Analysis of failures of urban buses in the conditions of the transit agency "Mosgortrans"

A A Zavgorodniy, V A Maksimov, N V Pozhivilov and G A Krylov

1 Moscow Automobile and Road State Technical University (MADI), 64, Leningradsky ave., Moscow, 125319, Russia
2 Research Centre, Mosgortrans, 22/21, b 1, Raushskaya naberezhnaya, Moscow, 115035, Russia

E-mail: zavgorodniy.aa@mail.ru

Abstract. The article presents the results of analysis of failures of low-floor urban buses LiAZ-529221, LiAZ-529222, LiAZ-621321 and LiAZ-621322 in the conditions of operation in Moscow. The research was based on the statistical data collected on failures of the bus modifications under consideration for the period from 01.08.2017 to 31.12.2018. As a result, the causes of failures of systems, assemblies and units, their seasonality, development of recommendations to improve the maintenance and repair system of LiAZ buses were identified. The research was carried out on the base of the branch of SUE "Mosgortrans".

1. Introduction

One of the most important issues with vehicle operation is to ensure the necessary level of reliability of the operated fleet [1]. Definition of reliability indicators and their further management at the expense of specific measures (organization of maintenance and repair, advanced training of personnel, modernization of production and technical base, etc.) has an impact on the durability and reliability of buses and their units [2].

In the process of fleet operation there is a decrease in its reliability, reduction in the probability of reliable operation of components and units and the operating time between failures. The aforementioned leads to an increase in the labor intensity of current repairs, downtime in repair and the cost of spare parts and maintenance.

The objectives of the research were to identify the most frequent causes of system failures, the seasonality of their occurrence in order to further develop recommendations on improvement of the system of maintenance and repair of the considered modifications of LiAZ buses. The solution of such tasks is primarily based on reliable and systematic information about failures, their operating time, spare parts costs and etc. [3].

2. Organization of research

The research was conducted at the testing site on the branch of SUE "Mosgortrans" in Moscow.

The following restrictions were imposed on the collection of data on bus failures:
- all LiAZ-529221, LiAZ-529222, LiAZ-621321 and LiAZ-621322 buses operated in the transit agency for the period of surveys from 01.08.2017 to 31.12.2018 were included in the quantity of 95, 107, 55 and 31 units, respectively;
the research did not take into account failures and repair operations performed by the manufacturer during the warranty period on these buses.

The frequency of observations of the monitored buses was carried out daily.

In the case of failure of the bus the driver filled out an application for current repair and provided the bus to the area of current repair for inspection (diagnostics). During the repair the foreman recorded the actual time of the beginning and the end of the repair, the list of repair operations, causes of malfunction, etc. in the observation report.

Subsequently, the statistics collected were entered into the SAP software database and presented in MS Office Excel spreadsheets. The spreadsheets contained structured data on the following key criteria:

- modification of the bus;
- garage number of the bus;
- date of failure and malfunction;
- mileage at the time of failure or malfunction;
- actual repair time;
- name of repair operations;
- mechanic's conclusion, etc.

The analysis of failures for the whole period of observations was carried out for the following factors:

- the amount of failures of the controlled modifications of buses;
- the amount of recorded system failures and their share of the total amount of failures;
- distribution of failures by months and seasonality of their occurrence;
- total time of downtime of the fleet in case of system failures;
- average time of repair of failure on the system;
- the proportion of fleet downtime in repairs.

The special statistical sample limited by the calendar year for the period from 01.01.2018 to 31.12.2018 was formed in order to monitor correctly the seasonality of failures. It has allowed to complete an estimation of influence of a natural-climatic conditions on reliability of systems of the fleet in use.

Due to similar technical characteristics and construction features [4–7], in the initial processing the statistical data on buses LiAZ-529221, LiAZ-529222 and LiAZ-621321, LiAZ-621322 were combined according to their type of vehicle – high capacity (HC) and especially high capacity (HCV).

3. Processing and analysis results

The obtained statistical data on the distribution of failures on the systems of buses LiAZ-529221, LiAZ-529222 is presented in Table 1 and for LiAZ-621321, LiAZ-621322 in Table 2.

Thus, in the period from 01.08.2017 to 31.12.2018, the current repair complex registered 3135 and 974 failures of LiAZ-529221, LiAZ-529222 and LiAZ-621321, LiAZ-621322 respectively.

Later on, the causes of failures for individual systems and units were analyzed.

According to the obtained statistics, the largest number of failures on the bus LiAZ-529221, LiAZ-529222 and LiAZ-621321, LiAZ-621322, was found in the following systems (given is the average failure rate for all bus modifications):

- engine and his systems – 28.1 and 32.4 %:
  - leak tightness of cooling system circuits (51 %) – replacement of thermostat tubes (11.6 %), expansion tanks (7.9 %), radiator tubes (6.2 %), etc. (25.3 %);
  - coolant pump failure (19.1 %), thermostat failure (4.8 %), cracks in expansion tanks (5.5 %);
  - burn-through of the exhaust silencer (62.5 %) and violation of the silencer attachment (37.5 %).

- brake system – 22.6 and 20.9 %:
  - leakage of power accumulators (49.9 %) and brake chambers (4.6 %);
  - jamming and excessive wear of brake mechanisms – supports (44.5 %), disks and pads (18.2 %);
  - loss of tightness of brake system circuits – replacement of brake hoses (9.0 %) and brake pedals (5.3 %).

| System                  | Failure Rate 1 | Failure Rate 2 |
|-------------------------|----------------|----------------|
| Engine and his systems  | 28.1           | 32.4           |
| 1. Cooling system       |                |                |
| 1.1. Circuit leak        | 51             |                |
| 1.2. Thermostat tube     | 11.6           |                |
| 1.3. Expansion tank      | 7.9            |                |
| 1.4. Radiator tube       | 6.2            |                |
| 1.5. Others              | 25.3           |                |
| 2. Coolant pump failure  | 19.1           |                |
| 3. Burn-through          | 62.5           |                |
| 4. Violation             | 37.5           |                |
| Brake system            | 22.6           | 20.9           |
| 1. Leakage              | 49.9           |                |
| 2. Chamber              | 4.6            |                |
| 3. Jamming and wear      | 44.5           |                |
| 4. Disks and pads        | 18.2           |                |
| 5. Tightness of circuits | 9.0            |                |
| 6. Brake pedal           | 5.3            |                |

Table 1. Distribution of failures by systems and units of buses LiAZ-529221 and LiAZ-529222
Table 2. Distribution of failures by systems and units of buses LiAZ-621321 and LiAZ-621322

| Bus systems                        | Amount of failures, pcs. | Amount of failures, % | Average time of failure repair, m/h | Downtime in repair, % |
|------------------------------------|--------------------------|-----------------------|-------------------------------------|-----------------------|
| Engine, including:                |                          |                       |                                     |                       |
| – Power system                     | 316                      | 32.4                  | 1.94                                | 33.4                  |
| – Exhaust system                   | 19                       | 2.0                   | 1.66                                | 1.8                   |
| – Cooling system                   | 272                      | 27.9                  | 1.86                                | 28.4                  |
| Transmission, including:           |                          |                       |                                     |                       |
| Suspension                         | 48                       | 4.9                   | 1.06                                | 2.9                   |
| Steering system                    | 71                       | 7.3                   | 1.77                                | 7.1                   |
| Brake system                       | 204                      | 20.9                  | 2.37                                | 27.1                  |
| Electrical equipment and devices   | 86                       | 8.8                   | 1.12                                | 5.4                   |
| Cabin, bodywork and his equipment  | 12                       | 1.2                   | 1.13                                | 0.8                   |
| Air conditioning and heating       | 42                       | 4.3                   | 1.47                                | 3.5                   |
| Pneumatic system                   | 135                      | 13.9                  | 1.78                                | 13.5                  |
| Front axle                         | 13                       | 1.3                   | 3.33                                | 2.4                   |
| Middle Axis                        | 0                        | 0.0                   | 0.0                                 | 0.0                   |
| Rear axle                          | 3                        | 0.3                   | 5.11                                | 0.9                   |
| Wheels and tyres                   | 5                        | 0.5                   | 1.00                                | 0.3                   |
| In total:                          | 974                      | 100.0                 | 1.93                                | 100.0                 |

Pneumatic system – 10.3 and 13.9 %:
- air tightness disorders of pneumatic system circuits (48.4 %) – replacement of main tubes and hoses of pneumatic system of air dryers (25.1 %) and compressor (23.1 %);
- failure of vacuum dehumidifiers (34.2 %);
- failure of floor level cranes (12.4 %).
The steering system is 9.1 and 7.3 %:
- leakage of circuits – replacement of power steering tubes (70.4 %);
- tight steering – power steering pump failure (12.7 %);
- lack of transverse (5.9) and longitudinal steering rods (6.8).
Electrical equipment and devices – 7.4 and 8.8 %:
- no battery charging – replacement of generators (22.4 %);
- blowing motor failure (20.2 %) and windscreen wiper drive motor failure (5.7 %), starter replacement (13.9 %);
failures of controllers of turns (10.4 \%).

Air conditioning and heating system – 8.5 \% and 4.3 \%:

- failure of cabin heaters (60.9 \%);
- air-tightness breach of the passenger compartment heating system circuit (30.0 \%);
- leakage of windscreen blower radiators (8.8 \%).

**Figure. 1.** Histogram of seasonality of LiAZ-529221 and LiAZ-529222 buses failure

**Figure. 2.** Histogram of seasonality of LiAZ-621321 and LiAZ-621322 buses failure

4. Conclusion

On the basis of the conducted researches and the collected statistical data it is possible to formulate recommendations on development of fleet maintenance service system within the "Mosgortrans". In particular, to apply objective corrections to the existing system of maintenance service, and form a number of additional, preventive operations of maintenance service for individual systems and units.
The analysis of statistical data gives a general view of the quantitative indicators of reliability and statistics of failure distribution of different systems and units of buses LiAZ-529221, LiAZ-529222 and LiAZ-621321, LiAZ-621322.

The collected statistical data make it possible to initiate the base for developing integrated reliability strategy of the considered modifications of buses by systems and units for different age groups of buses. In addition, the collected statistical data are applicable in foundation of the nomenclature and planning of norms for spare part consumption, distribution of the scope of repair, calculation of the required scope of equipment, labor etc.

Reference
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