ANALYSIS OF PUBLIC TRANSPORT VEHICLES MAINTENANCE COSTS

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Abstract

The present paper deals with maintenance in a public transport enterprise. It contains an overview of the implementation of the prescribed maintenance of vehicles while the main purpose is to analyse the maintenance costs, i.e., the costs of the service process logistics. In Pareto analysis, both mileage and maintenance costs were assessed. The maintenance costs of public transport vehicles were also analysed according to unitation criterion.

Keywords: Maintenance, transport, Pareto

1. INTRODUCTION

In Slovakia, public transport is provided primarily by buses, trains, trolleybuses, trams and taxis. The public transport system is particularly the most efficient due to its large capacity. The forecasts of the development of transport in Europe for the period by 2030 is as follows: passenger transport + 40 %; freight transport by 2030: + 60 %; and motor vehicles by 2020: + 50 %. According to the latest McKinsey Global Institute's study, despite the current depression in this industry, the number of passenger motor vehicles will double by 2030 [1].

Only the high-quality public transport may become the keystone of mobility that would also lead to the reduction of the environmental burden. Important aspects include not only smart electronic services, general comfort, and above-standard offer but also safety. In terms of operation safety, it is necessary to require that the means of transport are in a perfect condition and such requirement must be of primary importance.

The technical life of a vehicle represents a numerical expression of its service life that denotes the vehicle’s capacity to fulfil the required functions until it reaches the terminal state under the predefined system of prescribed maintenance and repairs that are carried out within the logistics of service processes in an enterprise. The fundamental function of maintenance and repair activities is to ensure the operational capacity of vehicles [2]. Thus, logistics as the multi-aspect support of the technical system also ensures the maintenance tasks [3,4].

If we depict the operation of a means of transport as an important section of its lifecycle (**Figure 1**), we may present the summary of purposeful activities as a set consisting of two sections: i) a summary of maintenance operations and ii) a summary of repair operations. The **Figure 1** presents a scheme of the curves of failure intensity, probability of a fault-free operation, and a typical development of wear of certain parts of a means of transport in three stage of its lifecycle - break-in, normal operation, and terminal states, i.e., the run-down [5]. The ways of how a user may affect individual monitored parameters are briefly described in the figure below.

As a result of gradual replacement of obsolete vehicles with new ones, the vehicles in a single fleet are of different ages and, therefore, there are different requirements for their maintenance and repair. Efficient processing of the long-documented maintenance data may provide a lot of information not only on the history of the vehicles but also on the maintenance system [6]. The fleet renewal depends primarily on the lifecycles of the vehicles and the carrier’s needs. One of the key qualitative characteristics, in terms of the theory of renewal of the means of transport, is reliability. Progressiveness of the new systems of vehicle renewal is based on the application of technical systems that monitor failure rates and evaluate vehicle reliability and quality, and on controlling and implementing systems of technical diagnostics. The decisive factors of reaching and maintaining high operational reliability of vehicles include the diagnostics tools, being the sources of objective information on a real technical condition of a unit and its parts [5]. General considerations regarding the diagnostics within the vehicle renewal systems are discussed in papers [7,8].

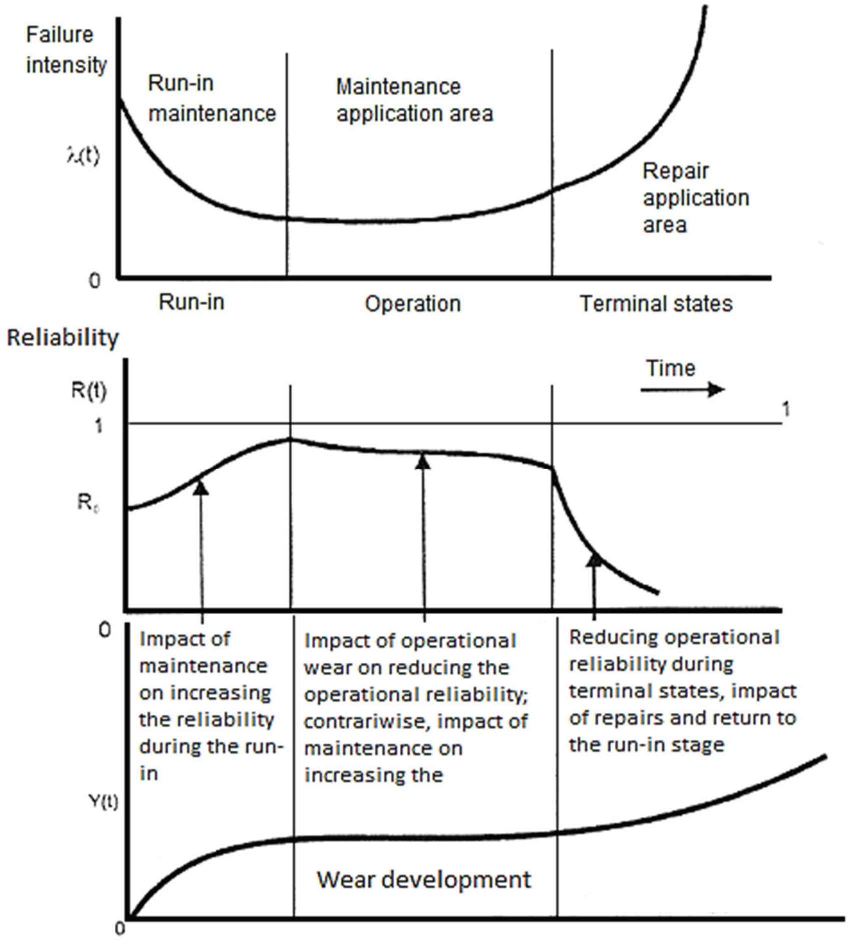

Figure 1 Means of transport lifecycle stages with monitored parameters [5]

The subject of this paper is the maintenance of means of transport used in public transport. The Pareto analysis was applied to assess the selected indicators - a number of driven kilometres and costs of maintenance of a means of transport. The main objective of the data analysis is to improve the efficiency of maintenance as a servicing logistic process that is closely related to increasing the reliability of the means of transport; this has a substantial impact on the quality of the logistics system in an enterprise.

2. METHODOLOGY

Decisions made when resolving individual situations were made on the basis of the recorded data, especially the data on their quality and amount, and the duration of the time period or the operational section of the performance of a particular means of transport. Following the data acquisition, decisions were made on the methods of data processing in terms of their frequency. Even with a small amount of data, the characteristics can be identified by applying the methods like the Pareto analysis [5] which belongs to the key decision-making tools used by maintenance manager. The Pareto analysis facilitates the identification of the main causes of undesired events and the subsequent focusing on these causes [9]. The Pareto analysis belongs to the analytical tools that are integrated in the concepts of maintenance management - RCM (Reliability Centred Maintenance) and TPM (Total Productive Maintenance) [10,11]. RCM is based on increasing safety of more cost-effective maintenance activities and it also deals with the evaluation of the occurrence of potential causes of equipment failures (e.g., neglected maintenance, wear, etc.). Practically, the TPM system is based on the principle of early detection of abnormalities occurring randomly due to the equipment operation and during professional removal of such abnormalities. Maximum amount of diagnostic and maintenance activities are therefore transferred in the TPM from conventional maintenance departments directly to the manufacture staff [12].

In paper [13], the Pareto diagram is applied to the control unit for vehicle repairs and maintenance. The Pareto analysis procedure is described in more details in paper [14]. Using the Microsoft Office Excel software, Pareto diagrams and the Lorenz curve were prepared; the curve joins the cumulative sums of percentages of the processed data. The shape of the Lorenz curve [15] indicates the level their differences. The more a curve looks like a line, the smaller the difference is, and vice versa. The Pareto analysis was carried out using the data obtained from the operation - the costs spent on maintenance of the means of transport and the number of driven kilometres for 57 types of buses while the last digit in the designations of individual bus types represents their age in years. The average age of buses in a transport company's bus fleet was 8 years, their minimum age was 1 year and the maximum age was 19 years.

3. RESULTS AND DISCUSSION

Maintenance of buses of transport companies is usually carried out by a third party contractor - an external service provider. With this regard, the key activities include the scheduled inspections and small repairs. Scheduled maintenance of the vehicles is carried out in compliance with the instructions given by the manufacturer of a particular vehicle type and as agreed with the servicing company that determines the intervals between individual inspections and the activities that must be arranged within the inspection. Regular maintenance depends on the number of driven kilometres and the corresponding period of time. All the detected defects, failures and damage are removed immediately, if possible, or a repair is scheduled at the earliest possible date. However, such repairs are not a part of the regular maintenance. Repairs of operational failures are carried out instantly or they are scheduled at an earliest possible date.

Monitoring the operation of the means of transport provides new data that must be evaluated applying appropriate methods aimed at identifying important characteristics and control parameters of maintenance, and at supporting the decision-making processes. In order to evaluate the data obtained with regard to the maintenance of the means of transport that are used in public transport, the Pareto analysis was applied. In the case of a simple Pareto analysis, the monitoring was focused on the number of kilometres driven by buses (**Figure 2**) and the costs of maintenance of such means of transport (**Figure 3**).

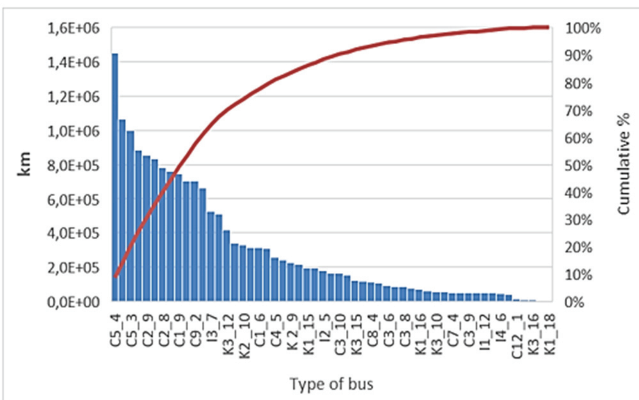

Figure 2 Pareto diagram for the numbers of kilometres driven by buses [own study]

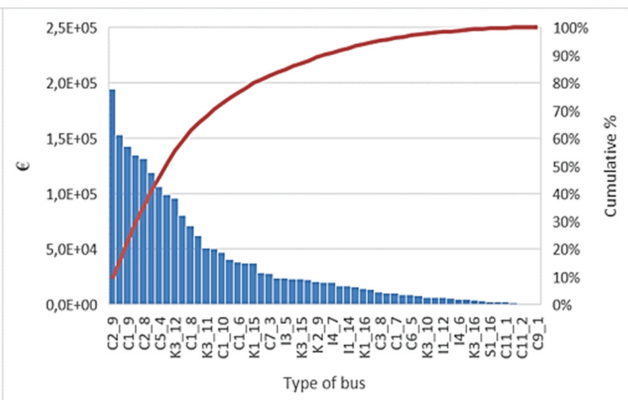

Figure 3 Pareto diagram for the costs of bus maintenance [own study]

The simple Pareto analysis was applied to identify the buses, in the total number of 24 types; out of them, both simple Pareto analyses identified 16 identical bus types as those that have the strongest impact on the logistics costs of a transport company. In 33 % of the monitored bus types the maintenance costs represent 80 % of the total maintenance costs.

As to the driven kilometres, 80 % of the total driven distances represent 37 % of the types of buses in the fleet. Particular types of buses are summarised in **Table 1** for individual performed analyses; the types of buses that occur repeatedly in individual analyses are differentiated by different colours.

Table 1 Types of buses representing 80 cumulated % of selected indicators [own study]

No.	€		km		€*km		€/km	
1	C2_9	C3_10	C5_4	C1_8	C2_9	-	K1_18	C1_9
2	I1_10	C1_6	C2_6	K2_10	C5_4	-	K3_11	K1_15
3	C1_9	C5_3	C5_3	I3_5	C2_6	-	K3_16	K3_15
4	C2_7	K1_15	C7_3	C1_6	C2_7	-	I1_14	C3_9
5	C2_8	-	C2_9	K3_11	C1_9	-	K3_14	C2_8
6	C2_6	-	C2_7	C4_5	C2_8	-	S1_16	C2_7
7	C5_4	-	C2_8	-	I1_10	-	C3_10	K2_10
8	K3_13	-	C10_2	-	K3_13	-	C1_10	I3_7
9	K3_12	-	C1_9	-	C2_5	-	I1_10	I5_7
10	I3_7	-	C2_5	-	I3_7	-	K3_12	C3_6
11	C1_8	-	C9_2	-	-	-	C2_9	C3_8
12	C2_5	-	I1_10	-	-	-	K1_19	I1_12
13	K3_11	-	I3_7	-	-	-	C1_8	I2_5
14	K2_10	-	K3_13	-	-	-	K3_13	C1_6
15	C1_10	-	K3_12	-	-	-	K1_16	-

In addition to the simple Pareto analysis, also the combined Pareto analysis is typically carried out (**Figure 4**); in the combined analysis, the costs of maintenance of the means of transport were multiplied by the number of driven kilometres. This Pareto analysis identified 10 types of buses, representing 18 % of the total number of means of transport for which the cumulative % reached the value of 80. All the types were also identified by the performed simple Pareto analyses.

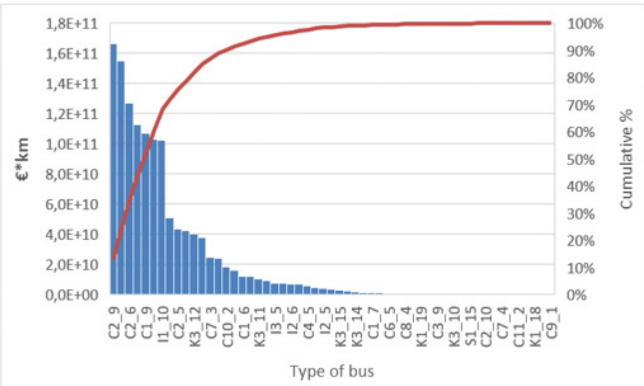

Figure 4 Pareto diagram of the combined analysis [own study]

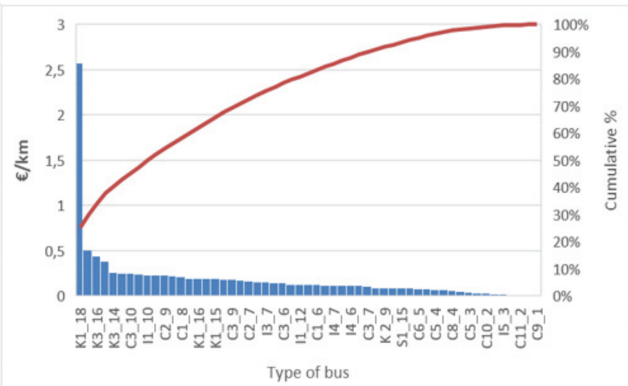

Figure 5 Pareto diagram for the unitation criterion [own study]

Moreover, the Pareto analysis was carried out using the unitation criterion - the costs of maintenance of the means of transport per 1 driven km (**Figure 5**). In this case, 51 % of the means of transport reached 80 cumulative %. The maximum €/km ratio identified for the K1_18 bus, i.e., the oldest vehicle, significantly exceeded the ratios of other bus types. The reason is the minimum number of kilometres driven by this bus.

4. CONCLUSION

The Pareto analysis represents an appropriate tool for the identification of important characteristics and control parameters of maintenance and it also supports the decision-making processes. The Pareto analysis was applied to evaluate the numbers of driven kilometres and the costs of maintenance of the means of transport. The costs of maintenance of the means of transport do not clearly indicate whether the given bus types are also the ones with the highest failure rates, whether they required replacement of the most expensive parts, or whether certain failures occurred repeatedly. Unfortunately, this transport company currently does not perform the registration of failures of the company fleet vehicles. An appropriate solution aimed at increasing the efficiency of maintenance, as a service logistics process, would be to extend the scope of registered interventions with the vehicles and of the data on failure rates of the means of transport, more extensively linked to the quality and the resulting operational characteristics. Data sources represent important tools that support the decision-making and the reliability may be increased using the long-term data on the development of changes in the technical condition of vehicles, failure causes, extent and types.

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REFERENCES

[1] MARASOVÁ, D., TARABA, V. and GRENDEL, P. Legislation and the related requirements for tunnel safety (in Slovak). *Acta Montanistica Slovaca.* 2010. vol. 15, no. 1, pp. 9-13.

[2] SPIŠÁK, J. *Logistics of service processes* (in Slovak). 1st ed. Košice: FBERG TUKE, 2005. p. 99.

[3] IVKOVIĆ, S., IVKOVIĆ, D. and TANASIJEVIĆ, M. The role of maintenance in logistic Serbian open pits mine. *Transport & Logistics: the International Journal*. 2002. vol. 2, no. 3, pp. 81-87.

[4] ANDREJIOVÁ, M., GRINČOVÁ, A., MARASOVÁ, D., FEDORKO, G. and MOLNÁR, V. Using logistic regression in tracing the significance of rubber-textile conveyor belt damage. *Wear.* 2014. vol. 318, pp. 145-152.

[5] DANĚK, A. *Modern tasks within the renewal of means of transport* (in Czech). 1st ed. Ostrava: VŠB - TU Ostrava, 1999. p. 28.

[6] JURČA, V. and HLADÍK, T. Maintenance data evaluation. *Maintenance and Reliability*. 2016. vol. 18, no. 3, pp. 15-18.

[7] TILLGER, O.E. Plannung und Steuerung der Reisezugwagen- instandhaltung in den Werken der Deutschen Bundesbahn. *Eisenbahntechn, Rundschau.* 1989. no. 10.

[8] KOECK, F. Fahrzeugdiagnose der ICE-Triebköpfe und anderer Hochleistungfahrzeuge. *Eisenbahntechn, Rundschau*. 1990. no. 6.

[9] GRENČÍK, J. et al. *Maintenance management, synergy of theory and practice* (in Slovak). 1st ed. Košice: SSÚ, 2013. p. 630.

[10] PAČAIOVÁ, H. *Maintenance management II: efficiency and safety in maintenance* (in Slovak). 1st ed. Košice: TUKE, 2011. p. 111.

[11] PAČAIOVÁ, H. Systematic approach in Maintenance Management - Maintenance audit. *Maintenance*. 2007. no. 3, pp. 10-12.

[12] VALENČÍK, Š. and STEJSKAL, T. *Basics of operation and maintenance of machinery* (in Slovak). 1st ed. Košice: TUKE, 2009. p. 105.

[13] MITREVA, E., PANCEV, D., GJORSHEVSKI, H., FILIPOSKI, O. and METODIJESKI D. The implementation of the Quality Costs Methodology in the Public Transport Enterprise in Macedonia. *TEM Journal*. 2017. vol. 6, no. 1, pp. 153-161.

[14] MATISKOVÁ, D. Evaluation of the effectiveness of engineering production processes using Pareto analysis. *TEM Journal*. 2015. vol. 4, no. 1, pp. 96-101.

[15] ŠADEROVÁ, J., ROSOVÁ, A., MALINDŽÁKOVÁ, M., KAČMÁRY, P. and PUŠKÁŠ, E. The proposal of ABC zoning in the warehouse. In: *CLC 2015: 5th Carpathian Logistics Congress*. Ostrava: TANGER, 2016, pp. 456-461.