V. ŞCHIOPÎRLAN

Technical-Economic Criteria for Determining the Moment of Equipment Replacement in Telecommunication

From the economic standpoint the problem of equipment replacement consists in choosing an optimum operating interval, extending from the moment an equipment is put into operation until it is replaced.

The problem of equipment replacement sometimes arises as follows: the timely appreciation for the immediate replacement of some equipment by another.

This second form of the problem is characteristic of cases where equipment of technical and economic performance and characteristics differring from the equipment in use appears.

Solving these problems requires the determination of certain criteria on whose basis either a time interval whatever, or even the optimum moment when equipment replacement should occur, is determined.

The situations appearing in practice being rather complex, it is impossible to determine a single criterion, but in most cases the amount of profit yields the suitable indications.

TIME VARIATION OF PROFIT ACHIEVED BY OPERATION OF AN EQUIPMENT

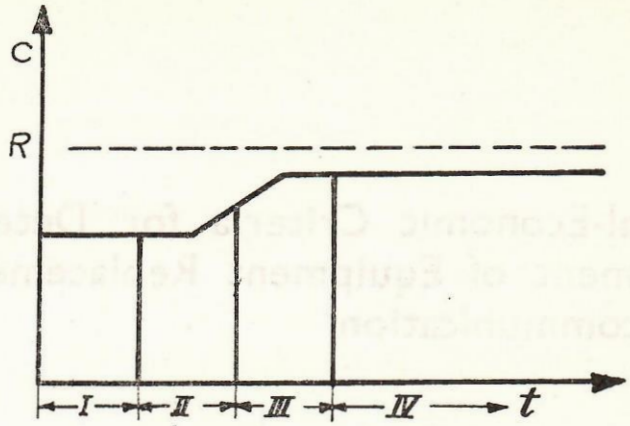
The profit is yielded by the relation:

$$P = I - C - A,$$

where I = income;
C = costs of operation, maintenance, repairs, etc.;
A = amortizing costs.

Among these variables, in the branch of Post and Telecommunication, under the conditions in which the equipment is used at its entire capacity, the repair and maintenance costs included in C vary with time.

They vary as a rule according to a curve (Fig. 1) whose shape is accounted for as follows:



1. Demands $D = d_0 [1 + 0.025 (t - t_0)]$.

In the first interval of operation I, the costs are constant due to the fact that only current maintenance costs and repairs of small importance are required.

In the second interval of operation, after the equipment has acquired a certain wear, repair costs increase more and more, without, however, showing a rapid increase.

The third interval corresponds to the situation where equipment wear has reached rather high values and its continued operation is subject to rapidly increasing costs.

If operation is also continuous in the fourth interval the expenses remain high and tend slowly toward an upper limit smaller than the value of reconditioning the equipment (R).

For equipment operated according to the cyclic system, with capital overhauling, this latter should correspond to the end of the second interval, i.e. when the costs begin to increase rapidly.

It therefore results that the profit will vary with time (curve 1, fig. 2).

Depending on the equipment technical and economic parameters, it is possible, due to the increase of costs, for the profit to become equal to zero or even negative at a certain moment, i.e. operation occurs at a loss (curve 2, Fig. 2).

LIMITS OF ACHIEVABLE PROFIT

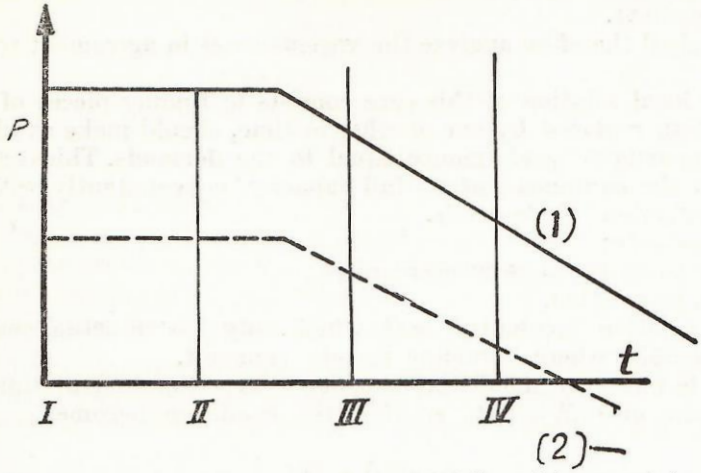
The investment of sums for acquiring equipment, tooling, etc., in view of developing a sector, may result in the increase of the profits achieved.

However, this increase cannot be boundless, being limited by the fact that the demand for service is also limited. Consequently, the excessive deve-

lopment of one sector results in profit limiting and in incomplete use of the equipment.

With respect to the problem of equipment replacement this phenomenon should be taken into consideration when the replacing equipment has a higher production capacity than the one replaced.

Likewise, the fact should also be taken into account that the replacing equipment is part of a technological process which does not usually



2. Capacity of existing equipment = 8,000 lines (at moment t_{10} the 2,000-line extension is added).

allow production (and hence profit) increase by increasing the productive capacity of only one technological step. Thus, profit increase by the introduction of one piece of equipment having a yield higher than the one replaced is also limited by the technical-economic characteristics of the technological processs of which the piece of equipment is a part.

When the development of one sector is foreseen, it is necessary to introduce some pieces of equipment having a higher productivity than that of the whole lot, so that the available capacity should be put into operation in the shortest possible time in relation to the operating lifetime of the equipment.

Hence, the achievable profit has an upper economic limit (imposed by service requirements) and a technologic limit when a piece of equipment from a technological set is dealt with.

If an entire productive technologic set is considered, the technologic limit is due to the production capacity of the respective set and it will be called "production limit".

COURSE OF DEVELOPMENT OF A PRODUCTIVE SECTOR AND THE PROBLEM OF EQUIPMENT

The problem of replacing a piece of equipment may arise under the influence of several factors which will be determined in the solution sought. Among them we list:

— physical wear;
— moral wear;
— changes in the technological set;
— lagging of equipment capacity in relation to increased demand.

The replacement problem once set under the influence of one or of several factors, its solution entails the necessity pursuing the aim in view — of taking into account an entire technological complex starting from the respective moment.

We shall therefore analyze the various cases in agreement with the aim in view.

The ideal solution of this case consists in finding pieces of equipment which, being replaced by one another in time, should make available a production capacity of performance equal to the demands. This corresponds to the use of the equipment at its full capacity, concomitantly with the complete satisfaction of demands.

If we note:

Q = quantity of service required;

P = production,

the ideal solution becomes $P = Q$, which only has an actual correspondent for the periods where demands remain constant.

As, however, Q should be considered as a function of time $Q = Q(t)$, there results also $P = P(t)$, so that the condition becomes

$$P(t) = Q(t) \tag{1}$$

which, practically, cannot be achieved (or, the achievement becomes completely uneconomic).

Taking this aspect into account, the suggested case acquires two variants, viz.:

a. Complete satisfaction of demands. This would be valid for the sectors of capital importance for which condition (1) becomes

$$P(t) \geqslant Q(t) \tag{2}$$

b. Satisfaction of average demands for a certain period. In this case we obtain, for period $t_0, \ldots, t$,

$$\int_{t_0}^{t} P(t)\,\mathrm{d}t = \int_{t_0}^{t} C(t)\,\mathrm{d}t \tag{3}$$

It is recommendable for the relative deviation from the mean value to be as small as possible in absolute value, i.e.

$$|A| = \left| \frac{P(t) - \dfrac{1}{t - t_0}\displaystyle\int_{t_0}^{t} P(t)\,\mathrm{d}t}{\dfrac{1}{t - t_0}\displaystyle\int_{t_0}^{t} P(t)\,\mathrm{d}t} \right| \tag{4}$$

The following specifications are made, likewise valid hereafter:

— If yearly figures are used, the integrals are transformed into amounts, expressions (3) and (4) becoming:

$$\sum_{a_0}^{a_n} P_{a_i} = \sum_{a_0}^{a_n} D_{a_i} \tag{3'}$$

$$|A| = \left| \frac{P_{a_i} - \frac{1}{n} \sum_{a_0}^{a_n} P_{a_i}}{\frac{1}{n} \sum_{a_0}^{a_n} P_{a_i}} \right| \tag{4'}$$

where:

a_0 = year of reference;
a_n = last year in the period considered;
a_i = year whatever in the period considered;
P_{a_i} = production in a year whatever;
D_{a_i} = demands in a year whatever.

$P(t)$ and $Q(t)$ are considered as being continuous functions in the time period considered and they are usually increasing functions.

Replacement appears as a problem under the influence of some phenomena.

The variables associated to these phenomena will hereafter be called variables of influence.

As it can be noticed, for the cases so far shown, the variable of influence is demand. In view of expressing completely the situation determined by this variable a further case will be expressed:

c. Satisfaction of demands in a certain percentage p. The practical problem amounts to achieve, on the average, for a period, a certain percentage p of satisfaction of demands; this percentage may also be variable in time.

That is:

$$\int_{t_0}^{t} P(t) = \int_{t_0}^{t} \frac{p(t)\, C(t)}{100}\, dt \tag{3''}$$

the relative deviation being small.

$$|A| = \left| \frac{P(t) - \frac{1}{t - t_0} \int_{t_0}^{t} \frac{p(t)\, C(t)}{100}\, dt}{\frac{1}{t - t_0} \int_{t_0}^{t} \frac{p(t)\, C(t)}{100}\, dt} \right| \tag{4''}$$

Physical wear

Physical wear occurs mostly as an influence variable in equipment replacement, but it can only constitute the single element taken into consideration in cases where the equipment lifetime is sufficiently small to only allow the other variables to change their initial values to a negligible extent.

If the other variables are neglected the conclusion is reached that the replacement should be made at the moment where physical wear is so important that the expenses made to maintain the equipment in operation cancel the profit.

Moral wear

In the conditions of a modern economy moral wear constitutes a very important element in what concerns equipment replacement problems.

Knowledge of the moral wear of existing equipment implies knowledge of the latest developments of science and technique in the respective domain.

To appreciate moral wear very good results are afforded by comparing the ratio between profit and productivity within a properly chosen time interval.

If we note:

M = moral wear;

P = profit brought in by existing equipment in a chosen time interval;

K = mean productivity of existing equipment in the same time interval;

P' = profit brought in by the best similar equipment in the same time interval;

K' = mean productivity of the best similar equipment in the same time interval,

moral wear is obtained in the form:

$$M = \left(1 - \frac{\frac{P}{K}}{\frac{P'}{K'}}\right) \times 100 \text{ per cent.}$$

Since P' and K' are variable in time owing to the appearance of equipment having ever better performances, moral wear M is also variable in time.

The greater the moral wear of the equipment involved in the problem of replacement, the more complete knowledge of the latest developments in technique will be necessary, a knowledge that should reach the forecasting of the technical-economic parameters and the year that the new equipment appears.

To solve the complex problems of equipment replacement an economic strategy should be determined contingent upon the aim in view and the parameters involved.

To this end the rudimentary estimation methods must be abandoned and rigorous scientific methods based on mathematical procedures of analysis should be adopted, such as the ones furnished by the theory of mathematical games, linear programming, stochastic and parametric programming, cet.

In conclusion an example of time determination is given, according to which telecommunication equipment in operation at a certain moment should be replaced.

Data of existing equipment:

a) *Technical*

Number of lines = 8,000

Capacity for extension = 12,000 lines

Number of simultaneous conversations = 10 per cent of number of lines.

b) *Economic*

Value of investment = 32 million lei;

Number of monthly conversations on a line = 200;

Yearly costs of operation, maintenance and repairs = 25% of investments value (may be considered constant);

Net yearly income In = 800 lei/line;

Investment for extension = 3,000 lei/line;

Duration of amortizing per total = 20 years;

Duration of life = 20 years.

c) *Requirements*

3,000,000 conversations/month distributed as 200 conversations/each line per month;

Yearly increase of demands = 2.5 per cent.

d) *Probable future conditions*

Similar equipment will be achieved within the next 5—10 years, with the following parameters assumed:

1. Number of lines: 10,000 to 20,000 according to requirements and depending on possibilities;
2. Number of simultaneous conversations = 15 per cent of the number of lines.
3. Value of investment = 3,500 lei/line
4. Net yearly income = 850 lei/line
5. Yearly costs of operation, maintenance and repairs are 20 per cent of investment value and may be considered constant.
6. Duration of life = 30 years
7. Duration of amortizing = 30 years.

The problem of equipment replacement arises consequently to the necessity of satisfying large demands.

The satisfying of demands is considered possible in a proportion of 40 per cent of the number of requests for the installation of telephones.

The problem requires a strategic economy to be determined in agreement with the present, future and prospective data.

The above data allow to determine graphically the situation of demands in the next few years and the proportion in which they can be satisfied (Fig. 3).

It is found that at a certain moment within the interval $t_5 - t_{10}$ years, the capacity of the existing equipment can no longer satisfy the proportion of 40 per cent of the demands and the phenomenon may be eliminated by introducing an extension.

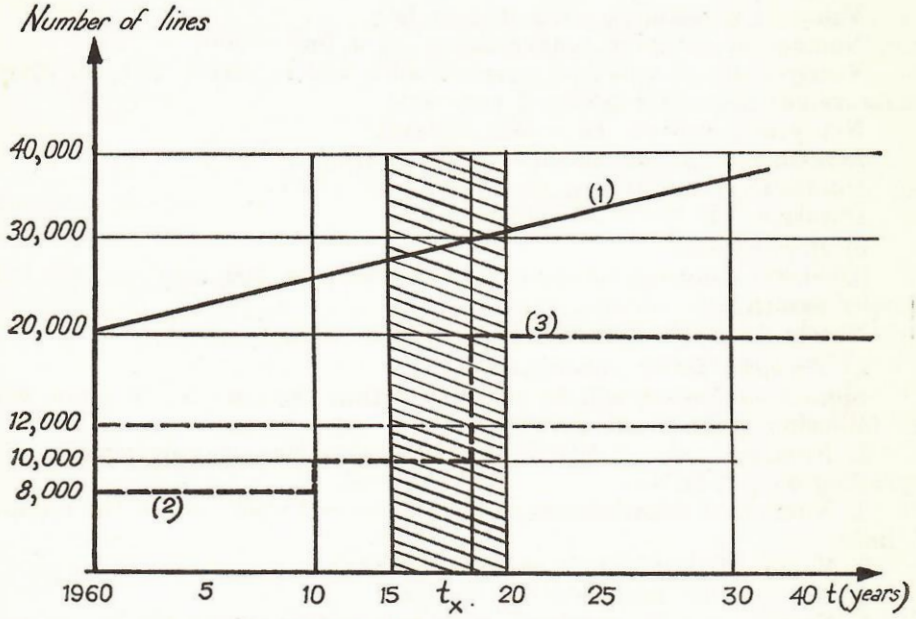
The problem being relatively simple, the following strategy will be assumed as a beginning:

1. Maintaining the existing equipment until new equipment appears.

2. An extension of 2,000 lines is introduced in view of permitting to maintain the level of demand satisfaction close to 40 per cent.

To make the problem somewhat simpler it is assumed that no important improvements of the parameters will occur in the next 40 years for the new equipment produced.

There results that replacement of the existing equipment will occur with the appearance of the new equipment, and the capacity of the repla-



3. Capacity of replacement equipment.
t_x = moment at which replacement equipment appears.

cing equipment will be so chosen as to enable demands to be satisfied in an increased proportion by successive extensions. Since modern equipment will appear between 1975—1980 ($t_{15} - t_{20}$) the second extension will no longer occur, new equipment, which will satisfy demands in a higher proportion, being then introduced.

In accordance with this strategy, the replacing equipment will have 20,000 lines (see Fig. 3).

The profit obtained by introducing the extension will be

$$p_{ext} = I_n - a_{ext} = I_n - \frac{i_{ext}}{d_a} = 800 - \frac{3{,}000}{20} = 650 \text{ lei/year line}$$

where P_{ext} = unitary profit obtained;
I_n = 800 lei/line year — unitary net income;
d_a = 20 years equipment amortizing duration;
i_{ext} = 3,000 lei/line, unitary investment for extension;
$a_{ext} = \frac{i_{ext}}{d_a}$ lei/year line unitary amortizing.

It is assumed that the maximum probability for new equipment to appear is at the moment $t_x = 18.5$ years.

Unitary integral profit P_u for the period $t_{10} - t_x$ is:

$$P_u = \int_{t_{10}}^{t_x} \left(I_n - \frac{i_{ext}}{d_a} \right) dt = \left(I_n - \frac{i_{ext}}{d_a} \right) (t_x - t_{10}) =$$

$$= \left(800 - \frac{3{,}000}{20} \right) (18.5 - 10) = 5{,}525 \text{ lei/line.}$$

Physical wear of extension equipment W_{ext} at the moment t_x will be:

$$W_{ext} = \frac{t_x - t_{10}}{d} = \frac{18.5 - 10}{20} = 0.425 \text{ i.e. } 42.5 \text{ per cent}$$

The residual value V_r of this equipment is:

$$V_r = W_{ext} \times K_{ext} \times i_{ext} = 0.425 \times 2{,}000 \times 3{,}000 = 2{,}550{,}000 \text{ lei.}$$

This equipment can be used again, requiring however the necessity of re-installation costs amounting to $R = 1{,}500{,}000$ lei.

There results that the total net profit P_{net}, obtained by integrating, will be:

$$P_{net} = K_{ext} \times P_u - R = 2{,}000 \times 5{,}525 - 1{,}500{,}000 = 9{,}555{,}000 \text{ lei.}$$

This shows that the introduction of the extension is justified. From the standpoint of the satisfaction of demands this extension offers the possibility of achieving the minimum percentage before the new equipment appears.

Considerations on the choice of the moment for replacement

Choice of the moment for replacement in the present case can be made in the interval $t_x - t_{20}$.

t_x has been considered equal to 18.5.

In order to also verify this aspect of the suggested economic strategy, the profits brought in by the two equipments will be compared for the period $t_x - t_{20}$.

Thus:

a) *For existing equipment*:

— net income $I_n = 800$ lei/year line;

— unitary amortizing $a = \frac{I}{K_{d_a}} = \frac{32{,}000{,}000}{8{,}000 \times 20} = 200$ lei/year line

— unitary profit obtained by integrating

$$P_u = \int_{t_x}^{t_{20}} \left(I_n - \frac{I}{K_{da}} \right) dt = \left(I_n - \frac{I}{K_{da}} \right) (t_{20} - t_x) =$$

$$= (800 - 200)(20 - 18.5) = 900 \text{ lei/line.}$$

b) *For extension*:
The following was computed above:

$$P_{ext} = 650 \text{ lei/year line};$$

$$P_{u_{ext}} = p_{ext}(t_{20} - t_x) = 650\,(20 - 18.5) = 975 \text{ lei/line}.$$

c) *For new equipment*
— unitary net income $I_n = 850$ lei/year line;
— unitary amortizing $a = \dfrac{i}{d_a} = \dfrac{3\,500}{30} = 117$ lei/year line;
— integral unitary profit

$$P = \int_{t_x}^{t_{20}} (I_n - a)\, dt = (V_n - a)\,(t_{20} - t) =$$

$$= (850 - 117)\,(20 - 18.5) = 1{,}100 \text{ lei/line}.$$

The total profit brought in by the existing equipment is

$$P = P_u \times K + P_{u_{ext}} \times K_{ext} = 900 \times 8{,}000 + 975 \times 2{,}000 = 9{,}150{,}000 \text{ lei}$$

The total profit brought in by the new equipment is

$$P_{new} \times K_{new} = 1100 \times 20{,}000 = 22{,}000{,}000 \text{ lei}.$$

Hence, introduction of the new equipment at the moment t_x brings in a supplementary profit of 22,000,000 — 9,150,000 = 12,850,000 lei.
Physical wear of the existing equip ment at the moment t_x is:

$$W = \frac{t_x - t_0}{t_{20}} = \frac{18.5 - 0}{20} = 0.925, \text{ i.e. } 92.5\%.$$

Moral wear is:

$$M = \left(1 - \frac{p_{old}}{p_{new}}\right) 100\% = \left(1 - \frac{600}{733}\right) \times 100 = 18\%$$

Advanced physical wear as well as moral wear and reinstallation costs to be met account for giving up the reutilization of the equipment.
This would lead to a loss equal to the residual value of the latter, i.e.:

$$R = (1 - W)\, I = (1 - 0.925) \times 32{,}000{,}000 = 2.290{,}000 \text{ lei}.$$

Thus, finally, the introduction of new equipment at the moment t_x brings in a profit increase of:
$P_{suppl.} - R = 12{,}850{,}000 - 2{,}290{,}000 = 10{,}560{,}000$ lei, which justifies the economic strategy chosen.

GENERAL CONCLUSIONS

The example chosen has allowed to determine the solution by simple means, by comparative economic analysis referring to case c), where the satisfaction of demands in a certain minimum percentage was our aim.

The variable influence in this case was the demand which was therefore the determining element in the choice of the economic strategy, according to which the verifications in value were carried out.

The subsequent replacement of equipment will be studied in agreement with the conditions to appear in the future. The problem, for this reason, acquires the aspect of a dynamic programming.

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CRITERES TECHNIQUES ET ECONOMIQUES POUR DETERMINER LE MOMENT DE REMPLACEMENT DE L'EQUIPEMENT DANS LES TELECOMMUNICATIONS

L'introduction de la technique nouvelle au fur et à mesure du développement des télécommunications soulève la question du choix d'un équipment dont les paramètres soient au niveau de la technique actuelle.

Selon la méthodologie actuelle de planification de l'introduction de la technique nouvelle dans les télécommunications, le plan technique ne traite pas de manière distincte de l'introduction de la nouvelle technique et ne fixe pas le moment critique pour le remplacement de l'équipement.

D'autre part, lorsque la question se pose de remplacer l'équipement en service, on n'applique pas dans la planification une stratégie économique fondée sur des calculs mathématiques.

La présente étude illustre pratiquement la manière de fixer le moment de remplacer l'équipement dans les différents secteurs des télécommunications.

En accentuant sur la rentabilisation de cette branche, l'étude met en évidence les principaux éléments susceptibles de constituer la base d'une stratégie économique dans ce domaine, tels que: le bénéficiaire, les exigences de l'économie nationale et de la population, l'usure morale, l'usure physique, etc.

L'étude présente une image d'ensemble de la manière d'établir l'efficacité économique de l'introduction de la technique nouvelle dans les postes et télécommunications lorsque le remplacement de l'équipement en service s'avère nécessaire.

ТЕХНИКО-ЭКОНОМИЧЕСКИЕ КРИТЕРИИ ОПРЕДЕЛЕНИЯ МОМЕНТА ЗАМЕНЫ СРЕДСТВ СВЯЗИ

Введение новой техники в рамках развития отраслей средств связи поднимает вопрос выбора оборудования, соответствующего уровню современной техники.

В современной методологии планирования внедрение новой техники в средства связи при составлении технического плана не всегда оговаривается отчетливо введение новой техники и не определяется критический момент замены оборудования.

С другой стороны, когда ставится вопрос замены существующего оборудования, в планировании не применяется экономическая стратегия, основанная на математических расчетах.

В данной работе практически демонстрируется возможность определения момента замены оборудования в секторе отрасли средств связи.

Делается упор на рентабельность отрасли, определяются главные элементы, лежащие в основе установления экономической стратегии в данной отрасли, как например: потребитель, потребности народного хозяйства и населения. моральный износ, физический износ и т.п.

Статья дает общее представление о методе определения экономической эффективности внедрения новой техники в почтовое дело и в средства связи, когда необходима замена существующего оборудования.