Urban buses gearbox faults analysis

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Abstract. Urban busses have to assure transport of thousands/tens of thousands/ hundreds of thousands passengers, on short distances and in extreme working conditions that stress the transmission. The multitude and diversity of buses that are used in public transportation in the cities of Romania, the structure of available fleets, the different road categories that are used for public transportation and the way that public transport is organised – are all factors that influence different faults of urban busses gearbox. In these conditions, reliability and durability of transmission composing elements are affected considerably. This paper is the result of a study that highlights the gearbox faults that appeared in the urban busses of one of Romania's important public transport company. The data analysed in this study has been collected from the order vouchers prepared in the workshop, containing information about the supposed fault that caused the bus to be called for repairs and the actual faults that needed intervention by the personnel, the last ones being considered as faults and noted as such.

1. Introduction

The multitude and diversity of buses that are used in public transportation in the cities of Romania, the structure of available fleets, the different road categories that are used for public transportation and the way that public transport is organised – are all factors that influence different faults of urban busses gearbox.

Compania de Transport Public Cluj-Napoca S.A. (CTP) – Public Transport Company of Cluj-Napoca is one of the most important public transport operators in the country, having to assure an annual transport of more than 200 million passengers [1]. CTP (delegated by Asociația Metropolitană de Transport Public Cluj – AMTPC – Cluj Metropolitan Association of Public Transport) ensures public transport services in the city of Cluj-Napoca and in the near-by settlements that are members of the AMTPC (Apahida, Baciu, Chinteni, Ciurila, Feleacu and Florești, region known as the Metropolitan Area of Cluj-Napoca) [2]. Established in 2014, CTP took over the actives and activities of until then Regiei Autonome de Transport Urban de Călători Cluj-Napoca (RATUC) – Administration of Urban Public Transport of Cluj-Napoca, an operator administrated by the municipality, but with a semiautonomous activity.

According to the Sustainable Urban Mobility Plan, the Cluj-Napoca Metropolitan Area was set up at the end of 2007 as an association, having as main objectives the sustainable development of its territory as a whole, the common economic and social development, the improvement of the quality of the environment and the quality of life. The metropolitan area is 1 630 km2, representing 24% of the total area of Cluj County, and includes 55% of the total population of the county. [3]

For providing the public transport services, in 2018 CTP used a fleet of 27 tramways, 257 buses, 81 de trolleybuses, 10 minibuses and 11 electric buses [4] and operates one minibus route, 3 tramway routes, 7 trolleybus routes, 43 urban bus routes and 24 metropolitan bus routes, summing a total length of 650,45 km of routes serviced [5]. The present study took into consideration only the data that referred to the buses used for providing public transport services, the fleet used in 2018 sorted by maker brand and model is presented in Table 1 [6].

Table 1. The fleet of buses available for providing public transport services, segregated by producer make and model, and number of each model available.

	Renault Ares	Renault Agora Long	Renault Irisbus	Renault R312	Irisbus Agora	MJT	MAN	Scania Hess	Iveco Urban way	Solaris Urbino 18	Mercedes-Benz Conecto G
No.	3	57	10	60	46	2	7	7	10	40	15

2. Study conditions

In case of buses that weight over 4 tons, the most common solution for the transmission is: rear drive, with the engine and the gearbox mounted in the back of the bus. This display has the advantage of a more simple construction, because of the smaller distance that appears between the engine and the driving axle, and the engine-gearbox assemble is positioned outside of the area destined for passengers, which ensures ease of access to the engine and the gearbox and offers the possibility to lower the floor for an increased accessibility. [7]

Causes of gearbox faults in urban busses can be accidental, or caused by the ageing of the components and auxiliary systems that are subjected to a very demanding exploitation regime. To implement an effective preventive and systematic maintenance in order to reduce and even anticipate fault developments, when considering such a large and vast fleet, considerable human, technological and financial resources are needed. Considering our country, where investments related to public transport, if even considered, are reduced to the renewal of the fleets due to the age of the vehicles, preventive maintenance is hard to implement because of the many shortcomings remembered that refer to technological resources and qualified personnel.

The faults identified in the present study can be divided by their technical nature in electrical faults, hydraulic faults, or mechanical faults. For the first category, the most representative are the faults that affected the wiring, electrical contacts and sensors. Representative for the hydraulic faults are the ones that occurred on hydraulic lines, while for the mechanical faults, the ones regarding shafts and gears are the most representative. The last ones, even if numerical there aren't many, they are the most serious faults, that couldn't be repaired and eventually led to the replacement of the gearbox, making them the most expensive faults registered.

The main way of collecting data for the analysis involved following a complex and somewhat rudimentary process, that relies on the deductions made by the drivers, who noticed an anomaly in the functioning of the bus, and reported that anomaly to the mechanics in the workshop. After the mechanics established the fault, they make a written request to the chief engineer to approve the repair and the removal from the storeroom of the needed components. Taking into consideration the fact that most of the buses that are in the studied fleet where acquired as second-hand vehicles so they didn't have the necessary equipment for maintenance, and being outdated from a technologically point of view, they don't have an electronic diagnosis, so diagnosing a fault relies only on the knowledge and experience of the personnel, but in order for the mechanics to evaluate the status of a gearbox, the bus needs to be recalled to the workshop and that leads to decreased productivity.

From the total of 257 buses studied, only 65 units have been bought first hand and have support from the producer and come with electronic diagnostic systems, making the maintenance easier and less time consuming. For three quarters of the studied fleet, the only way to establish faults depends on the drivers experience to notice changes in the functionality of the bus, and on the mechanics experience and knowledge to repair the faults in the workshop.

3. Urban buses gearbox fault analysis

From a total of 257 buses that have been used in 2018 for public transport services in Cluj-Napoca, 15 units were newly acquired and their delivery was spread out during the calendar year, so they weren't considered in this study. The remaining 242 buses that were used regularly in 2018 for providing public transport services in both urban and metropolitan area were analysed.

In 2018, in the bus maintenance and repair workshop, 14705 records were registered as faults in the order voucher. Of these, 359 interventions were planed according to the technical revision plan, 176 entries have been caused by road accidents, which leaves a total of 14170 records noted as faults. These faults are sorted in figure 3 based on the nature of the affected systems, as follows: 3331 electrical system faults, 2680 cooling system faults, 1742 braking system faults, 1546 faults were related to air system malfunctions, 1308 entries referred to engine fault, 977 body damages, 772 suspension system faults, 626 steering system faults, 589 transmission faults, 526 fuel system faults, 40 faults of the hydraulic system and 33 other interventions.

Analysing the diagram in figure 3, one can observe that most of the fault, 3331, were registered as electrical system faults, which is explainable considering that all functional systems of a bus use electrical components. In order to analyse the faults that affect a particular component of the bus, all of the systems faults that affect that component have to be considered. In this paper, the analysis that refers to the urban bus transmission, all faults that affected the functionality of the transmission were taken into consideration, including the ones registered in a general category named transmission faults and some faults of the electrical system.

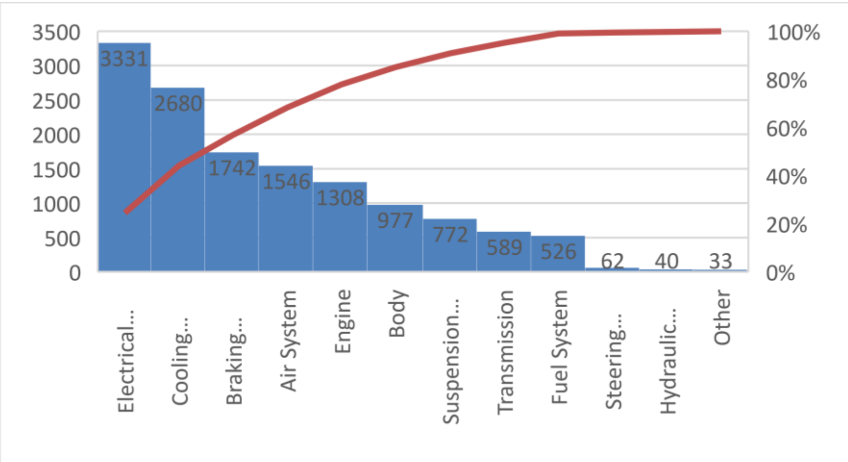
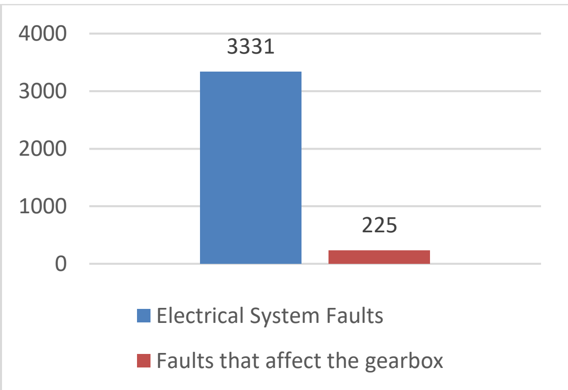
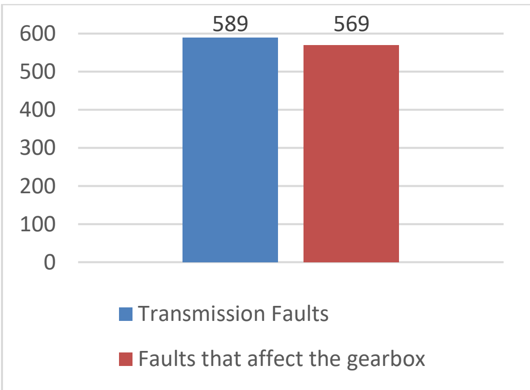


Fig. 3. Pareto Diagram showing the number of faults recorded in the studied buses based on the nature of the affected systems

Figure 4 shows the number of gearbox faults reported to the total faults registered in the electrical system and, respectively, the transmission.



a



b

Fig. 4. Number of faults that affect the electrical system (a) and the transmission (b) and how many of them are related to the gearbox the gearbox

Out of the 3331 faults registered in the electrical system, 225 directly influence the gearbox, representing 6,75% of total. But regarding the faults registered in the transmission, we have a completely different situation, where 569 out of 589 faults directly influence the gearbox, that is 96,6% of total.

Table 2. Gearbox faults segregated into categories corresponding to the affected component system.

	Lubrication System	Electrical System	Trans-mission	Preventive Verifications	Cooling System
No.	287	234	188	89	24
%	35	28	23	11	3

In total there have been recorded 823 faults that affected the functionality of the gearbox, representing 5,8% of the total number of faults registered on buses in 2018. It is noticeable that most of the faults were registered in the gearbox lubrication system – 287, meaning a percentage of 35% out of the total, but 130 entries refer to oil change adjacent operations that were needed in order to complete other repairs. Other than that, 69 entries refer to the necessity of filling the gearbox oil level, and other 67 times, an oil leakage needed to be sorted out. The rest of 21 recorded faults implied a change of a hose, a gasket, a grip ring or a pipe.

Gearbox electrical system faults in total of 235, registered only 2 operations, 121 entries note a necessary intervention on retarder electrical contacts, and the rest of 114 gearbox electrical system faults refer to the wiring of the gearbox. After the gearbox lubrication system faults, (35% of total) most of the faults recorded were caused by malfunctions of the gearbox electrical system, with 28% of total faults.

Out of the 89 preventive verifications, in 26 cases the purpose was an oil check, 52 times a general inspection of the gearbox was done, and in 11 cases that needed the bus to withdrawn from service, other components of the transmission were verified. It is worth mentioning that these checks were ordered by the bus drivers who noticed a different behaviour of the bus, so these operations are not part of the regular procedures scheduled according to the annual revision plan. These interventions represent 11% of the reasons to call a bus in the workshop.

In the case of the 24 interventions recorded that are related to gearbox cooling system faults, things are very straight forward, all of the 24 times there was a problem caused by the gearbox heat exchanger breakdowns. These faults represent only 3% of the total number of faults that have affected buses gearbox functionality.

Most of the mechanical failures sustained by the components of the transmission were related to the gearbox, not only to the selector section of the gearbox assembly, affecting the planetary gears and the shafts, but also to the other components included in the body of the gearbox – because of the complexity of such an automatic gearbox – like the clutch, part that suffered 13 faults, or the hydraulic retarder, part that recorded 23 failures. This category also contains the faults suffered by the gearbox shafts, diaphragm, or the rare cases that required a total repair of the gearbox or its replacement. Also, still in this category are mentioned the small interventions that implied a gearbox buffer change, or some gaskets, fastening collars and studs.

Although most of the faults that affected the functionality of the gearbox were recorded in the hydraulic system, almost half of them were, in fact, oil change operations necessary in the process of other repairs. So, after analysing the urban buses gearbox faults, it is noticeable that the biggest issue was the electrical system of the gearbox, with the most faults recorded during a calendar year. The faults recorded as transmission faults, although not the most common, were cause of the longest periods of inactivity, which translates into lack of productivity and implicitly loss of money, in addition to being the most expensive operations: shafts repairs, planetary gears repairs, and other components that needed special expert interventions.

The nature of these faults and their high number is explicable considering the age and the many years of service of most of the analysed buses, with only 50 of the 242 buses having less than 2 years of service in 2018, the rest of them, having more than 10 years of service in public transport. In addition, for the other 192 buses, being technologically obsolete, it is becoming more and more difficult to find the necessary spare parts and materials needed for their maintenance.

Another big disadvantage is the fact that these buses, as they were second-hand acquisitions, no longer benefit from technological support and know-how from the producer, and repair manuals and workshop instructions, if any available, are at most incomplete and in a foreign language. In such conditions, repairing and maintain a bus in a functioning state relies only on the experience and knowledge of the personnel that operate and repairs the buses, fact that doesn't help reducing the service time and the period of inactivity in case of a breakdown.

In these conditions, is in fact a remarkable achievement that there were 89 records of unscheduled checks, operations that prevented further damages and faults. And unfortunately, in these cases, also all the process depends only on the knowledge and experience of the drivers, who noticed and reported in a timely manner the possibility of an occurring breakdown of the gearbox.

On the other hand, it is worth mentioning that in 2018 there was no recording of a gearbox damage caused by road accident in which a bus was involved.

4. Conclusions

After analysing the gearbox faults of a fleet containing 242 urban buses destined for public transport over a period of a calendar year, 2018 respectively, a total number of 823 faults affected the functionality of the gearbox, representing only 5,8% of the total number of faults recorded in 2018. Taking into consideration the daily exploit conditions imposed by the urban area and the very busy traffic charts of these buses, which includes scheduled transports at regular intervals starting at 4:30 in the morning and ending at midnight, and considering that the average age of the fleet in 2018 was more than 15 years old, automatic planetary gearboxes prove once again, if there was any doubt, that they are the right choice for the urban buses destined for public transport, adding to the comfort and ease of the driving, the advantage of a reliability proven over time.

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