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Research Article

Aspects of Improvement in Exploitation Process of Passenger Means of Transport

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Effective exploitation of means of transport in transport companies is one of the most important ways of achieving competitive advantage. Mentioned problem is particularly important in the market of passenger transport services in large agglomerations, because it has a social aspect in addition to the economic dimension. In addition, most often the studies concern single objects of exploitation, while the subject of research are groups of objects of passenger transport means. The main objective of the study is to analyze and evaluate the system of exploitation of passenger transport means and to propose solutions for its improvement. On the basis of the theory of exploitation systems, quantitative utilitarian models have been built, which have been verified by applications using data obtained from Municipal Communication Company (MPK) in Wroclaw. Originality and innovation in the recognition of the research problem consist in applying to the analysis and evaluation of the Ishikawa diagram exploitation system, Pareto-Lorenzo analysis, and FMEA (Failure Mode and Effects Analysis) methods. On the other hand, a QFD (Quality Function Deployment) diagram was used to build a model of improvement of the exploitation system, with the use of which the target values of parameters for the operation of MPK passenger transport in Wroclaw were determined. The applied methods, techniques, and research tools are rarely used in the field of testing of vehicle operation systems. The work has a very practical character and built models can be used in other urban agglomerations in order to improve the operation of passenger transport means.

1. Introduction

Currently, one of the most important problems of city management is the issue of communication and development of urban transport systems [1–4]. This is mainly caused by a large number of vehicles on the road, low capacity of selected transport routes, and relatively weak condition of the linear transport infrastructure [5, 6]. In urban areas with a significant density of road infrastructure, solving transport problems by expanding the infrastructure is not very effective, because any bandwidth reserve obtained in this way is immediately used [7–9]. Among the effective methods of improving the efficiency and quality of the transport system, the use of advanced technological and organizational solutions is mentioned [10–13].

Efficient use of means of transport in any type of company is one of the major ways to achieve competitive advantage [14–17]. This problem is particularly important in the area of passenger transport market in large agglomerations, because except its social aspect it also has the economic dimension. In addition, most of the studies concern individual facilities, while the subject of research are groups of objects of means of passenger transport.

The issue of evaluating and improving the exploitation system of means of passenger transport is an extremely important issue from a practical and a theoretical point of view [15, 18, 19].

The main objective of the study is to analyze and evaluate the operation of the system of passenger transport and to propose solutions to improve it.

In the process of development of analysis and evaluation of the operating system, Ishikawa diagram, Pareto-Lorenz analysis, and FMEA (Failure Mode and Effects Analysis) [20], among others, have been used, while the QFD (Quality Function Deployment Diagram) was used to build a model for the improvement of the exploitation system, which determined

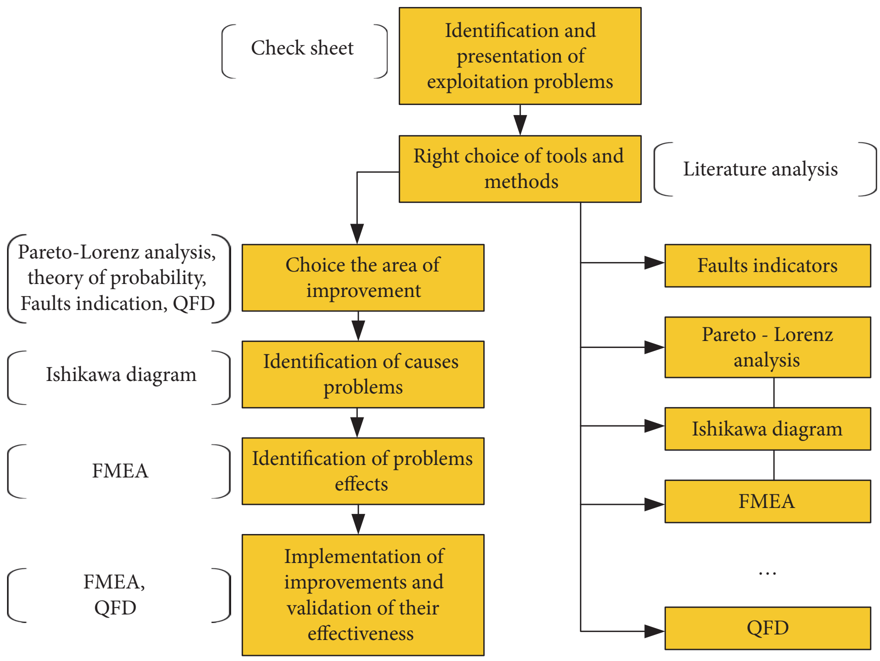


Figure 1: Improvement model of the exploitation process of means of passenger transport, on the example of urban buses.

the target values of the exploitation parameters of MPK passenger transport in Wroclaw [9, 21, 22]. The methods, techniques, and research tools used are rarely applied in the field of vehicle operating systems.

2. Modelling the Improvement of Exploitation Process of Means of Passenger Transport

2.1. Assumptions to Build a Model for Improving the Exploitation Process. Proper exploitation of buses contributes to the fulfilment of a certain level of quality of transport services. Operational technical parameters are used to assess these services [23]. With the development of cities and the increasing number of people in agglomerations, transport companies have to constantly search for optimal solutions. One of them is, among others, improvement of the vehicle exploitation process, which will ensure their reliability at a high level [21, 24, 25].

The article presents the model of improvement of the exploitation process and its verification on the example of urban public transport company in Wroclaw. This verification will be based on the analysis of bus damage from the year 2014. The study was carried out on the basis of selected systems failures occurring on buses, such as the braking system, electrical system, bodywork, transmission system, suspension system, steering system, engine with attachments, and chassis [22, 26, 27].

In Poland there are 12 agglomerations treated as metropolises belonging to the Union of Polish Metropolis: Bialystok, Bydgoszcz, Gdansk, Katowice, Cracow, Lublin, Lodz, Poznan, Rzeszow, Szczecin, Warsaw, and Wroclaw. Giving the city the character of a metropolis is to sanction the specifics of highly urbanized areas, stimulating the comprehensive economic development of the whole country. There are 17 million people living in metropolitan areas, over 40% of Poles. These cities produce 42% of Poland's GDP.

Accordingly, in the workplace of the place where the analysis of urban bus damage was carried out, the City Transport Company was selected, Wroclaw. The company has a large number of vehicles, due to its high density of population and a strong urban character of the city, which has made the most reliable test results possible, hence the choice.

Infrastructure of the Municipal Communication Company in Wroclaw (MPK Wroclaw) consists of 65 bus lines: 52 daily lines and 13 night lines. Fleet of MPK Wroclaw consists of over 300 buses, including 69 city bus subcontractors-Michalczewski Sp. z o. o. Out of all the bus operators that are stationed in city car barns, an analysis was performed on the damage of 110 selected buses.

2.2. Model of Improvement in the Process of Exploitation of Passenger Means of Transport. In city transport, the key element of management is control and the provision of the highest possible quality of service. This requires constant monitoring of the current state of affairs and processes to ensure their efficiency. Figure 1 shows improvement model of the exploitation process in means of passenger transport on the example of the Urban transport company (MPK Wroclaw).

3. Application of the Model for Analysis and Evaluation of the Passenger Transportation System

The first step in the improvement model is the identification and presentation problems of exploitation of the vehicle

Table 1: Damages and exploitation data of city bus operator MPK Wroclaw from 2014 within 1 year.

Name of damaged bus system	Model of the bus				
	Mercedes-Benz O530 K Citaro	Mercedes-Benz O530 Citaro	Mercedes-Benz O530 G Citaro	Mercedes-Benz O530 G Citaro 2	Jelcz 120MM
Braking system	11	56	48	8	217
Electrical system	19	89	71	10	167
Bodywork	2	52	32	1	184
Engine with attachments	0	16	14	2	134
Suspension system	5	37	29	1	15
Steering system	5	18	15	3	13
Transmission system	12	60	46	8	39
Chassis	0	20	15	2	31
Number of bus failures-LU	54	348	270	35	800
Average age [years]	3	5,7	5,7	3	18,7
Total bus mileage-P [km]	65,818	4,496,745	2,709,404	54,824	395,631
Number of buses (total)	1	58	42	1	8

group under study. It was done with a check sheet for damage to individual systems of different models of city buses. In addition, the average age and mileage of vehicles are reported. The data is shown in the Table 1.

The study was conducted on 110 city buses divided into 5 types:

(i) Mercedes-Benz O530 Citaro K-Class MAXI

(ii) Mercedes-Benz Citaro O530-Class

(iii) Mercedes-Benz Citaro O530 G-Class MEGA

(iv) Mercedes-Benz Citaro O530 G 2-MEGA

(v) Jelcz 120MM-Class MAXI

The second step for improving the operation process is to choose the proper methods and tools. Based on the analysis of literature and the results of the years of research in the field of improvement of operation, test sheet, analysis of Pareto-Lorenz, indicators of damage, Ishikawa diagram, FMEA, and QFD were chosen.

The third step of the improvement model is the choice of areas of improvement, which is to determine what damage should be seen about first. For this purpose, the Pareto-Lorenz graph was used. On the left side the total number of defects is found; on the right, the percentage of defects is found.

Analysis of the graph in Figure 2 shows that 80% of all the damage is caused by 4 systems: the electrical system, brake system, bodywork, and engine with attachments. This means that they need to be addressed first. For verification of this method of work, a fault indicator of individual systems of the type was also used. The damage analysis was based on the selected operational data of the Wroclaw City Bus Operator-MPK Wroclaw. An assessment of the number of damage to a certain type of system per thousand kilometers over one year of usage was made by using a W index that was determined from the relationship:

$$W = \frac{LU'}{P} \times 10^3 \tag{1}$$

where LU' is number of defects of each team within 1 year, P is total mileage of buses of a given type within 1 year.

The analysis mentioned in Figure 3 takes into account vehicle mileage and determines the failure rate for each of the systems considered, for each 1000 km traveled. It can be said that Jelcz 120MM has the highest damage index in 5 out of 8 systems: bodywork, electric system, brake system, chassis, and transmission system. The Mercedes-Benz O530 K Citaro has the lowest damage rating in 3 of the 8: suspension system, steering system, and engine with attachments (Figure 3).

After defining areas for further research, one must move on to the next, fourth stage of the model, identification of causes and propose solutions to problems. To that end, examples of potential causes are presented, in the form of Ishikawa diagrams (Figure 4), and there are proposed solutions in the form of Table 2 for each of the previously specified systems, for

(i) braking system, weak braking,

(ii) electrical system, problems with starting the engine,

(iii) bodywork, corrosion of the bodywork,

(iv) engine with attachments, weak air conditioning.

The Isikawa diagram allows identification of possible causes of damage. Figure 4 shows an exemplary Ishkava diagram for the engine system with attachments divided into 6 main causes of damage: materials, machines, personnel, measurements, methods, and environment.

Table 2 presents examples of solutions of the described problems for all systems. The table has been divided into three

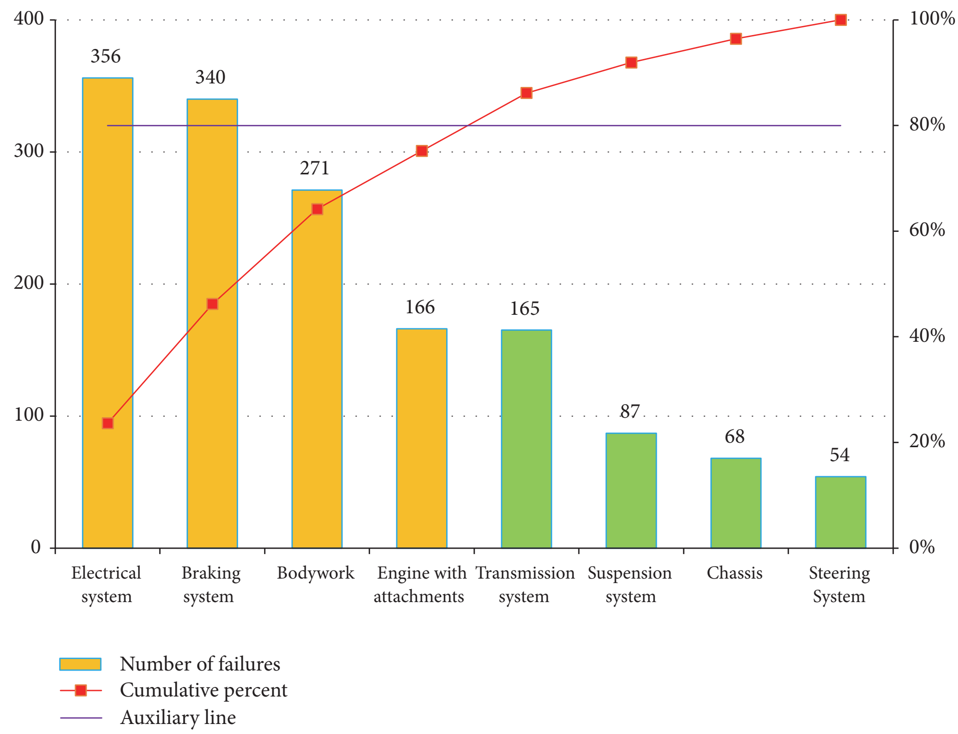


Figure 2: Pareto-Lorenz diagram of damage to individual bus systems based on the control sheet.

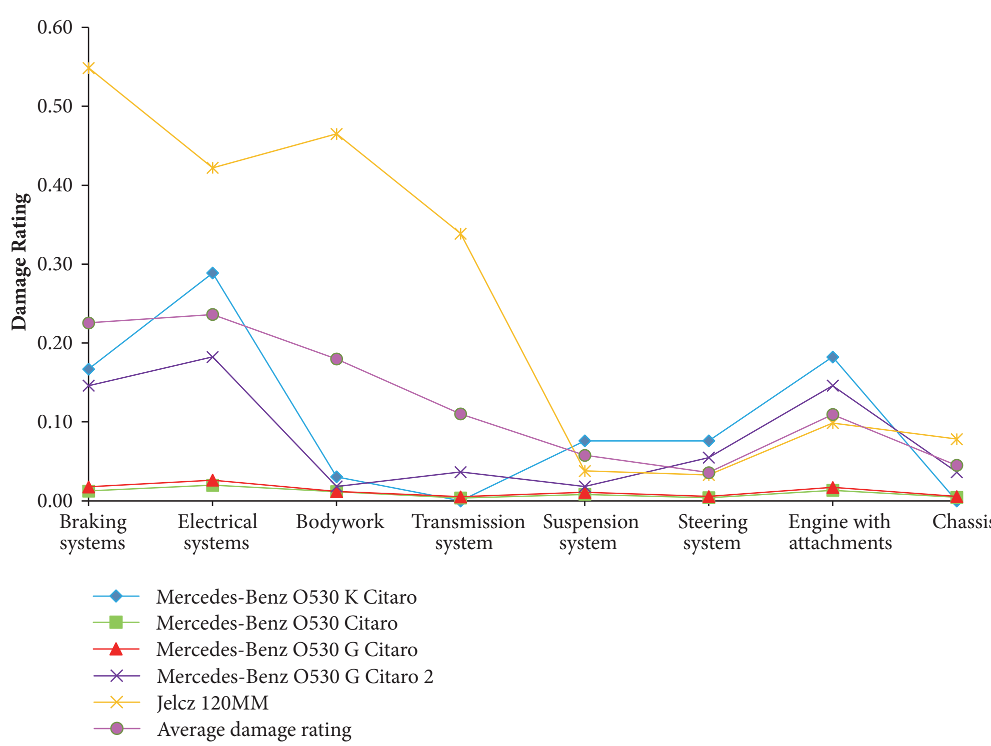


Figure 3: Damage indicators of individual buses of MPK operator Wroclaw.

columns: type of problem, its cause, and suggested solution. Considering the first system, the biggest problem and the cause of corrosion of the body are weak storage and improper maintenance. Therefore, actions are necessary to improve the storage and maintenance of buses by providing vehicles with heated garages (in winter), washing them frequently, and protecting them with protection measures. Problems with the engine system with attachments include inefficient air

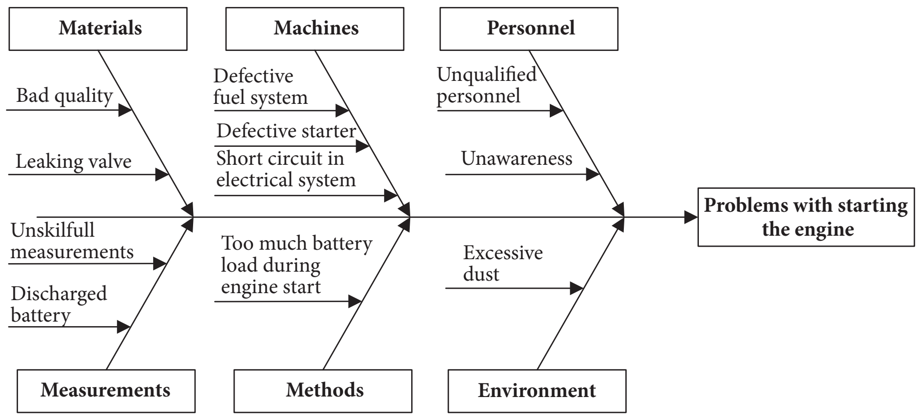


Figure 4: Ishikawa diagram for the electrical system.

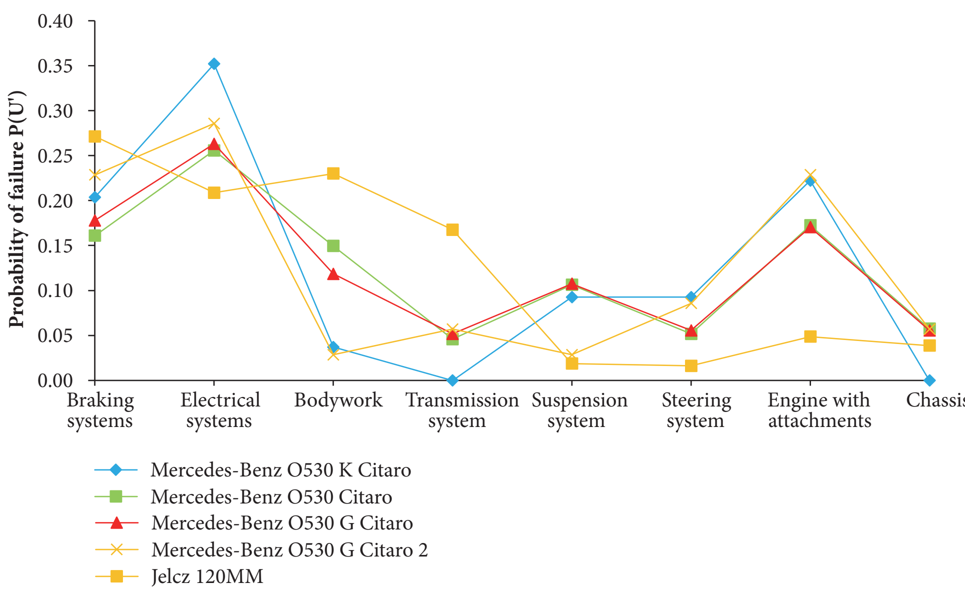


Figure 5: Values of the probability of failure for each of the bus systems in city buses.

conditioning. The main reasons for this issue can include primarily improper handling and use of the system. The proposed changes include starting the air conditioning system with the windows closed (securing the possibility of opening the windows to other passengers) and more frequent replacement of the refrigerant. In the case of an electrical system the most important causes are the lack of control over the battery level and improper use of vehicles by drivers. Proposed solutions include, among others, periodic training of employees increasing awareness and daily diagnostics of vehicle fleet by a qualified personnel. The last to be taken into consideration is the braking system, which is inefficient braking the vehicle. The reasons for this are the weak technical service of vehicles before leaving the depot. It is therefore necessary to daily service vehicles by checking individual fluids, condition of brake pads, and discs.

The next, fifth stage of the model is the implementation of improvements and validation of their effectiveness, implemented using FMEA method. This method consists in calculating the Risk Priority Number (RPN), which is designated by the dependence [18]:

$$RPN = S \times O \times D \quad (2)$$

where S is severity, O is probability of occurrence, and D is detection.

To determine the probability of failure of the analyzed system P, the following relationship is used:

$$P\left(U'\right) = \frac{LU'}{LU} \quad (3)$$

where LU' is the number of types of damage of a given system for the type of bus under examination within 1 year and LU is total number of failures for the type of bus under examination within 1 year.

Figure 5 presents the probability of failure of each system in vehicles per 1000 kilometers driven. The highest probability of failure is related to the electrical system

Table 2: Proposed solutions for detected problems.

(a)

Type of problem	Causes of the problem	Suggested solutions
	Bodywork	
Corrosion of the body	Weak storage of vehicles	Heating garages in winter
		Storage of vehicles in well-ventilated and dry garages
	Inadequate maintenance	Frequent washing of vehicles
		After cleaning, protective measures for varnish protection
	Inadequate manufacturer's corrosion protection	Increased control services in search of rust fires
		Inspections of vehicles for paint defects and their protection if necessary
		Additional anti-corrosion protection of closed profiles, e.g. doors

(b)

Type of problem	Causes of the problem	Suggested solutions
	Engine with attachments	
Weak air supply	Defective air conditioning compressor	Do not turn on the air conditioning system with the windows open
		Before switching on the air conditioning, ventilate the vehicle
	Leaks in the air conditioning system	Periodic checking of the tightness of air conditioning system connections
		More frequent diagnosis of errors using the OBD II interface
	Too small amount of refrigerant every 2 years	Compulsory refrigerant exchanges every 1 year
	Faulty condenser	Periodic checking of the condenser for mechanical damage
	Electrical systems	
Problems with starting the engine	Defective starter	Replacement of damaged starter components
	Defective fuel systems	Instructing drivers with shorter start-up time
	Uncharged battery	Periodic checking of battery voltage
		Charging the battery when stationary
	Short circuit in electrical system	Connection of diagnostic equipment and detection of faults
	Too much battery load during engine start	Disconnection of unnecessary current collectors
	Unqualified personnel	Increased number of employee training
	Unawareness	Software systems supporting analysis of driving parameters
	Braking systems	
Weak braking	Aerated braking system	More frequent de-aeration of the brake system
		Control of brake fluid level by drivers
	Used brake fluid	More frequent change of brake fluid
		The use of brake fluids with better technical parameters
	Badly installed brake pads or discs	Additional training for mechanics
		Disciplining the drivers of the machine park
	Greasy brake pads or discs	Cyclic use of degreasing agents

(Mercedes-Benz O530 K Citaro 35%) and average 22% concern on failures in the brake system. The third-largest probability is the transmission system.

To define the number of defect risks the average value of all bus failures for individual systems was used, as shown in Figure 6.

For the determined average values of damage of individual systems, the appropriate number O (Table 3) is assigned. O is the probability of occurrence of a given damage in a predetermined or determined time interval [11, 18].

S is a dimensionless number denoting severity, which is an estimation of how the effects of a given damage affect

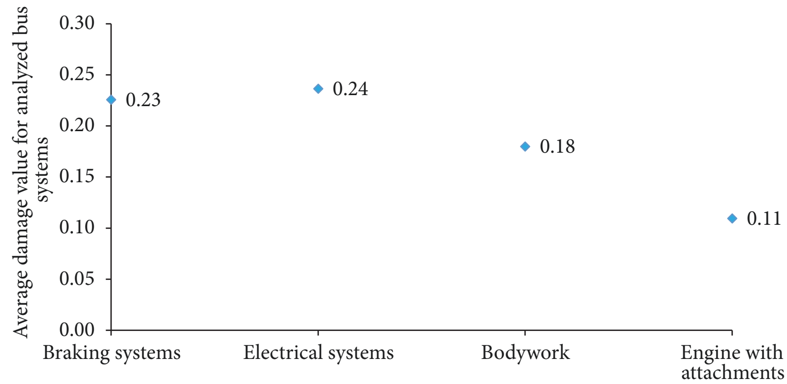


Figure 6: Average damage value for analyzed city bus systems.

Table 3: Failure mode occurrence related to frequency.

Failure mode occurrence	Frequency	Rating, O
Remote: Failure is unlikely	< 1/5000	1
Low: Relatively few failures	1/5000	2
	1/2000	3
Moderate: Occasional failures	1/1000	4
	1/500	5
	1/200	6
High: Repeated failures	1/100	7
	1/50	8
Very high: Failure is almost inevitable	1/10	9
	≥ 1/2	10

the use of a given system. In order to determine the severity for individual systems, the following evaluation was used (Table 4) [11, 18].

D means detection, i.e., determining the chance of identifying and eliminating a given damage before it hits the system or its use. Table 5 presents the evaluation criteria for determining the detectability for individual systems [11, 18].

After specifying the individual parameters S, O, and D, Table 6 shows the first FMEA analysis for the specified systems.

Such analysis is a valuable source of information for the manager of the operation of a public transport company, when choosing corrective measures. After the analysis, the target value of the Priority Risk Number (RPN) was determined and after analyzing the literature it was decided that the target RPN was set at RPN level of 240.

The next step is to check the effects of the proposed corrective measures, whether the RPN of each test system is less than 240; therefore four conditions must be fulfilled:

$$RPN > \mathrm{RPN}_{\text{BRAKING SYSTEM}} \tag{4}$$

$$RPN > RPN_{\text{ELECTRICAL SYSTEM}} \tag{5}$$

$$RPN > RPN_{\text{ENGINE WITH ATTACHMENTS}} \tag{6}$$

$$RPN > RPN_{\text{BODYWORK}} \tag{7}$$

If after the first FMEA analysis the values of the individual RPN's do not meet the above inequalities, the FMEA analysis with the subsequent corrective measures shall be repeated until the desired values are achieved. Before the corrective actions, all RPN values of each system exceeded the RPN = 240, which was also done and shown by the graph in Figure 7.

After corrective actions, FMEA analysis was again performed and the RPN values of individual systems were checked to see if they went under the below target value. Figure 8 shows a graph with RPN values for individual systems after the first FMEA analysis. It can be pointed out that for three of the systems the RPN value is below the target value (240). The greatest improvement was noted at the brake system, because the RPN value dropped from 810 to 180. In the case of the electrical system, the value decreased from 432 to 144, while in case of the body system the RPN decreased from only 324 to 140. However, further corrective actions for the 4th system (engine with attachments) are necessary.

Table 7 presents the second failure mode and effects analysis (FMEA) for engine with attachments systems and corrective actions for this systems. In turn, another results are presented in Table 8.

After performing the corrective action for the engine with attachments in the second FMEA analysis, it was found that the value of $\mathrm{RPN}_{\mathrm{EWA}}$ decreased to a value equal to only 98, which is the result of more than twice lower than that required. Finally, after all corrective actions, the RPN values were

$$RPN = \{98, 140, 144, 180\} \tag{8}$$

It was found that the improvement activities had the desired effect, as illustrated in Figure 9 showing a comparison of RPN values before and after corrective measures based on FMEA analysis.

The last (sixth) stage of the improved model for the exploitation of passenger vehicles is the QFD, which shows the relationship between customer requirements and the technical characteristics of products or services (Figure 10).

Table 4: Failure mode severity.

Severity	Criteria	Ranking
None	No discernible effect.	1
Very minor	The defect is irrelevant and the user will hardly feel its effects (perceived by less than 25% of users).	2
Minor	The defect is irrelevant and the user will hardly feel its effects (perceived by 50% of users).	3
Very low	A defect of medium importance, causing user dissatisfaction. Seen by the majority of users (about 75%).	4
Low	A defect of medium importance, causing user dissatisfaction. The user feels its effects and is a bit dissatisfied.	5
Moderate	A defect of medium importance, causing user dissatisfaction. The user feels its effects and is dissatisfied.	6
High	A defect of great importance, resulting in reduced system performance. User very dissatisfied.	7
Very high	Inoperative system (loss of the primary function).	8
Hazardous with warning	A defect of very high importance, affecting the safety of use and/or entails failure to comply with government regulations, with warning.	9
Hazardous without warning	A defect of very high importance, affecting the safety of use and/or entails failure to comply with government regulations, without warning.	10

Table 5: Failure mod detection evaluation criteria.

Detection	Criteria: likelihood of detection by Design Control	Ranking
Almost certain	The inspectors will almost certainly detect a possible defect and the subsequent damage.	1
Very high	A very good chance that the inspectors will detect a possible defect and the subsequent damage.	2
High	A high chance that the inspectors will detect a possible defect and the subsequent damage.	3
Moderately high	Moderately high chance that the inspectors will detect a possible defect and the subsequent damage.	4
Moderate	A moderate chance that the inspectors will detect a possible defect and the subsequent damage.	5
Low	Low chance that the inspectors will detect a possible defect and the subsequent damage.	6
Very low	Very low chance that the inspectors will detect a possible defect and the subsequent damage.	7
Remote	A small chance that the inspectors will detect a possible defect and the subsequent damage.	8
Very remote	A very small chance that the inspectors will detect a possible defect and the subsequent damage.	9
Absolutely uncertain	Inspectors will not detect and/or cannot detect a possible defect and subsequent damage. Or no system control.	10

4. Target Values of Exploitation of Passenger Transport Parameters

The QFD method is a way of "translating" opinions and needs of customers into a technical language, understandable in the company by designers, builders, and technologists. It serves to translate market requirements into conditions that an enterprise must meet.

The use of this method is caused by reflection, that the decisive factor standing behind the financial condition of the companies is the buyers of their products. Even if the product is correct from an engineering point of view, it does not have to provide economic success because it is determined by the consumer market, the customer.

Similar dependencies could be set for the vehicle designer and engineer having to build it. Based on the data above, a QFD diagram has been developed in the form of a "quality house", Figure 11.

The goal of a quality home is to set critical parameters and set their target values in such a way as to ensure success in the

Table 6: First FMEA analysis for individual systems.

Specificity defects	Effect	Cause	S	O	D	RPN	Corrective Action
Bodywork							
Corrosion of bus body	Dissatisfaction users Weakness of supporting structure of the bus	Wrong storage and maintenance of the vehicle	**4**	**5**	**9**	**324**	Improve the method maintenance and storage Make additional corrosion protection, in particular closed profiles
Engine with attachments							
Inefficient work of the air conditioning system	Too high temperature and air humidity in the bus, preventing comfortable traveling	Damaged compressor Leaks in the air conditioning system Insufficient amount of refrigerant	**7**	**9**	**7**	**441**	Regular servicing Don't turn on the air conditioning system while the windows open Replace the refrigerant every 1 year
Electrical systems							
Problems with starting the engine	Delays in commuting bus trips	Failed starter Uncharged battery Short circuit in electrical system Too thick engine oil during start-up	**8**	**9**	**6**	**432**	Replacement of damaged starter components Rechargeable batteries during stoppages The use of seasonal engine oils
Braking systems							
Inefficient braking	The bus driver is not able to brake hard enough in an emergency situation	Aerated braking system Badly fitted brake pads or discs	**10**	**9**	**9**	**810**	Frequent venting of the system and control condition of the brake fluid Additional training and disciplining their mechanics

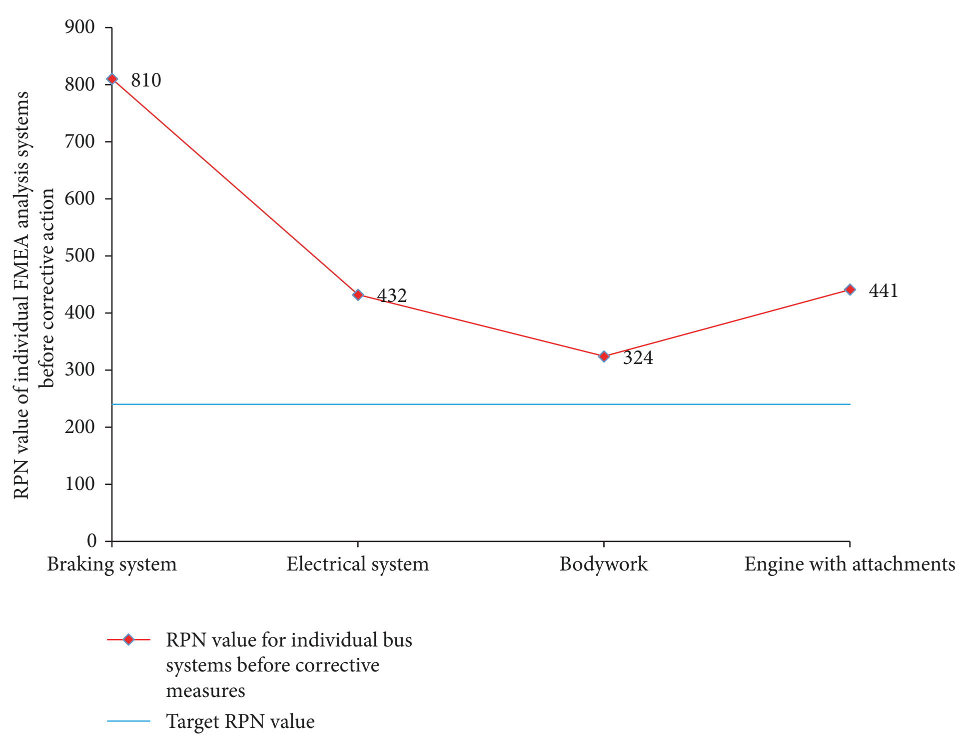


Figure 7: RPN value each of the bus systems before corrective action based on FMEA.

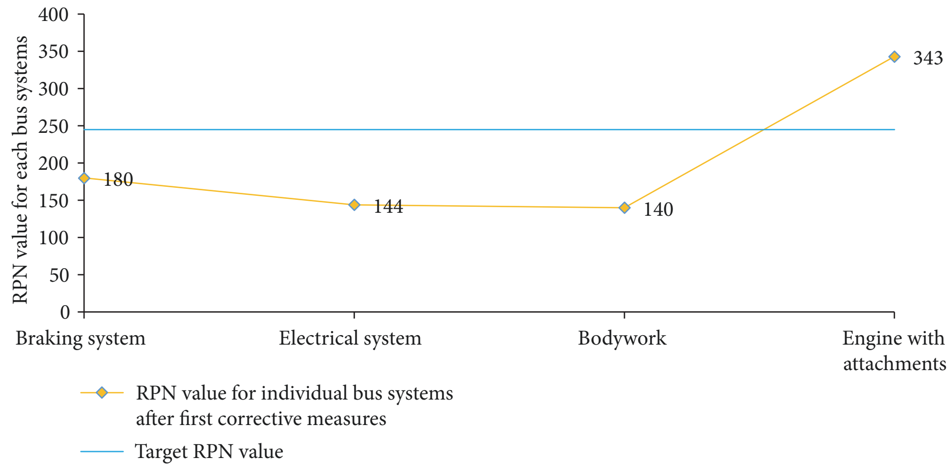


Figure 8: RPN value for each of the bus systems after the first phase of corrective action based on FMEA.

Table 7: Second FMEA analysis for the engine with attachments system.

Specificity defects	Effect	Cause	S	O	D	RPN_{EWA}	Corrective Action
Inefficient operation of the air conditioning system	Too high temperatures and humidity in the bus make it impossible to travel comfortably	Compressor damage Leaks in the air conditioning system Too little refrigerant	7	7	7	343	Ventilate the vehicle before turning on the air conditioner Periodic air tightness check

Table 8: Results after second FMEA analysis of the engine with attachments system.

Specificity defects	S	O	D	RPN_{EWA}	Further corrective action
Inefficient operation of the air conditioning system	**7**	2	**7**	**98**	No corrective actions

market for the services or products offered. In the presented case, 3 target parameters were defined:

(1) Servicing in the cycle 1 time per month for each of the buses.

(2) Driver training courses in the cycle 6 times per 1 year for each driver.

(3) Vehicle reliability at the average level of 1 failure per 2 weeks for each vehicle.

5. Conclusions

Based on presented study, the following conclusions were made:

(i) The process of exploitation of city buses in Wroclaw is not full correctly realized and requires improvement.

(ii) Based on the analysis of Pareto-Lorenz, it was stated that around 80% of all damage was generated by the half of investigated systems.

(iii) The proposed solutions to the problems in the various systems, based on the causes of their development and the Ishikawa diagram have brought measurable benefits in the FMEA method.

(iv) With the FMEA analysis, a reduction in the number of RPNs was achieved in the range of 57% to 78%, most already after the first phase of corrective action.

(v) Based on the QFD method, the relationships between customer requirements and the technical parameters of city buses were determined and 3 of them were diagnosed as critical parameters: servicing, driver training courses, and vehicle reliability.

In addition, one should choose the proper operating strategy, depending on the nature of the work of the vehicle. If sudden breakdowns that prevent the vehicle from operating properly will not cause additional losses such as lost earnings and loss of image, a reactive strategy can be used to repair after the failure; otherwise preventive strategies should be chosen, much more reasonable, that is, to prevent damage. Using the QFD method that allows to improve quality causes that a company dedicated to the well-known needs of the customer has a clear advantage over its competitors. Detailed knowledge about the current needs of customers allows

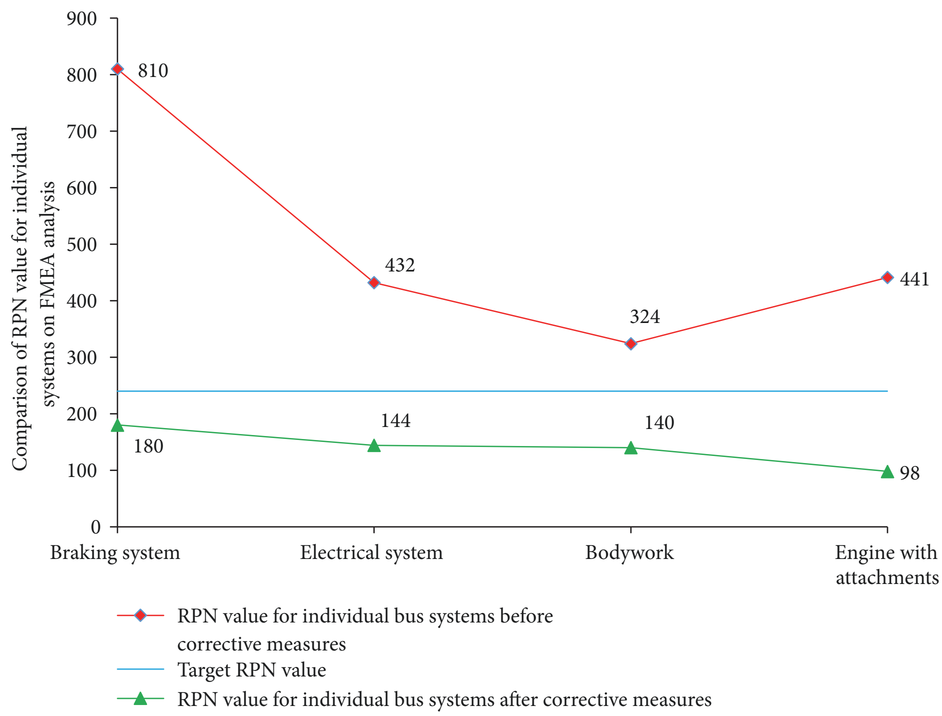


Figure 9: Comparison of RPN values for each of the bus systems before and after corrective actions based on FMEA analysis based on FMEA.

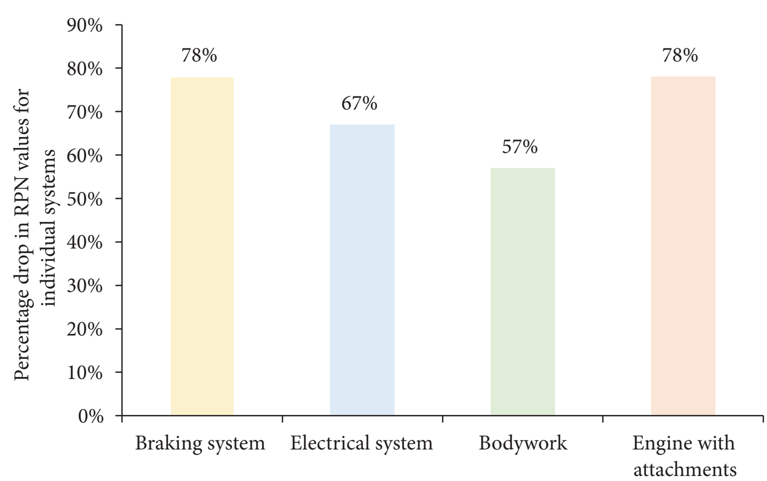


Figure 10: Percentage drop in RPN values for each of the bus systems.

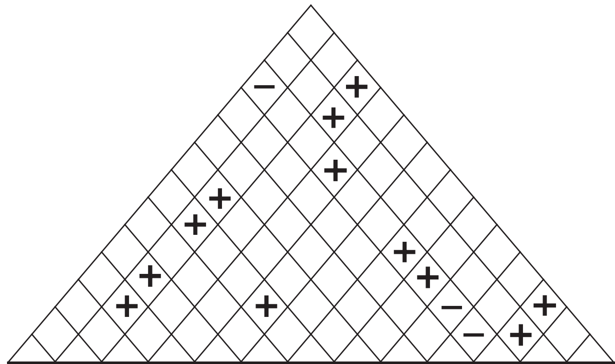
us to take action to ensure optimal satisfaction of them. When refining and modifying the undertaken activities, it is important for marketing of the company to remember to continually show its strong sides in order to provide the company with a competitive advantage.

At present, significant development of all types of quality improvement activities of processes or services is evident, due to increasing customer demands and ever-increasing competition.

Built analysis model and evaluation of the exploitation of passenger transport have been verified with actual data obtained from the MPK in Wroclaw. It can find practical use in other urban agglomerations, which would improve the operation of passenger transport.

Data Availability

The exploitation data used to support the findings of this study were supplied by MPK Wrocław under license and so cannot be made freely available. Requests for access to these data should be made to MPK Wrocław, bop@mpk.wroc.pl.



Customer Needs	Importance	accessories of the vehicle	climatic conditions in the vehicle	servicing	drivers training courses	disciplining drivers	modern technologies	washing & cleaning vehicles	quality od mechanics work	age of the vehicle	Service life of the vehicle	reliability of the vehicle	Adjustments and maintenance	daily service					
		↑	•	↑	↑	↑	↑	↑	↑	↓	↓	↑	↑	↑					
working interior lightning	2	3		1			1		3	2	2	2	2	2		B	A		C
pleasant smell	5	1	3	2				3	1	1	1						C	A	B
smooth driving	8			1	3	3	1		1	1	1	1	1			A		C	B
cleanliness inside & outside	8		1					3					1	1			A	B	C
efficient heating	8		2	3					3	1	1	1	1				B	A	C
efficient air conditioning	8		2	3					3	1	1	1	1			A		B	C
fast driving	5			1	3	3			1	1	1	1			B	C			A
punctuality od arrivals and	9	1		1	3	3	1					1			B	C			A
optimal temperature	7		3	2	3							3	1			A		B	C
collision-free driving	9	3		1	3	2											A	B	C
fault-free driving	8			3					3	3	3	3	3	3			A	C	B
safe diving	8	3			3	3						2					A	B	C
quiet driving	5			1					1	1	1	3					A	B	C
easy to open windows	4	1		1				1	1	1	1	1	1			C	B	A	
working validators	3			1					1				1	1	C		A	B	
Technical Evaluation		75	76	141	138	108	19	48	108	105	111	122	74	39	1	2	3	4	5
Specification Target Value		as expected of users	21°C	1/month	6/year	if necessary	as many as possible	1/week	no mistakes at work	max 5 years	max 2 mln km	1 failure/2 weeks	2/week	before & after using vehicle					
Technical Difficulty (1-Low, 5-High)		4	2	5	2	1	4	3	4	4	4	4	2	3					
Importance Rating				1.	2.							3.							

A	B	C
320	351	393

Color	Description
	Customer Needs
	Importance to the customer
	Engineering Characteristics
	Engineering Characteristics & Customer Needs Correlations
	Technical requirements type
	Technical Evaluation
	Engineering Characteristics Correlations
	Competitive Evaluation
	Customer perceptions Rating
	Customer perceptions Results
	Specification Target Value
	Technical Difficulty
	Importance Rating (Critical parameters)

Figure 11: "Quality home" the operation of city buses.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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