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The Quality and Costs of Urban Transport Services and Logistics of Cost Management

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Abstract
The subject of the article concerns the issues of the quality of transportation in urban public transport and the costs of urban transportation. Specifically, the article addresses topics such as the quality of transport services; characteristics of the quality of transport services; the structure of urban transport costs; procedures for estimating the operating costs of urban transport and factors shaping the cost levels; the characteristics of external costs as well as the role of logistics in estimating the value of time and congestion costs in urban transport. The article concludes with summarizing remarks, mainly of a utilitarian nature.

Keywords: urban transport, quality and costs of transport, logistics of cost management, transport congestion

INTRODUCTION

In an urban transportation system, public transport plays a particularly important role—both due to its significance for the proper functioning of a city from social and economic perspectives, and because it constitutes a specific area of economic activity. The distinctive nature of this field arises from the type of transport needs it fulfills and from the fact that, within a single system, it involves the operation of various modes of transport within a spatially limited urban area. The performance of urban transport is determined by two fundamental parameters: the quality of service and the cost structure.

The aim of this publication is to:

- the assessment of the quality of transport services (in terms of quality indicators, components of the journey, and market segments), with particular emphasis on the quality perceived by passengers and the transport demands directed toward public transportation,
- the assessment of the cost structure of urban transport, as well as the factors influencing the level of internal and external costs, including time costs and transport congestion costs (based on a multi-criteria analysis).

The research problem is encapsulated in the following question: What are the possible ways to effectively enhance the quality of services in passenger public transport, and how can internal and external cost levels be optimized, as well as transport congestion reduced?

The research method involves identifying the issues based on a review of subject literature (including works by W. Starowicz and O. Wyszomirski), as well as an analysis of statistical studies on transport service quality in urban transport, presented in the Bulletins of the Wrocław Roads and Transport Authority.

The analysis is conducted with consideration of three levels of responsibility involved in urban public transport: the municipal government, the transport organizer, and the transport operators (including, in most cases, at least one operator that functions as an agency or company owned by the municipal government).

1. QUALITY OF TRANSPORT AND CHARACTERISTICS OF TRANSPORT SERVICE QUALITY

The transportation process is a fundamental element of the transport service, whether it concerns the transport of passengers or goods. The quality of transport is the most important element of the quaity of transport service[17]. W. Starowicz [18], when analyzing the quality of transport in urban transport, proposed the following definition: the quality of transport is the degree to which the transport needs of city residents are met, measured by the set of transport demands submitted by passengers.

The authors of the publication [15], in formulating assumptions for research on quality in public transport, assume the thesis that the quality of transport should be assessed in regards to the following three layers:

1. quality carriers, e.g., stations, intermediate stops, vehicles, traffic services (this can be particularly useful for separating the responsibility for quality in transport service contracts),
2. components of the journey (so as to be able to influence the components that need improvement first),
3. market segments (e.g., populations of passengers characterized by decreasing mobility, in order to regain them as customers of the system).

The urban public transport system is primarily a techno-human system, meaning it has a complex internal structure and, thus, a complex process of quality assessment. The quality of the system's operation can be evaluated from the perspective of at least four entities [17]: the passenger, the carrier, the transport manager, and the local government (municipality). This evaluation is a complex process of value judgment, based on many criteria. The most important evaluation comes from the passenger's perspective, which should also be reflected in the assessment by the authorities. The carrier is interested in the evaluation result due to the competitive element and potential economic consequences as well as job satisfaction. For the manager, the evaluation of the existing public transport system is crucial information necessary for making rational decisions related to its ongoing improvement and further development.

The quality of transport services in urban public transportation is considered an issue inextricably linked to the production of services, as unsatisfactory quality can reduce the utility of the service provided. The organization of the production process of transport services creates the framework within which distribution, administrative, and passenger service processes take place. Mastering these processes and ensuring their continuous improvement are the essence of quality management. In the case of urban public transportation, there are three levels of responsibility for the shape and quality of transport services [17], namely the local government, the transport organizer, and the carriers, with at least one carrier typically being an agency or company of the local government. Therefore, when analyzing the quality of transport services, it is important to simultaneously consider the perception of this quality from the perspective of the carrier, the passenger, and through the lens of planning and implementation (Fig. 1) [17]. The shaping of quality will also depend on the adopted solutions in organization and management.

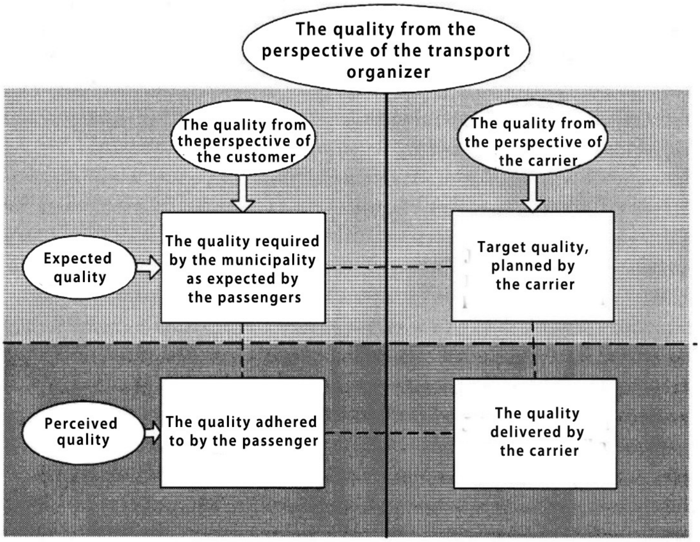

Fig. 1. The quality of service in urban public transport.
Source: Starowicz W.; Quality of service in urban public transport. Wyd. Politechniki Krakowskiej im. Tadeusza Kościuszki, Kraków 2007 [17]

An important issue is also the connection between the quality of public transportation, costs, competition between carriers, and passenger satisfaction.

In the search for effective ways to improve service quality in passenger public transport, one can also point to the conclusion of contracts with carriers that include quality criteria.

It is worth mentioning the results of the QUATTRO research project [12, 17], conducted under the 4th Framework Programme of the European Commission – Urban Transport. The focus of the project was to explore proposals for improving quality in urban public transport. The starting point for these proposals was the concept of a quality loop, based on the ISO standards, with the following concepts: expected (required) quality, planned quality, delivered quality and perceived quality.

Expected quality is the level of quality that the customer anticipates and should be defined by the municipality as the required level. Planned quality is the level of quality that the operator intends to provide to passengers. Delivered (actual) quality is the level of quality achieved under normal operating conditions. Perceived quality is the level of quality based on the evaluation (as objectively as possible) by passengers during the journey.

The quality loop illustrates perspectives from two points of view: one from the perspective of the customer and the municipal authorities representing them, and the other from the perspective of the carrier providing the services [17]. Improving the effectiveness of services and their quality means eliminating four "gaps" [17]

- between perceived quality and expected quality,
- between expected quality and planned quality,
- between planned quality and delivered quality,
- between delivered quality and perceived quality.

The most important gap is the first one, as it represents the difference between passengers preferences and their satisfaction.

The quality of transport services in urban public transport is determined by a set of characteristics that describe this quality from the perspective of the transport organizer, the carrier and the passengers. Due to the desired quality of the transport service, these characteristics are also referred to as transport requirements. They reflect the preferences expressed by passengers regarding urban public transport [17]. A classic presentation of transport requirements is provided by W. Starowicz [17] in Figure 2. Transport requirements formulated with regard to the practical possibility of analyzing them within marketing research most often include [2, 17, 24]: safety, cost, travel time, and travel comfort.

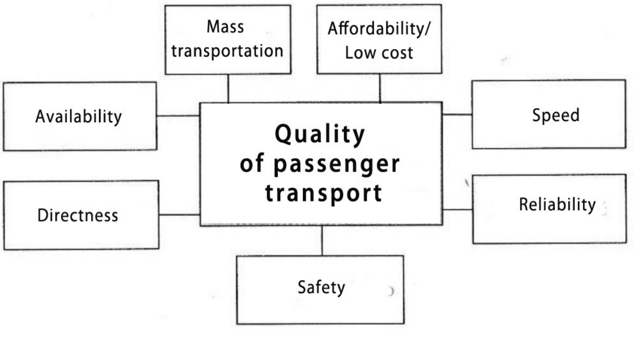

Fig. 2. The classic presentation of transport requirements addressed in regard to public transport
Source: Starowicz W.; *Quality of service in urban public transport. Wyd*. Tadeusz Kościuszko Kraków University of Technology Publishing, Kraków 2007 [17]

Travel time as a transport requirement is considered through the lens of factors defining its individual phases, which are [17]: walking to the stop, waiting for the means of transport, the ride, transfers, walking from the stop to the destination.

The partial requirements related to travel comfort, in this case, are formulated by O. Wyszomirski [17, 25] as follows: passenger service culture, ease of boarding and disembarking from the vehicle, appropriate standard of stop facilities, the possibility of resting during the ride (providing a seat and suitable temperature), ease of ticket purchase. An illustration of this approach, following an established convention, is presented in Figure 3 [17].

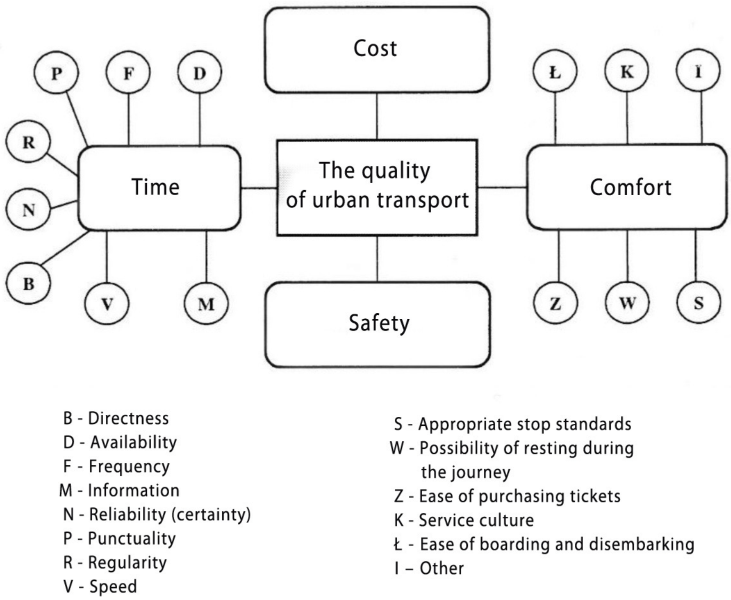

Fig. 3. Marketing approach to transport requirements addressed to public transport. Source: Starowicz W.; Quality of service in urban public transport.. Wyd. Tadeusz Kościuszko Krakow University of Technology Publishing, Kraków 2007 [17].

The perspective presented above on transport requirements was modified by A. Rudnicki in the technical environment. It encompasses five synthetic criteria [16, 17]: availability, reliability, travel time, travel conditions and travel ecology. The entire set of synthetic criteria is divided into 34 partial criteria. This approach is presented in Figure 4 in the form of a block diagram. The meanings of the symbols related to individual partial criteria are discussed in the publication [17]. For example, in the group of synthetic criteria "Availability," the symbol Dp, belonging to the group of partial criteria, denotes: "connections of urban public transport with other means of public (regional, national, international) and individual transport – convenience of transferring from a car (Park and Ride) and from a bicycle."

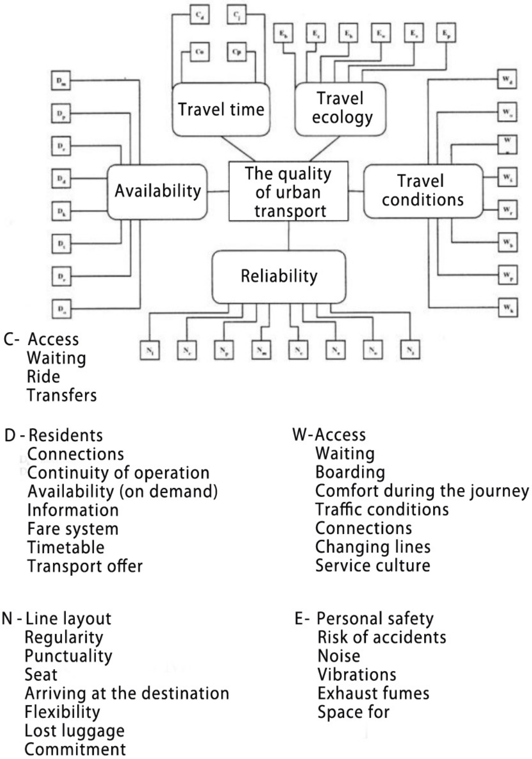

Fig. 4. Modified marketing approach to transport demands with an expanded list of partial criteria.

Source: Rudnicki A.; The quality of public transportation. Zeszyty Naukowo-Techniczne Stowarzyszenia Inżynierów i Techników Komunikacji, Seria MONOGRAFIE, No. 5, pp. 39-44, Kraków 1999 [16], Starowicz W.; Quality of service in urban public transport. Wyd. Politechniki Krakowskiejim. Tadeusza Kościuszki, Kraków 2007 [17]

In his publication [17], W. Starowicz presents a list of passenger service standards tailored to Polish conditions (Fig. 5), corresponding to the requirements set for public transport in urbanized areas of European Union countries. These standards are categorized into four synthetic groups [17]: availability (with two partial criteria), travel time (with five partial criteria), travel conditions (with two partial criteria), reliability (with three partial criteria). The significance of each partial criterion is discussed in the monograph [17].

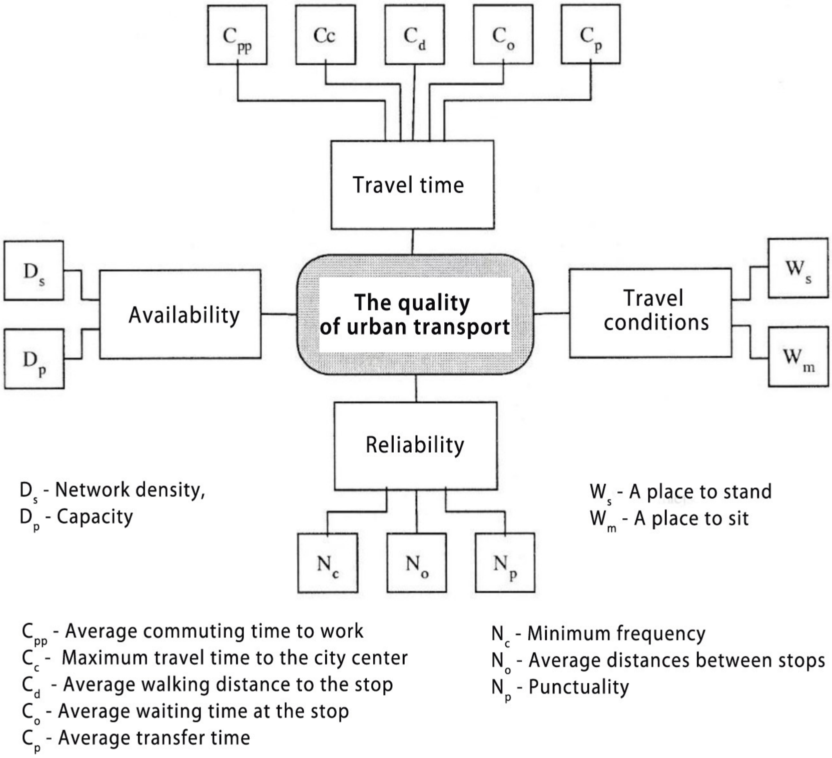

Fig. 5. Polish standards of passenger service.
Source: Starowicz W.; Quality of service in urban public transport. Wyd. Politechniki Krakowskiej im. Tadeusza Kościuszki, Kraków 2007 [17]

2. THE STRUCTURE OF URBAN TRANSPORT COSTS

Considering urban transport in a broad sense as all mechanized methods of passenger movement within an urbanized area, it is possible to distinguish the costs of: collective and individual transport [26].

Calculating urban transport costs per unit of transport work in collective and individual transport, taking into account the full scope of costs, forms the basis for rationally determining the sphere of substitution and complementarity between both types of transport [26]. Within urban and individual transport, costs can be divided into: direct costs, transport infrastructure costs and external costs. Direct costs are the costs borne by transport organizers and carriers in collective transport, and by vehicle operators in individual transport. Transport infrastructure costs refer to the expenses related to its construction and maintenance, which are not covered by user fees and are therefore borne directly by the state and local governments. External costs are environmental costs and the costs of transport accidents that are not covered by user fees. There are attempts to classify the time lost by passengers and drivers during individual transport trips as external costs. However, this approach is debatable, as time loss is considered part of the users' costs, being their own cost of taking the trip. Time, although a philosophical category, has a (known) value. Therefore, there is a need to account for time in urban transport costs. It cannot be included in direct costs, as the passage of time does not generate direct monetary expenses. Hence, there is the possibility of categorizing time costs as external costs or treating them as an additional category of urban transport costs [26]. Direct costs, transport infrastructure costs, external costs and time costs together form the so-called social costs of urban transport, which are presented in Table 1 according to [26].

Table 1. The cost structure of urban transportation.

<table>
<tr><td rowspan="6">Social costs of public transport</td><td>Direct costs</td><td rowspan="2">Costs of transport organizers, carriers, and those operating their own vehicles</td></tr>
<tr><td rowspan="2">Costs of transport infrastructure not indifferent to direct costs</td></tr>
<tr><td rowspan="2">Costs of the state and local governments</td></tr>
<tr><td rowspan="2">External costs</td></tr>
<tr><td rowspan="2">Costs of residents and society as a whole</td></tr>
<tr><td>Time costs</td></tr>
</table>

Source: Wyszomirski O.; *Urban Transportation. Economics and organization.* University of Gdańsk Publishing, Gdańsk 2008 [26]

A broad understanding of the concept of urban transport costs is essential for their proper assessment and analysis, which forms the basis for decisions related to the development of transport in urbanized areas. Among the key statements regarding this issue, it is worth citing the following [23]: "on a large scale, environmental aspects, including safety and social issues, must be at the core of transport policy at the national, regional and continental levels."

3. DIRECT COSTS OF URBAN TRANSPORT AND FACTORS AFFECTING THEIR LEVEL

The direct costs in public transport are borne by the companies involved in organizing and carrying out transportation services. The term "direct costs" in these companies refers to the economic expenditures that must be spent and accounted for during a specific period of their operations. Direct costs are classified according to various criteria based on their usefulness for making economic decisions. In the structure of direct costs of urban transport, classified by the type of cost, the following categories can be distinguished: depreciation, fuel, energy, tires, wages and wage surcharges, basic materials and other costs. In turn, according to the place of origin, the following categories are distinguished: fuel, oils and lubricants, tires, other materials and non-durable goods, energy, depreciation, operational repairs and maintenance, wages and wage surcharges, uniforms, business trips, other direct costs, departmental costs, general company costs and sales costs [26].

Depreciation plays an important role in the structure of the direct costs of urban transport. Depreciation allowances enable the accumulation of funds to purchase new vehicles. In the fleet structure of urban transport companies, there are vehicles that are:

- not depreciated, for which depreciation allowances are made,
- depreciated, for which depreciation allowances are no longer made. Companies should implement an appropriate policy regarding the purchase of vehicles to ensure the proper share of depreciation in costs and, at the same time, to avoid losses in the income statement with the given revenues [4, 26].

It is also crucial to determine the depreciation period of the fleet. The minimum period is regulated by appropriate regulations. In certain situations, adopting such a condition may lead to a significant increase in depreciation costs during a given period and, consequently, to the company being burdened with losses [26].

Another important item in the structure of the direct costs of urban transport are the costs associated with the work of vehicle drivers. The specificity of urban transport means that there are limitations on the potential to increase labour productivity with the introduction of modern technologies, as observed in other sectors [26].

The measure of efficiency for transport companies is the number of vehicle kilometers and passengers transported per driver. The increase in these two indicators is limited by the following factors [5]:

- parameters of the linear infrastructure (e.g., single-track tram lines with passing loops allowing vehicles to travel in opposite directions),
- passengers desire to increase travel comfort by reducing vehicle occupancy,
- passengers expectations regarding the increase in vehicle frequency,
- expansion of low-density areas served by urban transport,
- reduction in operating speed (due to growing traffic on the roads),
- the need to ensure rest for drivers (required stop times at tram and bus terminals).

The system of hiring and compensating vehicle drivers has a specific impact on the level of costs associated with their work.In the analysis of direct costs, the selection of the appropriate cost driver, i.e., the unit of calculation, is crucial. This is the unit to which the costs will be allocated. In urban transport, the primary cost driver is the vehicle kilometer, which represents the distance traveled by a vehicle over one kilometer. Other cost drivers include [26]: the vehicle hour (the work of the vehicle for one hour), the vehicle as a mode of transport, and the route on which the vehicle operates [26].

When analyzing the factors determining the level of direct costs in urban transport, it is necessary to classify costs based on their dependence on the respective cost drivers, such as [26]: costs dependent on the number of vehicle kilometers traveled, costs dependent on the number of vehicle hours worked, costs dependent on the number of vehicles in operation, and costs dependent on the length of the routes traveled.

Considering that vehicle kilometers are the basic unit of cost calculation in urban transport, costs dependent on the number of vehicle kilometers traveled can be considered variable, while costs dependent on the number of vehicle hours worked, the number of vehicles in operation, and the length of the routes can be regarded as fixed. These costs have this characteristic based on their relationship with the number of vehicle kilometers traveled [26].

The variable costs dependent on the number of vehicle kilometers traveled include [26]:
- fuel materials, oils and lubricants, as well as electricity for traction purposes (k_{mp});
- automotive tires (k_{op});
- operating repairs and overhauls of rolling stock, tracks, and traction network (k_{rt}).
- variable costs (k_z) per 1 vehicle-kilometer are expressed by the formula [26]:

$$k_z = k_{mp} + k_{op} + k_{rt} \tag{1}$$

When calculating the depreciation of rolling stock using the mileage method, depreciation of fleet should also be included in this group of costs.

The fixed costs dependent on the number of vehicle-hours performed include [26]:
- wages, social insurance and uniforms for the vehicle crew (k_{vr});
- movement materials, excluding fuel materials and tires (k_{mr});
- traffic department costs (k_{ow});
- overhead costs allocation (k_{oz}).

The fixed costs (ksg), per 1 vehicle-hour are calculated using the formula:

$$k_{sg} = k_{vr} + k_{mr} + k_{ow} + k_{oz} \tag{2}$$

The fixed costs dependent on the number of vehicles in operation include [26]:
- depreciation of rolling stock (k_{vr});
- technical inspections of rolling stock (k_{pw}).

A technical inspection is performed for each vehicle once a day, regardless of its daily mileage. Therefore, the costs of vehicle inspections are included in the group of costs mentioned above.

The fixed costs (k_{sp}), per 1 vehicle are expressed by the formula:

$$k_{sp} = k_{aw} + k_{pw} \tag{3}$$

The fixed costs dependent on the length of the operated routes, which are specific only to tram, trolleybus, metro and rapid urban rail transport, include [26]: depreciation of tracks and network (kal) and inspections of tracks and network (kpl). Isolating the costs of track and network inspections generates similar difficulties as isolating the costs of vehicle inspections. The fixed costs per 1 km of route (kss) are calculated as:

$$k_{ss} = k_{al} + k_{pl} \tag{4}$$

Based on the presented cost breakdown, the total direct cost (Kc) in urban transport is expressed by the following equation [26]:

$$K_c = W_{km}\, k_z + W_g\, k_{sg} + W_e\, k_{sp} + L_t\, k_s \tag{5}$$

where:

W_{km} – number of vehicle-kilometers performed,
W_g – number of vehicle-hours performed,
W_e – number of vehicles in the fleet (fleet inventory),
L_t – length of operated routes,(the other notations as previously defined).

The unit cost in urban transport (kwkm) is the ratio of the total direct cost to the number of vehicle-kilometers performed:

$$k_{wkm} = K_c\, (W_{km})^{-1} \tag{6}$$

Substituting into the above formula (5) gives the following:

$$_{km} = k_z + W_g\, k_{sg}\, (W_{km})^{-1} + W_e\, k_{sp}\, (W_{km})^{-1} + L_t\, k_{ss}\, (W_{km})^{-1} \tag{7}$$

The dependencies in the above formula are transformed into three specific technical and operational indicators developed by O. Wyszomirski [26]:

1. operational speed indicator (v_e):

$$v_e = W_{km}\, (W_g)^{-1} \tag{8}$$

2. Indicator of the number of vehicle-kilometers performed per year (w_{kmw}) by one vehicle in the fleet:

$$w_{kmw} = W_{km} (W_e)^{-1} = w_{tr} \cdot d_n \cdot g \cdot v_e \quad (9)$$

where:

w_{tr} – fleet utilization coefficient, which is the ratio of operational vehicle depots to total vehicle depots,

d_n – number of days in operation,

g – average daily operating time of vehicles, i.e., the ratio of the number of vehicle-hours in service to the number of vehicles in service;

3. Indicator of the number of vehicle-kilometers performed per year per 1 km of operated routes w_{kml}l):

$$w_{kml} = W_{km} (L_t)^{-1} = s_t \cdot w_{tr} \cdot d_n \cdot g \cdot v_e \quad (10)$$

where:

s_t – number of vehicles in the fleet assigned to 1 km of operated routes.

After substituting the expanded form of the technical and economic indicators into formula (7), the following version of the formula for calculating the cost per 1 vehicle-kilometer is obtained [26]:

$$k_{wkm} = k_z + k_{sg} (v_e)^{-1} + k_{sp} (w_{tr} \cdot d_n \cdot g \cdot v_e)^{-1} + k_{ss} (s_t \cdot w_{tr} \cdot d_n \cdot g \cdot v_e)^{-1} \quad (11)$$

The relationships of the unit cost per vehicle-kilometer in the formula (11) indicate that it is shaped by the following factors [26]:

- the level of unit variable costs, dependent on the number of vehicle-kilometers performed,
- the level of unit fixed costs allocated to 1 vehicle-hour, 1 vehicle in the fleet, and 1 km of operated routes;
- operational speed,
- the number of days of vehicle operation,
- the average daily operating time of vehicles,
- the fleet utilization coefficient,
- the number of vehicles in the fleet per 1 km of route.

The unit cost per vehicle-kilometer is lower when the levels of the costs listed above are lower and the levels of the aforementioned technical and operational indicators are higher.

Under specific conditions, it may be useful to conduct an analysis of the factors shaping the cost per seat-kilometer. Such an analysis requires substituting the number of vehicle-kilometers performed with the number of seat-kilometers performed in formula (7). According to [26], a possible solution for a transport line is to adopt a single cost carrier in the form of vehicle-kilometers.

The cost of a vehicle kilometer incurred by the carrier on a transportation line is shaped by [26]:

- the number of vehicles that must be in the fleet to service the line,
- the utilization rate of these vehicles,
- the average daily operating time of the vehicles, calculated on a weekly basis,
- the number of days per week during which the vehicles are in operation,
- the operational speed.

The cost of a vehicle kilometer on a transportation line should serve as the basis for the carrier to prepare an offer for the service of the line in response to a tender announced by the organizer.

In the analysis of direct costs, the calculation structure is of significant importance. A tool that can be used for calculating unit costs in urban transport is a spreadsheet. Such a spreadsheet (for bus fleets) was included in O. Wyszomirski's work [26]. It contains three groups of costs: direct costs dependent on the fleet's mileage, direct costs dependent on working hours, and indirect costs. Based on the spreadsheet, assessments are made regarding the impact of various factors on the unit cost.

The spreadsheet layout can be modified, for example, by replacing the consumption of liquid fuels with electricity consumption and adding costs for linear infrastructure (tram tracks); as a result, a cost calculation for tram transport is obtained [26].

4. CHARACTERISTICS OF EXTERNAL COSTS IN URBAN TRANSPORT

External costs are related to the negative environmental impacts of transport activities [26]:

- noise emission;
- air, water and soil pollution;

- transport accidents (partially not covered by insurance and compensation systems);
- land occupation.

External costs are not borne by transport companies or personal car users, but by a third party, that is, by society as a whole, consisting of individual citizens (residents).

The purpose of calculating external costs is their internalization. This means assigning the negative effects of transport to those entities that cause them and are responsible for them. Through the internalization of external costs, it is possible to introduce appropriate economic and fiscal regulations that aim to encourage users to choose the appropriate mode of transport. The internalization of external transport costs is an issue within transport policy. Implementing the internalization of external costs requires [22, 26]:
- knowledge of the types and levels of external costs,
- tools for transferring external costs to the company's own cost account.
- Three main objectives of estimating external costs in urban transport are distinguished [26]:
- obtaining a macro assessment of the consumption of environmental resources,
- establishing decision-making foundations for regulatory and pricing transport policies,
- assessing the impact of transport on the environment to determine the costs and benefits of infrastructure investments.

The valuation of external costs in transport is most commonly carried out using two complementary approaches, based on the valuation of [21, 22, 26]:
- damage caused by transport activities,
- the necessary expenditures to restore the original state or protect against external effects.

It is also important to focus on the costs of road accidents. These represent specific social losses related to death and injuries of individuals, as well as damage to vehicles and disruptions in traffic. In the literature on the subject, these costs are divided into [9]:
- direct costs, related to vehicle damage, treatment of the injured, administration, etc.;
- indirect costs, related to the reduction in national income due to death and injuries;

- losses related to moral damages and the risk of exposure to accidents.

In the field of methodology and accounting for external costs, two research institutes in Europe have made the greatest achievements [26]: the Swiss INFRAS (Zurich) and the German IWW (Karlsruhe). According to the results of studies by these institutes, the main types of external costs in transport are [1]:
- climate change (30% of external costs),
- emissions of engine exhaust gases into the atmosphere (27% of external costs),
- losses generated by road accidents (24% of external costs)

5. LOGISTICAL ASPECTS OF ESTIMATING THE VALUE OF TIME AND CONGESTION COSTS IN URBAN TRANSPORT

A specific feature of urban transport is its connection with the user's time. The time consumed by transport can be treated as a cost of its operation because – depending on the means of transport or mode of travel – the travel times in the 'door-to-door' relationship vary. The measure of the value of time is actually the utility derived from using it in a specific way, and this value depends on various factors [26]. According to J. M. Thompson [21, 26], the value of time differs depending on whether:
- the alternative is more time at home or at work,
- time savings can be predicted or not,
- time savings are regular or not.

In the monograph by I. Tarski [20], there is a discussion of methods for determining the value of time in passenger transport, with particular emphasis on the production, income, cost, and income-cost methods. According to O. Wyszomirski's assessment [26], none of these methods is fully satisfactory due to significant discrepancies in the results.

In the attempts to estimate the value of time lost in transport, two main methods are generally recommended [26]. The first method is based on assuming the value of an hour of work, including overheads, while considering the purpose of the journey. In the second method, the value of time is determined as the hourly value of national income produced by society. The first method, relating to the value of an hour of work, is most commonly used as the most measurable approach [14]. When determining the value of travel time in relation to one hour of work, the purpose of the journey is taken into account (work-related and non-work-related travel), as well as the socio-economic status of the passenger (working and non-working individuals).

In addition to the topic of time costs, it is important to highlight the issue of estimating the capacity of road and street intersections. In the procedures for calculating capacity, time losses are considered, which also represent costs, measured, for example, by fuel consumption. This issue belongs to the scientific discipline known as traffic engineering [6, 19]. Capacity is fundamental to the design or evaluation of intersections in relation to existing traffic needs. However, capacity is not the only measure of intersection efficiency. In practice, various measures are used to assess traffic conditions at an intersection, including [6, 19]:

- average time losses,
- average queue length,
- time loss distributions (standard deviation, quantiles, distribution shape),
- queue length distributions (standard deviation, quantiles, distribution shape),
- number of vehicles coming to a stop,
- probability of no vehicles waiting for service.

These measures can be estimated using queueing theory and simulation models.

For the purpose of designing new intersections and evaluating traffic conditions at existing intersections, traffic conditions are defined by the so-called levels of service (LOS) [6]. These levels are a qualitative characterization of traffic conditions, taking into account the perceptions and assessments of the driver population. They correspond to intermediate conditions between smooth traffic flow with minimal disruption and traffic at the saturation point, when the traffic intensity is equal to the capacity. In the Polish method for calculating capacity, the entire range of traffic conditions variability is divided into four states, describing the conditions as: very good (PSR I), good (PSR II), average (PSR III), and unfavorable (PSR IV). In the American HCM method and the German HBS method, six levels of service are distinguished [8, 10]. The primary criterion for dividing into these levels is the average time loss per vehicle. The boundary values of average time losses for the respective traffic levels, adopted in Poland, the USA and Germany, are provided in the handbook [6].

A key factor that significantly determines travel time is traffic congestion, which occurs in road transport. Traffic congestion is the result of the mutual interaction between infrastructure users and vehicle users. It leads not only to negative operational effects but also to economic ones, which increase as a function of the number of users.

Congestion costs arise from the shortage of infrastructure capacity. They are typically defined as the additional costs compared to the so-called free flow, where vehicles are able to travel without obstacles caused by other users of the infrastructure. The largest portion of congestion costs in urban transport is related to travel time costs (i.e., time losses). The second significant type of congestion costs is the increase in vehicle operating costs. This includes additional fuel or energy costs, additional wages, increased vehicle wear-and-tear costs, as well as additional repair and maintenance expenses. In the long run, without proper intervention from authorities to address congestion, achieving the same level of transport service requires deploying more vehicles. Congestion leads to higher vehicle operating costs due to extended operating times and deteriorating operating conditions. It is estimated that the share of congestion costs in vehicle operating costs in urban agglomerations ranges from 15-20%. J. Gronowicz [7] defines traffic congestion as the difference in resource costs between the road network operating under current traffic conditions and the road network operating under ideal conditions, where delays are eliminated, and traffic flows at the maximum safe speed.

In road transport, two types of congestion are distinguished [7]: congestion on the transport network and congestion in transport vehicles.

Regarding congestion on the transport network, there is congestion on transport routes (roads) and congestion at transport points.

Vehicles are affected by congestion on the roads, and its consequences are experienced by vehicle owners, cargo owners as well as drivers and passengers. Congestion at transport points impacts vehicles, and also directly affects cargo and passengers. Congestion on the transport network can also be caused by the need to control vehicles, cargo, and passengers or by road modernization, repairs, or reconstruction. A specific case of congestion on the transport network is the overcrowding of vehicle parking areas (e.g., parking lots) [11]. Well-known scientific studies show that the highest congestion costs occur during peak hours and within urban agglomerations.

The issue of the impact of congestion on environmental pollution also exists in the case of road transport (mainly urban), and it results, among other things, from [7]:

- engine running at idle,
- maneuvers such as braking and accelerating the vehicle, and other unfavorable phenomena occurring on congested streets.

O. Wyszomirski [26] recommends considering congestion costs in terms of average and marginal costs. The appearance of a new road user leads to an increase in total costs, equal to the sum of the average cost calculated at the existing traffic intensity and the congestion cost, which is borne by all vehicles. This is, therefore, the marginal cost, reflecting the additional costs caused by an extra vehicle in relation to the given traffic intensity levels. This cost depends on the number of traffic participants, the conditions on the road, time-dependent unit costs, and clearly, on the driving speed.

6. SUMMARY REMARKS

In the third chapter of this article, the issue related to the system of hiring and compensating drivers was mentioned, which can have a certain impact on the level of costs associated with their work. A recommended solution (by O. Wyszomirski [26]) in terms of cost levels is the application of a system of so-called equivalent working time norms, which involves accounting for working hours not on a daily basis, but over a longer period, at least a month. This eliminates the need to employ a driver for a specific period after completing a task for up to 8 hours without driving the vehicle and paying overtime for driving the vehicle beyond 8 hours. In urban transport, due to the need to adjust transportation tasks to demand, not using equivalent working time norms results in a noticeable increase in costs at the given level of personal classification rates. It is also a cause of waste of working time [26].

When analyzing congestion costs in urban transport, it is worth (according to O. Wyszomirski's proposal [26]) distinguishing between the direct costs of transport, transport infrastructure costs, and external costs, including time costs. Focusing on this category of urban transport costs (congestion costs) aims to emphasize the specific nature of transport costs in cities, in the context of the mass development of individual motorization. There is potential to minimize these costs through the appropriate division of transportation tasks.

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