differences in the price of capital goods

These effects may be demonstrated graphically, too: An isoquant for the same capital longevity intersects the axis at a higher value for durability in the high-interest/low-wage country which imports the investment goods, than in the other country. A higher price of durability, together with a higher price of "maintenance capital" will shift the optimum still more towards a greater share of labour-intensive maintenance in total longevity outlays (cf. Figure 3 b).

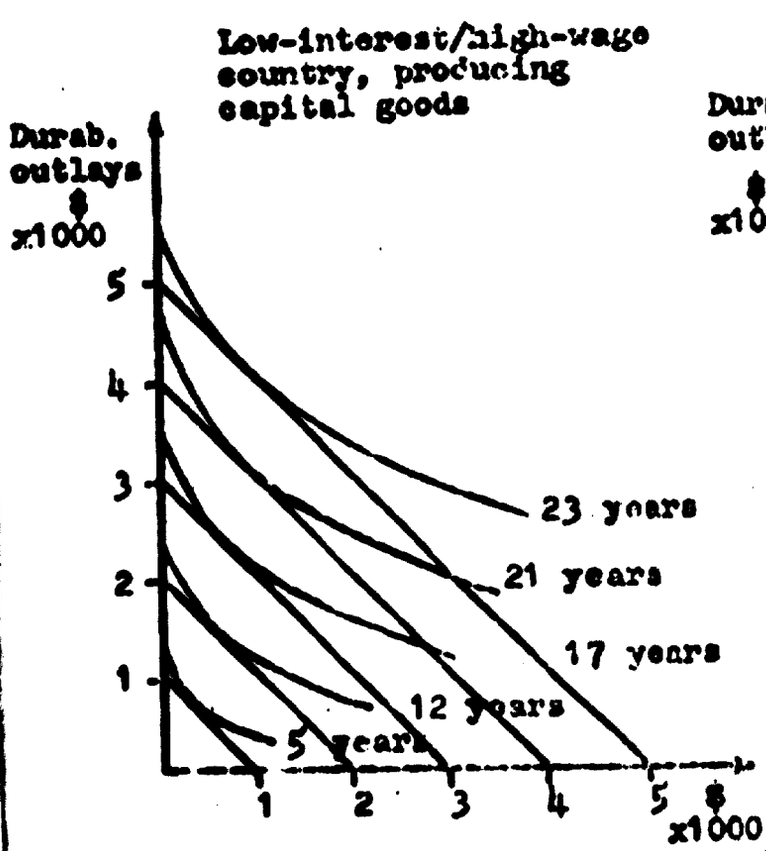

Figure 3 a

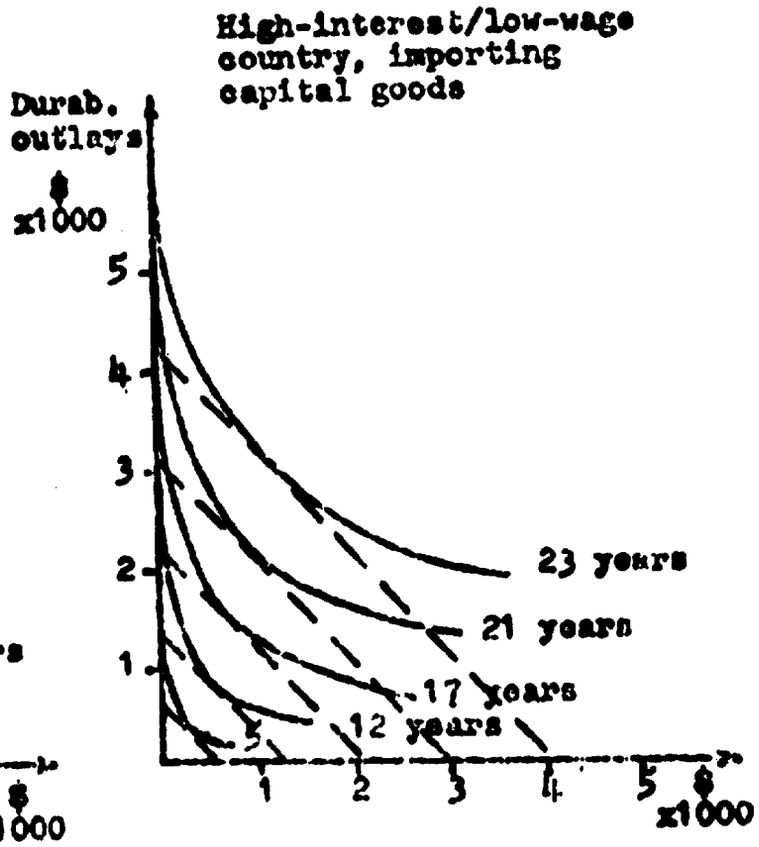

Figure 3 b

Maintenance outlays, discounted to present

D. <u>The combined impact of differences in interest rates, wages, and prices of capital goods</u>

The combined effects of the a..l three variables can be presented graphically, using the isoquant method as before (cf. figure 3 a and 3 b).

A comparison of these new graphs with the figures 2 a and 2 b proves the additional influence of wages and price differentials very clearly: the isoquants in figure 3 b intersect with the durability-outlay axis at a higher values and are shifted much more to the left.

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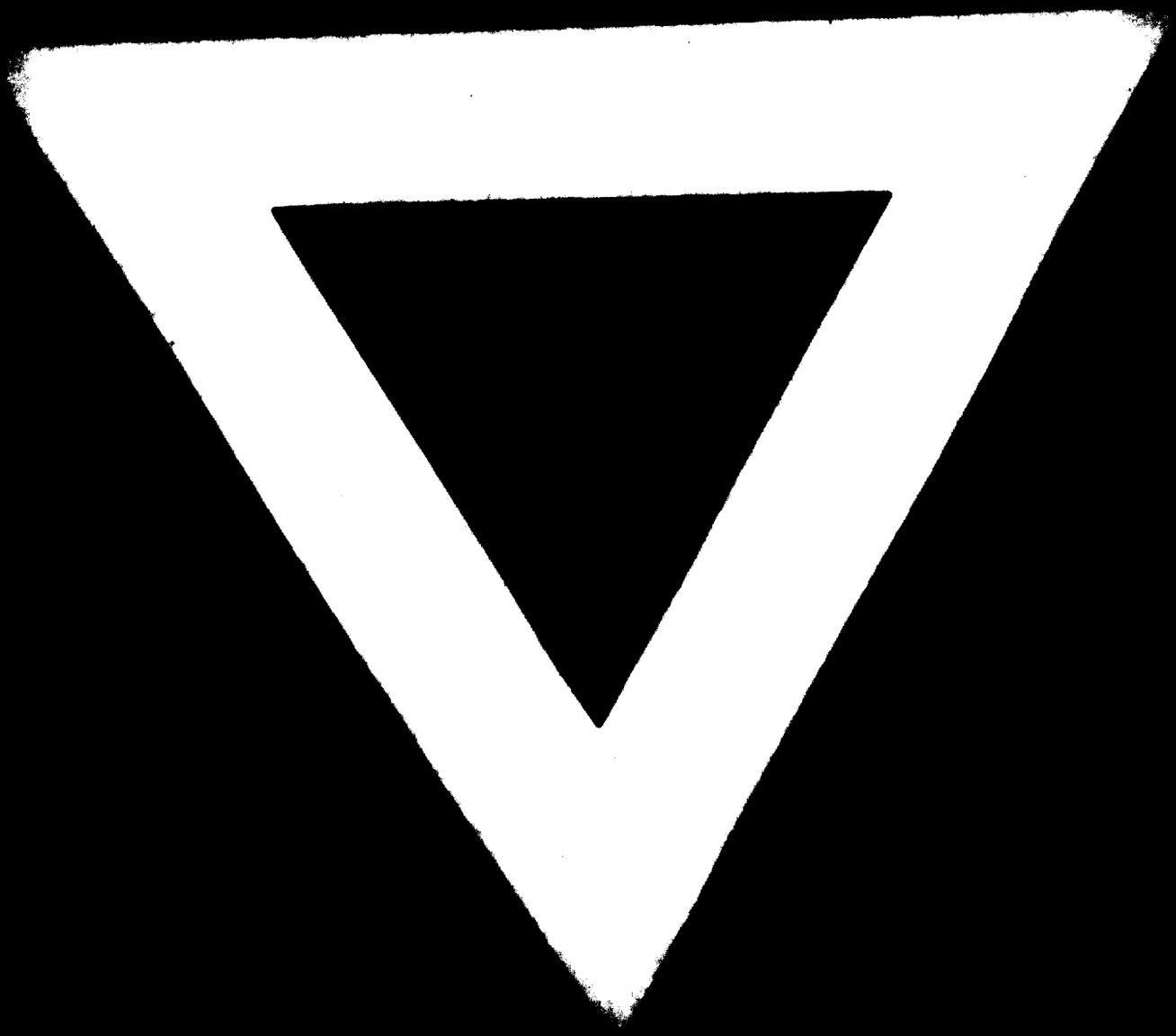

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outlined when discussing spare parts stocks at the national level will, of course, apply here, too. Generally speaking, central stocks of spares at the regional level are a reasonable compromise between easy availability of spare parts and the tying up of as little capital as possible.

One problem that may be better solved at the national than at the regional level is the allocation of orders for domestic spare parts production. If preference is given to those machine shops which are within the region (to avoid extra communication and transportation problems), capacities become unevenly utilized between the different regions, unless machine shops are evenly distributed, too.

Central stocks of spares at the branch level can be established for the country as a whole or on a regional basis. Unless it is a small country, centralization at the national level will bring hardly any advantages to a developing country for the same reasons that were mentioned before. Splitting up regional stocks of spare parts, according to the various industrial branches, into independent stock-keeping units may be economical provided the pre-conditions of good communication and transportation are met.

Specialised spares stocks for individual branches may reduce the technical and administrative standards which are required when keeping large general stocks for all industries. But certain derogations should not be overlooked: if an industry is not regionally concentrated, the choice would be either to keep fewer stocks, thus rationalizing the storage problem but creating transportation and communication problems, or to keep a larger number of stocks within good reach of all firms but giving up possible capital savings in storage. Regional spare parts stocks on the branch level would be favourable if industries are regionally concentrated; they would be very economical if different kinds of industries are concentrated in different regions.

D. Possibilities for import substitution of spare parts

In a developing country of type I all equipment has to be imported, and so have the spare parts. This may continue for a rather long period . It will be the normal situation even in the earlier stages of industrialization of a developing country of type II.[1] The step towards domestic machinery production is usually undertaken in the later process of development. In many developing countries as well as in the now industrialized countries, the local machinery production evolved from repair shops which branched out at a later stage.

In developing countries of type II which already have machine building and engineering industries of their own, the spares for domestically manufactured equipment can be, and are, produced by domestic manufacturers as well. Most spare parts for imported equipment - either new or second-hand - are imported, though. It is true that big business firms often produce the parts they need in their own workshops and, occasionally, spares for imported machines are ordered from local machine or repair shops. But this is not a general rule. There are various reasons why those countries defer domestic production of spares for imported equipment:

(i) Local facilities may not permit the production of technically complicated or high-precision items.

(ii) Imported parts are produced large-scale and are offered at comparatively low prices that leave little possibilities for domestic substitution at competitive prices.

(iii) Drawings and designs may not be obtainable from foreign producers, or patent rights may preclude reproductions.

(iv) Customers often prefer imported spares to their domestic substitutes because they apprehend inferior quality of the locally

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1 In India, for example, almost all the machinery and equipment needed for industrial development during the first planning period (1950/51-1955/56) was imported. Cf. Fourth Five Year Plan, A Draft Outline, Government of India, Planning Commission, (1966), p. 264.

produced items. The inferiority of substitutes need not be due to incompetent or less careful work of the local machine shops, but may be due to poor quality of available raw materials, e.g. steel.

(v) In a situation of acute shortage of raw materials it can be as lengthy - or as costly - to have spare parts produced locally as to get their import licensed.

It was reported, for example, that during a longer period of rationing strategic raw materials the - mainly small-scale - ancillary firms were left without any quota of essential raw materials, and if they wanted to continue production at all, they were forced to procure them at a higher price. 1

(vi) Inducement for the local production of spare parts may be lacking because the import of spares is not restricted, or because the national currency is overvalued. The import of spare parts may be just a habit developed during times of liberal import policies,[2] it may reflect sluggishness to look for other solutions, but far and formost it may be the cheapest way of obtaining spares if the currency of the developing country is considerably overvalued in relation to hard currencies. Even if there is a local machinery industry, it will not be able to compete with a foreign supply which is artificially cheapened by unrealistic exchange rates.

(vii) Sometimes, especially if the machine shops are of small scale and not locally concentrated, lack of information on the demand for spares may cause the producers aloofness from import substituting production. This lack of information, in turn, may reflect neglect of the spare parts problem on the side of the public authorities.

The possibilities for import substitution in a developing country may be larger or smaller depending on the obstacles which so far have prevented the substitution from gaining momentum. Any policy decisions must take these "barriers" into consideration.

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1 Saroj Kumar Basu, Alak Ghosh, Subrata Ray, Problems and Possibilities of Ancillary Industries in a Developing Economy, The world Press Private Ltd., Calcutta, 1965, p. 91.

2 Cf. Maintenance Imports, op. cit., p. 73.

The first two instances cited above indicate a situation where the comparative cost advantage is not - or not yet - on the side of the developing country. It would be a very costly policy for a country to force import substituting production of spare parts in such cases. This policy would compel a country to impose high import duties and initiate other administrative measures that are difficult to enforce. The possible outcome might be far from desirable.

In all other instances a developing country may - but must not - have a comparative advantage in the domestic production of spares. Before encouraging local production, the cost situation must thoroughly be analysed. It is of equal importance to identify - and to remove - those obstacles which impair the relization of comparative cost advantages.

(i) A more realistic exchange rate policy discontinuing the overvaluation of the domestic currency could bring about true comparative advantages in spare parts production, especially if production can be made labour-intensive. The distorting effects of an unrealistic exchange rate, of course, are not limited to spare parts imports.

(ii) The supply of raw materials for spares is a crucial point. The improvement of quality would require changes in pre-conditions the study of which goes beyond the scope of this paper. One of them, however, is better maintenance and repair. Where a shortage of raw materials has prompted a system of quota allocation, the discrimination of producers of spare parts should be avoided.

(iii) There are various possibilities to disseminate information on the local market of spare parts. The function of collector and transmitter of information could be assumed by the public authorities, professional organizations, e.g. employers associations, or by a spares stocking agency on the regional or branch level. The agency would be particularly suited as a "clearing house" for potential purchasers and manufacturers of parts.

(iv) If agreements on patent rights, designs and drawings have to be obtained from foreign owners of rights and documents, the spare parts agency or a professional organisation may take the initiative here, too. The necessary negotiations may be conducted under the sponsorship of International Organisations.