TRANSPORT
2008
23(1): 51–54

INVESTIGATING THE DYNAMICS OF PASSENGER ROLLING STOCK DETERIORATION

Gediminas Vaičiūnas[1], Leonas Povilas Lingaitis[2]

Dept of Railway Transport, Vilnius Gediminas Technical University, J. Basanavičiaus g. 28, LT-03224 Vilnius, Lithuania. E-mail: [1] vaic@ti.vgtu.lt, [2] leonasl@ti.vgtu.lt

Received 18 April 2007; accepted 20 November 2007

Abstract. One of the major economic criteria is associated with the growth of maintenance costs of old rail vehicles. The research aims to determine the ageing criteria of passenger rolling stock, which could take into account fuel, diesel oil and repair costs. Therefore, economic criteria based on the above costs are generated and their comparative analysis is made. The research object is Vilnius locomotive depot.

Keywords: passenger locomotives, diesel train sets, type of traction, fuel consumption, oil consumption, repair costs.

1. Introduction

The renewal of large rolling stock is not an easy task because of high cost of rail vehicles. Therefore, this should be done by gradually introducing new locomotives, diesel train sets and railcars into operation. For this purpose, the criteria of rail vehicle deterioration, used in decision making about its further use or writing off, should be determined. In this way, it could be possible to plan the renewal of the available rolling stock. The present article addresses this complicated problem.

One of the major economic criteria is associated with the growth of maintenance costs of old rail vehicles. The research aims to determine the ageing criteria of passenger rolling stock, which could take into account fuel, diesel oil and repair costs. Therefore, economic criteria based on the above costs are generated and their comparative analysis is made. The research object is Vilnius locomotive depot.

Optimization model of traction rolling stock operation and determination of a complex criterion for assessing the performance of traction rolling stocks are investigated by Lingaitis *et al.* (2002) and Vaičiūnas *et al.* (2004). Jurėnas *et al.* (2007) are investigating methods used for assessing the performance of diesel locomotives.

2. Determining the maintenance costs of locomotives

The analysis was based on the statistical data on rolling stock, but we could not find the information about the locomotives, diesel train sets and railcars of the same service life because, actually, such rail vehicles are nonexistent. Therefore, excerpts were made according to the actual age groups of rail vehicles (including 10 passenger locomotives and 14 diesel train sets). The processing of results yielded regression equations showing annual deterioration of rail vehicles based on the costs of fuel, diesel oil and repairs.

The relationship between average expenses of passenger locomotive per 10 000 tkm in Vilnius locomotive depot and its age is shown in Fig. 1.

The relationship between average expenses of diesel train set per 10 000 tkm and its age is shown in Fig. 2.

The analysis of Fig. 1 and Fig. 2 reveals that fuel costs make the largest part of overall expenses of both diesel train sets and passenger locomotives. The results obtained show that, renewing the rolling stock (by purchasing new rail vehicles), the problem of fuel costs should be paid special attention, and the choice of engine and gear box design should be carefully considered. For example, the efficiency of heat engines (i.e. part of thermal energy converted to work) usually ranges from 15 to 35 % depending on their design. The efficiency of the engine is closely connected with fuel consumption.

Fuel consumption depends on many factors (e.g. mass of the rolling stock, its speed, axle loading, carriage structure), however, since the operating conditions of rail vehicles are similar, these factors are equally important for all of them. On the other hand, service life and technical condition of a rail vehicle are the most important factors determining its fuel consumption. Thus, fuel

ISSN 1648-4142 print / ISSN 1648-3480 online
www.transport.vgtu.lt

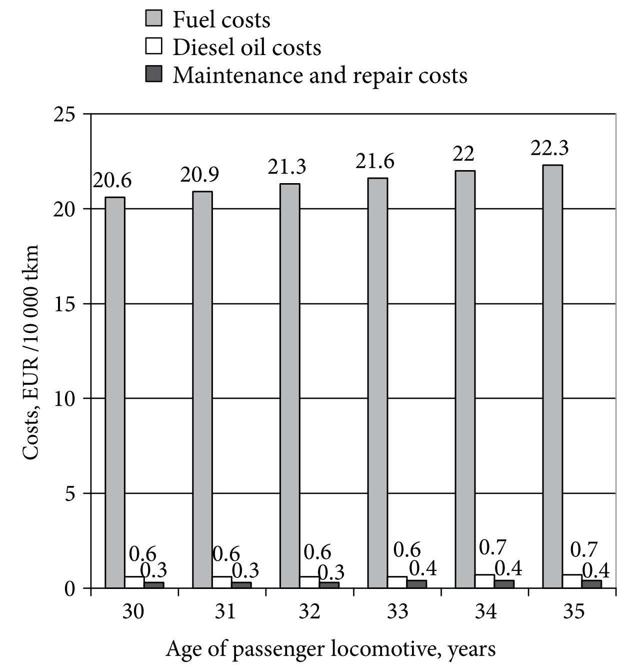

Fig. 1. The relationship between average expenses of passenger locomotive per 10 000 tkm and its age

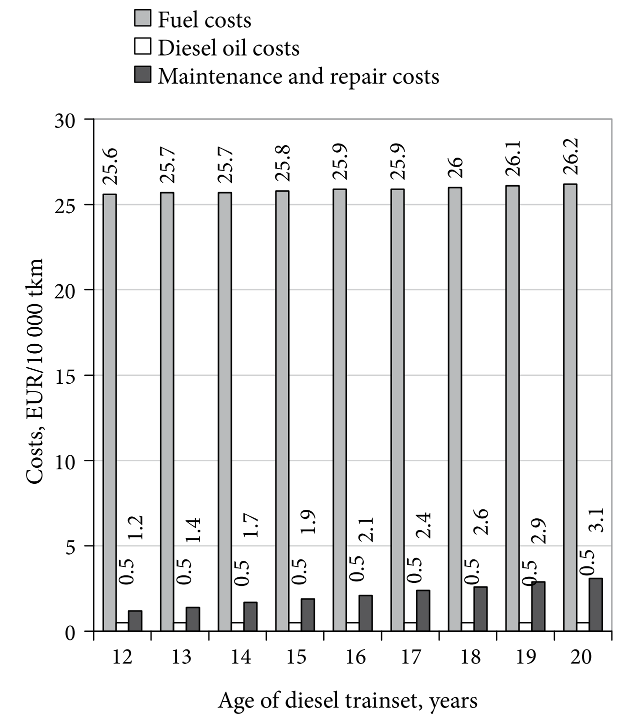

Fig. 2. The relationship between average expenses of diesel train set per 10 000 tkm and its age

consumption is the main indicator of the performance of traction rolling stock. Usually, it is expressed as a relative value, e.g. 1 000 tkm or 10 000 tkm. This quantity is referred to as relative fuel consumption. This method of calculating fuel consumption per unit of work is quite satisfactory for freight locomotives. However, as far as passenger locomotives are concerned, the above indicator shows the work done in carrying containers rather than passengers. Therefore, it is used only when passenger flows do not differ considerably.

The dependence of relative fuel consumption of passenger locomotives of various ages and the power of 2 200 kW on various factors, established in investigating their performance, is shown in Fig. 1. About 80 % of experimental data are in the solution interval ± 2 % of the presented equation.

Mathematically, the relationship between relative fuel consumption and the locomotive age may be expressed by a linear equation:

$$d_{kel} = 0.687 \cdot x + 21.46\,, \tag{1}$$

where: x is the age of a locomotive, years; d is relative fuel consumption, kg / 10 000 tkm.

As shown in Fig. 1, the variation of fuel consumption of passenger locomotives is about 0.3 kg / 10 000 tkm. (0.7 %) per year.

The variation of relative fuel consumption of diesel train sets with the power of 736 kW is approximated by the equation:

$$d_{Ddyz\_t} = 0.108 \cdot x + 51\,. \tag{2}$$

In the service life range from 12 to 15 years, 80 % of experimental data are in the solution interval ± 0.2 % of the equation (2).

As seen in the diagram, fuel consumption of diesel train sets, which are getting older, is uniformly increasing by approximately 0.11 kg / 10 000 tkm (0.23 %) annually (which is 2.5 times lower than that for diesel locomotives).

Relative fuel consumption of passenger locomotives vary in the range of 44.8 to 45.8 kg/10 000 tkm, while the variation range for diesel train sets is from 52.4 to 52.7 kg/10 000 tkm. Therefore, it is more economical to carry passengers by diesel locomotives than by diesel train sets, though the comparison is relative because diesel locomotives are twice as old as diesel train sets. On the other hand, the upgraded diesel train sets allow for varying the number of carriages (when required) more freely as well as using only one motor coach, while having the driver's cab in the other. Moreover, when less fuel is consumed, a smaller amount of pollutants (CO, CO_2, NO_x, C_xH_y, and solid particles) is released into the atmosphere.

Other materials are used by traction rolling stock besides fuel. The amount of diesel oil used is closely connected with the rolling stock condition. Diesel oil is not a source of power, therefore, its use indicates a poor state of the engine. The relationships between relative oil consumption and the age of rail vehicles are given in Figs. 3, 4.

The relationship between relative diesel oil consumption by passenger locomotives may be described by the following mathematical expression:

$$a_{Kel} = 0.069 \cdot x + 0.238, \tag{3}$$

where: a – relative diesel oil consumption, kg/10 000 tkm.

According to equation (3), the consumption of diesel oil by passenger locomotives grows by about 0.07 kg / 10 000 tkm (2.1 %) per year.

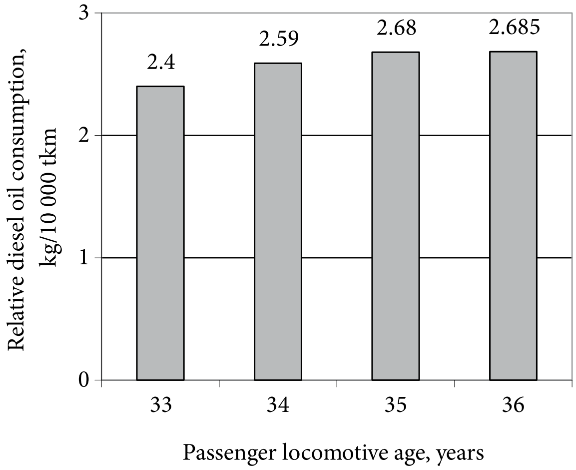

Fig. 3. The relationship between relative consumption of diesel oil by passenger locomotives and their age

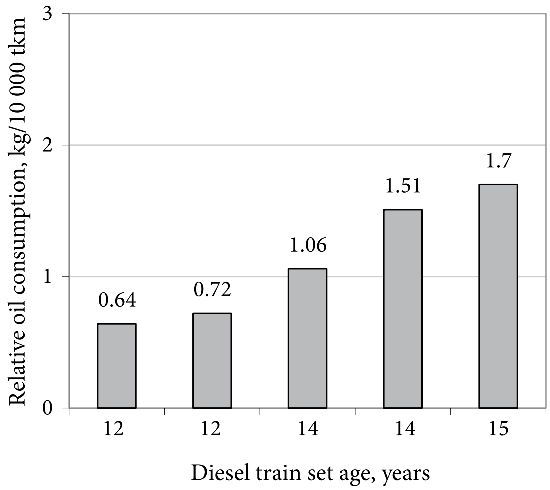

Fig. 4. Variation of relative diesel and transmission oil consumption by diesel train sets

The annual variation of relative oil consumption by diesel train sets is shown in Fig. 4.

The annual consumption of diesel oil by diesel train sets varies according to the expression:

$$a_{Dyz\_t} = 0.3275 \cdot x + 3.262. \quad (4)$$

According to equation (4), relative diesel oil consumption by diesel train sets annually increases by about 0.33 kg / 10 000 tkm. This shows the essential defect of diesel train set engine, which should be taken into account in upgrading engine coaches of diesel train sets.

Expenses on maintenance and repair costs of rolling stock may be assessed in hours of terminal delay. This evaluation method was used because delay hours are easy to calculate and operate. The delay time actually indicates the amount and effectiveness of repair work in Lithuania. It also shows the reliability of rolling stock. Another aspect is the correctness of this approach. The statistical data show that terminal delay time (in hours) is proportional to the expenses. It means that the relationship between terminal delay time and the locomotive age will be equal to the similar cost relationship. The relationships between relative terminal delay and the locomotive age are presented in Figs. 5, 6.

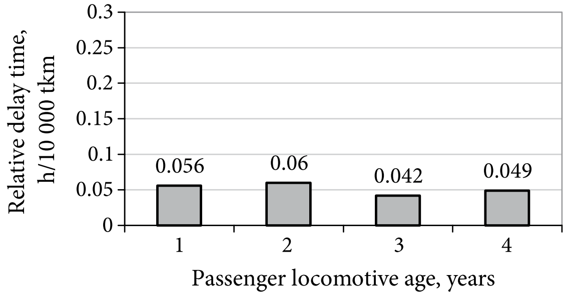

Fig. 5. The relationship between relative delay time and age of passenger locomotives

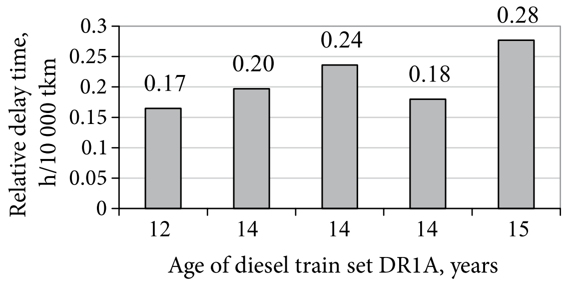

Fig. 6. The relationship between relative delay time and age of diesel train sets

By approximating the relationship given in Fig. 5, we get the regression equation:

$$p_{Kel} = 0.0035 \cdot x - 0.067, \quad (5)$$

where: p is relative terminal delay, h/10 000 tkm.

As shown in Fig. 5, the variation of relative passenger locomotive delay time makes about 0.0035 h / 10 000 tkm (7 %) per year.

By approximating the relationship given in Fig. 6, we get the equation:

$$p_{DR1A} = 0.0329 \cdot x + 0.243. \quad (6)$$

According to equation 6, the variation of relative terminal delay of diesel train sets is about 0.033 h/10 000 tkm (20 %) per year.

3. Integrated criteria for evaluating rolling stock performance

An integrated criterion evaluating the performance of rolling stock should take into account fuel, oil and unscheduled maintenance costs. It may be expressed as follows:

$$K = d \cdot I_d + a \cdot I_a + p \cdot I_p, \quad (7)$$

where: K is an integrated criterion evaluating rolling stock performance, EUR/10 000 tkm; d – denotes relative fuel consumption, kg/10 000 tkm; a denotes relative oil consumption, kg/10 000 tkm; p – means relative delay time due to unscheduled maintenance, h/10 000 tkm; I_d –

unit cost of fuel, EUR/kg; I_a is unit cost of oil, EUR/kg; I_p is arbitrary unit cost of unscheduled maintenance, EUR/h.

The integrated criterion K for passenger locomotives may be expressed as follows:

$$K_{Kel} = (0.687 \cdot x + 21.46) \cdot I_d + (0.069 \cdot x + 0.238) \cdot I_a + (0.0035 \cdot x - 0.0672) \cdot I_p. \tag{8}$$

For diesel train sets the criterion will be, respectively, of the form:

$$K_{DT} = (0.108 \cdot x^2 - 0.025 \cdot x + 51.92) \cdot I_d + (0.327 \cdot x + 1.745) \cdot I_a + (0.00329 \cdot x + 0.243) \cdot I_p\ . \tag{9}$$

4. Interpreting the integrated economic criterion of rolling stock

The graphs of the dependence of rolling stock integrated economic criterion on age were plotted based on the formulas (8) and (9). According to these formulas and the cost of fuel, diesel oil and repairs (0.483 EUR/kg, 0.248 EUR/kg and 0.095 EUR/h, respectively), the graphs of the dependence of rolling stock integrated performance criteria on its age were drawn.

The relationship between the integrated economic criterion of passenger locomotive and its age is shown in Fig. 7.

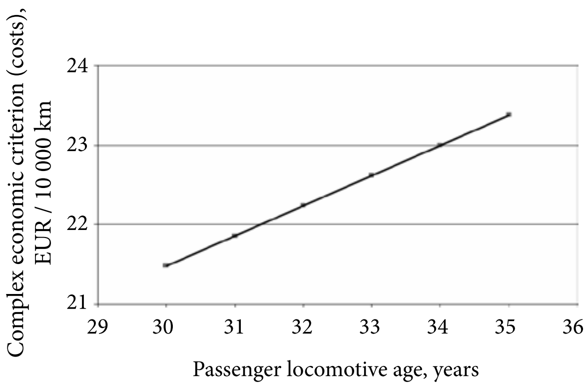

Fig. 7. The relationship between the integrated economic criterion of passenger locomotive and its age

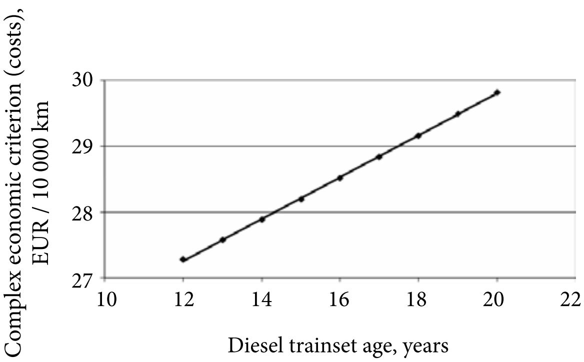

Fig. 8. The relationship between the integrated economic criterion of diesel train set and its age

The relationship given in Fig. 7 can be described by the equation:

$$K_{Kel} = 0.3804 \cdot x + 10.06. \tag{10}$$

The dependence of integrated diesel train set economic criterion on its age is shown in Fig. 8.

The relationship presented in Fig. 8 may be described by the equation:

$$K_{DT} = 0.3186 \cdot x + 23.43. \tag{11}$$

The comparison of Figs. 7, 8 shows that both criteria (describing passenger locomotives and diesel train sets) are changing uniformly in time, while the value of the integrated economic criterion of diesel train sets is by about 11.5 % higher than that of passenger locomotives. According to maintenance expenses, the deterioration rate of engine coaches is higher than that of passenger locomotives.

5. Conclusions

1. Fuel consumption of passenger diesel locomotives increases with their age according to linear dependence, while fuel consumption of passenger diesel locomotives increases by 0.7 % and of diesel train sets – by 0.23 % per year.

2. Relative diesel oil consumption of passenger locomotives increases by about 2.1 % per year. Relative diesel oil consumption of diesel train sets grows insignificantly.

3. Relative terminal delay of passenger rolling stock increases in time according to linear dependence: for diesel locomotives it increases by about 7 % per year, while for diesel train sets the increase makes 20 % per year.

4. The integrated economic criterion of diesel train sets is by about 11.5 % higher than that of passenger locomotives.

5. The difference in the ageing criteria can be accounted for the fact that fuel consumption of passenger locomotives increases with the increase of their age according to linear dependence and fuel consumption of diesel train sets is by 11.5 % higher than that of passenger locomotives.

6. It is more economical to use diesel locomotives than diesel train sets for passenger transportation on long routes with sufficient amount of passengers. To determine rational route section length, further research is needed.

References

Juršėnas, V.; Vaičiūnas, G. 2007. A survey of methods used for assessing the performance of diesel locomotives, *Transport* 22(1): 28–30. ISSN 1648-4142.

Lingaitis, L. P.; Vaičiūnas, G. 2002. An optimization model of traction rolling stock operation, *Journal of Maintenance and Reliability* 3(15): 26–30. ISSN 1507-2711.

Vaičiūnas, G.; Lingaitis, L. P.; Bureika, G. 2004. The determination of a complex criterion for assessing the performance of traction rolling stocks, *Transport* 19(2): 63–68. ISSN 1648-4142.