RELIABILITY ANALYSIS OF VEHICLES IN A FLEET IN BOSNIA AND HERZEGOVINA

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Abstract: Reliability can be observed as an item with a probability to perform at an unchanged rate maintaining its function without failure under declared conditions for specified time. Predicting events that can cause vehicle failure in the vehicle fleet is an everyday activity and the process is seriously monitored and its causes and consequences are considered. The fleet maintenance process directly improves and enables its application for the intended tasks.
The paper presents a reliability analysis for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd. from Visoko (Bosnia and Herzegovina).
Through the calculation and analysis of failure density function f(t), reliability function R(t), unreliability function F(t) failure rate function $\lambda(t)$ for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd. its efficiency and evaluation of the maintenance system as the most important lever for ensuring quality transport as well as the efficiency of transport from point A to point B in a given time frame are presented.
For the mentioned research, the arithmetic mean is: $\bar{t}$ =MTBF=1050 [h] and standard deviation is: σ=SD=522.4. Most of the failures, for 10 vehicles for transport in the heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd., occurred in the second and third intervals, which means that the largest maintenance intervention must be realized during the third interval (t=800-1200 [h]). Reliability R(t)=0.5 or 50% and unreliability F(t)=0.5 or 50% in the experimental model is for time t=750 [h].
Keywords: reliability, reliability analysis, maintenance, efficiency, availability, vehicle, truck fleet.

1. INTRODUCTION

The basic factors of the lifetime of the system are: reliability, maintenance, efficiency and availability, which greatly affect the increase and/or decrease of the same.
Reliability of technical systems is a numerical value that represents the probability, at a certain level of confidence, that the technical system will successfully perform the function for which it is intended, without failure, i.e., the failure, within the specified performance limits, taking into account the previous system usage time, during the specified task duration. The probability of reliability of technical systems ranges from 0 to 1 or from 0 to 100 [%]. The reliability of the technical system with a probability of 0[%] shows that the technical system is completely unreliable, i.e., that it is functionally defective and cannot successfully perform the function for which it was intended. The reliability of the technical system with a probability of approximately 1 or 100[%] shows that the technical system is completely reliable and performs its function without failure, i.e., the failure in high probability (Dašić, 2019; Kececioglu, 2002a, 2002b).
Reliability is an essential feature of the vehicle fleet which is in essence defined already in the research, construction and production phases. Reliability is the probability of maintaining the function of the system within the function of the criteria in a certain period of time, i.e., the property of the vehicle to work without the occurrence of malfunctions and to fulfil certain tasks in the given conditions of use. In order to have better reliability as well as better fleet efficiency, it is desirable to require a higher level of fleet availability.
Predicting events that can cause vehicle failure in the vehicle fleet is an everyday activity and the process is seriously monitored and its causes and consequences are considered. The fleet maintenance process directly improves and enables its application for the intended tasks.
Reliability analysis is a measure of the overall consistency of the item that is used to define a scale which as a result, gives sample size, number of items and reliability functions and indicators.
Maintenance is approached from a constant time interval and monitors the working day, working hour, and therefore the calculation of this task is focused on the total observed time and it was performed using the above formulas, regardless of the number of kilometres travelled, because all vehicles in a heterogeneous fleet do not have the same frequency of delivery of goods. Certainly, depreciation is calculated per kilometre travelled and it would be logical to calculate the intensity based on the kilometre travelled, but other factors that are monitored in the maintenance

system cannot be ignored and these factors directly depend on time, such as brake oil (oxidation or loss of kinematic viscosity), electrical installation, air installation.

Reliability analysis was the main topic of several research papers on transport equipment and systems. Authors (Altamura & Beretta, 2012) evaluated reliability assessment of hydraulic cylinders considering service loads and flaw distribution. In papers (Dziubak et al., 2021; Janić, 2021; Rathore et al., 2021; Sabitov et al., 2020; Sun et al., 2021; Yuan et al., 2021; Zemenkova et al., 2020; Zurek et al., 2020) authors made an analysing and modelling the reliability of transport systems and services. In papers (Kurganov et al., 2020; Sharov, 2020) authors made a reliability of passenger transport system. In papers (Savin et al., 2020) authors made an individual forecasting of reliability factors of mechanical transport units. Some practical applications of distribution models usage in the field of transport systems are given in papers (Repin et al., 2020; Santana et al., 2020; Tsarkova et al., 2020).

2. MATERIALS AND METHODS

The paper presents a reliability analysis for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd. (URL: http://www.susa.ba/) from Visoko (Bosnia and Herzegovina).

Through the calculation and analysis of failure density, failure intensity, reliability and unreliability, it is necessary to present its efficiency and evaluate the maintenance system as the most important lever to ensure quality transport and transport efficiency from point A to point B within a given time frame.

Basis of reliability indicators are shown in books [(Dašić, 2019; Kececioglu, 2002a, 2002b).

Failure density function f(t) or probability density function (PDF) is:

$$f(t) = R'(t) = \frac{\Delta n}{n}$$

(1)

Unreliability function F(t) or cumulative distribution function (CDF) is:

$$F(t) = 1 - R(t) = \frac{N(t)}{n}$$

(2)

Reliability function R(t) is:

$$R(t) = 1 - F(t) = \frac{n(t)}{n}$$

(3)

Failure rate function λ(t) is:

$$\lambda = \frac{f(t)}{R(t)} = \frac{\Delta n}{n(t)} = \frac{\Delta n}{n - N(t)}$$

(4)

where:

Δn – number of failures in the group interval;

N(t) = total number of incorrect elements or elements failure down up to the moment t;

n(t) = total number of correct elements or elements which have not failed down up to the moment t;

n = sample size or total down time number according to a group interval (between interval boundaries).

Processing of the experimental data was carried out using the software RATSC-CA (Reliability Analysis of Technical System Components on the Basis of Choice of Theoretical Distribution-Based on Comparative Analysis, which in the best way Approximate Experimental Data), which is described in papers (Dašić, 2001; Dašić, Natsis, & Petropoulos, 2008; Dašić, Živković, & Karić, 2015) and book (Dašić, 2019).

3. RESULTS

Based on working hours in two shifts of 16 working hours as well as observations of vehicle operation in a period of one year, where non-working days and holidays were neglected in the calculation, so the calculation was observed at an interval of 250 available working days. Due to easier monitoring and calculation of the work interval of 400 working hours in the interval, the calculation is divided into two cycles for easier presentation, which in the practical part is related to regular, extraordinary and control technical inspections of vehicles.

First is calculated in adopted the number of group intervals k=6, minimal value of first interval t_{1min}=0 [h] and interval wideness Δt=400 [h] and number of failures in the group intervals.

Table 1 shows the selected data on the number of failures per cycle and the number of failures Δn for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd. (URL: http://www.susa.ba/) from Visoko (Bosnia and Herzegovina).

Table 1. Data for fleet reliability calculation

Interval t [h]	Cycle	2016	2017	2018	2019	Number of failures per cycle	Number of failures Δn
0-400	I	1	0	1	0	2	
	II	0	0	2	0	2	4
400-800	I	2	3	5	2	12	
	II	4	2	4	2	12	24
800-1200	I	4	4	2	4	14	
	II	4	6	3	5	18	32
1200-1600	I	0	1	0	1	2	
	II	0	0	0	1	1	3
1600-2000	I	2	2	2	3	9	
	II	1	0	0	2	3	12
without failure	I	1	0	0	0	1	
	II	1	2	1	0	4	5

Table 2 shows the data on the basic experimental reliability indicators: Δn, f(t), N(t), F(t), n(t), R(t) and λ(t) for 10 transport vehicles in the heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd.
First is calculated in adopted the number of group intervals k=6, minimal value of first interval t_{1min}=0 [h] and interval wideness Δt=400 [h] and indicators of experimental distributions or experimental models of reliability (Table 2).

Table 2. Basic experimental indicators of the fleet reliability

k	Group intervals t [h]	t_{mi} [h]	Δn	f(t)	N(t)	F(t)	n(t)	R(t)	λ(t)
1	0-400	200	4	0.0500	4	0.0500	76	0.9500	0.0526
2	400-800	600	24	0.3000	28	0.3500	52	0.6500	0.4615
3	800-1200	1000	32	0.4000	60	0.7500	20	0.2500	1.6000
4	1200-1600	1400	3	0.0375	63	0.7875	17	0.2125	0.1765
5	1600-2000	1800	12	0.1500	75	0.9375	5	0.0625	2.4000
6	2000-2400	2200	5	0.0625	80	1.0000	0	0.0000	-

The arithmetic mean of the sample or MTBF (mean time between failures) is: $\bar{t}$ =MTBF=1050 [h] and standard deviation is: σ=SD=522.4.
Based on the calculated basic experimental reliability indicators (Table 2), Figure 1 shows the histogram of failure density function f(t), Figure 2 shows the comparative polygon reliability function R(t) and unreliability function F(t) and Figure 3 shows is a polygon failure rate function λ(t) for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd.

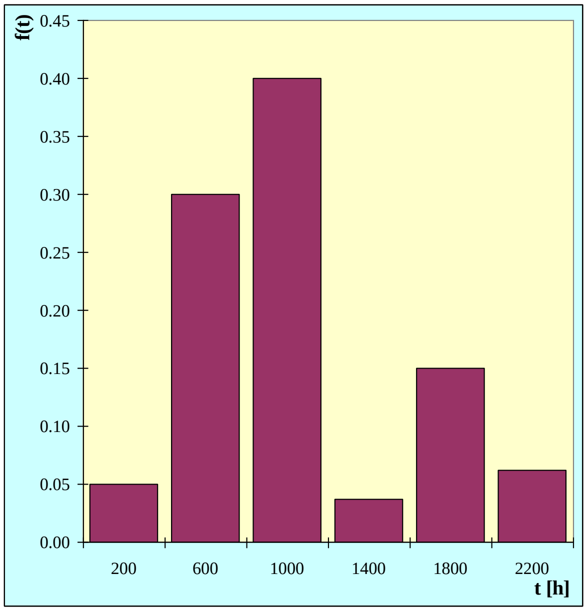

Fig. 1. Histogram failure density function f(t) for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd.

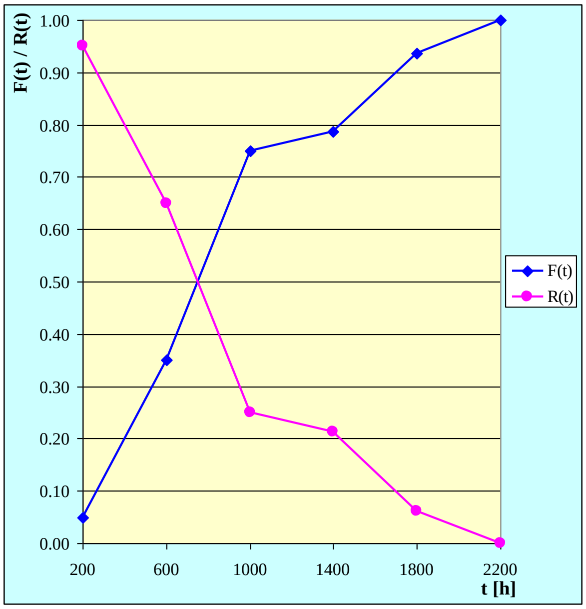

Fig. 2. Polygon reliability function R(t) and unreliability function F (t) for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd.

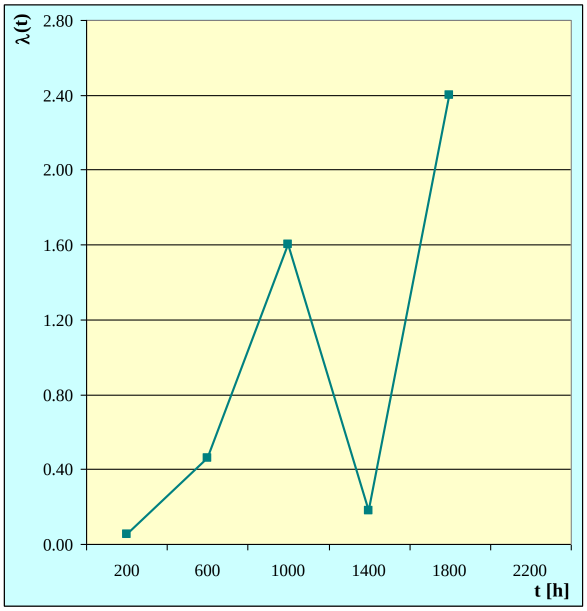

Fig. 3. Polygon failure rate function $\lambda(t)$ for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd.

4. DISCUSSIONS

The highest value of failure density function f(t) is in the third interval f(t)=0.4 or 40%, and the lowest in the next fourth interval f(t)=0.0375 or 3.75% (Table 2 and Fig. 1).

The arithmetic mean of the mentioned research is less than the final value of the third interval $\bar{t}$ =MTBF=1050<1200 [h]. This means that most of the failures, for 10 transport vehicles in the heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd., occurred in the first three intervals, so at the end of the third reliability interval only R(t)=0.25 or 25%, and unreliability F(t)=0.75 or 75% (Table 2 and Fig. 2).

Based on the above data, the largest maintenance intervention, for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 of the company Suša commerce Ltd., should be realized during the third interval (t=800-1200 [h]).

The value for reliability R(t)=0.5 or 50% and unreliability F(t)=0.5 or 50% in the experimental model is for time t=750 [h] (intersection point in Fig. 2).

The relatively small value of the arithmetic mean of the sample $\bar{t}$ =MTBF=1050 [h] and at the same time large values of failure density f(t) in the second and third intervals lead to the failure rate λ(t) having a large growth trend by the end of the third interval (Table 2 and Fig. 3).

5. CONCLUSIONS

There are repairable and non-repairable components in the driving system and they are eliminated by maintaining the vehicle which can be preventive, which is much more favourable for the company and corrective due to the occurrence of failures.

There are basic and additional indicators of reliability. The basic indicators show the reliability of the vehicles in the distribution network, while the additional indicators of the reliability of the distribution network refer to the logistics operators as a whole. One of the most important items of fleet availability quality is the confident reliance of the operator that the goods will be delivered on time and this makes the system efficient.

The calculation of failure density function f(t), reliability function R(t), unreliability function F(t) failure rate function λ(t) for 10 vehicles for transport in a heterogeneous fleet for the period from 2016 to 2020 by Suša commerce Ltd. it can be concluded that the company has good reliability and availability of the fleet, but it can also be noticed that due to poor maintenance and coordination in the system there is a decline that must be looked at with great seriousness, because poor maintenance can cause incalculable damages.

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