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ANALYSIS AND EVALUATION OF URBAN PUBLIC TRANSPORT – SELECTED QUANTITATIVE AND QUALITATIVE INDICATORS

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Purpose: The main purpose of the article is to analyze and evaluate collective public transport provided by a public transport company in the Upper Górnosląsko-Zagłębiowska Metropolis.
Design/methodology/approach: The study used a desk resarch to conduct an indicator analysis. Indicator analysis makes it possible to both measure and evaluate the activities of the company under study. In addition, it makes it possible to learn about the scale of operations (e.g., by providing information on the amount of rolling stock owned or transport performed), as well as to assess the quality of transport services provided. In addition, indicator analysis can provide information on the trends of changes in specific spheres of bus transportation activity.
Findings: Empirical studies indicate that the process of transporting passengers as part of public transport is characterized by a good level of reliability. In addition, the results indicate high values of individual monitored measures and indicators.
Research limitations/implications: The main limitation is the receipt of the necessary data from the public transport company, which may affect the results of the research and limit the generalization of the results.
Practical implications: The conducted empirical research contributes to the science and practice of management by providing insight into the assessment of urban public transport in the Górnośląsko-Zagłebiowskiej Metropolis.
Originality/value: The results of this article may be useful in understanding the usefulness of logistic metrics and indicators.

Keywords: public transport, the city's transport system, Górnośląsko-Zagłebiowska Metropolis.

Category of the paper: Research paper.

1. Introduction

Passenger public transport is of great importance within urban agglomerations, enabling the rapid movement of large streams of passengers. It is an important element of the transport systems of many highly urbanized areas. Correct communication solutions of public transport

allow avoiding many threats of modern cities related to traffic accidents and time loss due to traffic congestion (Gramza, 2011).

An efficient public transport system competes with individual transport. Only such solutions can become competitive and attractive enough for potential customers - passengers, which will allow meeting specific requirements regarding the quality of traffic (Gramza, 2011).

The appropriate quality of the organization of transport services, including urban public transport, shapes the level of market service, and customer satisfaction and the company's experience affect its position on the logistics services market.

Considering the above considerations, the need to analyze and evaluate urban public transport becomes very important.

Therefore, the main purpose of the article is to analyze and evaluate the collective public transportation provided by the public transport company in the Upper Silesia-Zagłębów Metropolis. The research was carried out using the desk research method. An analysis was made of the current state of the studied enterprise in 2015-2020/2021 and the degree of reliability of the services it offers using selected quantitative and qualitative indicators.

2. Theoretical background

The city's transport system. The transport system as a separate subsystem of the socio-economic system of the city was the subject of consideration in the literature on the subject already in the second half of the 20th century (Ejdys, 2017). According to J. Brudlak (Brudlak, 2016), the transport system is a set of organizationally, legally, technically, economically and spatially ordered - due to the condition of transport infrastructure - entities of socio-economic processes that contribute to meeting transport needs within the framework defined by the transport policy countries. In turn, L. Hoffman (Hoffman, 1968) defines the transport system as: the entirety of technical, organizational, economic and legal issues that occur in the process of cooperation of individual transport branches and determine the nature of the main dependencies and relationships between transport and other areas of the national economy. Whereas J. Kurowski (Kurowski, 2017) claims that the transport system should be perceived in a much broader sense, as it is a rather complicated system which, in a model simplification, allowing for better understanding of it, has been schematically presented as a system of three subsystems: technical, organizational and economic- legal.

Thus, taking into account the above statements, it can be argued that the city's transport system is a catalyst for both economic and social opportunities that stimulate the growth of cities' efficiency and productivity. Through its complementary nature, as well as links with the social and economic environment, it is an integrating factor, coordinating the urban economy,

becoming a universal and irreplaceable element of economic processes and manifestations of social life occurring in urban agglomerations (Ejdys, 2014).

Urban transport as a subsystem of the transport system is essential for the development of modern cities. In the past, urban transport was mainly focused on the internal service of the city. In addition, it contributed to the organization of the spatial structure of cities and enabled their further development (Ejdys, 2014).

Each transport system operating in a given urban area has a significant impact on its quality of life. It is an integral part of the urbanized city area, which influences its development (Banak et al., 2014).

The essence and importance of public transport. The concept of public transport is widely known in society. Many authors, however, attribute different scopes and areas of activity to it. Often and not quite correctly, public transport is equated with urban transport. This issue was raised by O. Wyszomirski (Wyszokomirski, 2008) who pointed out that replacing the term public transport with the term urban transport is intended to facilitate translation into foreign languages. The author points out, however, that in Poland the concept of public transport is still correct and correctly identified with "local collective transport performed as a commune's own task".

A seemingly similar approach is represented by W. Rydzkowski and K. Wojewódzka-Król (Rydzkowski, Wojewódzka-Król, 1997), who also compared urban transport to public transport, writing that "the term urban transport is most often identified with passenger transport and is used interchangeably with the term public transport". The authors explain this by the fact that the basis for separating urban transport from other types of transport is not its spatial range of operation, but the operational and economic specificity resulting from the nature of passenger transport needs and the way they are met. It is worth noting, however, that a few pages later, the authors included a functional division of means of transport used in urban transport.

E. Gołębska (Gołebska, 2010) treats public transport as an important element of the urban transport system. This is the final confirmation that public transport is not synonymous with urban transport, but only one of its components.

Summarizing the considerations related to the meaning of the concept of public transport, it can finally be stated that, in accordance with the Act on public road transport, public transport is generally accessible, performed regularly at certain intervals and along designated routes, public passenger transport operating in the area of one or several cities or neighboring communes with each other, which have concluded an agreement on the joint implementation of public collective transport in their area. Urban transport understood in this way will be the subject of consideration in the further part of this work.

After a thorough exploration of terminological issues and clarification of inaccuracies related to the concept of public transport, one can proceed to examining the role that public transport plays in the functioning of cities. Urban public collective transport basically meets the same transport needs as any other passenger transport within the city, i.e. it allows people to

travel long distances, meeting their transport needs. Theoretically, individual or group transport, such as (private car or taxi), could completely replace public transport in the form of, for example, bus or tram transport, because they offer better comfort, travel time and flexibility.

3. Methodology

A wide range of logistic indicators are used to measure and evaluate the activities of a public transport company. Using some of them, you can obtain the necessary information about the level of transport processes, including urban public transport, notice deviations from the assumed plans, and introduce the necessary improvements, thanks to which the company will increase its competitiveness. Therefore, they are the basis for evaluating the decisions already taken and at the same time show the directions of solutions in the future.

Ratio analysis is a relatively simple method of examining the processes carried out in the company. It is based on constructing and evaluating relations between different quantities. At the same time, it is very important to properly select and estimate the size of the tested parameters and correctly interpret the obtained results, which is made on the basis of a comparison with the adopted reference bases (Dmuchowski, 2019).

The notions of measure and indicator are related to ratio analysis. A gauge is a number characterizing a certain phenomenon, expressed in an appropriate unit of measurement that allows to compare it with other phenomena. Meters in logistics perform an informative function and do not have evaluative properties in themselves. The measured values, expressed in absolute units, determined on the basis of conducted research, make it possible to quantify the actual state. Indicators can also be created on the basis of measures (Twaróg, 2003). On the other hand, logistic indicators are used to measure the effectiveness of logistic systems, to define goals formulated in a quantitative way, to check the level of achievement of company goals and the degree of satisfaction of customer needs. Properly formulated logistic indicators enable early recognition of negative and positive trends in the process (early recognition function), and also contribute to ensuring proper control of logistic processes (steering function) (Twaróg, 2003).

Thanks to the analysis of transport process indicators, it is possible to obtain information on the transport processes in progress and to notice deviations from the assumed plans, and thus the need to introduce improvements to the process (Gaschi-Uciecha, 2018).

Indicators provide a basis for evaluating decisions taken previously and also facilitate the selection of the direction of future actions.

Quantitative indicators and measures were used for the quantitative assessment, such as:

- transport performance indicator,
- bus size meter,

- utilisation rate of fleet
- failure and defect rate of fleet

The qualitative assessment was carried out using measures and indicators such as:

- vehicle equipment malfunction meter,
- fleet age indicator,
- measure of lack of bus stop,
- passenger satisfaction index,
- punctuality index.

3. Results

Based on the data received from the research subject, an analysis of the current state of the enterprise and the degree of reliability of the services offered was carried out, and the trend of changes was assessed by comparing current data with historical data using quantitative and qualitative indicators and measures.

The measures and quantitative indicators selected for the analysis of the research subject are presented in table 1.

Table 1.
Selected quantitative indicators

Name	Method of calculation	Description
Transport performance indicator	$\frac{Completed\ transport\ work}{Planned\ transport\ work} * 100\%$	Indicates the extent to which the planned transport work has been achieved.
Bus size meter	Number of buses of a given type	Indicates the number of Type A, B and C buses owned.
Utilisation rate of fleet	$\frac{Running\ vehicles\ of\ a\ given\ type}{Owned\ vehicles\ of\ a\ given\ type} * 100\%$	Shows the ratio of actively running to all owned vehicles of a given type
Failure and defect rate of fleet	$\frac{Number\ of\ forced\ departures\ to\ depots\ due\ to\ technical\ reasons}{Number\ of\ completed\ services} * 100\%$	Shows the ratio of the number of forced departures to depots to the total number of services

Source: Own study based on literature.

The transport performance indicator expresses the ratio of the number of vehicle-kilometres carried out to the number assumed in the route charters. The most frequent reasons for missing or incomplete journeys are fortuitous events (e.g. road closures due to accidents) and line congestion on transport routes. Missed journeys also include sections of journeys carried out with too much delay, e.g. when the vehicle of the next journey serving the same line served the stop faster than the vehicle of the previous journey.

The company's aim is to keep the indicator above 99.7%. The indicator values for the period 2015-2020 are shown in Figure 1.

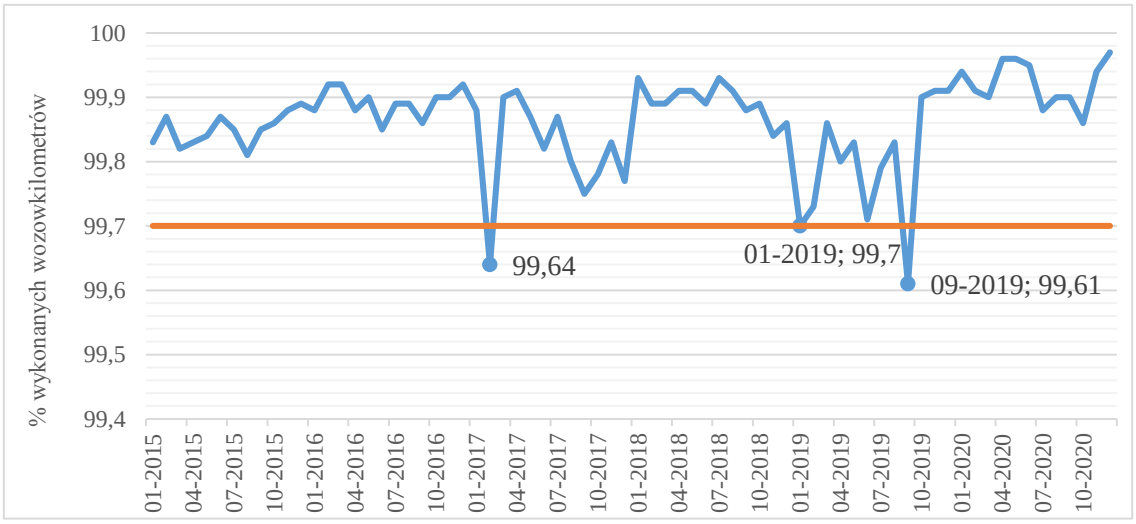

Figure 1. Wartości wskaźnika realizacji przewozów w latach 2015-2020.

Source: Own study based on research results.

From an analysis of the data presented in the figure above, it can be seen that during the period in question, the company only missed its target twice (99.7% of transport operations). The periods in which the target was not met are highlighted in the graph and described. This happened in February 2017 and September 2019. In addition, it is worth noting that in January 2019 the company was on the verge of meeting its target. Overall, however, the level of the indicator can be assessed positively, as in the vast majority of periods the target level of transport fulfilment was met, often even with a large margin. It is also important to note the recorded improvement in the value of the indicator in 2020, in which as many as 6 months (January, April, May, June, November, December) recorded record-breaking high results of the analysed indicator, which could be influenced by reduced traffic related to the Covid-19 pandemic.

The bus **size meter** reports the number of A(N), B(N) and C(N) buses owned by the company. Type A buses correspond to the midi class, are about 10 metres long and accommodate about 60 passengers. Type B buses correspond to the maxi class, are approximately 12 metres long and accommodate approximately 90 passengers. Type C buses correspond to the mega class, accommodate approximately 140 passengers and measure over 13 metres in length. Most C-class buses are articulated buses measuring approximately 18 metres. The bus size measure values for 2017-2020 are shown in Figure 2.

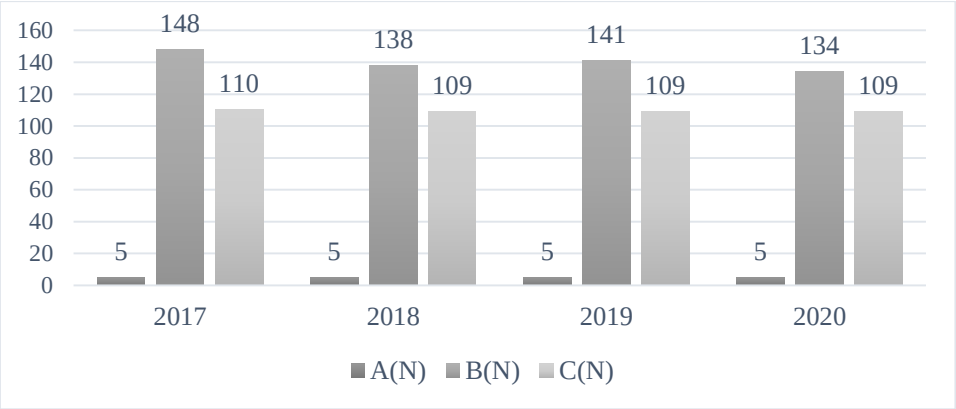

Figure 2. Bus size measure values for 2017-2020.

Source: Own study based on research results.

Analysis of the measure indicates that despite the high turnover of buses in the fleet, the company maintains a relatively constant proportion between the different types of bus. The fleet is still dominated by B(N) buses, with slightly fewer C(N) buses and A(N) buses making up a very small part of the fleet. The only change in the period under study that can be seen in the graph is a gradual decrease in the total number of buses of type B(N) with an almost constant number of buses of the other types.

The fleet utilisation indicator shows the ratio of buses of a given type actively in line use to the total number of buses. It makes it possible to determine the utilisation rate of the existing fleet, but also to assess the size of the reserve. Due to the very small size of the A(N) fleet, the company does not keep separate utilisation records for these vehicles, instead they are combined with B(N) vehicles. The results of the fleet utilisation rate for most of 2020 and the first month of 2021 are shown in Figure 3.

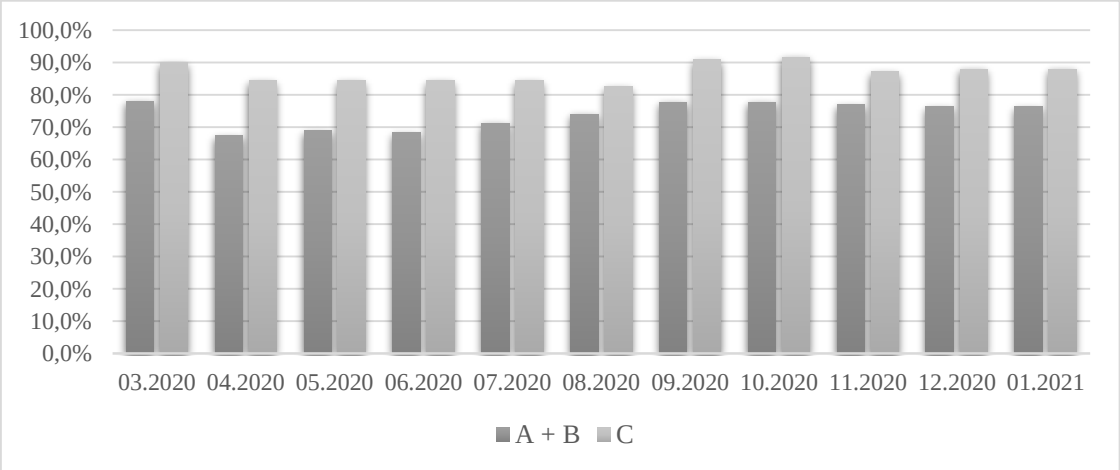

Figure 3. Utilisation rate of fleet.

Source: Own study based on research results.

The analysis of the value of the indicator shows that the research entity makes optimal use of its fleet. Most of the vehicles are used linearly for the services, so that the company does not incur large losses due to underutilisation of its transport potential. On the other hand,

it maintains a more or less constant proportion of reserve vehicles, ready to replace line vehicles in the event of a breakdown or road incident; for the A(N)+B(N) fleet it is around 25% and for the C(N) fleet around 10%. Having a reserve allows the company to maintain a high level of readiness and gives it the ability to respond quickly to incidents by allowing the immediate replacement of a bus if necessary. In the graph, it is noticeable that there is a periodic decrease in the value of the measure during the months of April to August. During this period, a smaller proportion of the owned fleet was used, in the case of B(N) vehicles in the months from April to June the utilisation dropped below 70% which is already a relatively low value. Utilisation of C(N) fleet fell to around 85%, which is correct. However, there is a reason for this periodic drop in the measure. It was the limited number of courses in the first months of the Covid-19 pandemic due to the transition of schools and some workplaces to remote study/working mode. After the summer holidays of 2020, the values of the measure returned to their standard levels. It is worth noting that throughout the period under study the utilisation of the C(N) fleet has been higher than that of the A(N) and B(N) types, this is probably due to the greater number of B(N) buses owned, which are dominant in the fleet of the company under study, although their predominance over the larger fleet is gradually decreasing as indicated by the data in Figure 2.

The fleet failure and defect rate shows the ratio of the number of courses interrupted by the need to return to the depot for technical reasons. It takes into account major vehicle failures that prevent them from continuing with their courses. Examples of dysfunctions include door, driveline, suspension, tyre (tyre burst) and other failures. In the event of a vehicle going down at the depot, it must be replaced by another bus from the reserve to continue the service. The cause of a technical failure can also be a road traffic collision, even if the consequences are not serious and only end in a scratch on the paint, it is necessary to clarify the matter, determine the guilty party, sign the documents and sometimes (in case of doubt about the fault) wait for the police. The dispatcher, in order to reduce delays in such cases, sends a replacement bus to pick up passengers and continue the journey (similar procedure to a failure). Another factor that is not a failure, but which also makes it necessary to return the vehicle to the depot included in this indicator, is the discharge of the traction batteries of electric buses. When the battery level falls below a predetermined level (about 30%), the driver must return to the depot to load the bus if possible. The failure and defect rate values are shown in Figure 4.

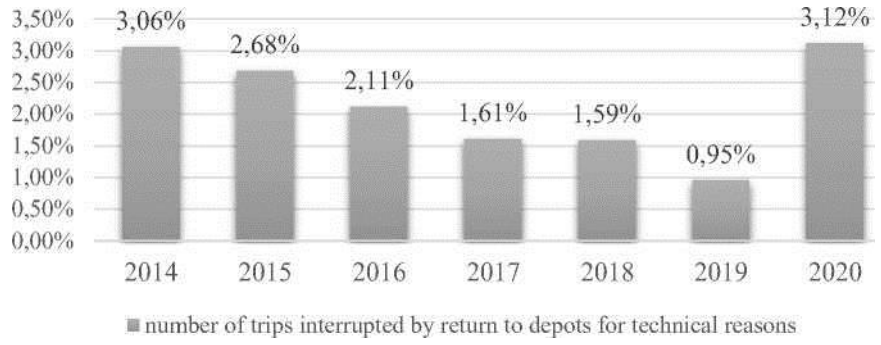

Figure 4. Values of failure rate and defects in fleet for 2014 - 2020

Source: Own study based on research results.

As can be seen from the figure, there was a continuous decrease in the number of bus defects and failures between 2014 and 2019, but 2020 turned out to be a record year in terms of forced departures to the depot for technical reasons. The gradual decrease in failure rates between 2014 and 2019 can be explained by the replacement of the older more defective fleet with new one. What is puzzling, however, is the sharp increase in the index value in 2020. There may be several reasons for this. Firstly, the Covid-19 pandemic that broke out in Poland in March 2020 may have had an impact. Depot returns may have resulted from the need to disinfect buses after incidents involving passengers. Another reason for this increase could be the adoption of electric buses for regular service in 2020. Admittedly, the first electrobus already started running in 2019, but it was only one. In 2020, nine more electric buses were taken into service. For most drivers, but also for planners, this was a new situation. Employees may have been initially surprised by the significantly lower range offered by the electrobuses compared to the proven conventionally powered buses. On top of this, it is much more difficult to set the courses for electric buses, as their range on batteries is highly variable and depends on many factors such as air-conditioning running, terrain, as well as the temperature outside (buses at lower temperatures have less range than on normal days, and they are also less effective in hot weather). Conventionally powered buses do not have such problems. Drivers and planners who are not used to the different characteristics of electrically powered vehicles may not have been able to cope with the new type of vehicle at first.

However, without data from 2021, it is impossible to determine definitively what caused this increase and whether it was just a one-off spike or the start of a new trend. Either way, a value in excess of 3% is relatively high, and unless it is just a one-off spike, related to the temporary reasons mentioned above, the company should take steps to reduce the value of this indicator.

The qualitative indicators and measures selected for the research subject's analysis are shown in Table 2.

Table 2.
Selected quantitative indicators

Name	Method of calculation	Description
Vehicle equipment malfunction meter	Number of bus equipment faults detected that do not result in a forced descent to the depot.	It reports on the number of minor bus faults mainly affecting the comfort of the journey.
Fleet age indicator	$\frac{Number\ of\ age\ group}{Number\ of\ all\ buses} * 100\%$	Shows the shares of specific age groups of buses.
Measure of lack of bus stop service	Number of stops not served	Informs about the number of missed stops.

Cont. table 2.

Passenger satisfaction index	$1 - \frac{Number\ of\ complaints - number\ of\ praises}{Inumber\ of\ completed\ services} * 100\%$	The ratio of all odds to the number of complaints minus the number of praises. In fact, it reports the number of customers extremely dissatisfied with the service.
Punctuality index	$\frac{number\ of\ delayed\ courses + number\ of\ courses\ before\ time}{Number\ of\ all\ courses} * 100\%$	It shows the ratio of the journeys on which delays or accelerations occurred to the total journeys made.

Source: Own study based on literature.

The Vehicle Equipment Malfunction Measure indicates the number of occurrences of minor equipment faults on buses that do not necessitate an immediate return to the depot and thus interrupt the service or provide a new vehicle to continue it. These are faults that do not pose a threat to passengers and traffic, and most often only reduce the comfort of the journey. Examples of faults include: faulty passenger information systems, faulty air conditioning, faulty information boards and the like. The company keeps separate records of faults of ticket punchers and the rest of the equipment. This is due to the fact that an external service is responsible for servicing the ticket punchers, and the malfunction of this element alone, although it does not pose a threat to passengers, is associated with a reduction in profits (the passengers will not punch their tickets). The values of the measure for the period 2018-2020 are shown in Figure 5.

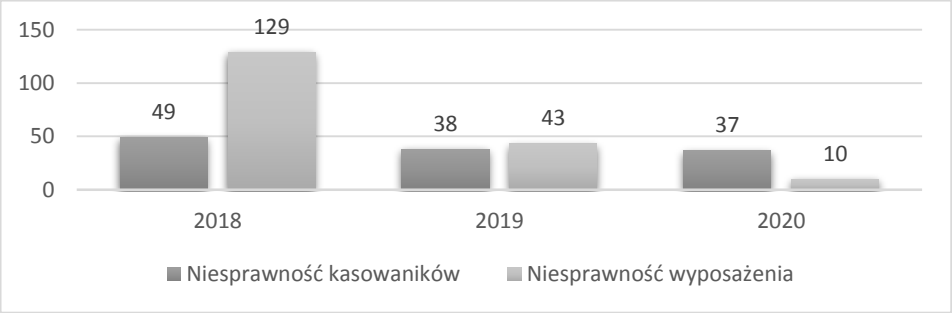

Figure 5. Values of the vehicle equipment malfunction measure between 2018 and 2020.
Source: Own study based on research results.

Analysing the data presented in Figure 4, it is possible to see a clear decrease in the number of minor faults occurring on buses in the company under study. This is a result of the intensive replacement of the company's fleet, where many old vehicles being taken out of line service and replaced with new ones. It is worth noting that the number of faults is also decreasing gradually for ticket punchers, but at a much slower rate than for buses. The current number of faults on buses is very low (only 10 such cases have been recorded throughout 2020), in the case of ticket punchers the number is slightly higher, but in their case the company cannot do anything about it anyway, because the SKUP system (Śląska Karta Usług Publicznych -

Silesian Public Services Card) was imposed by PTA and it is it who is responsible for signing service contracts for ticket punchers.

The **fleet age** indicator shows the shares of the different age groups of buses in the surveyed company's fleet. In order to carry out the analysis, the fleet was divided into three age groups: buses older than 10 years, buses between 5 and 10 years old and buses newer than 5 years old. The age of a bus was counted from its date of manufacture, not the start of line service with the company. In order to show the trend of change, data from the last 4 years were analysed. The results of the analysis of the age of the fleet by index are presented in Figure 6.

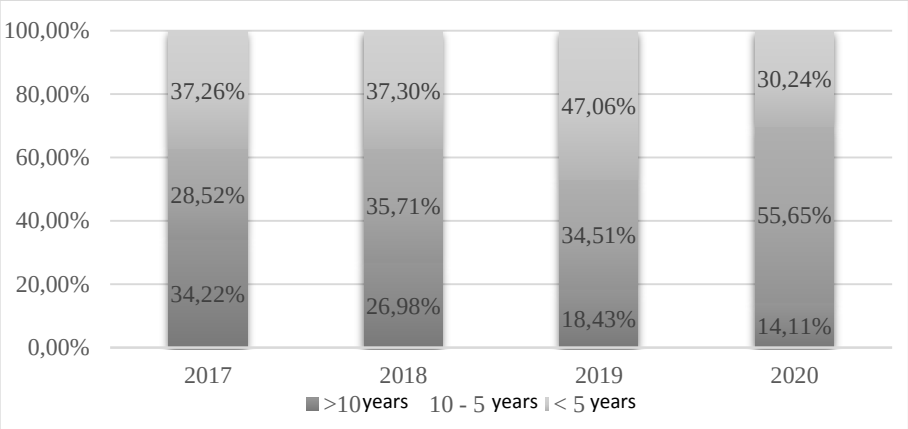

Figure 6. Values of the vehicle equipment malfunction measure from 2018 to 2020.
Source: Own study based on http://phototrans.pl/, 31.05.2021.

From the analysis of the indicator values, it can be concluded that the subject of the study is consistently upgrading its fleet by replacing old buses with new ones. The best evidence of this is the steadily decreasing number of buses older than 10 years, which decreased by about 20 percentage points in the period under study (from 34.22% to 14.11%). At the end of 2020, the fleet of the company surveyed was dominated by buses in the age range of 5 to 10 years, older buses constituted only just over 14% of the fleet, which considering the size of the fleet can be considered a good result.

The **measure of lack of bus stop service** is a very important measure affecting the reliability of public transport, and therefore one of the most important transport demands. Lack of service at a stop means that passengers are not able to start or finish their journey at the desired location. The reasons for a stop not being served can be, among others, that the stopping place is blocked by another vehicle or that the driver has made a mistake. Mistakes can occur, for example, when a driver leaves on an unfamiliar line (e.g. as a substitute) which has a variety of route options. In such situations, the new driver may inadvertently operate the wrong variant of the route, which in turn will result in some stops not being served. Such situations are very rare, as they are eliminated by dispatchers who have a full overview of the vehicle and its route, including GPS monitoring, so they can warn the driver in time that he or she is taking the wrong route. The measure results for 2018- 020 are shown in Figure 7.

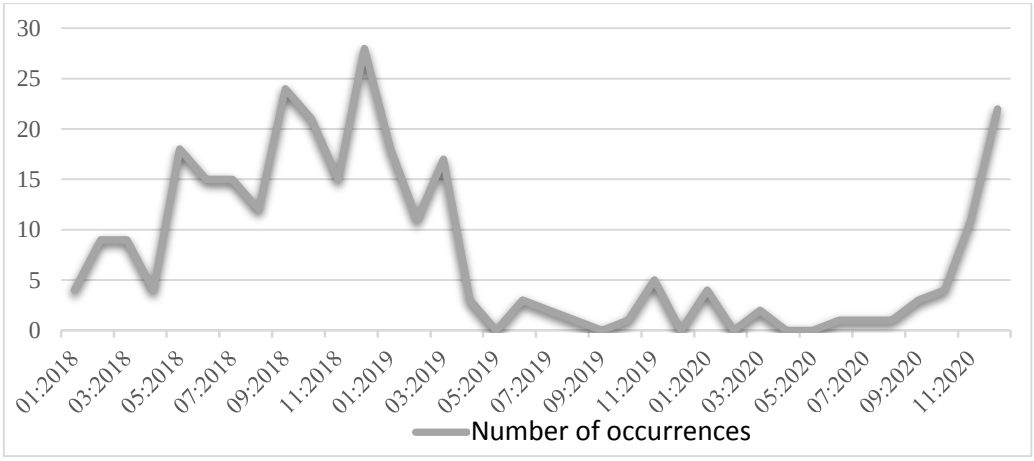

Figure 7. Measure of lack of bus stop service between 2018 and 2020.

Source: Own study based on research results.

From the analysis of the graph, it can be concluded that, although skipping stops is not a frequent phenomenon, it does occur consistently. The least amount of deviation was recorded from April 2019 to October 2020, with the number of skipped stops not exceeding five in a single month during this period. At the end of 2020, however, the measure again reached higher values, so it is difficult to say clearly whether there is a downward or upward trend. However, the number of occurrences of missed bus stop services over the entire study period is not high, as it should be borne in mind that, in addition to driver errors (which occur relatively rarely), factors beyond the control of the subject of the study also affect the lack of bus stop service, such as lack of access to the bus stop as a result of another vehicle blocking the bus stop bay, e.g. due to a breakdown or traffic incident.

The Customer Satisfaction Index allows us to determine what proportion of journeys were extremely unsatisfactory for passengers (so much so that they decided to write a complaint). Passenger complaints most often relate to lack of bus stop service (a person standing at the bus stop was not able to board the bus because it did not stop), faulty equipment (no air conditioning in 30 degree heat), faulty passenger information system, long delays or rude behaviour of the driver. The indicator values are shown in Figure 8.

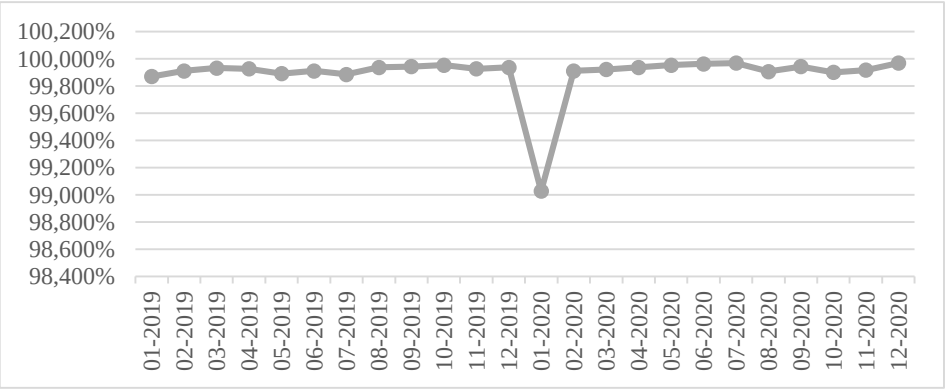

Figure 8. Customer satisfaction measure.

Source: Own study based on research results.

An analysis of the graph shows that the satisfaction index has remained at a consistently very high level over the period studied. The only significant drop was recorded in January 2020, but even then the index did not fall below a value of 99, which is a very good result. On the other hand, it should also be realised that there is probably a large group of dissatisfied passengers who simply did not make their dissatisfaction known by writing complaints. Nevertheless, an indicator that oscillates almost consistently between 99.8 and 100% can be considered a very good result.

The punctuality index shows the ratio of the number of total journeys made to those on which delays or accelerations (departures from a stop ahead of schedule) occurred. A tolerance of < 7 minutes is expected for delays. This means that only trips with a delay of 7 minutes or more are counted in the indicator. For accelerations, on the other hand, no tolerance is applied, all journeys on which at least one stop was missed before the scheduled time to the nearest 1 minute are counted. The main cause of delays is congestion. Traffic congestion prevents the smooth passage of the means of transport and thus the punctual service to the stops. The causes of congestion are usually high traffic volumes, traffic incidents and road repairs and narrowings. Not without significance is also the continuous increase in priority for pedestrians and cyclists manifested in extreme cases even by narrowing of lanes and speed limitation of motor vehicles and construction of infrastructure facilities aimed at "traffic calming" consisting in artificial speed limitation of means of transport. This unfavourable trend harms not only individual transport, but also public mass transport by lowering travel speeds, increasing travel times, reducing the capacity of vehicular roads and thus making them more prone to congestion and ultimately reducing the quality of service. Other causes can be breakdowns or traffic incidents involving the bus (ending up with the need to send a reserve vehicle, which generates delays) or extreme weather conditions combined with the lack of a proper response from the city authorities, as metropolitan residents experienced at the beginning of February 2021, when, as a result of heavy snowfall and the late response of the city's cleaning services, buses were running with delays of up to an hour, but these are extreme situations, occurring very rarely in practice. The values of the punctuality index are shown in Figure 9.

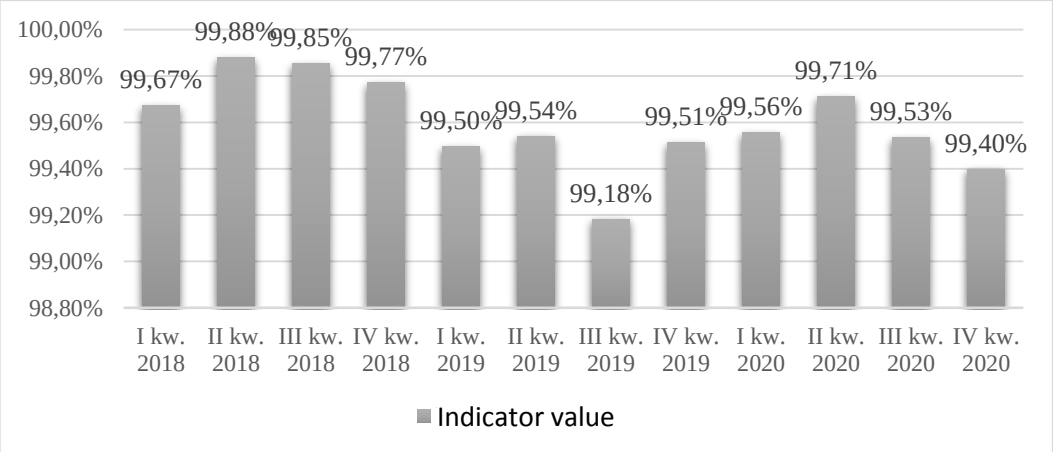

Figure 9. Punctuality index

Source: Own study based on research results.

An analysis of the values of the indicator leads to the conclusion that the number of delays and accelerations remained at a good level during the study period. The punctuality index never once fell below 99%, which is a very good result, but it should be borne in mind that a fairly large tolerance for delays of up to 7 minutes was applied. In any case, the performance of the indicator can be considered very good, analysis of the graph does not identify any repeatability other than a slight increase in punctuality in the second quarter of each year. The indicator reached its lowest value (99.18%) in the third quarter of 2019. However, this is not a large deviation, as less than 1% of courses were not on time. What is worrying, however, is the observed trend of change, showing that punctuality is on a downward trend over the period under review. Objectively speaking, however, the company has relatively little influence on the values of this measure, as traffic fluidity and the quality of the road infrastructure are dependent on authorities beyond the control of the research subject. Taking this into account, as well as the fact that the company operates traffic lines in very densely populated areas, it can be concluded that the values of the indicator are at a good level.

On the basis of the metrics and quality indicators shown above, an assessment of the reliability of the passenger transport services provided by the research subject was carried out. Each measure/indicator was given a weight corresponding to the importance that passengers attach to the parameter in question and a score according to the scale adopted below:

1. insufficient, immediate action is required to improve the parameter,
2. unsatisfactory, the company should take measures to improve the performance of the parameter in question,
3. satisfactory - the value of the indicator/measure is at an acceptable but still low level,
4. good, the value of the measure is satisfactory,
5. very good, value of the measure at a very good level, no need for any improvement actions, the company should focus on maintaining the current state.

The sum of all weighting coefficients is equal to one, and ratings were assigned according to the value of the respective measure. Based on the weights and ratings of the individual measures and indicators, a process reliability rating was calculated. It should be borne in mind that this is an assessment of indicators/measures created on the basis of data obtained from the research subject, which cover only the selected aspects of reliability and may be incomplete, i.e. not every dissatisfied passenger writes a complaint, while a relatively high tolerance for delays is used in the punctuality measure. The ratings of the adopted indicators and quality measures are summarised in Table 3.

Table 3.
Selected quantitative indicators

Name of the measure/indicator	Weight	Rating	Assessment indicator
Vehicle equipment malfunction measure	0.1	4	0.4
Fleet age indicator	0.05	4	0.2
Measure of lack of bus stop service	0.3	4	1.2
Passenger satisfaction index	0.25	5	1.25
Punctuality index	0.3	4	1.2
TOTAL	1	-	4.25

Source: Own study based on research results.

According to the ratio analysis, the overall reliability of the services of the surveyed company can be assessed as good (score 4.25). The indicators with the greatest impact on the final rating include: the passenger satisfaction indicator, the indicator of the lack of service at stops (linked directly to the postulate of certainty) and the indicator of punctuality (linked directly to the second very important transport requirement, which is punctuality).

However, it should be remembered that the indicator analysis was based on data received from the enterprise and it does not have to coincide with how these parameters are assessed by residents traveling by public transport. The indicators do not allow to analyze all the aspects that passengers may pay attention to (for example, air conditioning, travel time, etc.) and which, due to the lack of historical data, cannot be included in the indicator analysis.

Other indicators may be incomplete due to imperfections in the data collection process, such as the Passenger Satisfaction Index, which assumes that dissatisfied passengers will write complaints, which is relatively rare in practice.

4. Conclusion

Based on the ratio analysis, based on the data received from the company, it can be concluded that the public transport passenger transport services provided by the research subject are characterized by a good level of reliability. This is indicated by the high values of individual monitored measures and indicators, as well as the weighted assessment of individual criteria calculated at the end. However, it should be borne in mind that the values of the measures do not have to coincide with the passengers' opinion on the analyzed criteria, as well as the fact that there are many factors influencing the reliability, which were not included in the conducted ratio analysis due to the lack of necessary data.

Indicator analysis makes it possible to identify, those factors whose performance should be improved. However, it should be borne in mind that the indicator system does not determine the success of the enterprise, but makes it possible to improve the management of operations.

References

1. Brdulak, J. (2016). *Problemy programowania inwestycji infrastrukturalnych w transporcie*. Warszawa: ITS, p. 52.
2. Dmuchowski, R. (2019). Sposoby oceny sprawności procesów logistycznych. *Kwartalnik Naukowy Uczelni Vistula, no. 4(62)*, p. 94.
3. Ejdys, S. (2017). System transportowy w aspekcie funkcjonowania aglomeracji. *Transport i logistyka w przedsiębiorstwie, mieście i regionie. Wybrane zagadnienia*. Katowice, pp. 67-76.
4. Ejdys, S.(2014). *Optymalizacja miejskiego transportu zbiorowego na przykładzie miasta Olsztyna*, rozprawa doktorska. Białystok, pp 42-43.
5. Gołembska, E. (2016). Kompendium wiedzy o logistyce. Warszawa: PWN. p. 316.
6. Gramza, G. (2011). *Autobusy. Technika, Eksploatacja, Systemy transportowe, 12*, pp. 128-133.
7. Hofman, L. (1968). *Ekonomika żeglugi śródlądowej*. Gdynia.
8. Kurowski, J. (2017). System transportowy i jego uwarunkowania – aspekty gospodarczo-obronne. *Zeszyty Naukowe ASzWoj, no. 2(107)*, pp. 98-104.
9. Rydzkowski, W., Wojewódzka-Król, K (1997). *Transport.* Warszawa: PWN, p. 239.
10. Twaróg, J. (2003). *Mierniki i wskaźniki logistyczne.* Poznań: Biblioteka Logistyka, ILiM.
11. Wyszomirski, O. (2008). *Transport miejski. Ekonomika i organizacja*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego, pp. 9-10.