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EFFECT OF RECONSTRUCTION ON CHANGES OF THE RAILWAY'S VEHICLE ECONOMIC LIFE

Summary. Since many years were point of view a specially to railway vehicle czuses that economic life depend of rate of actual price and mauntance and repair cost. Elaborated from 400 years function formula has absolutely different shape now.

WPŁYW PROCESU ODNOWY NA TRWAŁOŚĆ EKONOMICZNĄ POJAZDÓW SZYNOWYCH

Streszczenie. Od wielu lat uważa się specjalnie dla przypadku pojazdów szynowych, że ich ekonomiczna trwałość zależy od kosztów produkcji oraz od kosztów ich utrzymania. Opracowane 40 lat temu zależności funkcyjne posiadają obecnie zupełnie inną postać.

Introduction

More then 4O years ago (30.6.1956) the article „WHAT'S THE LIFE OF A DIESEL?" with subheading „ ECONOMIC LIFE OF A LOCOMOTIVE CAN BE PREDETERMINED" was published in RAILWAY AGE [1]. The method used in today's practice, especially for predetermination of railway's vehicle economic life . Time period of optimal economic life of railway's vehicle is given out from square root of the rate actual price Ho and a half coefficient straight trend line of maintenance and repair costs rise B (generally takes Ho=100% and B=B/ H0 *100 %,) :

$$t_{opt} = \sqrt{\frac{2.H_0}{B}}$$

The following estimate is actual enough, having of course some defect, which were already mentioned by BROWN . Since railway vehicle is expensive , we expect its optimal economic life is greater then e.g. 10 years - what means square root of 100. In this case of year's linear growth of cost for maintenance and repairs is even 2% - (which means, how are we able detect growth 2 per cent, with regression of operational data (within satisfactory correlation's coefficient)). It is possible only over long time series.

BROWN allege necessary time section is at least 8 operational years (e.g. basic innovate cycle in engineering takes approximately seven years), so we must wait consequently relative long time for estimation of refinement depreciation per cent. Entrance of electronic and automation elements into railway vehicle therefore relatively great advance theirs purchase price. This fact lasts owners compensate the situation with improvement of economic life (20 till 40 years) in order depress year's depreciation. On the other side it makes certain obsolete effect of final part vehicle's life cycle. However actual economic situation does not allow to purchase new vehicles to change vehicle park composition. The way for removing moral wear is modernization. Acts about such partial technical improvement, thereby themselves vehicle approximate to technical highness of new one - it acquisites better operational parameters. Generally we can say , that in actual period of fast technical advance is considered to applicate modernization as one form of technical evolution, of complicated and expensive machine.

Modernization generally continues in conjunction with repair and reconstruction. Modernization evidently need not be efficient in all cases. Sometimes it is better to prefer to discard older vehicle from operation.

A serie of several realized reconstruction convinced us that these trends are applied at present, , either by railway vehicles [2] or by trams [3].

Reconstruction are solved as unique, for one realization, alternatively in wide range [4].

Generally is few spoken about, what time is suitable for such act execute. At instance exists not consensus between operational economists and renewal experts about depreciation per cent for reconstructed vehicle.

This paper is addressed direct answer the question of right determinate reconstruction's realization and assigning time period of new economic life of reconstruct vehicle. All at once with new economic life time of reconstructed vehicle set new depreciation per cent.

Technical life

Vehicle's life can be determined by physical, economic and technical-moral criteria. Then vehicle using period, assigned with physical factors, has its technical life. Technical life is define as sum of all object operation period from operation beginning to the moment of rise of their limiting condition. Limiting vehicle estate is identified by impossibility of his further operation at account of effectiveness decrease, profitability, improvement wear alternatively by reason of operational security reduction. Practical life cycle pointer is e.g mileage in km and physical age in years. Global life cycle is then sum of all object's operation period from operation beginning into his definitive outage, qualified by limiting estate. Physical life is especial case of technical life - attached to limiting physical estate. Values of technical life and their credibility and objectivity depend on instant on limiting estate entries. Economic life is then the length of operation, assigned of increase operational costs to insure their operationality.

Period of operation, during which the moral wear occures is called moral life. Life cycle is one of attributes,with which is needed to calculate at the time when the product was constructed.In ideal case would have had pay equality technical, physical, economic and moral life. To affect the life cycle of complicated machine and influence the direction of reducing lenght or extend its technical existence can even the economic devaluation, ever call as moral wear.

In contrast to failures mechanism, developed by operation or by other action, consists cause of the economic devaluation in the very vehicle. The phenomena occures at the newly deliver vehicles, especially of complicated construction. In consequence of backward vehicle's evolution and fabrication of jobbing character, whereby protracts the delivery of everyone exemplar onto few years, is railway's vehicle more or a less antiquated already in an instant, when comes from fabrication in railway's operation. Current phenomena - „moral wear" - is already supported by above mentioned large railway's vehicle life cycle.

Economic devaluation is caused by the grow of social working productivity (alternatively by decrease of aggregate sociable working consumption), by action of technical advance in reproduction technique. Generally two forms of economic devaluation are defined:

- economic devaluation 1.form - based on grow of social work productivity with effect of technical advance in reproduction of the same machine (fabrication a same machine is step by step cheaper);
- economic devaluation 2.form - based on with the grow of social work productivity below action of technical advance in reproduction of accomplished machines (actual machinery exemplar replaces of new, accomplished)

The possibility of abatement offers the planned modernization, concern chosen vehicle component's life cycle shortening, as a rule those, aboard this the antiquity shows distinctly and where can their displacement of technically fashionable components allow economic asset. This way pursuit modernizing may be economic preferable, than their allowance of new vehicles, because modernize vehicle can fill conformable requirements, in accordance with actual conditions of technique evolution, along with exploitation of component series, that may be leave in original estate.

Review of methods for vehicle's economic life determination

Let's introduce the short review of used methods for determination of vehicle economic life without demand on theirs extended analyses, though with the indication of eventual operation augmentation of method in other models of cost trends in maintenance and repairs (especially in Brown's method).

Brown's calculation method

This method come out of consideration, that a optimal vehicle economic life can be such period of vehicle operation, in which the sum of average year's costs of maintenance and repairs and yearly depreciations is minimized i.e minimize of average year's costs.lt is trying to assign the minimum from sum of depreciation and average year's costs in maintenance and repairs. The changes of depreciation (linear) in dependency to period of application (allowances for deprecations), see Fig., there're after given as :

$$O_d(t) = \frac{H_0}{t}$$

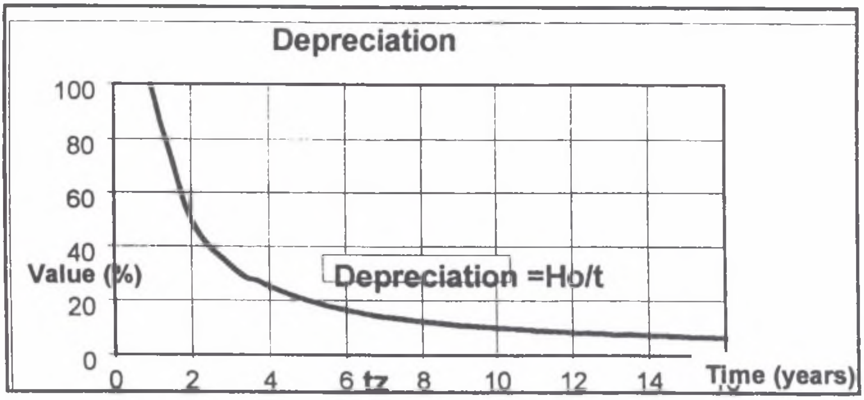

Fig.1

Other terms are maintenace and repairs costs - see Fig.2.

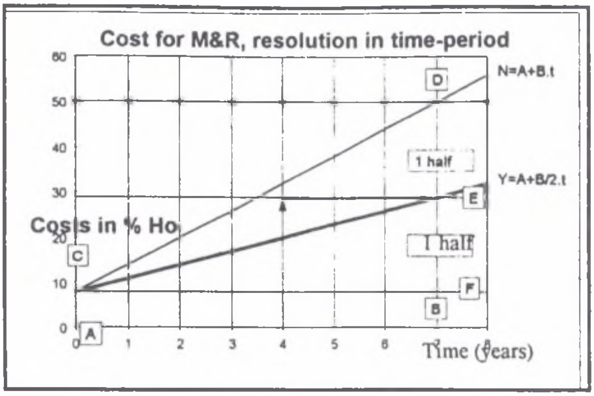

Fig.2

For measure of temporal period Brown's optimization we must in present regression assignment maintenance and repairs costs at indicated date - e.g. close of 7^{th} year distribute to average value into all period. In other words, the area of trapezoid ABDC is perhaps assigned to area of rectangle - AB*BE (it is the sum of rectangle area ABFC and triangle area CFD). In regressions line of maintenance and repairs costs we obtain these in period about length (0,t) as follows :

$$Y(t)=A+B/2.t$$

Generally we can chew over regressions multinominal of costs in maintenace and repairs at form: $N_{uo}= a_0+a_1.t+a_2.t^2+......$

Area below thereby multinominal is: $P_N= a_0.t +a_1.t^2/2 +a_2.t^3/3+......$

Conversion into alternate rectangle come in with divide section (0,t) : $Y(t)= a_0+a_1.t/2 +a_2.t^2/3$

We see, that for regression can we apply common multinominal, hardness would been after, by solving own optimization - which means algebraic equation step about 2 higher, until term, whereby will multinominal Y(t) completion.

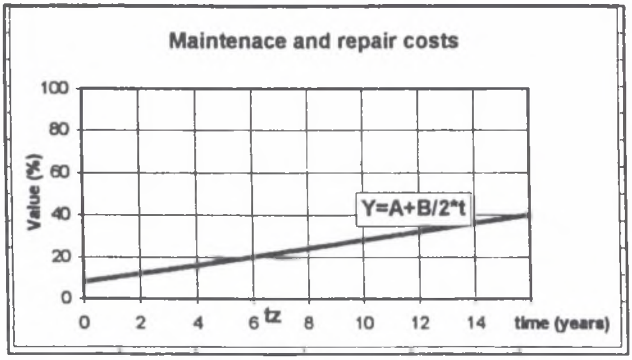

Fig.3

Brown's sum function, at which the optimization is then implemented :

C(t)= Od/t + Y(t)

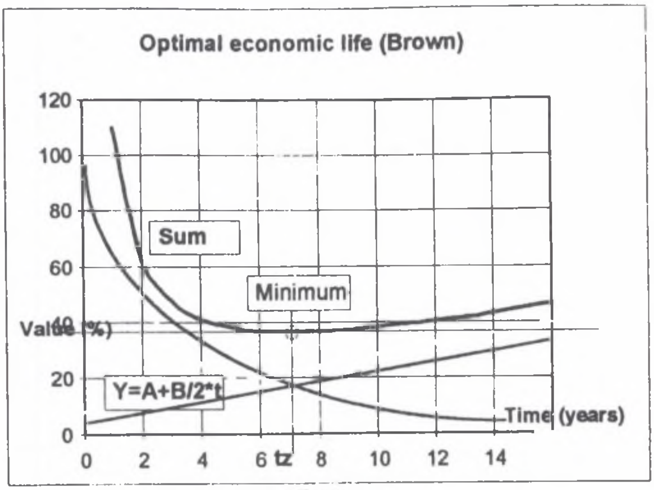

Fig.4

After differentiation sum function (e.g. in linear regression of costs in maintenance and repairs) keep we resultant relation behalf optimum period of lifetime (and thereby actually and greatness of depreciation) from:

$$\frac{dC(t)}{dt} = 0$$

$$t_{opt} = \sqrt{\frac{2 \cdot H_0}{B}}$$

After assignment of topt in the second derivation we get positive numerical value, which is then a local minimum of costs sum - that we're looking for.

Method J.B. ŠOR

Lifetime is defined as a period of time, at that vehicle operation has minimum average maintain costs. Basic advantage on Brown's method is application of considerably wider of index spectrum, which advance calculus accuracy, on the other hand advance its demandity indeed. Method arise out of assumption, that cost heavy repairs have the linear trend, respectively period between basic repairs growth linear abbreviate, if it is to be on the same level.

Average maintenance is assigned from equality:

$$S_n = \frac{C_0 + g_1 \cdot t_1 + g_2 \cdot t_2 + \ldots\ldots + g_n \cdot t_n + C_1 + C_2 + \ldots\ldots + C_{n-1}}{p_1 \cdot t_1 + p_2 \cdot t_2 + \ldots\ldots + p_n \cdot t_n}$$

Method is more precise, but is designate especially for single-purpose machine-tool. In railway traffic, where operation have complicated conditions would be difficult to use thise method .

Method UIC

In 1965 Committee of UIC work out a suggestion of technical conditions for the assignation of optimal railway's vehicle life. In principle it is applied BROWN method , which is to find lifetime, that is minimum sum of all year's expenses allied along with vehicle operation. UIC arise out of calculation annuity (year's payment), in to the hold the view, that at present isn't enough evincible the action of the vehicle application period in yields, in consequence consider in calculation with constant year's yields.

Method German federal railways (DB)

Method for determination of optimal lifetime of vehicles used in DB is in principle equal as method UIC, but calculation is simpler. For search of optimal vehicle lifetime is assembled the scale of different periods of vehicle operations, graduate e.g. a five years. For each of these alternative is assembled terminal calendar sum of costs.

These costs are assembled from capital investment costs, i.e.. depreciation plus interest of maintain costs. For different searching alternative of lifetime is after most economic regarded that, for which average year's charges adventitious of calculation are lowest. For assessment of optimal lifetime is applicated the relation:

$$t_{opt} = -\frac{U_{st} + W_{st} \cdot e - K_{rv} - U_{rv}}{Z_u + Z_v}$$

Problematic of modernization - reconstruction

Chew over application of classic Brown's method for calculation railway vehicle lifetime, or about its edits to answer to look in injection of certain expense in date t*. Before the reconstruction the vehicle depreciation pass off according ancient chart, because - we're nibble, whether we will anywise modernize, even the reconstruction generally considering technical progress given await

- we're ignore nothing, alternatively we're a few gnosis as will appear the costs in maintenace and repairs („waiting" myself even 8 years - after we tent optimal lifetime specification), consequently we depreciate fine.

  Residual value of the vehicle is at common time t :

$$H_z(t) = H_0(1 - t/t_z) \qquad\qquad H_R(t^*) = H_z + R = H_0\left(1 - \frac{t^*}{t_z}\right) + R$$

After reconstruction oneself depreciate from value (Fig.5). Certainly exist optimum for both cases. Optimization is again solved concerning effect function of aggregate residual sum value, assigned of residual value of the vehicle and increase in value maintenance and repair cost.

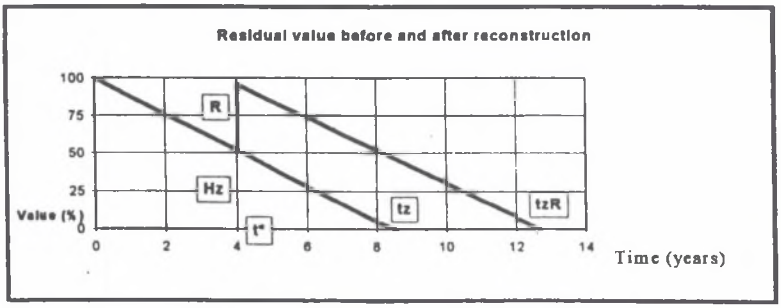

Fig.5

$$C_R(t-t^*)=\frac{H_0\left(1-t^*/t_{opt}\right)+R}{(t-t^*)}+A_R+\frac{B_R}{2}.(t-t^*)$$

From where after differentiation and equal 0 we obtain :

$$t_R=\sqrt{\frac{2.\left[H_0.(1-t^*/t_{opt})+R\right]}{B_R}}$$

This is optimum lifetime into section, following after time t*. Then aggregate vehicle's life period would be :

$$t_{Rz}=t^*+\sqrt{\frac{2(H_0+R)}{B_R}-\frac{\sqrt{2BH_0}}{B_R}.t^*}$$

consequently after optimization considering moment of reconstruction t* (differentiation along t* and equal = 0) comply behalf t* :

$$t^*_{\max}=\sqrt{\frac{2H_0}{B}}.\left[1+\frac{R}{H_0}-\frac{B}{4B_R}\right]$$

and is it : $\rho=\frac{R}{H_0};\ldots\beta=\frac{B}{B_R};then\ldots\frac{t^*_{\max}}{t_{opt}}=1+\rho-\frac{\beta}{4}$

Dependency of t* into these factors shows Fig.6.

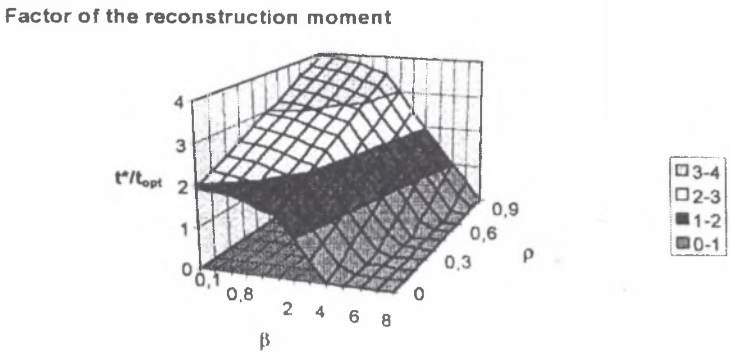

Fig.6

So as t* would have sense, must be $1+\rho-\frac{\beta}{4}\geq 0, \rho\geq\frac{\beta}{4}-1$. Because currently $\rho\geq 0$ (costs in reconstruction, so far as oneself execute, are positive), have to pay : $\beta\geq 4$. Situation is demonstrated in Fig.7.

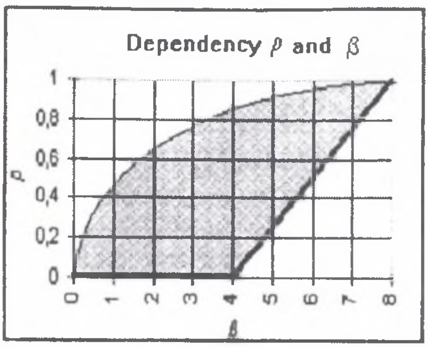

Fig.7

Current result deserve discussion, means namely, that **reconstruction hasn't sence**, until it brings **at least fourfold depression** in trend of costs in maintenance and repairs. Following requirements would be difficult to satisfy only from the views of cut-down maintenance and repair's costs, it is important to look for assets in aggregate operational economies, savings of traction energy and other savings.

Conclusion

Adventitious calculation effect behalf moment of reconstruction execution (and resultant impact in aggregate vehicle lifetime) is represents of relations :

$$t^* = (1+\rho-\frac{\beta}{4}).t_{opt} \qquad t_{Rz} = \left(1+\rho+\frac{\beta}{4}\right).t_{opt} = \left(1+\rho+\frac{\beta}{4}\right).\sqrt{\frac{2H_0}{B}}$$

so that aggregate lifetime period oneself extend about multiple of basic lifetime $\rho+\frac{\beta}{4}$ across conditions of efficient optimization, explicitly in precedent parts of paper. It is especially about condition , where it'd be $\beta \geq 4$ though comprise and operational profits. Profits would be risen conformable with suggestions, explicit in [6] :

- **savings of energy - e.g. in electrical driving vehicles by modernizing the system of vehicle's drive power supply and peripheries; in diesel driving vehicles by application of new engines , transfer and drives of wheelsets, electronic controls of effort and ride velocity; with application central power supply for illumination, air conditioning and heating**
- **savings in maintenance and repair, e.g. in advance of aggregate reliability, displacement of aggregates with new models along with better maintenance and less demand on repairs, prolongation between repairs period**
- **savings of numbers of worker in technological handling process of vehicle and in following traffic technological process.**
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It'd be eventual assign of series of additional factors for expediency of modernization in reconstruction, fundamentals for the use in paper presented by philosophy and dependencies is accurate evaluation of action of these factors onto depression of costs demand in operation, in maintenance and repairs.

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Streszczenie

Na trwałość ekonomiczną maszyn w szczególności typu pojazdy szynowe posiada wpływ wiele czynników, w tym przede wszystkim: koszty ich produkcji (w których znaczący udział mają jakość i dokładność wykonania) oraz szeroko pojęte koszty utrzymania (obsługa, remonty itd.). Ostatnio, przyjęte już 40 lat temu proporcje pomiędzy tymi czynnikami zostały zmienione (czasem bardzo silnie), jak również pojawiły się nowe czynniki, np. zużycie moralne i inne. W artykule przedstawiono szereg stosowanych aktualnie w Europie metod analitycznych do określania optymalnego czasu ekonomicznej trwałości pojazdów szynowych, która jest różna od pojęcia trwałości technicznej. Na bazie analizy różnych metod określania optymalnego czasu zużycia pojazdów szynowych opracowano własne oryginalne zależności matematyczne, które są najlepszym przybliżeniem wyników uzyskanych z badań statystycznych.