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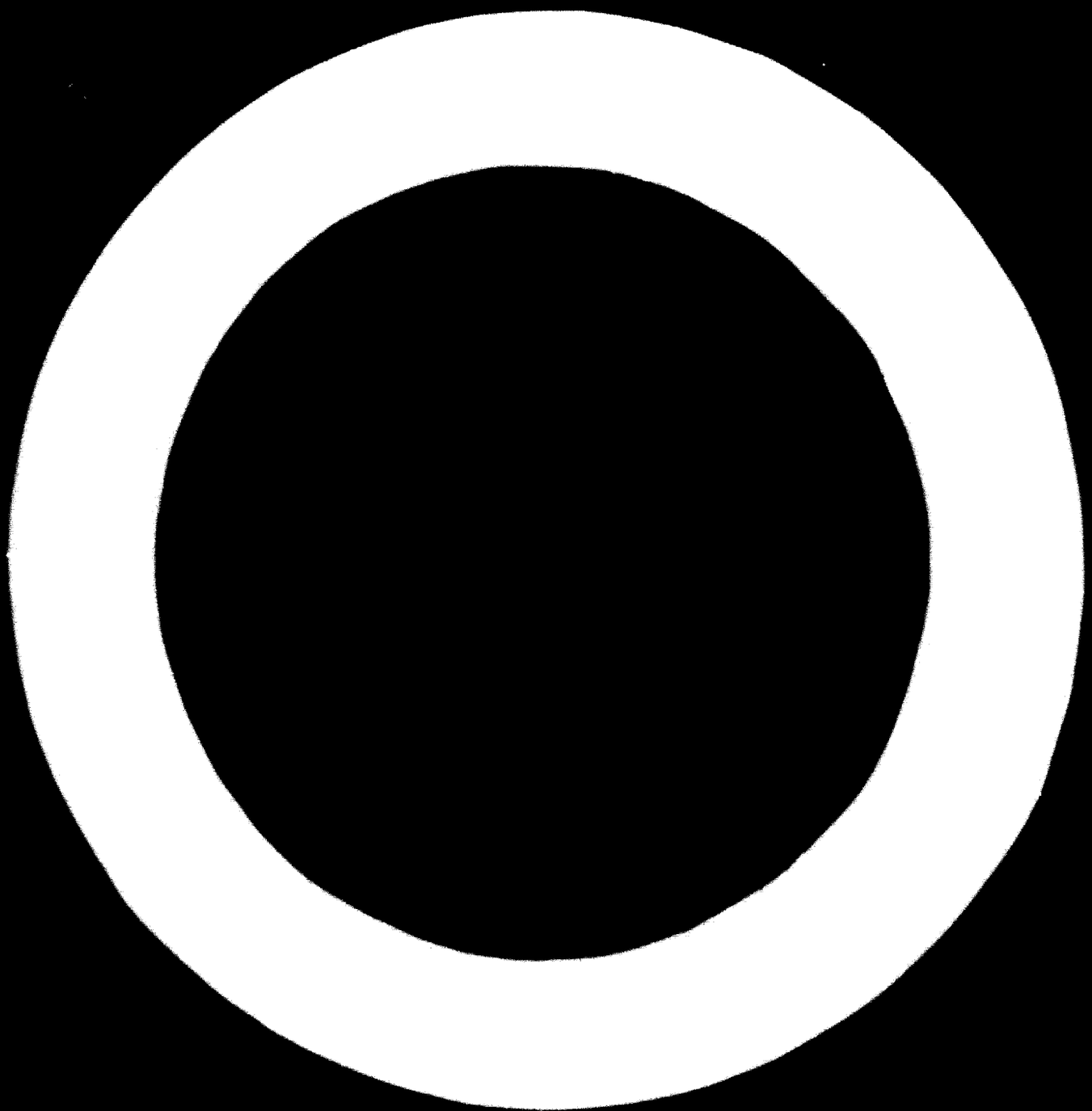

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*The role of maintenance and repair in the development of manufacturing industries**

This article considers maintenance and repair and the supply of spare parts in manufacturing industry with reference to the problems of developing countries. The subject is treated within the framework of a market economy with some degree of planning, which is the prevalent economic system in developing countries. The purpose of the article is:

(a) To describe the role of maintenance and repair in economic development;

(b) To review the situation in developing countries;

(c) To highlight specific aspects of maintenance and repair activities that should be focused at the national level;

(d) To outline some possible ways and means to improve or rationalize maintenance and repair in developing countries, with their specific problems taken into consideration.

For the sake of simplifying the terminology, "maintenance" will often be used in this article broadly to include also "repair", especially in such standard terms as "maintenance cost", "maintenance workers" instead of "maintenance and repair costs" etc. If, however, the context requires a clear distinction between "repair", meaning replacing or mending of parts after breakdown of equipment, and "maintenance", meaning the set of measures to keep plant and equipment in good operating condition in order to prevent breakdowns as far as possible, "maintenance" has been used with a qualifier, e.g. "preventive maintenance" or "maintenance proper".

Current status 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 will be maintained better than in industrially developed countries, which have a relative abundance of capital goods. Furthermore, the natural conditions in many developing countries call for special care of machinery and structures. A tropical climate and extremely high or low humidity pose particular maintenance problems unknown in temperate zones.

Unfortunately, the actual situation is far from what one could wish. For over a decade, 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 capacity which even economically stronger countries could hardly afford."[2]

The situation has hardly changed since 1958. The same complaints about neglect of maintenance and inadequacy of spare parts supply that were made in

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

[2] United Nations (1959) *Management of Industrial Enterprises in Under-developed Countries*, para. 84, as cited in *Industrialization and Productivity Bulletin* No. 2, March, p. 55 (Sales No.: 59.II.B.1).

a report of United Nations technical assistance experts in 1959[3] reappear in a case study of the steel industry in a developing country published in 1966.[4] So the United Nations Secretariat's plea for urgent action made in 1958 is also relevant today:

> "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."[5]

The lack of proper maintenance practices has serious consequences for 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.

Possible losses in production and growth resulting from poor maintenance and repair

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 report of the United Nations technical assistance experts cited above mentions numerous instances where equipment was allowed to deteriorate beyond repair and had to be replaced.[6] Negligence in the maintenance of buildings and structures can cause – in addition to direct losses – secondary damage to machinery that is inadequately protected. Since capital is scarce in developing countries, the importance of the destruction of capital is much greater than it would be in an industrialized country. Thus, the marginal impact on growth is likewise greater.

Production losses

Deterioration or destruction of equipment leads to losses in production. These losses are twofold: *(a)* undetected or unredressed wear and tear of machinery, or neglect of control devices, usually results in deterioration of product quality; *(b)* inadequate maintenance or incompetent repair causes frequent breakdowns of machinery leading to disruptions in the production process. During downtimes, when no productive services are being rendered, wages of idled labour and capital cost for idled equipment still have to be paid. The situation is aggravated if the repair cannot be carried out or the spare parts cannot be delivered immediately. The economic penalty for cessation of operation is highest for continuous-process type industries. The cost of interruption to operations is lower for fabrication or assembly of discrete units.[7]

Induced (secondary) losses

Primary production losses caused by poor maintenance and repair in one firm have negative effects on firms that are customers of this firm. If the quality of the intermediate goods is poor, the quality of the final products will also be poor unless the final manufacturer carries out further processing. 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.[8] 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 small. Frequent breakdowns of machinery, which reduce the output of a firm or lead to irregular deliveries, also affect the industry that is supplied by this firm. Here, too, disruptions in production may become unavoidable. To reduce their dependency on unreliable suppliers and thus to keep their production flow more regular, many firms customarily carry large stocks of intermediate products. This practice is normally unnecessary and ties up scarce capital uneconomically and hence wastes resources.

The construction industries provide particularly good examples of induced losses. Negligence in the maintenance of construction equipment causes delays in the completion of buildings and structures. In important industrial projects such delays will cause new delays and inconveniences in the "interrelated" industries; the setback in the implementation of the country's economic plan will be multiplied.

Other induced losses occur because of bottlenecks in the supply of spare parts, which may arise if their import is restricted or if their shipment is impossible without lengthy delays.[9] Hence, many firms try to hold an abnormally large stock of spare parts. For the individual firm, this policy is absolutely reasonable; but for the over-all national economy, it means a waste of resources. This type of loss might be avoided if the country revised its policy with respect to the supply of spare parts.

[3] United Nations (1959) "Some Problems of Industrial Management Reported by Technical Assistance Experts", *Industrialization and Productivity Bulletin* No. 2, March, pp. 53–57.

[4] William A. Johnson (1966) *The Steel Industry of India*, Harvard University Press, Cambridge, Massachusetts, pp. 174ff.

[5] *Management of Industrial Enterprises* as cited in *Industrialization and Productivity Bulletin* No. 2, p. 57.

[6] "Some Problems of Industrial Management" *Industrialization and Productivity Bulletin* No. 2, p. 55.

[7] Anon. (1958) "Better Way to Compare Your Plant's Maintenance Practices", *Factory Management and Maintenance*, August, New York, p. 140.

[8] Cf. Johnson, op. cit., p. 163.

[9] Cf. "Some Problems of Industrial Management", *Industrialization and Productivity Bulletin* No. 2, pp. 55–56.

Disguised losses

It is well known that in many developing countries installed capacities are underutilized.[10] It is less well known that excess capacity quite often disguises inadequate maintenance, at least temporarily. The breakdown of a poorly kept machine need not disrupt the firm's production process: a switchover to idle equipment is a frequently used device to keep production going. Only if the practice of poor maintenance and incompetent repair is continued for some time will deterioration and frequent breakdowns of the whole set of equipment become apparent.

The cannibalization of machines also belongs to the category of losses disguised by excess capacity: parts are stripped from idle machines to obtain the spares needed for broken machinery. This is only a temporary solution to the problem of obtaining spare parts. The basic issue is the failure of the Government to adopt a development policy that provides for an adequate supply of spare parts. As a consequence, the single firm makes uneconomic investment decisions.

Deterioration and delays in delivery can be disguised in a seller's market. Producers are always able to dispose of poor-quality products when 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 that forces consumers to purchase from firms not necessarily of their own choosing.[11] Here, consumers have to accept whatever quality is made available at whatever time.

Foreign exchange losses and damage to goodwill

The developing countries generally have to import most of their industrial capital equipment 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 that suffer notoriously from severe shortages of hard currencies.

Possible losses on the export side should not be overlooked either. Poor-quality products and lengthy times of delivery will not win customers in export markets. Once buyers realize that quality has deteriorated, future exports may be jeopardized. The "MADE IN . . ." mark of origin may lose its attraction, and the loss of confidence may not be confined to the actual low-quality product -it may well affect other exports of the country. The loss of prestige may become so serious that not even expensive marketing campaigns abroad or participation in international trade fairs will fully restore it.

An optimal approach to maintenance and repair activities in developing countries[12]

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

Maintenance and repair costs can be conceived as outlays aimed at extending the service life of the equipment that occur only after the equipment has been installed and has begun to operate. Spending on maintenance is one way to extend the service life -the "longevity" - of capital goods. The other way is to spend 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,[13] into durability outlays and maintenance outlays. Both are interrelated and should 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 that 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.[14] Whereas greater durability can 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 will be altered. On the other hand, greater durability for equipment of the same kind is possible only 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

[10] Cf. National Council of Applied Economic Research (1966) *Under-utilization of Industrial Capacity*, New Delhi, esp. p. 44—49.

[11] Cf. Johnson, op. cit., pp. 158, 162.

[12] A graphical presentation is given in the appendix.

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

[14] Cf. W. Paul Strassmann (1968) *Technological Change and Economic Development*, Cornell University Press, Ithaca, N.Y., pp. 195ff.

extreme case, longevity can be obtained by spending only on durability, without any maintenance.[15] On the other hand, it is not possible to achieve longevity by maintenance only; 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."[16]

Within the above-mentioned 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.

Durability outlays occur at the time of the initial investment, maintenance outlays 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 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 lower (higher). In other words: the amount of money to be put out at interest now to accumulate a given sum at a future date 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 low, the other a high interest rate. The equipment invested, the maintenance techniques and the future price of a "maintenance unit" (labour plus materials) are assumed to be identical 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 that results in minimal total outlays for a given longevity in a low-interest country is, however, not the optimal policy for a high-interest country with its different conditions. Since in the latter country "maintenance" is cheaper than "durability", economic rationality requires that more maintenance and less durability be bought 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), but it reflects also another combination of the two cost ingredients: more will be spent on maintenance and less on durability, compared with the low-interest country (substitution effect).

Hence follows the first recommendation for an optimal policy: other things being 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.

The influence of the interest rate on the longevity chosen

So far the analysis has been based on 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. The question now is which longevity will be chosen. The decision, again, is influenced by the prevailing interest rate.

To determine the optimal longevity of equipment when the investment decision is made, two factors have to be taken into consideration. One is the cost of additional longevity, the other is the "savings" that result from postponing the capital replacements in the future.[17]

If a machine of higher longevity is chosen for initial investment, there will be 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 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 cost of the initial investment and the discounted values of all future replacements is a minimum.[18]

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

[15] This is possible when the capital goods are buildings etc. For example: more expensive construction material is used that need not be painted instead of a cheaper material that has to be painted periodically to reach the same longevity.

[16] Blitz, *IPL*, p. 561.

[17] Cf. Blitz, *AER*, pp. 314ff.; Strassmann, op. cit., pp. 195ff.

[18] For a mathematical treatment see Fred M. Westfield (1958) "A Mathematical Note on Optimum Longevity", *The American Economic Review*, Vol. 48, No. 2, June, pp. 329–332.

rate. If the savings are smaller, the increment in cost of longevity has to be smaller, too. Hence, the optimal longevity will be shorter if the interest rate is higher. Other things being equal, the optimal choice of capital longevity in the country with a high interest rate would thus be a lower capital longevity compared with the country with a low interest rate.

The combined effect of the interest rate on the level and structure of longevity

In the two preceding sections, 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 the 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. The effect on the level of longevity (i.e. the longevity chosen) consists of a direct tendency towards shorter lifetimes of capital goods combined with an indirect effect via the substitution of maintenance for durability. The indirect effect works in the opposite direction: it lowers the total cost of longevity and therefore curbs the tendency towards a shorter lifetime. The change 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 above-mentioned indirect effect. This is assumed because all savings occur in the future, and therefore the interest rate affects the total savings. As for the cost aspect, only part of the longevity mix, namely, expenditure on maintenance, occurs in the future. Thus, the higher interest rate affects only part of the cost side, and the impact on the savings side should be greater. The higher the share of maintenance costs in the total longevity costs, the less the longevity will be reduced by the impact of a high interest rate.

Other things being equal, the country with a 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 an extreme case, it may remain almost unaltered.

The effects of differences in the wage rate

Up to this point, the analysis has been 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 regardless of whether the countries had high or low interest rates. This assumption is now dropped.

Differences in the interest rate between two countries – excluding 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 labour, and vice versa. That is why a country with a relatively high interest rate may also 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. If the same techniques for maintenance and repair are applied in both the high-wage and the low-wage countries, the maintenance wage per hour, and therefore the total cost of maintenance, will be less in the low-wage country.

Maintenance and repair costs are composed not 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 with less mechanical aid; repair may be more labour-intensive 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, especially if the price of maintenance capital in the low-wage country is higher. In the ideal case, this substitution will take place until the marginal costs of labour and capital are equal to one another and to their marginal products. The substitution of cheaper maintenance labour for maintenance capital will result in an even greater reduction of total (future) maintenance costs.

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

The conclusion drawn in the previous section ought to be modified now, with the influence of wage differentials taken into account. The combined effect of a high interest rate and a low wage rate will make it economically optimal for the country to choose a greater capital longevity than the low-interest, high-wage country. The higher longevity should be achieved by substituting maintenance for durability and, in addition, by choosing labour-intensive maintenance techniques. On the other hand, the optimal policy

Table 1

COMPARATIVE COST DATA ON DEPRECIATION AND MAINTENANCE FOR A NITROGEN FERTILIZER PLANT WITH ALTERNATIVE LIFETIMES OF 10 AND 15 YEARS, UNITED STATES AND CENTRAL AMERICA

(Thousands of US dollars per year per one million dollars of investment in the United States)

	United States		*Central America*			
			Same techniques in maintenance and repair as in the United States		*Greater relative use of labour in maintenance and repair*	
	Ten years	*Fifteen years*	*Ten years*	*Fifteen years*	*Ten years*	*Fifteen years*
Depreciation	100	67	135	90	135	90
Maintenance and repair	40	80	35	70	29	58
Labour	20	40	8	16	14.5	29
Spare Parts	20	40	27	54	14.5	29
Total	140	147	170	160	164	148

SOURCE: United Nations (1959) "Problems of Size of Plant in Industry in Underdeveloped Countries", *Industrialization and Productivity Bulletin No. 2*, p. 22 (Sales No.: 59.II.B.1).

for a country with a low interest rate and a high wage rate will be to choose equipment of less longevity, to spend more on built-in durability than on maintenance, and to apply capital-intensive maintenance techniques.

The effects of differences in the price of capital goods

If the capital goods that two countries invest and some of the "maintenance capital" (e.g. spare parts) that is used in both are produced in only one of the countries namely, the low-interest, high-wage country, the price of these capital goods is likely to be higher in the other country, which has to import these goods. Transport cost and customs duties will raise the price. It has already been pointed out 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 level will also make the (initial) capital expenditure on built-in durability less attractive.

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

The combined impact of differences in interest rates, wages and prices of capital goods between two countries can now be summarized. 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 with a short lifetime, to obtain the chosen longevity by spending more on built-in durability and less on maintenance, and to carry out the indispensable maintenance and repair work by capital-intensive methods. The optimal policy for country B would be to choose capital goods with a 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 labour-intensive techniques.

The preceding analysis can be illustrated by a numerical example computed by the United Nations Bureau of Economic Affairs (see table 1). The example compares the average yearly costs of depreciation and maintenance for a nitrogen 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 differences in wages and prices.[19]

It is assumed that the extension of longevity of the fertilizer plants can be achieved by increasing the outlays for maintenance and repair. According to the practice in the United States, maintenance costs are divided equally between labour cost and outlays for spare parts. Plant equipment and spare parts are produced only in the United States and have to be imported to Central America. This raises their costs in Central America to 135 per cent of the cost in the United States. On the other hand, labour cost in Central America is estimated at 40 per cent of the labour cost in the United States.

It appears that the shorter lifetime of ten years is most economical in the United States, whereas in Central America the extension of longevity to fifteen years is the economically rational choice, even if the

[19] For another example see United Nations (1961) "Use of Industrial Equipment in Underdeveloped Countries: Problems of Maintenance, Repairs, Replacement and Obsolescence", *Industrialization and Productivity Bulletin No. 4*, pp. 33–36 (Sales No.: 60.II.B.2).

same techniques in maintenance and repair were applied as in the United States. Central America could even gain a higher cost advantage from the extension of longevity to fifteen years, if more labour were 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 absolute terms is lower in the United States even if a lifetime of fifteen years is chosen; Central America achieves a relative cost advantage only by extending the service life of the capital good.

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 with industrialized Europe. There is enough evidence, indeed, that the United States, which has had a high wage rate and a low interest rate since 1945, has been acting according to the principles arrived at in the preceding theoretical analysis. It is well-known that in the United States, equipment is designed so that it will be easy to service. Parts and units are exchanged rather than repaired; repairs and replacement of parts are executed with a maximum of mechanical aid. All this is done to avoid the high costs of labour-intensive maintenance and repair.

In industrialized Europe in the post-war period, wages were lower than they were in the United States and interest rates higher. Labour-intensive maintenance and repair were of much greater importance than they were in the United States.

There is not much reliable information on the longevity of capital goods. In the United States, many "durable" consumer goods can be bought cheaply and are disposable after a short service life. There are some indications that the longevity of capital goods in general is lower in the United States than in Europe and that it is declining with time in all industrialized countries.[20]

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 high interest rates and low wage rates and the prices of capital goods are high, compared with those in industrialized countries. However, some modifications have to be introduced that take the specific conditions of developing countries fully into account.

The effect of 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) are interchangeable. In reality, however, this is not the case, and the impact of this fact on the model must be considered.

Generally, an abundance of aggregate labour exists 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 structure in industrialized countries. Since most of the maintenance and repair activities require skilled or even highly skilled workers, the cost of labour-intensive maintenance and repair may be extremely high in the developing countries, too. The actual situation in the developing countries requires that a differentiation be made between short-run and long-run solutions as well as between developing countries.

For the purposes of this article, developing countries can be divided into two groups:[21]

(a) Type 1—traditionally purely agrarian countries that are now taking the first steps towards industrialization, have only a poor tradition in handicrafts and are not familiar with even the simpler modern technologies;

(b) Type 2—countries that have already a certain industrial tradition, 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 1

What is the optimum short-run policy for countries of type 1, where skilled maintenance workers are exceedingly scarce? The most obvious solution would be to choose projects that do not require maintenance and repair because they have enough built-in durability to reach a certain longevity. However, this is possible only for a very restricted category of projects, such as buildings, roads, or bridges. All kinds of machinery with moving parts need a certain amount of maintenance.[22] Hence, other solutions must be found.

In the short run, these countries have to employ foreign specialists for practically all maintenance and repair work for complicated industrial devices. These specialists receive an even higher remuneration than they do in their home countries. All investment goods and maintenance equipment, too, have to be imported from industrialized countries and hence will be more expensive than in the exporting countries. In this situation the factor-price relationship will not induce substitution of maintenance labour for maintenance capital, nor in general, of maintenance outlays for

[20] Cf. Blitz *AER*, pp. 326—7; Blitz *JPE*, pp. 562—4; L. Rostas (1948) *Comparative Productivity in British and American Industry*, New York.

[21] Under certain circumstances, this distinction may reflect two stages of development.

[22] Cf. Hirschman, op. cit., pp. 141—2; Blitz *AER*, p. 324.

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 effect of the interest rate will be moderated or totally equalized.

Under these conditions, the optimum short-run policy for a country of type 1 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. If there is a choice between two types of equipment, one requiring highly specialized production workers but less skill in maintenance and repair (simple machinery), the other requiring semi-skilled workers in production but highly skilled maintenance workers (sophisticated equipment), the decision should be in favour of the second type of equipment (the optimal choice also in the industrialized country). This is so because maintenance workers have to be "imported" anyway—for both types of equipment. The differences in wages for these specialized foreign workers are only "marginal"; so it is economically rational to employ them in maintenance activities where professional skill requirements are highest. Semi-skilled production workers, on the other hand, can be trained in a relatively short time; hence, foreign assistance is needed here only in the first stages of industrialization.

When policy is considered in terms of the long run, the dynamic effects of economic development come into play. Within the context of the theoretical model, the most important effect of economic growth is the development of manpower skills. Countries in the early stages of industrialization do not command 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 in which a country in the early stages of development can reach eventually the point of substituting abundant—skilled—labour for scarce capital, i.e. it profits from its natural comparative advantage by using its cheaper (abundant) factor of production.

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 debatable; experts have expressed opinions on both sides. Hirschman, for example, considers preventive maintenance (not repair) an administrative process "intrinsically harder to master than production jobs".[23] Consequently, it presents a particular problem in the 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."[24]

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."[25]

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

The type of industry best fitted for vocational training in maintenance skills in developing countries depends to some extent on the "weakest" point in skill deficiencies, which in turn depends on the degree of industrialization already reached. 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

[23] Hirschman, op. cit., p. 154.

[24] Ibid., pp. 154 and 141.

[25] William A. Haven (1954) "Selection of Steelmaking Processes and of Locations for Integrated Iron and Steel Works", *A Study of the Iron and Steel Industry in Latin America*, Vol. II, p. 356. Cited by Strassmann, op. cit., p. 201, United Nations Publication (Sales No.: 1954.II.G.3, Vol.II).

that maintenance habits are the most difficult to promote. Some experts therefore give preference to industries having the highest "educational" effect. Hirschman, for example, recommends that developing countries concentrate on new ventures with a complicated technology (preferably machine-paced, process-centred) that compels maintenance:

> "... 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."[26]

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

Hirschman's propositions imply that the capital- and maintenance-intensive ventures chosen at the early stages of industrialization should not only be continued but should even be expanded during the following stages. 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 proposal is "generally too expensive in terms of capital and skilled labour to be introduced on a mass scale".[27] 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 provide additional opportunities for trained workers to acquire professional skills and to be trained to adopt maintenance habits—"breakdown maintenance" in the case of simpler technical equipment.

Repair after breakdown is said to have the same psychological assets as production activity: success or failure in performance is immediately apparent.[28] Moreover, "breakdown maintenance", or "replacement at failure", is by no means an inferior way of maintaining equipment. It may be cost-saving if the cost of downtimes is smaller than the cost of preventive maintenance. 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 equipment falls into this category.[29] Examples include 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 that it familiarizes workers with simple techniques and avoids the discouraging "latitudes" and the high organizational requirements of preventive maintenance.[30] This form of training appears to be particularly suitable for developing countries with very few skilled maintenance workers. The training of experienced repairmen for preventive maintenance would be the next step. The country would eventually reach the stage typical for countries of type 2.

Countries of type 2

Countries of type 2 are better supplied with labour than the predominantly agrarian countries of type 1. Countries of type 2 can already count on a cadre of workers familiar with maintaining and repairing simple, conventional equipment. In the short run, these countries may have to rely on foreign specialists for the servicing of some complicated modern industrial equipment, but these foreign specialists act mainly as advisers, training people rather than doing the job themselves for a long period.

The problem of training in manual skills may be solved satisfactorily and reasonably quickly, but the problem of developing a maintenance habit remains the pivotal point of long-term development efforts. As pointed out before, maintenance and repair are not valued highly in most developing countries, where not only the labour force but also management shows lack of interest in maintenance activities—if not outright hostility to them. A change in the mentality of management is as important as the acquisition of maintenance and repair skills by the worker. The training of managers and the instruction of foremen ("a necessary social stratum lacking in preindustrial societies"),[31] may be added to the catalogue of preconditions for raising the production factor of labour to a level comparable to that of industrialized countries.

Once a maintenance habit has been formed, the developing countries in the long run should gain an advantage in maintenance and repair costs compared with the industrialized countries.[32] Although the training and upgrading of maintenance workers as well as a greater awareness of the maintenance problem will eventually cause wages to rise, maintenance labour is likely to remain cheaper than in industrialized 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 the already industrialized countries.

[26] Op. cit., p. 142.

[27] "Use of Industrial Equipment in Under-developed Countries", *Industrialization and Productivity Bulletin* No. 4, p. 31.

[28] Hirschman, op. cit., p. 154.

[29] D. W. Jorgenson, J. J. McCall, R. Radner (1967) *Optimal Replacement Policy*, North-Holland Publishing Company, Amsterdam, esp. pp. 45ff., 70–71, 132ff., 146ff., 156ff.

[30] "Use of Industrial Equipment in Under-developed Countries", *Industrialization and Productivity Bulletin* No. 4, p. 43.

[31] Strassmann, op. cit., p. 273.

[32] Cf. also Blitz, *IPL*, pp. 560 and 564ff.

With regard to the theoretical two-country model, it may be concluded that developing countries of type 2, especially in the long run, are adequately presented in the model of the low-wage, high-interest country, whereas, paradoxically, the model of the high-wage, low-interest country (normally the industrialized country) is applicable for the short-run conditions of countries of type 1.

Alternative choices of capital and techniques in developing countries

Except for a country of type 1 under short-run conditions, the factor relationships in developing countries suggest as optimal policy, a "two-stage" substitution of labour for capital: (1) spending less on durability than in industrialized economies, but extending the lifetime of equipment by more intensive maintenance and repair; and (2) relying on more labour-intensive methods of maintenance and repair than is customary in developed countries. The applicability of this policy under present-day conditions may now be examined.

Degree of durability of equipment

The decision for greater or less built-in durability at the time the initial investment is made may be considered first. Enterprises in a developing country buy most of the investment goods from producers in industrialized countries. Naturally, this equipment is generally designed to meet the needs and requirements of firms in industrialized countries. In these cases, the developing countries have no choice between more durable or less durable capital goods. They have to accept equipment that is more 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 by repairing installed plant and equipment when they would have been replaced in developed countries.

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

(a) Some of the equipment supplied by developed countries has different degrees of built-in durability and repairability, that is, requires more maintenance or less maintenance. Firms in industrialized countries make use of this choice, and so could the industrially less developed countries. Sometimes changes in maintenance requirements entail changes in operating characteristics (machines may be run at different speeds etc.). As long as these changes do not impair the quality of the final product, they are unobjectionable. They may sometimes suit the needs of developing economies even better (smaller-scale production, lower speeds of output etc.)

(b) In the more advanced developing countries (countries of type 2) where machinery is already produced locally, foreign prototype machines may be redesigned to suit local materials, standards, or skills of operators. Maintenance and repair requirements may also be redesigned.[33] Initial costs for durability can be reduced (but this means higher maintenance and repair costs) by using cheaper materials, a simpler construction, or by permitting less accuracy in assembling.

(c) A third way to purchase less durability is to import second-hand equipment from industrialized 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 2, 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 this machinery profitable in the high-wage countries without doing so in the low-wage countries; the latter may find it a bargain to buy these machines. The problems involved in the use of second-hand machinery will be analysed more thoroughly later in this article.

The capital intensity of maintenance and repair

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

[33] Cf. Gerard Karel Boon (1964) *Economic Choice of Human and Physical Factors in Production*, North-Holland Publishing Company, Amsterdam, pp. 55ff.

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

(a) Auxiliary work may be mechanized by introducing mechanical aids for mounting and demounting machines, handling of machine parts and in transport.[34]

(b) The labour content of repairs may be lowered by adopting a policy of "unrepairability and expendability" of components; the single broken part is not identified, removed, repaired and replaced, but a "package" of parts, or "functional unit", is replaced by a new one.[35] By this method the time and manpower involved in fault identification is reduced, and handicraft repair (regrinding, reconditioning, soldering etc.) is made unnecessary.

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

These rather 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 2, where wages of skilled workers are comparatively low. These countries may realize their comparative advantage by:

(a) Avoiding all capital-intensive forms of maintenance and repair;

(b) Relying on more conventional practices for auxiliary work as well as repair work proper;

(c) 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 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.[36] Production of spare parts in industrialized 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 could produce them without economic losses. Import substitution for economic reasons should then be avoided.

The balance-of-payments aspect

Shortages of foreign exchange have become common to all but a fortunate few of the developing countries regardless of the degree of industrialization they may have reached. These shortages place limits on all economic plans for industrial development. Import substitution and export promotion have been popular recommendations for improving the situation, whereas the maintenance and repair aspect has enjoyed much less attention. Its influence on the balance of payments, however, is anything but negligible.

It is evident that the premature destruction of equipment owing to poor—or lack of any—maintenance causes the need for replacement, and hence imports, to arise prematurely and this places 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 industrialized 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 when the initial investment is made, high expenditure on spare parts and other "maintenance capital", and finally, high replacement outlays after a short time.

An investment aimed at reducing production costs and saving foreign exchange and based on the developing country's factor endowments would be determined by the following considerations:

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

(b) 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 is reduced, and so is the total amount of requisite foreign exchange.

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

At first sight, the highest savings in foreign exchange would seem to follow from the domestic production of the equipment itself. In this case, however, raw materials and components must often be imported all

[34] Cf. British Productivity Council (1952) *Plant Maintenance, Report of a Visit to the U.S.A. in 1952 of a Specialist Team on Plant Maintenance*, London, December, pp. 46—49.

[35] Cf. Anon. (1960) "Maintainability of equipment" in *McGraw-Hill Encyclopedia of Science and Technology*, Vol. 8, McGraw-Hill, New York, p. 75.

[36] Cf. also: "Use of Industrial Equipment in Under-developed Countries", *Industrialization and Productivity Bulletin No. 4*, pp. 32, 46.

Table 2

SECOND-HAND EQUIPMENT AS PERCENTAGE OF TOTAL FIXED ASSETS IN JAPANESE INDUSTRY, BY SIZE OF FIRM

Size of firm (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 1,000	4.6	4.1	4.9	3.3	3.1

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

the same, and this makes for smaller over-all savings. (Of course, the development of a domestic machinery industry may still be economically advantageous for other reasons.)

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

BASIC CONSIDERATIONS WITH REGARD TO THE IMPORT OF NEW VERSUS SECOND-HAND EQUIPMENT

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 consideration 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 is of importance to the public authorities. Moreover, the system of import licensing and foreign exchange controls practised 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 United States in the mid-1960s, almost 95 per cent of the second-hand machinery offered on the market was purchased by United States firms.[37] At least two second-hand machine tools were sold in the United States for every new one.[38] 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.

There has been a certain tendency among developing countries to refuse the import of second-hand equipment. The situation in industrialized countries like the United States or Japan suggests that the arguments against using second-hand equipment need some rethinking. A developing country should no more be advised to acquire only used machinery 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. The main factors that have obviously influenced the employment of second-hand equipment are the size of the firm, type of ownership, the physical characteristics of processes and their rate of obsolescence.[39]

[37] United Nations (1966) *Report of Expert Group on Second-Hand Equipment for Developing Countries*, para. 15 (Sales No.: 66.II.B.9).

[38] Albert Waterston (1964) "Good Enough for Developing Countries?" *The Fund and Bank Review: Finance and Development*, Vol. I, No. 2, September, p. 91.

[39] Cf. Strassmann, op. cit., pp. 201—205.

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*	*Undecided or no response*
Small	10	6	1		
Medium-size	11	7	2	1	5
Large	7	16	3	1	
US subsidiaries	17	10			1
European subsidiaries	1	1			
Immigrant	1	6	1		1
Private national	9	8	5	1	3
Public national	-	4	-	1	
Non-durables producers	9	20	4	1	1
Durables producers	19	9	2	1	4
Total	28	29	6	2	5

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

Preference for second-hand equipment has been strong in metalworking and in the production of items of low precision. Second-hand purchase is also preferred for equipment with an average rate of technical obsolescence. It is popular with small firms whose financial resources are limited, since it enables them initially to obtain equipment cheaply. 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 for second-hand equipment. To illustrate the use of second-hand equipment in developing countries, the results of an investigation covering 70 Mexican and Puerto Rican 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."[40] 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 equipment that was replaced because new machines were available that produced improved goods. Yet in most cases the acquisition of second-hand equipment is lucrative when the machinery produces goods of the same quality as the new machinery but does so at a lower cost under the conditions of a developing country. In the following discussion only this latter case is considered, the analysis being limited to the maintenance aspect.[41]

The isolated effect of differences in maintenance costs

In the absence of technological progress, the operating characteristics of a new machine will be the same as those of the replaced machine. The only reason for installing a new machine is the increase in maintenance costs of the machine in use. Theoretically, this would be the time for a low-wage country to buy the old machine if its maintenance costs are below those 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 a "premature" replacement of the machines, the potential buyer may fear—and his apprehension may actually be justified—that the old equipment is being replaced only because it is physically worn out and that satisfactory performance may no longer be expected from this equipment. Even if the equipment still works rather well, the difference in maintenance cost may not exceed the "threshold of perceptibility"; whether it does will depend largely on the extent of the wage differentials.

While in fact differences in maintenance costs are likely to affect the decision in favour of second-hand

[40] *Report of Expert Group*, para. 62; see footnote 37.

[41] For a more comprehensive discussion see *Report of Expert Group*; Sen, op. cit.; Strassmann, op. cit. As for second-hand transportation equipment, see John R. Meyer (1966) "Transport Technologies for Developing Countries", *The American Economic Review*, Vol. 56, No. 2, May, pp. 83–90.

Table 4

ARITHMETICAL EXAMPLE: "NET SAVINGS" FOR INDUSTRIALIZED COUNTRY AND DEVELOPING COUNTRY ON NEW AND USED MACHINES

	Industrialized 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 (per cent)	3.65	3.65	7.30	7.30
3. Opportunity cost of outlay on machine	$365/year $1/day	$182.50/year $0.50/day	$730/year $2/day	$365/year $1/day
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 [1 × (25 + 1)]	$229.50 [9 × (25 + 0.50)]	$4 [1 × (2 + 2)]	$27 [9 × (2 + 1)]
7. Expected yearly interest and breakdown cost per machine	$365.00 26.00	$182.50 229.50	$730.00 4.00	$365.00 27.00
	$391.00	$412.00	$734.00	$392.00
8. Expected "Net savings" (−) on new over used machine	+ $21	.....	− $342	.....

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

equipment only in connexion with other factors (to be discussed later), the influence of differences in maintenance costs is isolated in the following discussion so that the proper effects of these differences can be seen more distinctly.

The rising maintenance costs of older equipment are largely due to a higher probability of unexpected breakdowns. The impact of breakdowns varies, depending upon 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: in particular, 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.[42]

In highly capital-intensive production of the 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.[43] Here 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 industries supplied by the afflicted industry, a temporal setback in economic growth may result. A developing country should, therefore, refrain from buying used equipment of the above-mentioned 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.[44]

The situation is different in industries of fabrication-and-assembly type or benchwork type that use light equipment and are less capital-intensive. Here, the breakdown of one machine affects the operation at other production stages only slightly, or not at all. The cost of breakdowns consists mostly of the wages of idled operators, and these are low in developing countries. Under these conditions, a low-wage, capital-scarce country could still find it a "bargain" to buy 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 industries of the second type can be illustrated in an arithmetical example (table 4).

[42] Cf. Blitz, *JPE*, p. 568; Strassmann, op. cit., p. 203.

[43] Cf. "Better Way to Compare Your Plant's Maintenance Practices", pp. 139–140; see footnote 8.

[44] Strassmann, op. cit., p. 213.

In this example, yearly interest and breakdown costs of a new versus a used machine are compared in an industrially advanced and in a developing country. It is assumed that each breakdown interrupts the production for exactly one day. 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 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 preferring a 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 choose a used machine instead of a new one. In the arithmetical example presented here, the cost of each repair may even be ten times as high as daily operating costs, i.e. $20 per repair executed, but the advantage of using an old machine instead of a new one would still be substantial: $342 — $160 = $182.

This extremely favourable result with regard to the use of second-hand equipment is due to the assumed high wage differentials between an industrially advanced and a developing country. But even if a higher daily labour cost in the developing country is assumed, e.g. $8 instead of $2, 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" on 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.

The effect of premature obsolescence

For a developing country planning to import second-hand equipment, the physical condition of this equipment is very important. The physical condition is primarily influenced by the factors that have caused the generation of second-hand machinery, the most important of which—besides mergers of firms and liquidations of plants—are: *(a)* the switchover to a larger scale of operations, caused by increased market demand; and *(b)* modernization of plants and equipment up to the point of automation, caused by a labour shortage and high wages. In both cases, the equipment is replaced by technically improved machinery that will suit the changed demand or factor-supply conditions better than the old machines. Technical progress has thus caused premature obsolescence in the industrialized country of machinery that is actually still working well, but the conditions in the country do not permit an economic use of these machines.[45]

The very factors 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 underutilization of large-scale capacities; and, as pointed out before, the factor-price relations in developing countries suggest the use of machinery needing more labour than capital, both in operation and in maintenance. Premature technical obsolescence (in industrialized countries) will, therefore, give developing countries a special incentive, in addition to the maintenance aspect, to acquire second-hand rather than new equipment.

Special problems of maintenance and of supplying spare parts for second-hand equipment

As a United Nations group of experts on second-hand machinery 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".[46] Much depends, however, on the existence or absence of technological improvements of the equipment in use. Under the assumptions made in the section dealing with the isolated effect of differences in maintenance costs, 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 the section dealing with the effect of premature obsolescence, 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 fewer skills than that of modern machinery, whereas the skill requirements for the operation of old machines are higher than for new ones.[47] But there is no simple solution to this question; it may also be true that modern machines are easy to service, with expendable units in order to save on highly paid, skilled maintenance workers. The situation differs from industry to industry.

The special problems of maintaining second-hand machinery are mainly practical ones. Sometimes,

[45] Regarding the optimum replacement policy, cf. George Terborgh (1949) *Dynamic Equipment Policy*, McGraw-Hill, New York; Vernon L. Smith (1961) *Investment and Production*, Harvard University Press, Cambridge, Mass.; Ingrid and Per Welin (1967) *The impact of Technological Progress on the Economic Life of Industrial Equipment*, Handelshögskolan i Göteborg, Skrifter 1967—2, Akademiförlaget, Göteborg.

[46] *Report of Expert Group*, para. 45; see footnote 37.

[47] Ibid., para. 69.

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."[48]

The purchase of second-hand equipment is to be recommended only if the supply of spare parts can be secured. The difficulties of getting spare parts should not be overestimated. No doubt, spare parts are more easily available for new machines than for old ones, particularly 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 apt to hold a certain stock for some years more. It has been reported that some manufacturers of textile machinery continue to make spare parts for machines they produced forty years ago.[49] The time will come, however, when the availability of spares will be a real problem—when stocks are depleted or when the manufacturer of the machinery is no longer in business. Missing catalogues or blueprints needed to identify the spare part exactly will add to the difficulties.

Before deciding to import second-hand machinery, a country would do well to explore the availability of spare parts thoroughly, including possibilities for producing 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 2) should not encounter insurmountable difficulties, provided the necessary steps are taken in time. Local production of spare parts for very complicated modern machinery is likely to be extremely difficult.

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

Availability of spare parts

The importance of a regular supply of spare parts

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 to uninterrupted production. The supply of spare parts, therefore, deserves the greatest attention of policy-makers.

In a mixed economy, the individual firm is not able to follow a good spare parts policy without the co-operation of the public authorities. Problems of priority allocation arise between public and private enterprises if spare parts are generally scarce or not easily obtainable. The public authority may exercise its influence on the allocation of spare parts through import licensing, foreign exchange control, multiple exchange rates etc.

Stockpiling is essential. There should be no question today regarding the general importance of keeping adequate stocks of spares, although time and again experts report a lack of recognition of this fact, especially during the first phase of new industrial ventures.[50] Failure to stockpile always has a detrimental effect on production.

One solution recommended is that individual enterprises keep large stocks of parts, in particular when poor transport facilities, rigid foreign exchange controls, and unforeseen circumstances impede their quick supply. Other solutions proposed are to establish central stocks of spare parts at the national, regional and branch levels and to undertake their domestic production. The advantages and shortcomings of these proposals will be considered in the following sections.

Decentralized large stocks of spare parts at the individual plant

The advantage of maintaining large stocks of spare parts at the plant level is that spares are quickly and easily available when needed. Downtimes of equipment can be kept as short as possible. This is especially important in heavy process type production or continuous lines, where the economic penalty for any stoppage of operations is highest. The most serious disadvantage of decentralized large stocks is that considerable amounts of capital are tied up. Many firms tend initially to keep spare parts inventories at a very low level, but after bad experiences they fall into the other extreme of hoarding whatever spare parts they are able to get.

[48] Strassmann, op. cit., p. 213.

[49] *Report of the Expert Group*, para. 48; see footnote 37.

[50] See, for example, Anon. (1962) "Solveen Report on Rourkela Steel Plant", *The Eastern Economist*, Vol. 34, No. 7, August 17, pp. 304, 307. "Some Problems of Industrial Management Reported by Technical Assistance Experts", pp. 55–56, *Industrialization and Productivity Bulletin No. 2*.

Firms in developing countries keep greater stocks of parts than is customary and necessary in similar industries in developed countries for several reasons:[51]

(a) Specific climatic conditions in many developing countries cause parts to deteriorate that usually do not deteriorate in countries in temperate zones. Wrong treatment and overloading of machines by inadequately trained operators and incompetent maintenance – both more frequent in developing than in developed countries – also contribute to higher degrees of deterioration.

(b) The poor communications and distribution systems in many developing countries make it often impossible to place emergency orders for spare parts and have them delivered quickly. If parts have to be ordered from abroad, the customs clearing retards delivery substantially; delays of ten days and more are not unusual.

(c) The import licensing and foreign exchange controls practised in most developing countries cause many firms to stock more spares than they need. Uncertainty with respect to future quotas makes it appear safer to take full advantage of import opportunities when they are offered rather than to trust to future allocation of import licences or foreign exchange when spares are 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 stockkeeping. It may be pointed out that it is the economic system rather than the deficiencies of management that leads here to the wasteful use of scarce capital resources.

When manufacturing processes require the prompt availability of spare parts, the system of decentralized stockkeeping of spares has many advantages over other systems. If this system is chosen, it is necessary, however, to do everything to realize optimum stocking levels, that is to say:

(a) Operators and maintenance workers should be well trained to work with the equipment so that breakdowns will be minimized.

(b) Communications and distribution systems for spare parts should be improved. Much could be gained by facilitating and accelerating the customs clearing of imported spares.

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

The establishing and keeping of central stocks of spare parts at the national, regional, and branch levels

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

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

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

(c) Spare parts for older models no longer produced are better identified; central stockkeeping makes them more readily available.

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

The smooth functioning of central stockkeeping, however, depends on several conditions that must be met in order to avoid damages to the economy that would be more serious than any possible gains:

(a) The communications system must function well and permit the prompt placement of orders.

(b) Management of the central stocks must be of a high professional standard. Accurate bookkeeping and inventory control should be a matter of course. Moreover, those in charge of planning the inventories and purchasing the parts must be qualified technicians, familiar with the technologies in the various industries.

(c) 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 disturbances.

Most of these conditions are far from being met in most developing countries. Their communications and transport systems have bottlenecks of various kinds. Besides, the distances within many developing countries are enormous by European standards. Yet, the most crucial point seems to be that such a central agency must master the administrative task of securing the supply for so many and different firms. Even in a country with a small industrial sector the centralization of stocks requires highly sophisticated management.

The best way to run a central agency for spare

[51] The Indian National Council of Applied Economic Research has estimated that in a large number of industries spare parts constitute almost 15 per cent of the total inventories, which is considered a rather high proportion. See National Council of Applied Economic Research (1967) *Maintenance Imports*, New Delhi, p. 74.

parts efficiently may be as a commercial enterprise, e.g. as a purchasing and storing co-operative or agency. The individual firms must have confidence in this agency as a prompt supplier. In turn, the agency can provide this quick supply only if it has secured access to spare parts, whether through imports or local production. The main role of the central agency would be to rationalize the storage of spare parts, and thus save scarce capital.

If conceived as a public authority and endowed with the power to control and approve the orders of individual firms for spare parts, the central agency would be in danger of turning into a super-bureaucratic institution, an obstacle rather than a promoter of economic investment, maintenance and replacement of capital. The experience of European countries with rationing and controlled supply during the Second World War and the early post-war years may be worth considering. The experience of a large steel mill of the public sector in a rather advanced developing country may also illustrate this 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 forwarded by offices which are not in a position to judge the necessity or urgency of the purchases. Repeated requests of the plants were unsuccessful."[52]

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

From the preceding discussion it appears that central stocking of spare parts at the national level is likely to be rational only in a very small country with a fairly well-developed communications and transport system serving an industry 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 agency 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 at the regional level. This solution would be similar to central stocking at the national level in a small country. The distances between the various firms and the regional stock of spare parts are shorter, transport problems are reduced, the difficulties for management decrease. The disadvantages of stocking spare parts at the national level will also be found here. 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 machine shops within the region (to avoid extra communications and transport problems), capacities become unevenly utilized between the different regions, unless machine shops are also evenly distributed.

Central stocks of spares at the branch level can be established for the country as a whole or regionally. Unless the developing country is small, centralization at the national level will bring it hardly any advantages for the reasons that were mentioned before. Splitting up regional stocks of spare parts into independent stockkeeping units according to the various industrial branches may be economic provided that the preconditions of good communications and transport are met.

Stocks of specialized spares for individual branches may reduce the technical and administrative work required when large general stocks are kept for all industries. But certain disadvantages should not be overlooked. If an industry is not regionally concentrated, the choice would be either to keep fewer stocks—this would rationalize the storage problem but create problems of transport and communications—or to keep a larger number of stocks within good reach of all firms but at the possible sacrifice of capital savings in storage. Regional stocks of spare parts at the branch level would be favourable if industries are regionally concentrated; they would be very economic if one kind of industry is concentrated in one region and another kind in another region.

Possibilities for import substitution of spare parts

In a developing country of type 1, all equipment has to be imported, and the spare parts as well. This may continue for a rather long period. It is the normal situation even in the earlier stages of industrialization of a developing country of type 2.[53] Domestic machinery production is usually begun in the later stages of development. In many developing countries as well as in the now industrialized countries, the local production of machinery evolved from repair shops.

In developing countries of type 2, which already have machine building and engineering industries of their own, the spares for domestically manufactured

[52] "Solveen Report on Rourkela Steel Plant", p. 304; see footnote 50.

[53] In India, for example, almost all the machinery and equipment needed for industrial development during the first planning period (1950/1951—1955/1956) was imported. See Government of India, Planning Commission (1966) *Fourth Five-Year Plan, A Draft Outline*, p. 264.

equipment can be, and are, produced by domestic manufacturers. 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. The following are some of the reasons why these countries defer domestic production of spares and import equipment:

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

(b) Imported parts are produced on a large scale and are offered at comparatively low prices that leave few possibilities for domestic substitution at competitive prices.

(c) 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 have developed during a period of liberal import policies[54] and its continuation may reflect inertia. More importantly, it may be the cheapest way to obtain 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 that is artificially cheapened by unrealistic exchange rates.

(d) Customers often prefer imported spares to their domestic substitutes because they think that the quality of the locally produced items will be inferior. 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 the available raw materials, e.g. steel.

(e) When an acute shortage of raw materials exists, it can be as lengthy—or as costly—to have spare parts produced locally as to get their import licensed.

(f) Sometimes, especially if the machine shops are of small scale and are widely scattered, lack of information on the demand for spares may keep producers from undertaking import-substituting production. This lack of information, in turn, may reflect neglect of the spare parts problem on the part of the public authorities.

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

In the first two instances cited above *(a)* and *(b)*, the developing country does not yet have a comparative cost advantage. 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 measures that may be difficult to enforce, with an outcome that might be far from desirable. In all other instances a developing country may—but does not have to—have a comparative advantage in the domestic production of spares. Before local production is encouraged, the cost situation must be analysed thoroughly. It is of equal importance to identify and to remove obstacles that impair the realization of comparative cost advantages.

A realistic exchange rate policy discontinuing the over-valuation of the domestic currency (cf. *(c)* above) could bring about true comparative advantages in spare parts production, especially if production can be made labour-intensive. The supply of raw materials for spares (cf. *(d)* and *(e)* above) is a crucial point. The improvement of the quality of raw materials would require changes in preconditions, the study of which goes beyond the scope of this article. One of them, however, is better maintenance and repair. When a shortage of raw materials has prompted a system of quota allocation, discrimination against producers of spare parts should be avoided.

There are various methods of disseminating information on the local market for spare parts (cf. *(f)* above). The function of collector and transmitter of information could be assumed by public authorities, professional organizations (e.g. employers' associations), or by a spares stocking agency at the regional or branch level. The agency would be particularly suited to be a "clearing-house" for potential purchasers and manufacturers of parts. If agreements on patent rights, designs and drawings have to be obtained from foreign owners, (cf. *(g)* above) the spare parts agency or a professional organization may take the initiative here, too. The necessary negotiations may be conducted under the sponsorship of international organizations.

The establishing of specialized repair and maintenance shops in the context of industrial estates

Medium-sized and small 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 economic. Further, the repair shop of a firm has to be supplied with a certain minimum of machines and tools; these cannot be adequately utilized in a small enterprise. The small firms, therefore, have to rely generally on outside contractors, who are not easily found in developing countries. If maintenance is assigned to the firm's own employees who have not undergone appropriate training, the performance will most likely not be of the desirable quality.

[54] *Maintenance Imports*, p. 73, see footnote 51.

The maintenance problem of small-scale and medium-sized industries could be solved to the best advantage by establishing nearby specialized repair and maintenance shops. The creation of such repair shops may be promoted by the Government or by a special public agency, or they may be established through joint action of the industrialists themselves, possibly on a co-operative basis. Sometimes, when 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. This would be promotion of small-scale industries in a double way: repair shops are not only essential for the working of other small firms, but they are also themselves a typical small-scale activity.

A precondition for setting up specialized repair shops is a certain regional concentration of firms demanding these services. The condition is particularly well met in industrial estates. Industrial estates have been founded, within the last decade, in almost all developing countries, with the general purpose of promoting small-scale industries. Industrial estates have been defined as "a planned clustering of industrial enterprises, offering developed sites, pre-built factory accommodation and provision of services and facilities to the occupants".[55] Whereas in industrialized countries only general services, such as power, water, sewerage, roads and railroads, are usually provided, the services and facilities offered in developing countries are broader. The special services, which differ from country to country or even from estate to estate, include training facilities, technical counselling, marketing assistance, toolrooms and machine shops. In some countries, maintenance and repair shops have already been added to this programme of subsidizing small-scale industries.

Industrial estates must be large enough to guarantee that the equipment installed in the repair shops will be used to capacity. When the shops are being planned, the number of firms outside the industrial estate proper that may share in the services of these shops may be taken into consideration, but special allowance must be made for the regional factor: longer distances impair fast servicing. The transport conditions in developing countries make this factor more restrictive than it would be in developed economies.

Repair shops in industrial estates may be established in connexion with regional stocks of spare parts. It would permit the production of some of the spares in the repair shops, or, if they exist, in the machine shops of the estate. Repair shops may also be used as training centres where employees of the customer firms can be trained in routine maintenance work so that specialized craftsmen at the repair shops will be free for the more complicated maintenance jobs, check-ups and repairs.

Most of the industrial estates that are promoted in developing countries are non-specialized, general-purpose estates accommodating all categories of small-scale industries. Servicing of firms belonging to a variety of branches makes higher demands on the skills of the craftsmen and on the equipment of the shop; specialists in various fields and a variety of machines and tools are needed. On the other hand, better utilization 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 accommodation only to firms belonging to the same trade, repair shops can be smaller. The shops could be connected advantageously with regional stocks of spare parts at the branch level.

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

Quantitative aspects of maintenance and repair

The individual firm facing an investment decision and the public authorities engaged in national economic planning need to have estimates on present and future maintenance requirements: the total cost, import content, and the manpower needed. In this section, 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.

Maintenance and repair in industrialized countries: U.S.1

The cost of maintenance and repair in manufactures

Surprisingly, very little statistical information exists on maintenance and repair activities in the manufacturing industry of developed countries. Only one comprehensive report has been published by the United States Bureau of the Census as part of the 1958 Census of Manufactures. 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, $9 billion was spent in

[55] United Nations (1966) *Industrial Estates — Policies, Plans and Progress, A Comparative Analysis of International Experience*, p. 4 (Sales No.: 66.II.B.16).

Table 5

COST OF MAINTENANCE AND REPAIR IN US MANUFACTURING INDUSTRY, 1958

Industry group	*Gross book value of depreciable assets, on 31 Dec. 1957 ($ million)*	*Expenditures for maintenance and repair on structures, grounds and equipment ($ million)*			*Maintenance and repair expenditures as per cent of gross book value*	*Maintenance and repair wages as per cent of total maintenance and repair expenditures*
		Total	*Salaries and wages paid to own employees*	*Other maintenance and repair costs*		
All industries	110,489	9,011	4,539	4,472	8	50
Food	11,731	778	357	421	7	46
Tobacco	400	24	11	13	6	46
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	68	32	36	7	47
Pulp, paper	7,165	514	239	275	7	46
Printing	3,697	172	78	94	5	45
Chemicals	13,105	910	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	390	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
Electric machinery	4,089	360	186	174	9	52
Transport equipment	9,303	986	563	423	11	57
Instruments	1,263	98	54	44	8	55
Miscellaneous	1,987	188	96	92	9	51

SOURCE: United States Bureau of the Census (1961) *US Census of Manufactures: 1958, Summary Statistics*. US Government Printing Office, Washington, D.C., Vol. I, pp. 9-8 and 9-9. Percentages: own computation.

NOTE: Details and percentages do not necessarily add up to totals because of the use of round figures.

the United States 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 new plant and equipment totalled $12 billion of which expenditures for new machinery and equipment came to $8 billion, a sum that is lower than the total spent on maintenance and repair.[56]

The outlays for maintenance and repair average 8 per cent of the gross book value of the fixed assets (that is, the actual cost of the assets at the time of the purchase, including transport and installation costs). The data for the individual industry groups show a very even and narrow distribution around this mark of 8 per cent (which is also the median): 16 out of 20 industry groups spent between 6 and 10 per cent 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 $9 billion spent on maintenance and repair went for 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 per cent. Once more 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 expenditure 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

[56] United States Bureau of the Census (1959) *Statistical Abstract of the United States: 1959*, Washington, D.C., table 1061, p. 796.

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. Owing to economies of scale, maintenance and repair work may be performed more cheaply by outside specialists than by own employees. There has been a vague indication cited by Morrow that expenditure on maintenance materials, equipment, and supplies makes up 90 per cent of the amount paid for maintenance wages and salaries.[57] This implies a relationship between labour cost and cost of material in the order of 53 to 47 per cent. *Modern Manufacturing*, an American review mainly concerned with management and maintenance problems, uses for its *Maintenance Cost Index* the relation of 60 per cent labour to 40 per cent materials outlays. This breakdown seems to be realistic, and it is used in the later computations.[58]

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

The average manufacturing firm in the United States spends about 8 per cent 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 greatly over time either. Thus, a percentage from 7 to 9 per cent should be representative for a number of years around 1957.

About 50 per cent of maintenance and repair outlays consists of wages and salaries paid to own employees of the manufacturing establishment. Again, there is very little deviation from this average in the various industry groups, so it can be regarded as a typical percentage over some time, too. The share of total labour cost in maintenance and repair expenditure will be around 60 per cent.

Since the aggregate "United States manufacturing industry" covers an exceptionally wide range of establishments, it can be assumed that the total capital stock recorded on 31 December 1957 was composed of plant and machinery of every age (the only exception being equipment using very recently developed techniques) — so to say that a sum of about 8 per cent 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 per cent of its purchase price is made. Because of the uncertainties involved, a margin of at least ± 10 per cent should be allowed here, too, so that a percentage range of 7 to 9 per cent would be realistic.

It should be emphasized that this is an average that is true only for the total manufacturing industry. The individual industry groups will show deviations from this average; the deviations will be greater the more the statistical total is split up. This percentage should not 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 every year in the course of the lifetime of a machine; the expenses will be lower for new pieces of equipment and then increase with its age.

If the average annual expenditure for maintenance and repair is multiplied by the average lifetime of fixed assets, the average total cost of maintenance and repair incurred during the lifetime of plant and equipment is obtained.

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. 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, an average lifetime of 15 years is assumed, a figure that can be considered conservative,[59] then a total amount equivalent to 120 per cent 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.

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 with the total payroll and with the sum of production workers' wages.

On average, 6 per cent 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 per cent.

Here, in both relations, the individual industry groups show greater deviations from the average than in

[57] J. C. Morrow (1958): "Introduction" to *Exhibitors' Plant Maintenance and Engineering 1958* (1958 Plant Maintenance Show, Inc., New York), p. 7.

[58] Cf. "Maintenance Cost Index Revised for the 1970's", *Modern Manufacturing*, February 1970, p. 80.

[59] Vaclav Nesvera (1970): "Study on Renewal, Repair and Maintenance", *Industrialization and Productivity Bulletin* No. 16 (Sales No. 70.II.B.31).

Table 6

SALARIES AND WAGES PAID TO OWN MAINTENANCE AND REPAIR WORKERS IN US MANUFACTURING INDUSTRY IN 1957

Industry group	*Total payroll ($ million)*	*Wages of production workers*	*Salaries and wages of maintenance and repair workers*	
		Percentage share in total payroll	*Percentage share in total payroll*	*As percentage of the sum of production workers' wages*
All industries	76,379	69	6	9
Food	7,143	59	5	9
Tobacco	284	85	4	5
Textile	3,183	83	5	6
Apparel	3,664	78	1	2
Lumber	2,110	82	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
Electrical machinery	5,133	64	4	6
Transport equipment	10,486	68	5	8
Instruments	1,571	60	3	6
Miscellaneous	2,826	65	3	5

SOURCE: US Bureau of the Census (1961) *Us Census of Manufactures: 1958, Summary Statistics*. US Government Printing Office, Washington, D.C., Vol. I, pp. 9–8 and 9–9; US Bureau of the Census (1959) *Statistical Abstract of the United States: 1959*, Washington, D.C., table No. 1054, pp. 782ff. Percentages: own computation.

table 5. The actual values range from 1 to 23 per cent for the share of maintenance workers' wages in total payroll, and from 2 to 34 per cent 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 paper 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 examines this relationship more closely. 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.[60]

It can therefore be concluded that the share of maintenance workers' wages in the total payroll of the United States manufacturing industry 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 it will also be strong in other years, and perhaps indicates a general regularity.[61]

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 industry. The estimate is based on the data on maintenance and repair cost and on the number of employees in the manufacturing industry in 1957.

[60] 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 this deviation.

[61] See also Nevvera, op. cit.

Table 7

CAPITAL/LABOUR RATIO AND SHARE OF MAINTENANCE WORKERS' WAGES IN TOTAL PAYROLL IN US MANUFACTURING INDUSTRY IN 1957

Industry group	*Capital/labour ratio*[a]		*Share of maintenance workers' wages in total payroll*	
	Value	*Ranking*	*Per cent*	*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
Textiles	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 equipment	0.89	13	5	10
Printing	0.86	14	2	17
Electrical 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 tables 5 and 6.

[a] Ratio of gross book value of fixed assets to total payroll.

The number of employees occupied in in-plant maintenance was 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 permit only calculation of 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 above the general average.

Several considerations that cannot be further expounded in this study lead to the assumption of a maintenance workers' wage 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 computed for the number of maintenance workers are therefore margins determined by these limits.

The results of the 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 the United States manufacturing industry in 1957. This corresponds to 4 to 7 per cent of the total working force in the manufacturing industry (column 4). Again, the highest, or respectively the lowest, percentages are shown by the same industry groups as in table 6.[62]

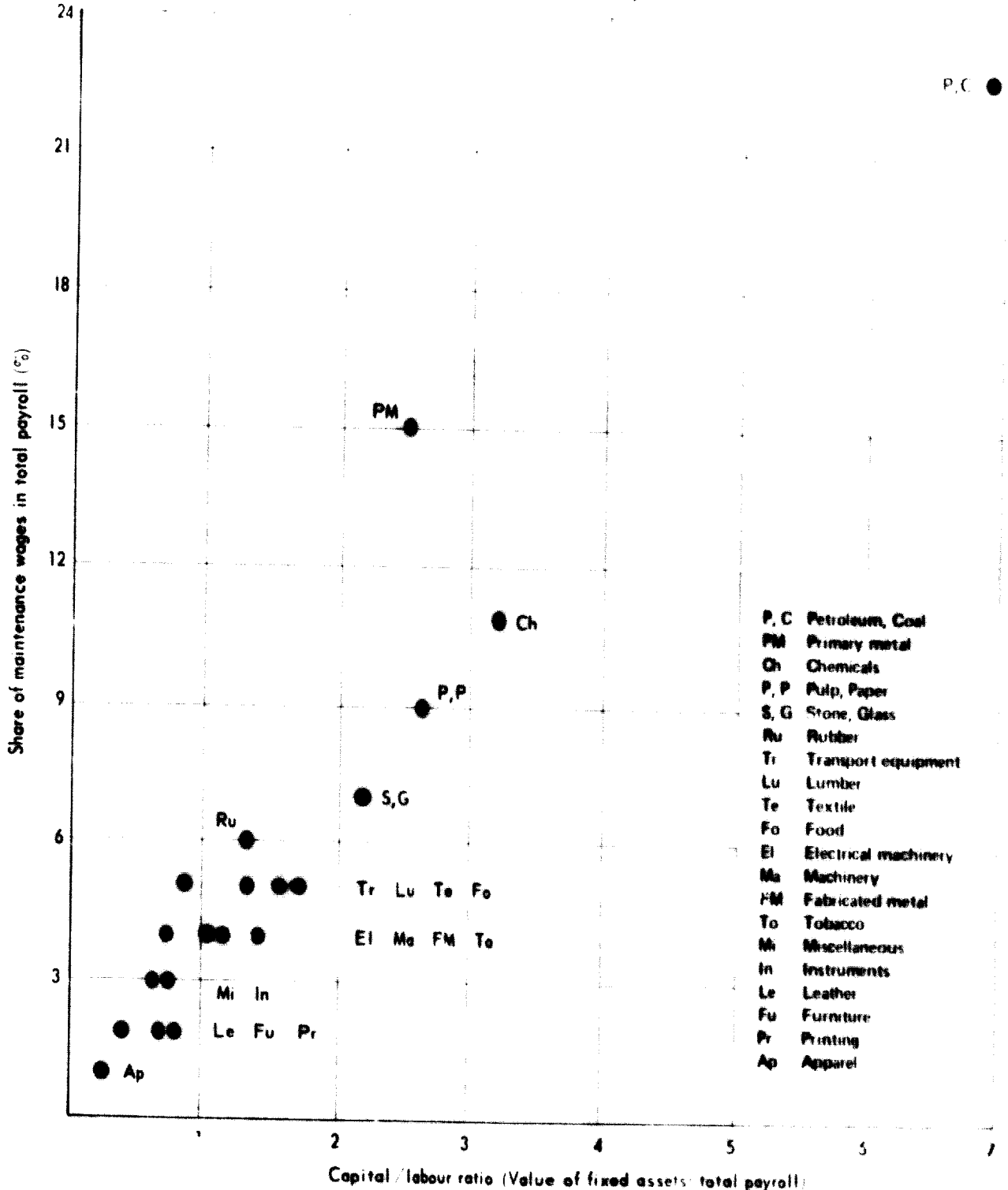
These results obtained from the statistical survey of 1957 are surprisingly in line with an earlier survey and with the latest figures available.

According to data for 1935 that cover a "cross-section of plants engaged in manufacturing many kinds of products", the average proportion of maintenance to total plant employees was 6 per cent, the proportion actually varying between 4 and 10 per cent.[63] Exact comparison between these data and those

[62] This is not surprising, since simple arithmetic proves that the values listed in column 4 of table 8 are only margins around the figures listed in column 3 of table 6.

[63] L. C. Morrow (1935) "Maintenance Organization and Management", *Factory Management and Maintenance*, Vol. 93, Nr. 12, December Supplement: Plant Operation Library, p. S–163. Reprinted in: Massachusetts Institute of Technology (1941), *Factory Management and Maintenance Plant Operation Library*, Cambridge, Mass.

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, 195-



SOURCE: Table 7.

given in table 8 is, however, not feasible because the industry groups covered in the 1935 investigation are not indicated. Table 9 lists the latest figures available. They are part of a sample survey, published in March 1970, which covers 502 firms, mostly of medium to large size (59 per cent of the sample firms had over 500 employees, 40 per cent over 1,000).

In this survey, industries are grouped according to *Modern Manufacturing*'s industry classification system. "Heavy equipment, fabrication-and-assembly type" or "heavy fabricating" covers electrical equipment, non-electrical machinery, aircraft and spacecraft etc. "Light

Table 8

NUMBER OF MAINTENANCE AND REPAIR WORKERS IN US MANUFACTURING INDUSTRY IN 1957

Industry group	*All employees (1,000)*	*Production workers (1,000)*	*Maintenance and repair workers (1,000)*		*Number of maintenance and repair workers as percentage of total number of employees*	
			minimum	*maximum*	*minimum*	*maximum*
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	566	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 equipment	1,900	1,401	85	110	4	6
Instruments	307	212	8	12	3	4
Miscellaneous	665	514	15	27	2	4

SOURCE: US Bureau of the Census (1959) *Statistical Abstract of the United States: 1959*, Washington, D.C., table No. 1054, pp. 782ff. Columns 3 and 4: own computation on basis of data published in: US Bureau of the Census, *US Census of Manufactures: 1958, Summary Statistics*, US Government Printing Office, Washington, D.C., Vol. I, pp. 9—8 and 9—9.

Table 9

PERCENTAGE SHARE OF MAINTENANCE EMPLOYEES IN TOTAL PLANT EMPLOYEES IN US MANUFACTURING INDUSTRY

Heavy equipment, fabrication-and-assembly type	2.5
Light equipment, fabrication-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 1971, p. 22.

fabricated" 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.[64] This classification makes comparison of percentages with the 1957 survey rather difficult because the 1957 survey followed the International 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.[65]

[64] "Better Way to Compare Your Plant's Maintenance Practices", pp. 138ff., see footnote 7.

[65] Two other sample surveys giving, *inter alia*, information on the importance of maintenance workers in total plant force, are even less comparable: Anon. (1958) "Maintenance Management Practices in Industry Today", *Factory Management and Maintenance*, September, pp. 90ff., and Anon. (1966) "The Pulse Beat of Maintenance Today", *Factory*, June, pp. 98ff.

Conclusions for the planning of maintenance and repair in developing countries

This study of the quantitative aspects of maintenance and repair in the United States can be of great value to those who have to estimate the requirements in developing countries, particularly the requirements for aggregate manpower, over-all capital and foreign exchange for future maintenance of new projects in manufactures.

Maintenance and repair costs

As has been seen, the average annual cost of maintenance and repair in the United States manufacturing industry amounts to about 8 per cent of the capital invested; labour costs account for 60 per cent and costs of material for 40 per cent of total maintenance and repair expenses. The maintenance cost is 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 experience must take these differences into account. To illustrate what the average cost of maintenance will be in the manufacturing industry of a developing country where conditions differ from those in the United States, three numerical examples, presented below, have been computed. The import content of maintenance costs, i.e. necessary foreign exchange outlays, is also computed.

United States:

		Dollars
Investment		1,000
M&R * costs per annum: 8% of investment		80
Wages thereof: 60%	48	
Materials thereof: 40%	32	

Developing country:

	Dollars
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)

	Dollars
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)

	Dollars	*Dollars*
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 cost	12.8	
Total cost of materials per annum		35.2
Total M&R cost per annum		54.4
Foreign exchange outlays thereof		22.4

* Note: M&R means maintenance and repair.

Case 3

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

	Dollars	*Dollars*
Relation of M&R wages to materials: 70:30		
Wage rate: 40% of US wage rate		
M&R wages per annum		22.4
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 cost	9.6	
Total cost of materials per annum		26.4
Total M&R cost per annum		48.8
Whereof foreign exchange outlays		16.8

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

In all three cases, the wage rate in the developing country is only 40 per cent of that in the United States, and the equipment used in production is always imported. This latter assumption means that transport 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 the examples they are assumed to be 40 per cent of the value of the fixed assets. The same additional charge is imposed on the import price of spare parts and other maintenance materials.

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 United States statistical survey may be a useful economic guide for developing countries. It will be remembered that the share of maintenance and repair workers within the total labour force of the United States manufacturing industry averages 4 to 7 per cent, depending on the kind of computation used. Planning authorities in developing countries should regard these percentages as the minimum to be reached, but in most cases they should be surpassed. Although developing countries may have little possibility to adapt production techniques to their factor endowments, this is not true for maintenance techniques. Developing countries can 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 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 United States ought to be considered minimum figures, provided more labour-intensive maintenance techniques are applicable.

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 unutilized production capacities. By employing labour that is cheap in activities that can be made labour-intensive, developing countries will be able to realize 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 from the viewpoint of their relevance for economic policy. Conclusions and recommendations resulting from the analysis have always been made in the context of the theoretical discussion. Some reflections on the practical implications for policy-making are outlined below.

Planning activities

The planning of industrialization cannot be confined to the simple installation of new plant and equipment. The costs for maintenance and repair and the manpower

needed in these activities are so considerable that they cannot be neglected when investments are being planned. On the average in all manufacturing industries in the United States, the same amount spent initially on investment is spent again in less than fifteen years on the maintenance and repair of the plant and equipment. In developing countries the 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 for meeting these requirements. The import needs deserve special attention in countries that 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 in a particular industry or region disclose lack of proper maintenance and repair, the public authorities could improve the performance by establishing regional repair shops, or by encouraging private enterprise to set up such shops, perhaps on a co-operative 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 the solution of the problem. Stocks of spare parts should preferably be linked with a regional repair shop. Possibilities for domestic production of spare parts should be explored thoroughly. The production of spares may be the appropriate first step towards domestic 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 that may conflict with production is encouraged. Preoccupation with maximizing output in the short run resulted in some cases in total neglect of product quality as well as maintenance and in-plant training programmes. 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 similarly motivated since bonuses were related only to physical output.[66] 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.

Other policy measures

In view of the scarcity of capital in developing countries, policy should be directed towards encouraging optimal maintenance activities that will be carried out in a labour-intensive way. Actually, negligence of maintenance on the side of the management or a bias against labour-intensive methods of maintaining capital has often been 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 that do not penalize the hiring of workers when labour is abundant. A bias against employing more labour may also originate from minimum wage regulations that 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.[67] The hiring of additional workers, however, does not give rise to tax benefits. 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 against labour-using techniques would be to grant the reinvestment allowance also for the employment of additional workers.[68] 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

[66] Johnson, op. cit., pp. 156–7, 163–4, 180–1. The economic history of the USSR and other centrally planned economies provides similar examples that induced these countries to change their original emphasis on tons of output.

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

[68] An interesting recommendation to promote labour-intensive methods of production by way of a tax deferral has been made by Strassmann, op. cit., p. 128.

advantages in a developing country. Policy should therefore not discriminate *a priori* against the use of second-hand equipment. Difficulties in getting credits for the purchase of second-hand equipment and the imposition of high excise taxes on used vehicles are examples of discrimination that have been reported.

Import regulations

As long as equipment and spare parts have to be imported by a developing country, import regulations remain a crucial point of maintenance policy. That public authorities underestimate the importance of maintenance and repair is shown by their refusal to issue import licences or their failure to do away with cumbersome administrative procedures that delay imports.

A quick and unimpaired import of spare parts is essential for the full utilization of installed capacity, a problem facing most developing countries. Refusal to grant foreign exchange for one missing spare part may put a unit out of operation for a long time, a unit whose installation 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 imported spares, furthermore, prevents their unnecessary and wasteful hoarding 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.

Standardization of machinery and equipment

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

Regarding the equipment that has to be purchased from abroad, the simplest way to get largely standardized products is to purchase only from a single foreign country, or even from a limited number of firms. This would ensure a minimum of different types of machinery, but reliance on a single supplier country or even on one firm may create undesirable secondary problems and political or economic dependence, which is unacceptable 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 with each other will bring advantages.

Technical information

Lack of information creates many difficulties in maintenance and repair. The indigenous staff quite frequently lacks proper information on the maintenance and repair of complicated foreign machinery. 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 importance of maintenance, since the adverse effects of inadequate maintenance cannot be seen immediately. Fragmentary information on buying and selling possibilities often makes it difficult for firms to obtain spare parts, and sometimes induces firms not to choose optimal production techniques.

Governments can encourage firms to co-operate at the branch level to furnish better information on maintenance problems specific to that branch. Where this is not feasible, a Government can set up an organization for the purpose of collecting and forwarding technical information. The organization may be a technical supervisory agency, as outlined below.

Governments should request the assistance of international organizations to furnish more detailed information on maintenance requirements and to rationalize actual performance. Information on second-hand equipment could also be disseminated internationally.

Creation of technical supervisory agencies and statutory check-ups

Technical information by itself 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 that are aimed primarily at promoting occupational safety. These check-ups may, however, also be considered a means 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 TÜV, or they may be a public institution directly responsible to a Government. The establishment of such an agency should in both cases be considered a public task.

Checking safety devices and the safe operation of equipment should be the main functions of a supervisory agency. This would already cover a wide field of activity and would include control of most of the important maintenance operations. Beyond this, the periodical check-ups could be given a broader scope. Additional technical counselling 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 guidelines for the use of anti-corrosion material under special climatic conditions.

Training of maintenance personnel

In the industrialized countries, a cadre of maintenance workers has developed step by step with—and induced by—the gradual development of capital goods production. Developing countries, on the other hand, skip most of these stages. They import modern equipment 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.[69] Therefore, Governments should take deliberate action to ensure the training of maintenance personnel within their manpower planning programmes.

Training for maintenance has a double aspect. One is the training of technical skills, the other the creation of a maintenance habit. Experts agree 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 be aware of the role of maintenance and repair in modern industry. Educational programmes 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 accelerated training that have proved successful in industrialized countries can be recommended 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."[70] The description of the experience of the Netherlands in this field may be of interest.

"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."[71]

Avalanche effects are obtained by training first a group of instructors in accelerated training courses. These instructors can 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, setting up of maintenance training shops in big firms could be encouraged, e.g. by offering 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, for example, employ mobile training shops for practical training in welding. Training in these shops is particularly economical. Since the shops can be moved from town to town, the same equipment and the same instructors can be used for training a large number of people. The use of mobile training shops seems to be particularly suitable for developing countries.

[69] Blitz, *IPL*, p. 570.

[70] Boom, op. cit., p. 69–70.

[71] Boom, op. cit., p. 70.

Appendix

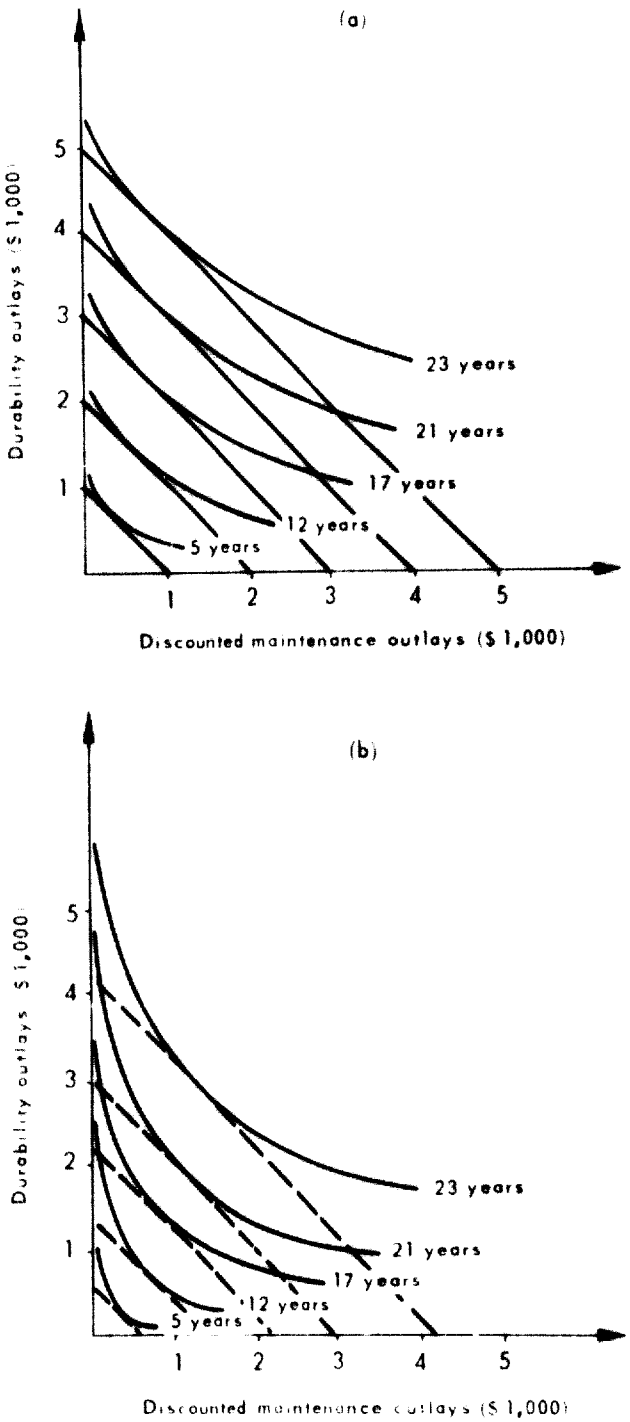
A GRAPHICAL PRESENTATION OF OPTIMAL MAINTENANCE AND REPAIR ACTIVITIES OF A COUNTRY

The effects of differences in the interest rate

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

[1] Figure 1a is a slight modification of a graph used by Blitz, *IER*, p. 322.

Figure 1. (a) Low-interest country; (b) High-interest country



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 that 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 1a indicates the optimal combination of maintenance and durability costs that together amount to $4,000. 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.

The assumptions underlying figures 1a and 1b differ in only one point, other things being equal: figure 1a represents a country where the interest rate is low, figure 1b, 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 necessary for maintenance outlays in the future is lower because the interest rate is high. Therefore, the isoquants in figure 1b—as compared with those in figure 1a — 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 1b do not touch the same constant-outlay curves as in figure 1a. 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 different combinations of the two cost ingredients. When the interest rate is higher, more will be spent on maintenance and less on durability (substitution effect). A comparison of the co-ordinates 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 higher spending on durability to 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 1b (dotted isoquant). The optimal combination in this case also contains more maintenance outlays and less durability outlays (cf. point p'' in figure 1b and point p in figure 1a).

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, a reduction of the present value of future "savings" 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 1a.

It is not only the present value of future savings that is reduced in a high-interest country, at the same time the effect of the higher interest rate on the combination of durability and maintenance outlays will come into play. Future maintenance costs will have a lower present value and, by substituting maintenance for durability outlays, the "longevity mix" will be changed to include 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 1b). For a total outlay of, for example, $4,000, a longevity of 22 years instead of 21 years (as in the low-interest country, figure 1a) may now be purchased. The optimum point on this shifted isoquant is situated more towards the maintenance-outlay axis.

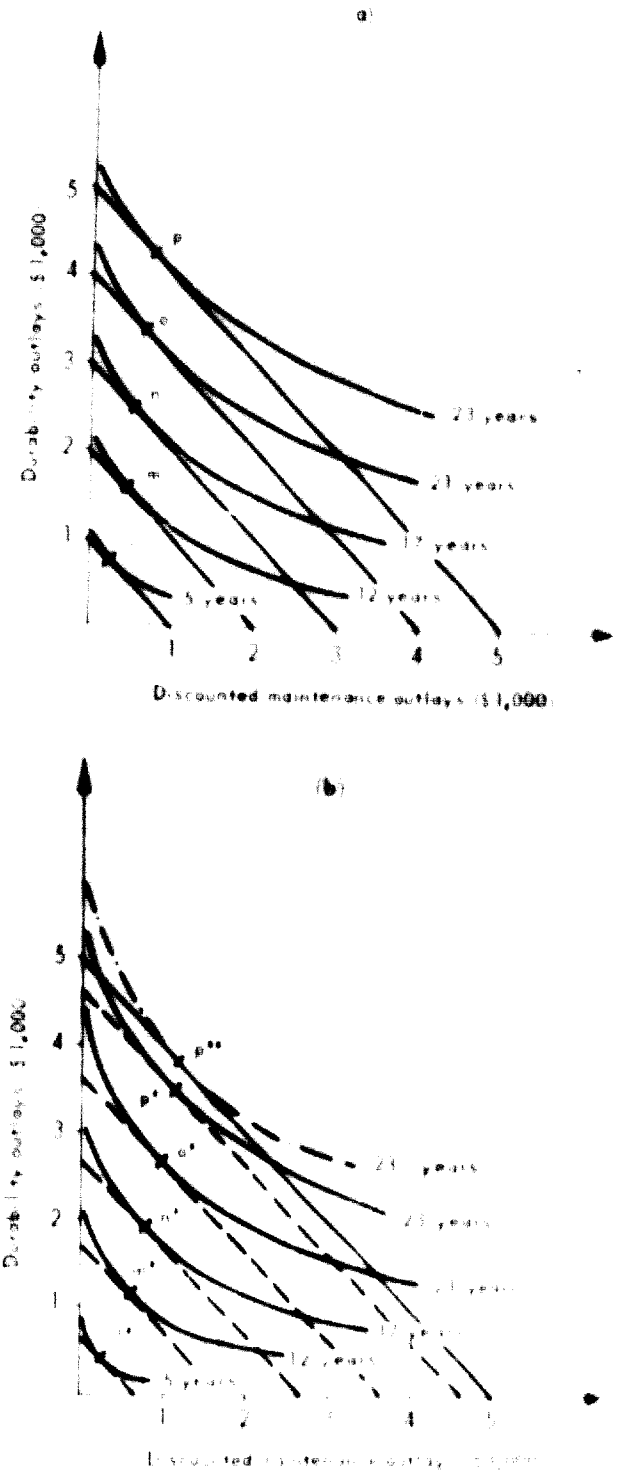
The effects of differences in the wage rate

The combination of a high interest rate and 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 1b. 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 and may even extend it.

The effects of differences in the price of capital goods

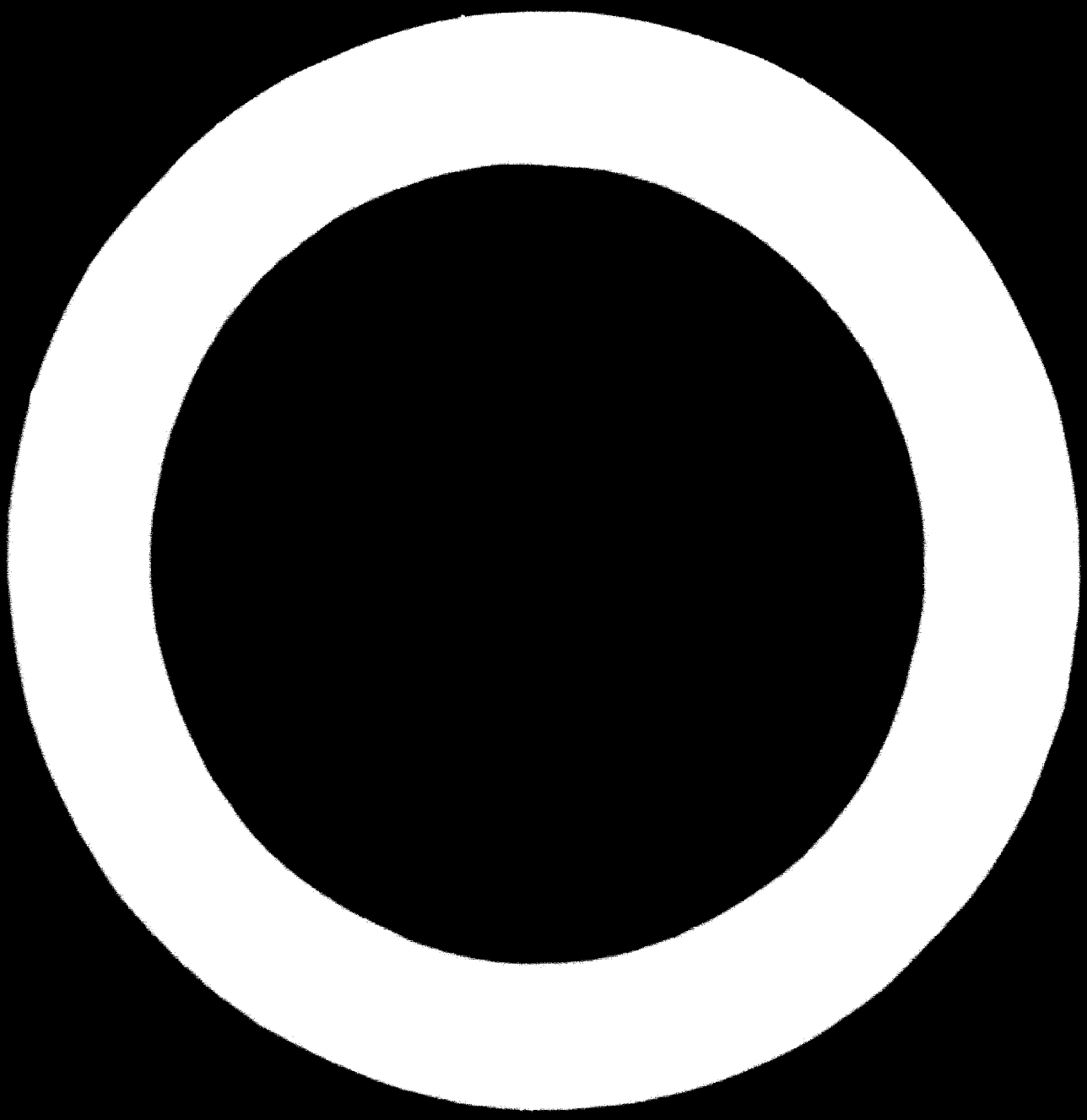
The effects of differences in the price of capital goods may be demonstrated graphically, too. An isoquant for a given capital longevity intersects the ... higher value for durability outlays in the high-interest low-wage country that imports its capital goods than in the other country. A higher price 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.

Figure 2. (a) Low-interest, high-wage country, producing capital goods. (b) High-interest, low-wage country, importing capital goods



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

The combined effects of differences in interest rates, wages and prices of capital goods can be presented graphically, using the isoquant method as before (cf. figure 2a and 2b). A comparison of these new graphs with figures 1a and 1b proves the additional influence of wages and price differentials very clearly. The isoquants in figure 2b intersect with the durability-outlay axis at higher values and are shifted much more to the left.



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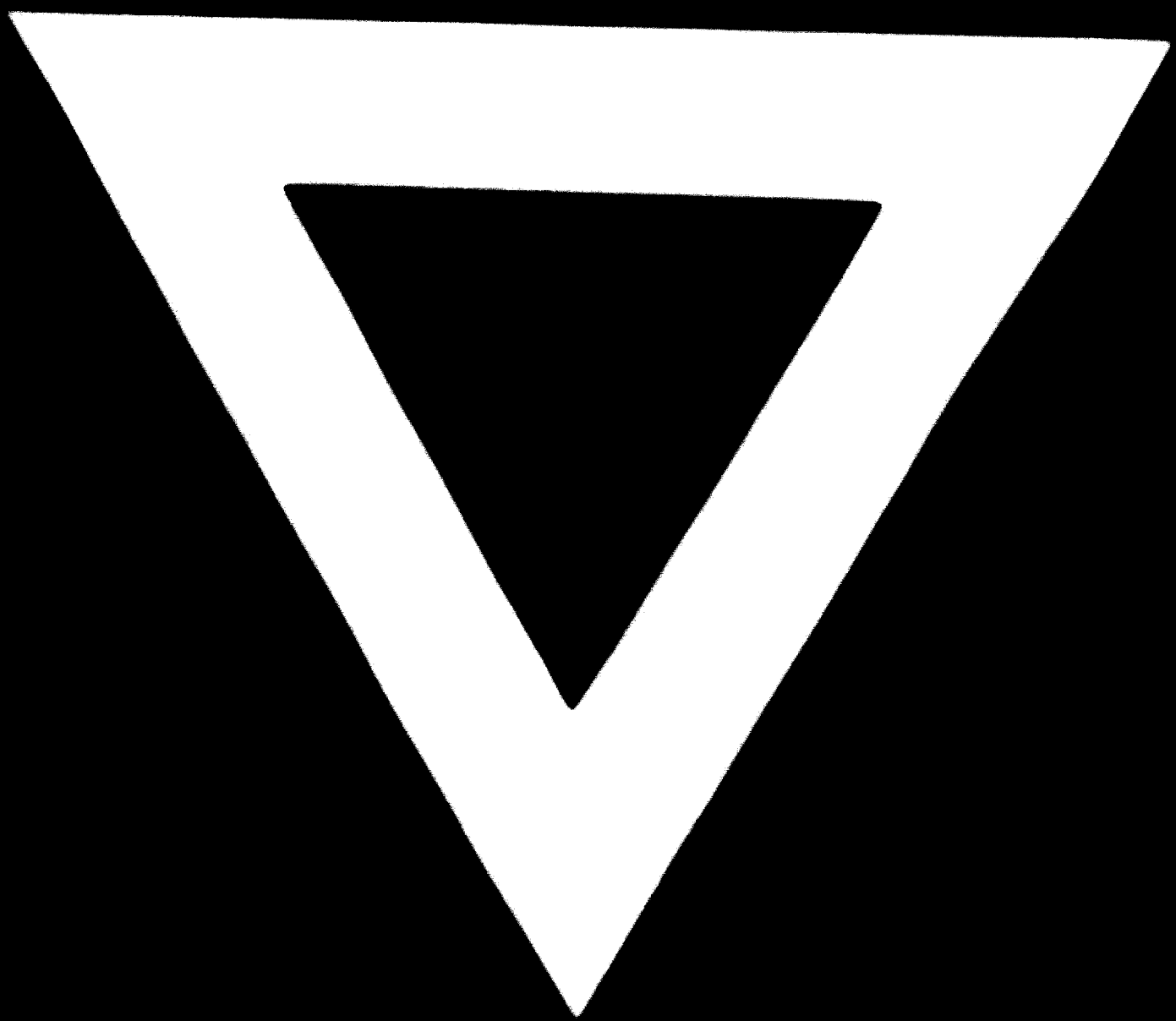

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