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SUMMARY

PhD Thesis

Research on improving the quality of urban public transportation
CERCETĂRI PRIVIND CREȘTEREA CALITĂȚII TRANSPORTULUI PUBLIC URBAN DE CĂLĂTORI

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Chapter 1. THE NEED AND OPPORTUNITY OF THE RESEARCH TOPIC

1.1Introduction

The development of urban settlements cannot be achieved without the contribution of quality public services. These are no longer considered the privileges of cities, and even less of large cities, but their smooth operation in large urban agglomerations involves special obstacles, the difficulty of which exceeds the level estimated from the simple increase in the population served.

Although it has acquired an important position within human activities, urban public transport continues to be a problem in modern cities and is generally subordinated to political currents. On an international level, technicians, economists and specialist bodies are increasingly alerting the political class to the importance of public transport in the planning and efficient use of the territory, as well as the need to analyze this activity and through the indirect advantages that the whole society benefits from, including the categories who do not use this service (UNDP 2015). These advantages justify the involvement of the authorities in financing the development and exploitation of public transport, whose malfunction or temporary interruption can cause serious disturbances in all fields of activity.

Increasing levels of traffic congestion and poor air quality in many urban agglomerations have led to the need for a reliable public transport system to reduce city dwellers' dependence on the private car. Public transport is an efficient and ecological alternative compared to individual car use (Kathuria 2020)(Kouvenhoven 2014)(Ferreeira 2014).

Focusing on the interests of pedestrians in their daily journeys to a public transport station or from such a station to their home, at the end of their journeys in urban planning actions can lead to increasing the urban accessibility of the inhabitants by reducing the discomfort and inconvenience caused by walking . A reduction in the use of motorized travel is well known to have an impact on air quality. The solutions of smoothing road traffic and the location and arrangement of more parking become obsolete after a certain period of time when the rate of motorization increases again. In conclusion, we can say that the city that is based on motorized mobility and road transport ends up being no longer efficient or economical, in addition to the aggressions on the natural environment that the solutions aimed at the development of road traffic infrastructure generate.

The public transport of passengers in the urban environment represents a benefit, a useful activity, a service, for the movement of travelers in space on predetermined routes, with a predetermined and known (published) timetable and with predetermined tariffs known to the traveling public. Costs for public transport services can be fully or partially supported by the users, or they can be supported by the public budgets of the communities.

Public passenger transport is an obligation of local, regional or central public authorities to ensure the "right to mobility" of the inhabitants.

At the same time, public passenger transport, as an independent activity, can only be initiated under the conditions of a certain level of economic development in an urban space, i.e. where there is the possibility of economic support from the entire society/community served (called in the literature "supportability") (Gómez-Lobo 2011).

The community supports the development of the infrastructure of the public transport network, terminals/stations, service centers, rolling stock and all other elements necessary for the operation of the public transport system through the responsibility it has transferred to the local public authority to ensure access to public services of transport.

The development of the public passenger transport system is closely intercorrelated with the development of the entire urban, regional or national environment that it serves. Thus, an urban environment in development, with economic and social activities with accentuated intensity, requires the consequent development of the passenger transport system both for trips to workplaces, but also for all other purposes that the literature mentions as significant (Popa 2009, Raicu&Costescu 2020): trips for educational, commercial/supply purposes, but also those for health or business. Trips for recreational purposes were gradually transferred to individual mobility by car, no longer representing a purpose of travel using public passenger transport.

The structure of economic activities (e.g. cities with industrial development located on the periphery) influences the operating characteristics of the public passenger transport system, concentrating services especially at the times for entry/exit to/from the activity schedule of factories/factories

1.2. The vicious circle of urban decline

In the congested urban environment, where economic activities have experienced a significant development, the incomes of the population have increased and the car has become financially accessible to more and more residents. Economic development and hence the increase in incomes of the population was accompanied after the Second World War by technological and managerial innovations that led to the explosive increase in the number of cars manufactured at an increasingly reduced price . These elements (economic growth, income growth, reduction in the cost of manufacturing accompanied by the reduction in the price of fossil fuels) have been the generator of a vicious circle amplified over the last eight decades or so.

We can signal several stages in the establishment and consolidation of this vicious circle of urban decline which, unfortunately, persists in many of the large urban agglomerations, as will be described in the following figure:

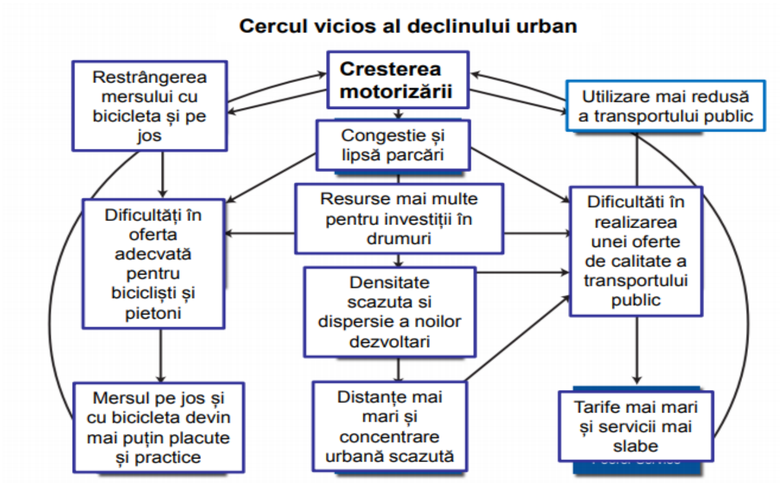

Figure 1. 1. The vicious circle of urban decline

(Source: **Pharoah 1992**)

Attempts to solve the problems of motorized road traffic congestion in large urban agglomerations have led to the development of research with multidisciplinary characteristics, with uncertain and temporal results.

In a classification of some of the research regarding the identification of solutions to reduce traffic congestion and their consequences, the following categories can be identified (some of which will be detailed/addressed later in the thesis), namely:

1. Urban and peri-urban development solutions for real estate development in correlation with the development of technical infrastructures, including transport and traffic infrastructure;

2. Research on the transport and traffic network infrastructure in congested urban areas, where the design of traffic lights intersections and the regulation of traffic in intersections, with and without automated indication adjustment, play an important role. This is also where the research regarding the dedicated infrastructure for public passenger transport (lanes dedicated to buses, tram lines with exclusive lane, lanes for bicycles and non-motorized and/or electric two-wheeled travel) can be included (Costescu et al, 2021);

3. The public passenger transport system, the design of its network to respond to the structure of economic activities and their locations in the urban area, the design of services (lines, stations, timetables, the rotation of the vehicle fleet and drivers, location of the service centers of park etc.) and their reliability/robustness etc.;

4. The integration of public transport services at different levels (schedules, pricing, information for the public, etc.) and the development of the IT systems necessary to create an environment of easy use, without interruptions between the types of urban transport systems and between them and the new systems for ensuring individual mobility (MaaS- mobility as a Service) (Gkiotsalitis 2022);

5. Choosing the location of the car parks, the connection with the street network, their dimensions, the type and level of pricing for their use;

6. The study of mobility behaviors and the design of educational programs necessary to transform them into sustainable mobility behaviors favorable to traveling without a car.

7. Extensive research on the evaluation of the impact of transport and traffic on the socio-economic and natural environment, often the basis of researched improvement solutions.

1.3. Limited urban space and the need for integrated urban transport – the role of public urban passenger transport

The need to create viable and attractive travel and transport alternatives for the car user who is encouraged to leave his use in the congested urban environment has led to the implementation of integrated solutions that are generically called "Mobility-as-a Service"-MaaS. However, solutions of this nature are only complementary for a quality public service.

The use of even electric cars does not completely solve the need to move the inhabitants, because the electric vehicle, no matter how small in size, occupies both the static space of the city and especially the dynamic space.

1.4. Proposed research objectives and questions

The objectives of the research carried out within the doctoral university studies, proposed by the topic of the doctoral thesis, are the following:

- the acquisition and synthesis of some concepts and regulations in the field of the topic with constant reference to the vast specific bibliography,

- development of investigation, analysis, analytical modeling skills, for:

a. identifying the level of satisfaction of passengers of public transport services and its most important determinants through quantitative records and experiments,

b. the characterization of the public passenger transport service, for different types of public transport services (peripheral bus line/transit service "supply"/high capacity) from the point of view of operation precision/timekeeping,

c. proposing a method of adapting the service to comply with the announced timetable,

d. proposal of solutions for an inclusive public transport.

Thus, the research questions to which the paper answers can be formulated as follows:

Q1. How are the relevant concepts of the research topic defined in the literature and in national/European regulations (quality from the passenger/operator perspective, urban public passenger transport)?

Q2. What are the challenges to which public urban passenger transport must respond (or in other words, what are the requirements addressed to public transport?) Which of these challenges are addressed by the solutions targeted by the research theme?

Q3. How can the level of quality of public passenger transport service be determined? What characteristics of service quality are relevant to the user (traveller)?

Q4. Can they be determined and what are the deviations from the displayed schedule for a bus line? What variability do they have?

Q5. Can waiting times at the station be determined? What is their variability and how can it be determined?

Q6. How can line operation be adapted for a robust (on-time) service?

Q7. How can an urban public transport service be adapted to be inclusive for a passenger with motor disabilities? Can they be determined and what is the impact of more inclusive public transport services on the operator, but also on ordinary travelers?

The answers to the seven research questions posed are complex and can be found in one or more chapters/sections of the thesis.

Chapter 2. CONCEPTUAL CLARIFICATIONS AND STATE OF RESEARCH IN THE FIELD

2.1. Conceptual clarifications regarding the quality of transport services

According to the first definitions of quality (Juran 1999), quality represents the suitability for the intended use of goods or services, or the suitability for a certain purpose of an action. Another definition stated only a few years later connects quality with compliance with technical product specifications (Crosby 1980). The above definitions for the meaning of the notion of quality were stated at the beginning of research in this area.

Quality can also be defined by the extent to which the good product responds very well/excellently to expectations from the first consumption/use and then every time it is requested again.

Another way of defining and understanding the notion of quality is through the lack of quality of a good product.

The definition of quality in transport is carried out starting from the same objective of fully or partially satisfying the demands of the users, but other aspects are also taken into account that broaden the analysis framework of the transport system, reaching the entire economic environment- social and natural in which the transport system is based and with which it interrelates (Raicu 2009).

The quality analysis method can be separated into the following two components, namely:

- *Satisfaction* – defined as the customer/stakeholder's perception of the extent to which both explicit and implicit requirements have been met,
- *Satisfaction evaluation* – systematic process of analysis to objectively determine the extent to which the activities provided by the organization/operator met the requirements of customers/users/stakeholders, with the aim of substantiating the process of continuous improvement of the organization's performance.

In the research undertaken to solve the theme of the present thesis, the quality of public urban passenger transport services is addressed as a relative concept, which takes into account the expectations of travelers.

2.2 Operator and user perspective in defining quality in public passenger transport

The perceived quality, ex-post type, represents the quality evaluated by the traveler after using the transport service, which later influences him in future travel decisions. User communities can further influence both transport operators and administrations/local authorities in this area, pushing for the requested improvements, which will then influence the projected quality of service.

Perceived quality is the element among the four aspects of quality, which, if it has the support of a critical mass of the population, can produce beneficial effects on the quality achieved by transport operators. This realized, ex-post quality is produced when the service provided confronts everyday reality.

The quality designed for the service by the operator, ex-ante, is the quality resulting from the design of the service (after going through the strategic, tactical and operational planning stages) and it can also be changed later, if the quality expected by the user is identified/known. The level of quality expected can be determined using various survey and survey methods.

Quality expected by the user, of an ex-ante type, is influenced by several factors such as: the purpose of travel, the existence or non-existence of previous experiences, a certain level of demand towards public services, in general, and towards transport services , in particular, the quality of life, which contains to a good extent the general level of economic and social development.

Therefore, the quality of public passenger transport has several aspects/types of manifestation, depending on the part of the system considered (request/user, or offer/operator) but also on the time of evaluation, before the service is performed but also after it was consumed/realized.

The most well-known methods of evaluating the quality of urban public transport services address, on the one hand, the quality perceived by the user and consist of surveys on passengers either in public transport or in stations, and on the other hand, the quality achieved by the operator by monitoring the services and their characteristics.

There is thus the need to introduce two notions/concepts into the quality analysis and assessment:
- the performance of the public passenger transport service, relative to the design and implementation of the service, performance that can have different levels in relation to certain milestones, and which can represent the "distance" between the designed and realized characteristics of the service,- the satisfaction of the user of the public passenger transport service,

which is also felt through a "distance", between the user's expectations and the perception he has of the offer "consumed" systematically/periodically or non-systematically/non-periodically.

2.3. Evaluation of the quality of public urban passenger transport services - national and European regulations

The Romanian standards for evaluating the quality of public passenger transport services are SR 13326/1996 - Vocabulary and SR 13342/1996 - technical parameters of public urban passenger transport.

These two standards, not replaced until today, define the main terms used in public passenger transport activities, grouped into general terms and terms referring respectively to the vehicles in the park, to the specific facilities and equipment and to indicators with which the quality of the service can be appreciated, called "performance indicators". Most of the indicators refer to the designed or realized quality of the public urban passenger service.

In contrast, qualitative indicators assess travelers' perceptions and are intended to identify aspects of service quality that are difficult to measure directly – such as aspects of travel security, staff friendliness, etc.

Only two indicators are designated to encompass the quality perceived by the user and these are composite indicators, without the clear highlighting of the constituent elements of the perception, namely:

- "number of complaints" and
- "passenger satisfaction indicator".

2.4. Level of service (LOS) and reliability of public passenger transport service

Starting from the concept of the level of service (LOS - Level of Service) offered by a road transport infrastructure, in order to evaluate the quality of a transport service, an evaluation "scale" has been adapted over time and used in many sectors of the transport field with six levels, from A (best performance or quality) to level F (lowest performance or quality).

To assess the quality of public transport services, for example, according to the number of hours of service in a day is presented below, in table 2.1, and the level of service regarding the scheduled time interval between vehicles on a line is presented in table 2.2 (TRB 2003)

Table 2. 1. Service levels relative to the number of hours of the day open for operation

Level of service	The duration of the operation in one day	Features of the service
A	19-24	Serviciu non-stop sau ”aproape permanent”
B	17-18	Operare până seara târziu
C	14-16	Operare până seara devremee
D	12-13	Operare doar în orele de lumină (de zi)
E	4-11	Operare doar în orele cu vârf de trafic de călători sau limitat la orele din mijlocul zilei
F	0-3	Operare foarte redusă sau inexistentă

Source: (**TRB 2003**)

Table 2.2. Service levels relative to the time interval between vehicles

Nivelul serviciului	Interval programat între vehicule [min]	Frecvenţa [veh/h]	Caracteristici ale serviciului
A	< 10	> 6	Nu este necesară afișarea unui orar de circulație
B	10 – 14	5 – 6	Serviciul este destul de frecvent, însă călătorii au nevoie de consultarea unui orar de circulaţie
C	15 – 20	3 – 4	Timp de aşteptare suplimentar trebuie să fie foarte mic
D	21 – 30	2	Serviciu în general neatractiv pentru persoanele care au la dispoziţie alte alternative
E	31 – 60	1	Servicii pentru care este necesară comunicarea/afişarea orarului de circulație și respectarea lui
F	> 60	< 1	Servicii atractive doar în cazul adaptării lor la deplasări pendulare pentru activități cu program cunoscut

Source: (**TRB 2003**)

The service levels established in this way are indicative, and for the new perspective regarding attracting as many users as possible from individual car mobility to public transport services, a greater rigor in the precision with which the operator offers the services will probably require the revision of the time margins from Table 2.2.

For urban public transport, the quality level of the service is subsumed by the concept of "reliability of the public transport service", as reflected in the specialized literature. The wider acceptance of the notion of reliability understood as the ability of the system to ensure the success of the entrusted mission is inappropriate in the case of the concept of the reliability of the public transport service because certain difficulties arise in correctly defining the operation of the system and "mission success".

In the present thesis, the research undertaken to identify solutions to increase the quality of public passenger transport services, I mainly addressed the concept of reliability of the bus transport service, for which I used the concept defined below.

The reliability of the public transport service represents the certainty of its realization by referring to the public information about the conditions for the realization of the service and to the users' perception of the fulfillment of those conditions (Van Oort 2011).

Most of the large urban public passenger transport operators (TRB 2018) consider that the punctuality of the service is the most important tool for evaluating the reliability of the service, also considering that this punctuality is ensured if the circulation of a means of transport is carried out according to the schedule in a margin of -1 min and +5 min. However, there are also operators who assume stricter punctuality, meaning an interval of -1 min and +3 min, and others, even assuming deviations from the schedule of 0 min.

On the other hand, from the traveler's perspective, several surveys, carried out over time, have highlighted the following as determining characteristics of the choice of services and of the quality perceived by travelers: frequency of service, punctuality, duration of operation in one day (Trompet 2010).

2.5. The relationship between strategic, tactical and operational planning for reliable transport services

Reliability in public transport is defined here as the intersection of planning and operation. The operators offer a transport network and a timetable, which represents the offer promised to the traveller. Reliability defines the extent to which operators deliver on this promise. Since two elements must overlap, two ways of improving reliability are possible, through: (i) - planning, and (ii) - through operation.

In urban areas, especially in those characterized by high road traffic congestion, it is not possible to completely reduce the delay times on the route, but methods can be found to recover these delays.

Strategic planning followed by tactical planning, which takes into account variations in route travel times, can lead to high quality of service (delay-free) operation, known as robust operation.

Chapter 3. PERCEIVED QUALITY IN URBAN PUBLIC TRANSPORT BY TRAVELERS

3.1 Construction of traveler perception evaluation tool

3.1.1 Data collection techniques in transport

Conducting a survey is not an informal procedure, but must follow a series of interconnected steps that lead to the final results and conclusions of the survey. These stages of a survey are shown in the figure below (Fig.3.1).

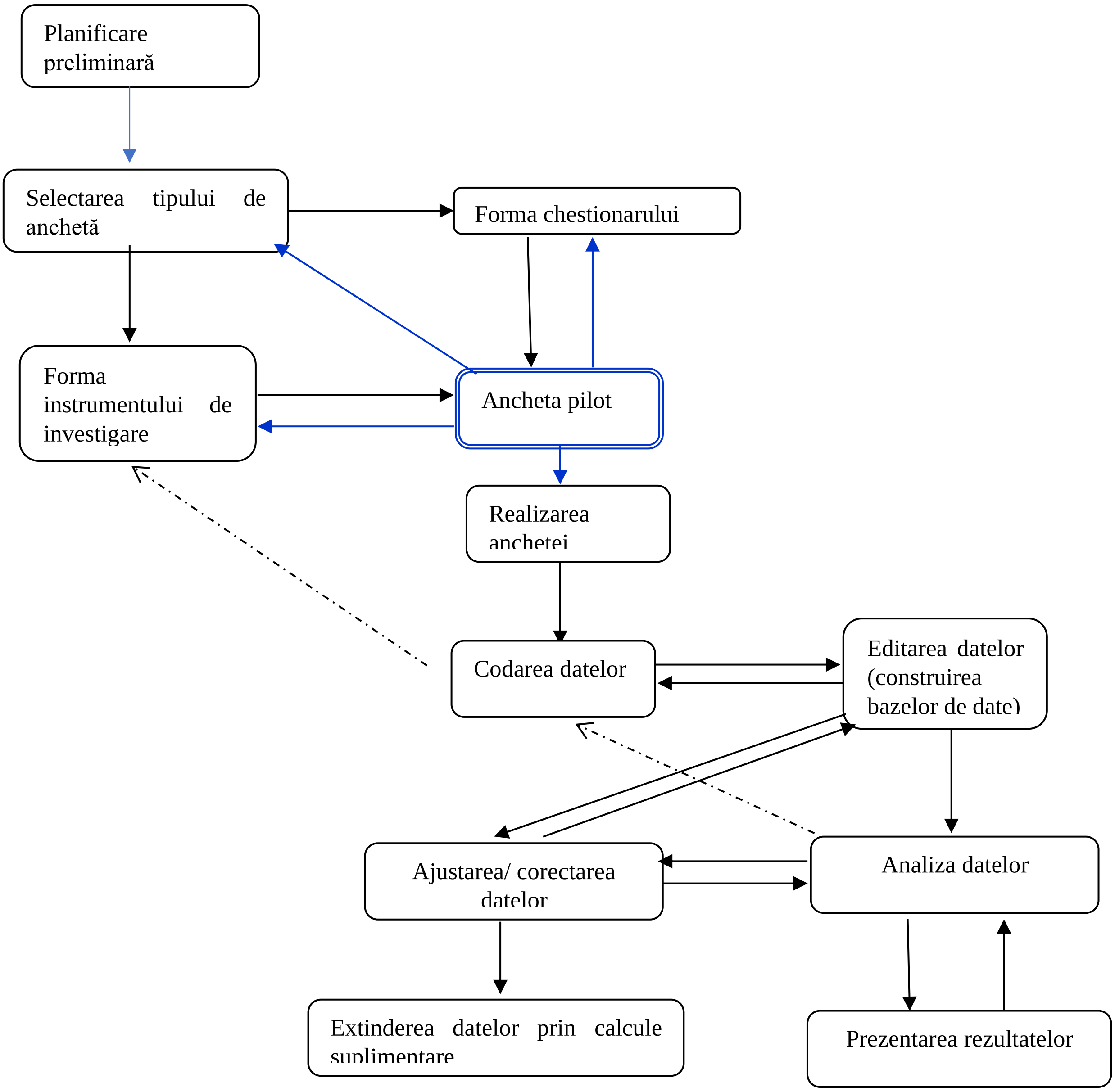

Figure 3. 1. Stages of carrying out a transport survey
(Source: Richardson et al, 1995)

3.1.2 Choice of evaluation scale

To resume, evaluation is defined as the act of expressing, generally quantitatively, the level/degree to which a service has a certain characteristic or property by reference to a value considered as a benchmark. For the ease of evaluation/measurement of that property, a benchmark range of values is used, which constitutes a rating/measurement scale/scale.

The rating/measurement scale is an assessment tool and can be with evenly spaced/constantly spaced marks. However, there are evaluation scales whose benchmarks are spaced according to certain mathematical laws (exponential, logarithmic scales, etc.).

The construction of the evaluation tool is carried out prior to the evaluation and is called scaling, a process that appears more difficult in the case of implicit/unexpressed elements such as some of the characteristics of transport services, which are only perceived by users. In the following, some scaling methods and the associated references are presented, which will be analyzed for the selection of the most suitable method for evaluating the results of the surveys included in the paper.

3.2. Question format

The structure of a question describes how the question is asked and, more importantly, how the answer is recorded (Ortuzar & Willumsen 2011). The choice of how to formulate the question is closely related to the choice of data processing procedures that will be used later in the investigation process.

3.3. Questions to identify travelers' stated and revealed preferences

Revealed preference surveys refer to choices that users have already made. In the case of a public transport survey, the disclosed information refers to the actual trip or the number of trips made by the user considering the origin, destination, departure station, arrival station, purpose of the trip and mode of transport chose to use it from the available alternatives. The strength of this type of survey is that it gives us the real choices made by users in an environment full of challenges and possibly some shortcomings.

On the other hand, stated preference surveys collect responses to hypothetical situations presented to users, in this case about public transport. This type of survey attempts to overcome some of the limitations of relevant preference surveys. One of the limitations of relevant preference surveys is that many scenarios provide insufficient variability in observations, observed behavior might be difficult to relate to certain qualitative variables (e.g. comfort), and the inability to measure choices between alternatives that do not yet exist (Louviere et al. 2000).

3.4. Sample size and anonymization of responses

Most of the time, conducting a survey is addressed to a target population, depending on the objective(s) of the research.

Since the investigation is carried out only on a segment of the target population, it is necessary that the results at the end of the research/investigations done on a specific group (more heterogeneous or more homogeneous) can be extended with sufficient confidence to the rest of the individuals not surveyed. So, how extensive the investigated group is, what the particularities of different natures are (in relation to the research objectives) are elements that ensure that the results will also be valid for the rest of the individuals who were not subjected to the investigation.

Establishing the group under investigation/the sample through specific rules from a statistical point of view is a first step in the development of an investigation (Ortuzar & Willumsen 1994).

The choice of sample size should be made taking into account:

- Dispersion of the analyzed parameter;
- The level of precision required to determine the parameter of interest;
- The total population in relation to which the sample is selected.

In collecting the experimental data of the thesis I used:

- investigation in stations of interest selected in relation to their importance in urban spatial accessibility, to identify the factors that primarily influence the satisfaction of users of urban public transport services;
- inquiry regarding the importance given to the timetable
- records of departure times on the route and from each selected station collected with AVL to determine departure and route delays, as well as to determine their periodicity and statistical distribution;

Chapter 4. FACTORS INFLUENCING THE LEVEL OF SATISFACTION – DETERMINANTS FOR AN URBAN AREA

4.1 Introduction

The need to anonymize the urban public transport operator required that the name of the urban area where the records necessary for the doctoral research analyzes were made should be generic.

The characteristics of this urban area (referred to further in the content of the thesis as "generic urban area" - AUG) are, however, found in many urban areas with important economic development, high population density, well-developed urban public transport network in Romania.

In order to identify the determining factors of the satisfaction index, we started from the aggregate results obtained from a survey carried out between 09.09 and 11.09.2013 regarding Europeans' satisfaction with urban transport (TNS 2014)[1].

Aggregated results for Romanian users are selected in Tables 4.1.

Table 4.1. Overall satisfaction in urban transport from România - European′s Satisfaction with Urban Transport

	High	Good	Medium	Low
Satisfaction index of urban public transport stations	28%	25%	23%	24%
Satisfaction index with travels of urban public transport	21%	37%	20%	22%

(Source: **Flash Eurobarometer 382b, 2014**)

A difficulty of the study, in the opinion of the author, is that the investigation took place during a school vacation period at least in Romania, 09.09 – 11.09.2013, which leads to results of questionable relevance.

The study has the disadvantage that it is only a "picture" of the situation at a given moment and, above all, it does not correlate the results with the level of use of public transport services and does not explain the poor performance of several urban public transport operators.

In addition, the European-wide assessment only investigated users' opinions, not taking into account the European strategic objectives in the field of mobility and sustainable transport that support the need to attract car users to public transport and complementary mobility services.

The opinions of non-users of the urban public transport service and those who rarely and very rarely use these services are sometimes more important, because they reflect a higher demand, at least from the respondents' desire to reflect the comparison made between the two modes of travel.

4.2 Designing and carrying out the survey to determine the factors that relevantly influence the perception of travelers

4.2.1. Introduction

In order to determine the factors that influence the quality perceived by users of urban public transport by bus passengers in the considered AUG, also taking into account the fact that in many Romanian cities important investments have been made for the modernization of public transport (investments in the modernization of waiting stations, purchases of buses with Euro 6 pollution standards, or electric buses, the implementation of modern applications for fleet monitoring, etc.)

[1] Flash Eurobarometer 382b, (2014) Europeans' satisfaction with urban transport, TNS Political & Social

a survey was carried out to determine the perceived quality and the most important factors specific to the urban traveler in Romania.

The objectives of the investigation were:

1. identification of the most important factors that define the satisfaction of bus users in the considered urban area;
2. quantifying the level of satisfaction perceived by travelers;
3. identifying the most important shortcomings that can then be analyzed in order to develop solutions to increase the quality of public transport.

On a Likert scale from 1 to 5 (1 – very dissatisfied, 5 – very satisfied), we rated the degree of satisfaction regarding the characteristics of a public transport experience, listed in table 4.2. The five response options are easy to understand by to respondents because it contains 2 extremes and a neutral option connected to intermediate response options.

Table 4 2. The proposed structure of the questionnaire

Attribute/ influencing factor of perceived quality	Note				
Cleanliness of vehicles (Q_1)	1	2	3	4	5
Driving style (Q_2)	1	2	3	4	5
Seating capacity (Q_3)	1	2	3	4	5
On-board information (Q_4)	1	2	3	4	5
Temperature on-board (Q_5)	1	2	3	4	5
Crowding (Q_6)	1	2	3	4	5
Safety on-board (Q_7)	1	2	3	4	5
Stop location (Q_8)	1	2	3	4	5
Waiting conditions (amenities) (Q_9)	1	2	3	4	5
Adherence to schedule (Q_{10})	1	2	3	4	5
Ticket price (Q_{11})	1	2	3	4	5
Attitude of other travelers (Q_{12})	1	2	3	4	5
Frequency of vehicles (Q_{13})	1	2	3	4	5
Schedule displayed in stations (Q_{14})	1	2	3	4	5

The 14 attributes were selected from the study of several works dedicated to the traveler satisfaction index (Abenoza et al. 2017) (Imam, 2014) (Morton et. al 2014).

The questionnaire was applied to 350 respondents and took place in three waiting stations located in different areas of the analyzed city. Out of the 350 people surveyed, 324 answered all the questions of the questionnaire. (Şerban 2021)[2]

The survey was carried out on working days, through individual interviews (about half men and half women of various ages) sufficient to cover the entire range of public transport users. Some adjustments were made to some questions to be clear, concise and easy to understand: only fully completed questionnaires were considered and divided by age and gender.

Table 4.3. Characteristics of the waiting stations where the questionnaire was applied

Station	Linii deservite	Location	Numărul de respondenți
S_1	6 linii urbane de autobuz și 2 linii urbane de troleibuz	Zona de sud-vest a orașului analizat	106

[2]Şerban, M.A., (2021) Methods, Instruments in Evaluating the Satisfaction Index ofPassengers in Urban Public Transport, Advances in Science and Technology, ISSN: 1662-0356, Vol. 110, pp 71-80

S_2	2 linii urbane de tramvai/8 linii periurbane de autobuz/9 linii urbane de autobuz	Zona de sud-vest a orașului analizat	150
S_3	3 linii urbane de autobuz	Zona de nord a orașului analizat	94

The waiting stations were selected for the survey according to several criteria.

4.2.2 The results of the survey

Attributes denoted with Q_1, ...,Q_{14} were evaluated by the respondents with notes from 1 to 5 points, according to experiences with public transport in AUG.

The calculated indicators are:

- The range of variation – the difference between the highest and the lowest marks in the answers received; the range is calculated by subtracting the lowest score given to an attribute from the highest score given to the same attribute.

- Variance (s^2): the ratio between the sum of the squares of the deviations (errors) between the arithmetic mean of the series of grades and the degree of freedom (df = n-1)

$$s^2 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1} \tag{4.1}$$

- The standard deviation represents a variance of the average distance from each value of the variable (note) to the arithmetic mean. The more dispersed the data, the larger the standard deviation. The result of this process is variance (s^2).

To convert the squared units of the variance back to units compatible with the data set, the square root of the variance must be calculated. This calculation produces the standard deviation (s):

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n}} \tag{4.2}$$

The mean of the standard error (ES) – a small value of the error implies that the degree of dispersion of the answers in the questionnaire is smaller and thus the result obtained indicates that the selected attributes are relevant for the vast majority of the traveling public:

$$ES = \frac{s}{\sqrt{n}} \tag{4.3}$$

Descriptive analysis was carried out to examine respondents' perceived satisfaction according to the attribute specified in the questionnaire and overall satisfaction with the quality of the public transport service.

Table 4. 4. The main influencing factors of the perception of the quality of urban public transport service by passengers - Descriptive Statistics – (SPSS)

	Answers number	Range	Minim	Maxim	Sum	Average	Standard error	Standard deviation	Variance
Cleanliness of vehicles	350	3,00	1,00	4,00	644,00	1,8400	,03653	,68349	,467
Driving style	336	4,00	1,00	5,00	784,00	2,3333	,03962	,72620	,527
Seating capacity	335	4,00	1,00	5,00	831,00	2,4806	,04287	,78463	,616

	Answers number	Range	Minim	Maxim	Sum	Average	Standard error	Standard deviation	Variance
On-board information	335	4,00	1,00	5,00	819,00	2,4448	,04442	,81294	,661
Temperature on-board	335	3,00	1,00	4,00	831,00	2,4806	,04117	,75348	,568
Crowding	335	4,00	1,00	5,00	844,00	2,5194	,04471	,81825	,670
Safety on-board	334	4,00	1,00	5,00	949,00	2,8413	,04859	,88801	,789
Stop location	334	4,00	1,00	5,00	833,00	2,4940	,04503	,82289	,677
Waiting conditions (amenities)	332	4,00	1,00	5,00	834,00	2,5120	,04504	,82071	,674
Adherence to schedule	330	3,00	1,00	4,00	815,00	2,4697	,04585	,83283	,694
Ticket price	330	4,00	1,00	5,00	830,00	2,5152	,04444	,80731	,652
Attitude of others travelers	327	3,00	1,00	4,00	818,00	2,5015	,03943	,71305	,508
Frequency of vehicles	324	4,00	1,00	5,00	826,00	2,5494	,04286	,77141	,595
Schedule displayed in stations	324	3,00	1,00	4,00	804,00	2,4815	,03643	,65574	,430
Valid answers	324								

The analysis of the concentrated results in Table 4.4 leads to the following conclusions:

Out of the 14 attributes that were evaluated by the respondents in the sample, the top three ranked highest are: safety on-board, crowding, waiting conditions and the bottom three ranked the lowest are: cleanliness of vehicles, driving style and schedule displayed in stations.

The values of standard error were below 0.05 and that shows a low degree of spreading in the sample distribution is lower and as a result the average in our sample has a higher degree of probability to be representative compared to the average in the population

For all sample observations, it was found that the general satisfaction was between minimum and maximum score recorded by the 14 attributes.

The smallest standard errors were found in the evalution of the answers regarding the cleanliness of the vehicles, respectively the schedule in the stations, meaning that most of the respondents are dissatisfied with these two attributes of the public transport (all the answers are closest here than to the other questions)

Results show that the mean range from a low of 1.84 to a high of 2.84, indicating that respondents had a varied perception of all the dimensions of the transport service attributes. The standard deviation for these satisfaction items ranged from 0.65 to 0.88

Table 4. 5. Characteristics of the sample of respondents

<table>
<tr><td>Age between 18 and 35 years</td><td>105</td><td>Men</td><td>Women</td></tr>
<tr><td>Age between 35 and 55 years</td><td>122</td><td rowspan="2">198</td><td rowspan="2">152</td></tr>
<tr><td>Age over 55 years</td><td>123</td></tr>
<tr><td colspan="4">Everyone uses public transport at least twice a week</td></tr>
<tr><td colspan="4">63 men and 104 women don't have a driving license</td></tr>
</table>

In the graphs below, we have illustrated the distribution of marks given to the following factors:

- Adherence to the traffic schedule;
- Frequency of public transport;
- Display of the traffic schedule in the waiting stations.

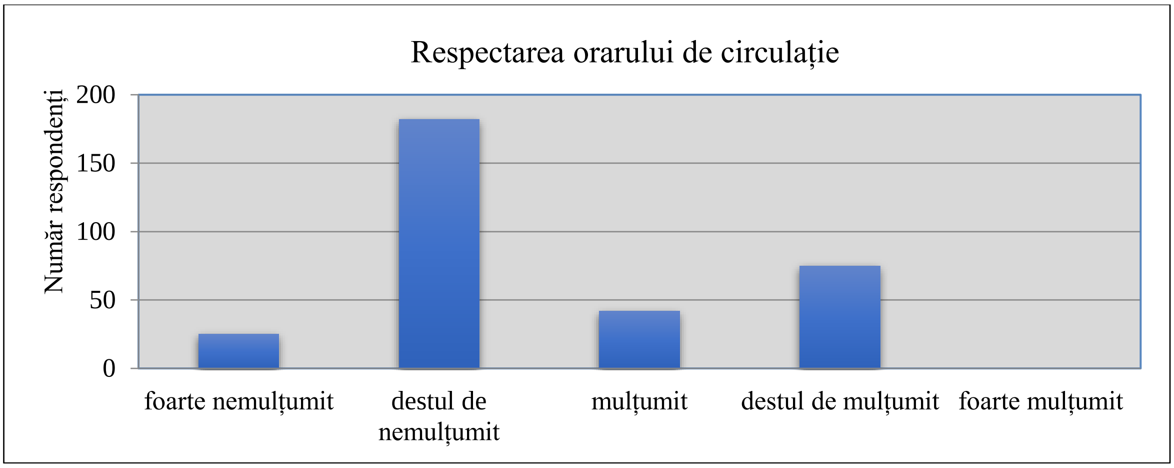

Figure 4. 1. Respondents' satisfaction with the adherence to the traffic schedule

56.17% of the respondents were quite dissatisfied with the adherence to the timetable of public transport, especially those who use public transport daily to go to work/school. Those who have given higher marks use lines with a dedicated track, where the schedule is respected with a smaller deviation than in the other cases.

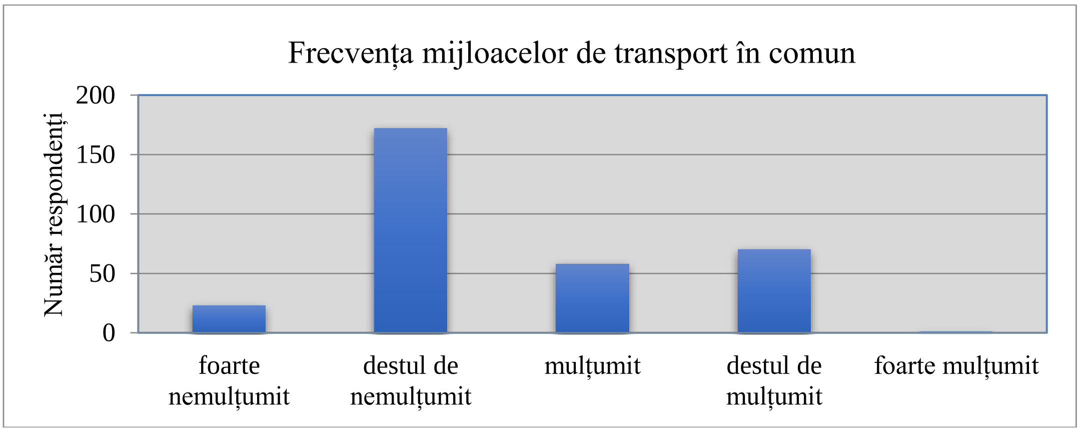

Figure 4. 2. Respondents' degree of satisfaction regarding the frequency of public transport

Regarding the respondents' satisfaction related to the frequency of public transport, 53.08% noted with two points this factor specific to the public transport system, which is closely related to the observance of the traffic schedule. Those who are dissatisfied with the frequency of public transport, mainly use public transport daily, going to work/school. The 21.60% who declared that they are quite satisfied are older respondents who do not travel frequently by public transport, especially on weekdays, when the degree of congestion is high.

The timetable displayed in the waiting stations is missing in most of the waiting stations, along with other facilities. This finding also emerges from the graph above, where it can be seen that 62.03% of respondents are quite dissatisfied with this factor. Those who use public transport less often, and especially the lines that have a dedicated track, scored three or four points, because along those lines, the timetables are displayed, although in some places, they have not been updated.

Table 4.6. Survey results from the generic urban area

Factor	Very satisfied	Quite satisfied	Satisfied	Quite disatisfied	Very disatisfied
Cleanliness of vehicles (Q_1)	0%	6.17%	24.69%	30.86%	38.27%
Driving style (Q_2)	2.77%	8.02%	32.40%	41.97%	14.81%
Seating capacity (Q_3)	4.62%	11.72%	29.32%	44.13%	10.18%
On-board information (Q_4)	10.18%	11.11%	6.17%	66.35%	6.17%
Temperature on-board (Q_5)	0%	14.19%	30.24%	53.39%	2.16%
Crowding (Q_6)	5.86%	12.03%	27.46%	45.98%	8.64%
Safety on-board (Q_7)	10.18%	22.83%	28.70%	26.23%	12.03%
Stop location (Q_8)	0.30%	16.66%	25.30%	55.24%	2.46%
Waiting conditions (amenities) (Q_9)	6.17%	11.11%	33.33%	32.71%	16.66%
Adherence to the schedule (Q_{10})	0%	23.14%	12.96%	56.17%	7.71%
Ticket price (Q_{11})	1.54%	18.51%	29.62%	35.18%	15.12%
Attitude of other travelers (Q_{12})	0%	18.51%	25.00%	46.91%	9.56%
Frequency of vehicles (Q_{13})	0.31%	21.60%	17.90%	53.09%	7.10%
Schedule displayed in stations (Q_{14})	0%	19.44%	13.89%	62.04%	4.63%

Since most of the respondents stated that the frequency of bus arrivals and adherence to the schedule were essential factors in their perception of service quality, the research undertaken to identify solutions to increase the quality of public passenger service focused on determining adjustments to the operating schedule that would lead to more accurate adherence to the posted schedule.

4.3 Displayed timetable - important factor in the perceived quality of users

4.3.1 Introduction

Passenger information systems are the main communication channel between transport operators and the traveling public. In addition to the safety of travel and the attractiveness of the system, the ease of accessing accurate information on the arrival and departure times of public transport at each station is a key component of user satisfaction, as the survey will illustrate.

The objectives of the questionnaire applied on a peri-urban transport line were:

1. Identification of travel habits (frequency, of travelers to/from a peri-urban area, served by a single bus line;
2. The degree of dependence of travelers on the analyzed public transport line;
3. The importance of improving the quality of public transport by displaying the timetables of the only line that serves the entire area.

We designed a questionnaire made up of 19 questions aimed at characterizing as accurately as possible the traveling public, users of the studied transport line and leading to the evaluation of the degree of importance of displaying the traffic schedule in the waiting stations.

The traffic schedule of the studied bus line is important for travelers, because most of the respondents declared that they continue their journey with other urban lines to the points of interest, correlated with other traffic schedules. Therefore, not knowing the traffic times makes it difficult for them to accurately plan their daily trips.

The survey was carried out both on working days and on weekend days (Saturday and Sunday), at different times of the day, through individual discussions with each individual passenger (at waiting stations and inside the bus, in the time of their movements).

4.3.2 The results of the survey

The most important results of this survey are presented below:

- The people interviewed, from the peri-urban area where the questionnaire took place, declared that they depend on the bus line that serves the entire residential area, because they have no other travel alternatives (they do not have a driver's license, own or family car, there is no infrastructure road designed for walking).
- The people who stated that they filed complaints with the transport operator did not get any changes in terms of bus frequency, but only official answers according to which all the necessary steps are being taken to ensure public transport for the area, which is why very few file such complaints.
- Although there were some respondents who stated that they use a smartphone application or consult the traffic schedule displayed on the official website of the transport operator, they mentioned that there is no correlation between the scheduled arrival times and the actual ones;
- In the absence of a regularly updated traffic schedule and displayed in the waiting stations, as well as the lack of passenger information through other modern means (mobile applications), approximately 92% of the respondents declared that there were days when they waited for long periods of time time (20-40 minutes) for various reasons (defective bus, high degree of crowding on the route, illegally parked vehicles that confused bus traffic, suspended routes).

Chapter 5. ADJUSTING SCHEDULES FOR ROBUST OPERATION

5.1 Introduction

In public transport, the lack of compliance with the traffic schedule and/or the tracking interval creates confusion for the traveling public and thus the degree of dissatisfaction increases, leading in most cases to a decrease in the number of users of urban public transport, especially when they are not totally dependent on this mode of travel.

Adherence to the traffic schedule is a determining factor of the quality perceived by users because non-adherence generates additional waiting times in the station for users.

Variable delays caused by traffic congestion in the case of public transport can be integrated into timetable planning, thus reducing the impact on deviations and waiting times in stations (Strathman et al. 1999). Timetable adjustments, however, cannot be made repeatedly, because the permanence of the times and the line must be maintained for long periods of time because together these two elements complete a behavior of use.(Cevallos et al. 2011)

A timetable for urban public passenger transport services must be correlated with the traffic conditions in which they operate.

Starting from this necessity, we analyzed the traffic schedule of several categories of public transport services, as follows:

A- A "feeder" bus line that runs from the periphery of the urban/peri-urban area, to other "collector" lines of the public urban passenger transport network

B- A tram line with a circular route, with the role of a ”collection” route.

The table below summarize the characteristics of the types of public transport services in the AUG considered and the objective(s) of the research.

Table 5. 1. The characteristics of public transport services for which the database for determinations is established

Linia	Tipul de serviciu	Lungimea traseului, km	Nr. de stații	Lungimea medie între stații, km	Interval min/max între mijloacele de transport, min	Viteza medie realizată, km/h	Perioada înregistrărilor/locul	Obiectivul cercetării
A	Linie de autobuz ”alimentare” /periurbană	9,13	20	0,456	12/25	15,29	Lunile ian-mai 2022, în stații selectate cu accesibilitate ridicată	Calculul și analiza abaterilor de la programul afişat, a așteptărilor suplimentare în stații de interes și a variației acestora pentru prognoza abaterilor și ajustarea orariilor
B	Tramvai (parțial cu cale	26,91	60	0,449	4/12	15,48	4 zile ale săptămânii (luni, miercuri,	Calculul și analiza abaterilor de la programul afişat în fiecare din stațiile

Linia	Tipul de serviciu	Lungimea traseului, km	Nr. de stații	Lungimea medie între stații, km	Interval min/max între mijloacele de transport, min	Viteza medie realizată, km/h	Perioada înregistrărilor/locul	Obiectivul cercetării
	exclusivă) de ”colectare”						vineri și duminică) între aprilie 2019 și mai 2020/	liniei și proiectarea unei soluții de ajustare a programului pentru întârzieri minime (cu un algoritm genetic)

5.2 Acquisition of traffic data with the automatic vehicle location system and establishment of databases for analysis

5.2.1 Automatic vehicle location systems

Automatic Vehicle Location (AVL) systems are increasingly being introduced in many cities to monitor the public passenger transport system. Satellite-based location and communication systems, in particular the Global Positioning System (GPS), form the basis for AVL systems that can provide real-time information for passengers, for fleet management and operation, for public transport prioritization of passengers in relation to car traffic at an intersection, etc

The reports that can be made using the AVL system are presented in the figures below.

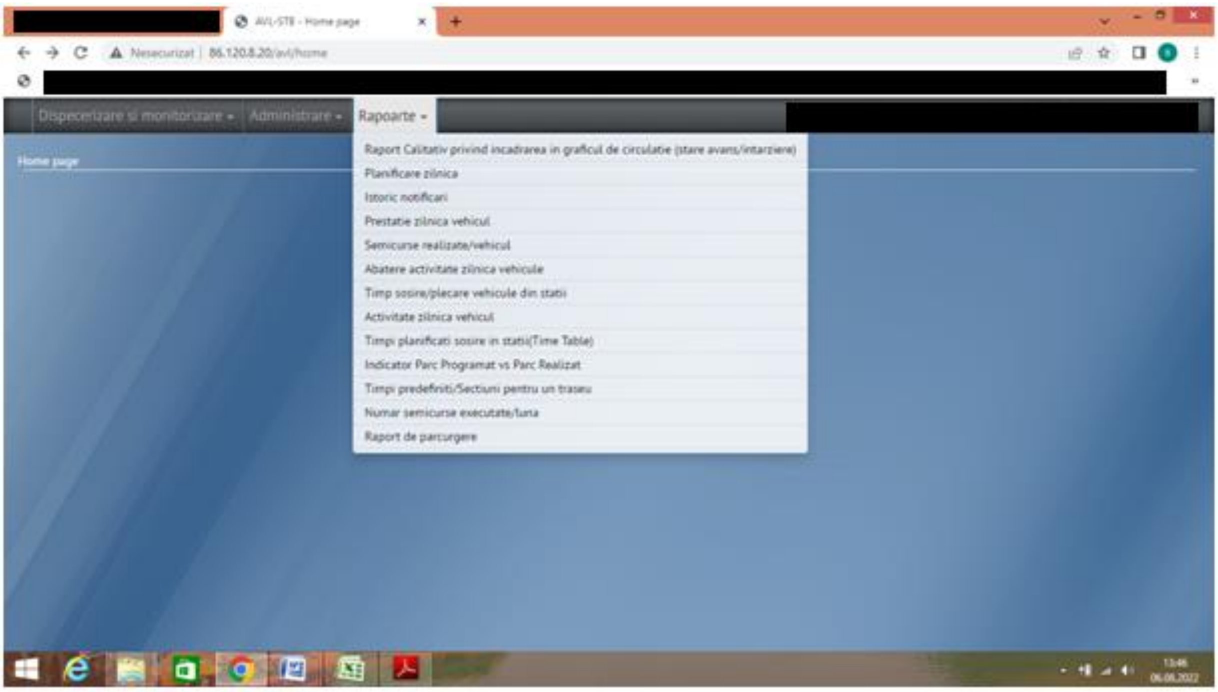

Figure 5.1. Options for reports issued by the AVL application

5.2.2 Data selection, correlation and recording for peri-urban line analysis

In order to create the necessary database for the analysis of deviations and maximum expectations in the stations, the AVL application was used to extract the data regarding the arrival/departure times from the stations located along the studied transport line.

The establishment of the database for the analysis of deviations and maximum expectations in the stations was carried out in the following stages:

1. Choice of interest stations of the line for the odd direction and for the even direction,
2. Choosing the intervals of the day for analysis,
3. Selecting the planned departure times from the station of interest, in the selected time intervals, as well as identifying the order number of the journey starting from the schedule start time,
4. Selection of the departure times registered with AVL from the station of interest corresponding to the order number of the planned journey.
5. Calculation of the difference between the achieved and the planned transition time in minutes and decimals of minutes, called deviation from the schedule.
6. Calculation of the average waiting time at the station – determination of the negative effects on the user of public urban passenger transport.

The access line from the periphery (also called peri-urban in the thesis), is delimited by the two ends of the route, A1 - the one located in the central area and A2, the end located in the periphery.

The selected data refer to the departure times in two stations of interest, relevant on the route, for the two directions:

- Station Ai, on the direction of travel of the line from the center, from the end of A1, to the periphery, to the end of A2 (the odd direction), and
- Station Ap on the direction of travel of the line from the periphery, from the end of A2, towards the city center, at the end station A1 (par direction),

The two stations are not paired, they are selected in relation to the points of interest in the areas covered and the volume of passengers boarding and alighting for the line/mode change. The choice of the station for records of deviations from the posted schedule and additional waiting times was not an objective of the research in the thesis.

The demand for the two directions is not equal, because the odd direction and therefore the Ai station are requested in the afternoon hours, with trips to the periphery, and the even direction and the Ap station are requested more in the morning hours. So Ai≠Ap.

The morning time interval considered in the analysis is 6:00-9:30, and the afternoon time is 16:00-20:00, the choice of intervals for data recording being based on bibliographic references.

The planned and announced schedule is considered as a benchmark for determining deviations and passenger expectations. It is displayed for each station and is known to the public especially by accessing the web page of the operator, public service provider and not by physical or digital display in the stations.

5.2.3. Deviations from the program

Deviations can be: delays compared to the planned and announced traffic schedule or they can be ahead of the schedule, in which case they receive a negative algebraic sign. Deviations can occur from the departure from the end station and persist until the end of the line (without recovery on the route).

Most of the cases of deviations are those that occurred on the route, which accumulate constantly, even if the departure from the end was carried out according to the schedule.

The data extracted from the AVL reports is in hh:mm:ss format, but calculations relative to deviations and expectations are converted to numeric values with decimals, representing time intervals of deviations or delays, in minutes and decimals of a minute. An example of the BD structure for the calculation of deviations from the schedule and in the evaluations of the proposed solutions is shown in Table 5.2.

Table 5.2. Database structure built with AVL records for a station on one direction of travel

Nr. crt.	Record date	Station	Time of departure achieved	Scheduled departure time	Deviation (min)
1	11-05-22	Ai	4:47:33	4:47:00	0.55
2	11-05-22	Ai	05:02:51	5:01:00	1.85
3	11-05-22	Ai	05:45:36	5:15:00	30.60
4	11-05-22	Ai	05:45:36 ~~05:56:21~~	5:28:00	17.60
5	11-05-22	Ai	05:45:36 ~~06:06:32~~	5:41:00	4.60
6	11-05-22	Ai	~~06:20:34~~ 05:56:21	5:53:00	3.35
7	11-05-22	Ai	~~06:30:13~~ 06:06:32	6:05:00	1.53
8	11-05-22	Ai	~~06:42:30~~ 06:20:34	6:17:00	3.57

Suspended departures

In the case of suspended departures, a "correction" is carried out, constantly specified in the literature (Trompet 2010), which takes into account the fact that the analysis is oriented towards the user and therefore the moments of circulation through the station, which are missing, are replaced with the moment of circulation of the first immediately following bus that traveled. In a DB establishment verification/validation algorithm for timetable analysis, this correlation is achieved through a simple procedure of successive checks, at each station, as illustrated in the logic diagram in Figure 5.6, below, where they are adopted the following notations:

- r_k^i represents the time of departure from station Ai, made by journey k, in the order recorded with the AVL system, and i indicates the station on the impar sense

- p_k^i - represents the time of departure from the Ai station, in the order of the displayed traffic schedule (by any of the means - physical and/or digital)

Suspended departures on the considered public transport line are counted by means of counter S and, similarly, the number of departures made according to the schedule, through R, departures that were late, with î and the number of departures that traveled through station i ahead of schedule.

It should be noted that for a detailed study of the effects on passengers waiting in stations, it is necessary to know the volume of passengers boarding and alighting at the station, the pace of their arrival at the station and the level of demand for the transport capacity (sitting and standing). to the bus performing the journey after one or more suspended journeys. This was not an objective of the thesis and is considered one of the future research directions.

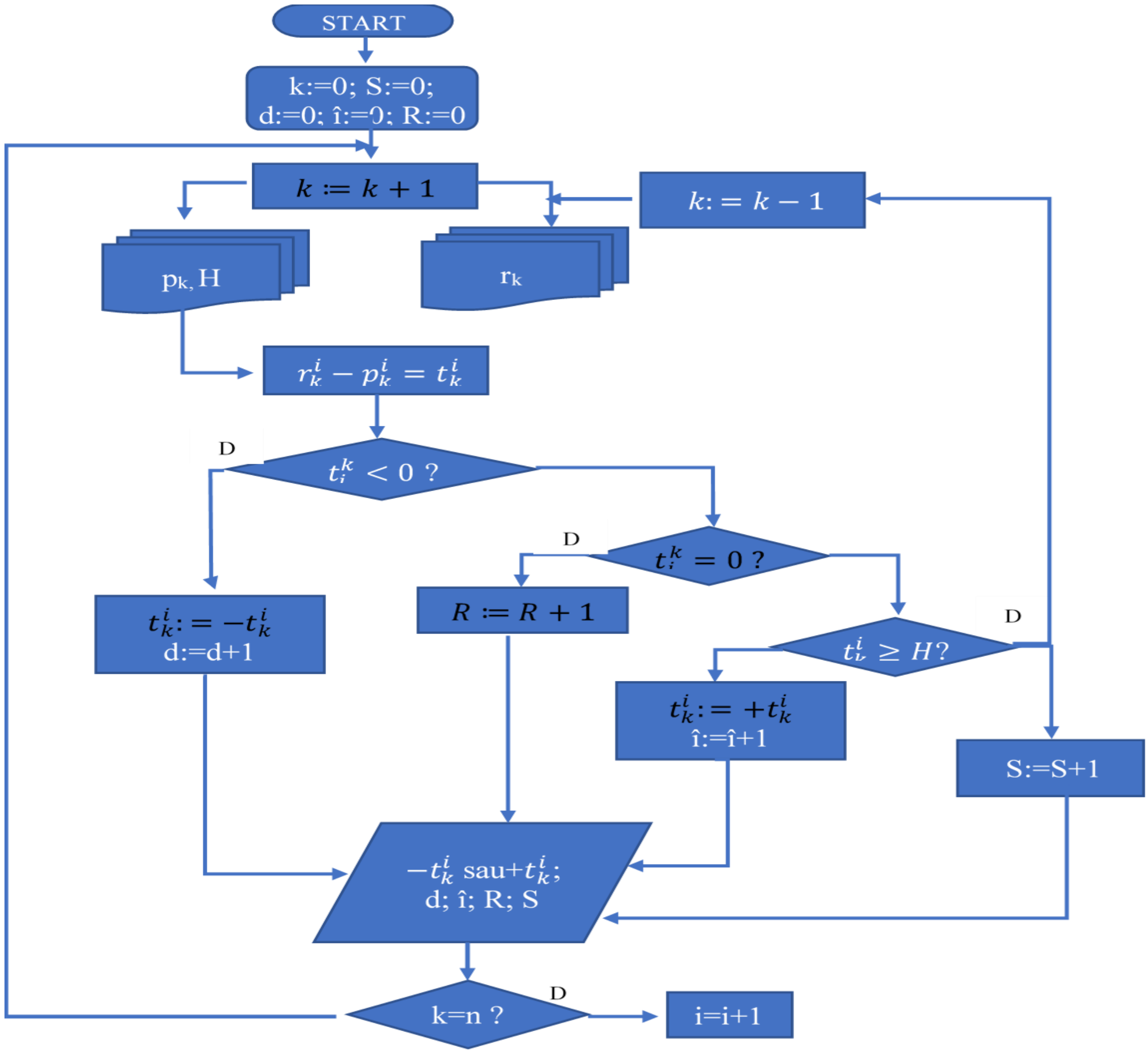

Figure 5. 2. Chart for calculating delays, early traffic, scheduled traffic and departures suspended, in a station i

5.2.4. Waiting times in stations

5.2.4.1. Problem description

For the calculation of waiting times at the station, we consider the following assumptions:

a) The bus with order number k of an operating day has no delay in the analyzed station Ai. The time of departure from station k recorded by the AVL system is the same as that provided by the displayed schedule (for bus/departure k) in the direction of traffic analyzed (Fig. 5.7).

The wait for a user arrived at the station immediately before the departure of bus k is $t_a^{min} = 0,$ or almost 0. At the same time, the user who arrives at the station immediately after the departure of bus k-1, will wait $t_a^{max} = H,$ where H represents the scheduled interval between two successive departures between buses on the line, in one direction of travel. To begin with, we consider a constant interval for both directions of the route and for the entire duration of the day. The simplification does not affect the considerations of the method.

In the figure, the dashed red line shows the simplified diagram of the bus flow, and the blue continuous line shows the simplified diagram of the planned flow.

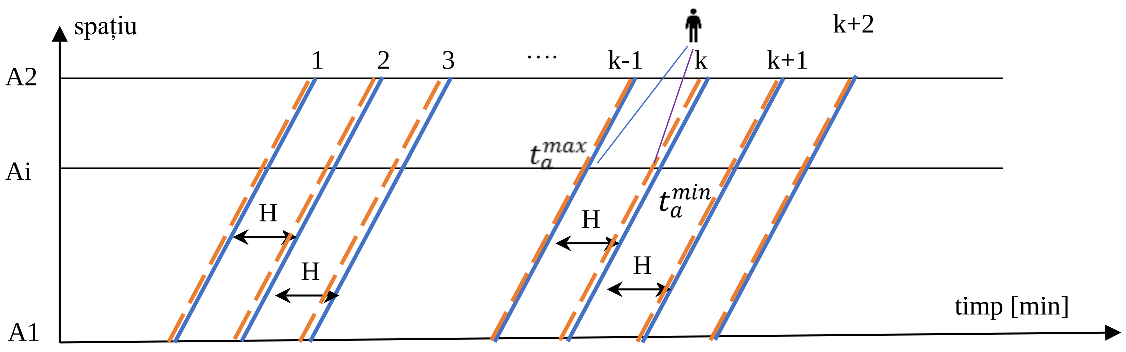

Figure 5. 3. The minimum and maximum wait for bus k, which runs according to the announced schedule

When traffic is running according to the schedule, the average wait at the station is equal to half the following/succession interval between buses, assuming uniform passenger arrivals at the station:

$$t_a^{med} = H/2 \tag{5.1}$$

b) The bus with order number k from a day of operation runs ahead, and in the analyzed station Ai, the AVL system registers a departure time located at -t compared to the schedule (Fig.5.8)

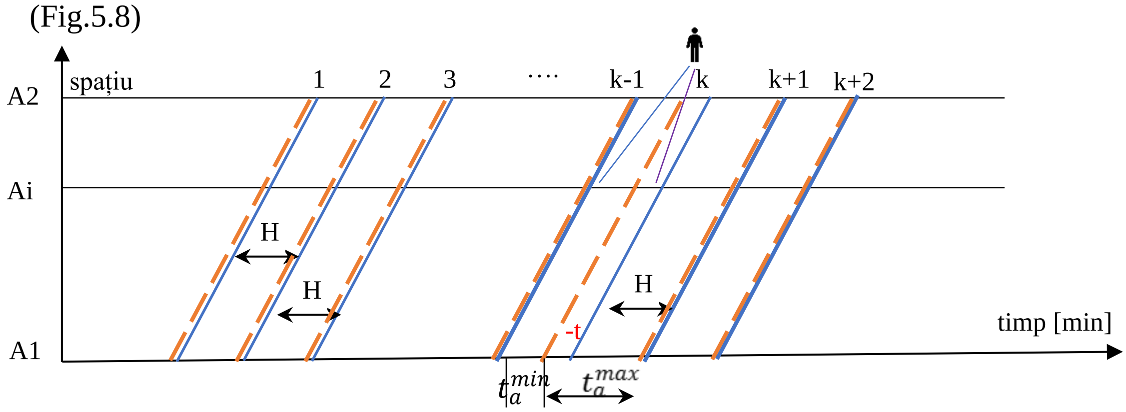

Figure 5. 4. Waiting times at station Ai, when the movement of bus k is realized/registered – t minutes ahead of schedule

The waiting of a user arriving at the station immediately after the scheduled departure of bus k-1 waiting for the circulation of bus k is denoted by figure 5.4 with $t_a^{min} = H - t$, because bus k runs earlier. The next users who arrive at the station after the earlier departure of bus k wait for the circulation of bus k+1. Their wait at the station will be prolonged, that is, it will be $t_a^{min} = H + t$. Thus the average waiting time will be

$$t_a^{med} = \frac{H-t+H+t}{2} = H \tag{5.2}$$

Compared to scheduled traffic when the average wait is H/2, in case of early arrival the average wait doubles.

In the same way we determined the waiting times from several possible situations

c) The bus with order number k from an operating day runs late, and in the analyzed station Ai, the AVL system registers a departure time located at +t compared to the schedule of bus k (Fig.5.9.).

d) The bus with order number k from an operating day is suspended, and in the analyzed station Ai, the AVL system does not record a departure moment for bus k and only for the next bus k+1, which runs according to its schedule. (Fig.5.10)

The situations analyzed up to this point are considered isolated, since the schedule for buses at positions 1,2,…, k-1 and k+1, k+2, …., n is respected, only the bus whose order in the schedule is k, expected by the user, having traffic different from the schedule, and n is the number of trips planned for a day of operation on the considered line.

In the thesis I analyzed several combinations of journeys with deviations from the schedule and their influence on waiting times in the station.

5.3. Analysis of bus traffic data on an access line to the center

For an adjustment of the bus timetable to take into account the variable traffic conditions during peak periods of urban road traffic, it is necessary to determine if the deviations from the timetable have a certain "pattern" (structure) which, once identified, can be used in forecasting deviations and thus in the justified adjustment of the planned and announced schedule.

Due to the particular economic-social situation in which the data were collected (the months of January-May 2022), I appreciate that the data are not sufficient to identify with great confidence a pattern of movements, but instead offer the possibility of establishing an analysis methodology with annual periodicity, to be used in adjusting the traffic schedule for operation without large deviations.

5.3.1. Analysis of deviations from the program

5.3.1. Description of deviations and expectations in the station

In this section we have carried out the statistical description to identify the variations of deviations from the schedule between the hours of a whole day of operation for one direction and the other, as well as to compare these deviations between different working days of the week, in two weeks of May.

Another category of deviations from the schedule, described statistically, we narrowed it down to the hours with the highest (observed) passenger flow, in each of the considered weeks from January to May 2022, different in the two directions, peak traffic hours from the morning from the periphery to the center and the peak evening traffic hours, for the direction from the center to the periphery. The database with experimental records collected from AVL records contains the following records used in the development of the methodology for adjusting the traffic schedule displayed to the traveling public on its own web page:

(i)- traffic records made in the period January-May 2022, two weeks from the middle of each month, for working days and weekends, for the two directions of traffic in two stations of interest selected by the survey, as one station each way during rush hour.

(ii)- the traffic schedule, displayed on the operator's page, unchanged throughout the months of January-May 2022, corresponding to the traffic records made, described in point (i)

(iii) - traffic records for the entire day of operation for six days from May 2022, for both directions of traffic in the same stations of interest

(iv)- the traffic schedule, displayed for the three selected operating days from May 2022

In total the database contains respectively 929 and 940 records for the January-May 2022 peak hour operation analysis for the two directions/stations, as well as another 373 and 384 respectively six working day operation records from May 2022 (11, 12, 13 and 18, 19, 20 May 2022, i.e. two days - Wednesday, Thursday and Friday) for the same stations/directions.

In the Annex to the thesis is presented the BD with traffic records, collected with the help of the AVL system, the traffic schedule, deviations from the schedule and expectations in two stations of interest for both directions, access line to the city center.

5.3.1.1 Variability of deviations from the program

We analyzed several cases and compared their size in order to identify a specific "pattern" of these deviations to be taken into account when substantiating a methodology for adjusting the scheduled schedule. Thus, we investigated the following categories:

a) Deviations from the schedule during a full day of operation during the week of May 2022 in each of the two stations on the impar sense, and respectively par, are highlighted in the figures below.

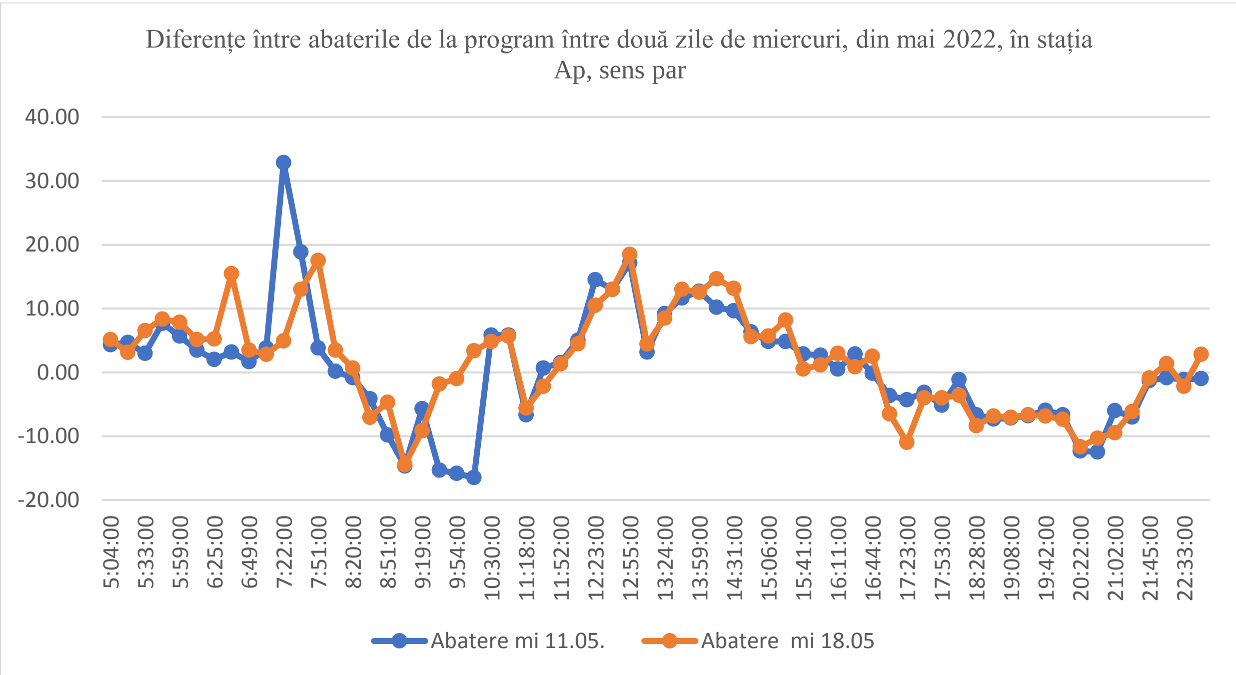

Figure 5.5. Differences between schedule deviations between Wednesdays of the same month, par sense

b) Variability between operating days on certain relevant intervals is also important (see the case represented in Figure 5.18). If we analyze how big the differences are between the days of operation in a certain time interval, we see delays from the schedule that reach up to 60 minutes (which indicates the same cause of the suspended departures).

At the same time, it can be noted that the school holiday (15.04 – 1.05.2022, period indicated in green in the figure) led to fewer deviations from the schedule, both delays and advances. A causal link, however, was not possible due to the limited size of the database collected with the help of AVL.

c) Variability between operating days during the week and, respectively, from weekend days, on certain relevant intervals

A highlight of the influence that the suspensions have from the traffic schedule, for the odd direction, I have separated the representation from Figure 5.18. above in the following two (Fig.5.20. and Fig.5.21), each analysis addressing a different type of day, in which the circulation is made, respectively, working days and weekend days.

d) Analysis of deviation variation in a station, at a selected moment of the program

For impar sense, towards the periphery, in the station of interest Ai, we analyzed how, on the working days of the weeks from January to May 2022, in the afternoon/evening hours, the schedule was not respected, having positive deviations - delays as well as negative, advances (Fig. 5.6), the most scattered values being recorded for the scheduled hours from 5:00 p.m. to 7:00 p.m.

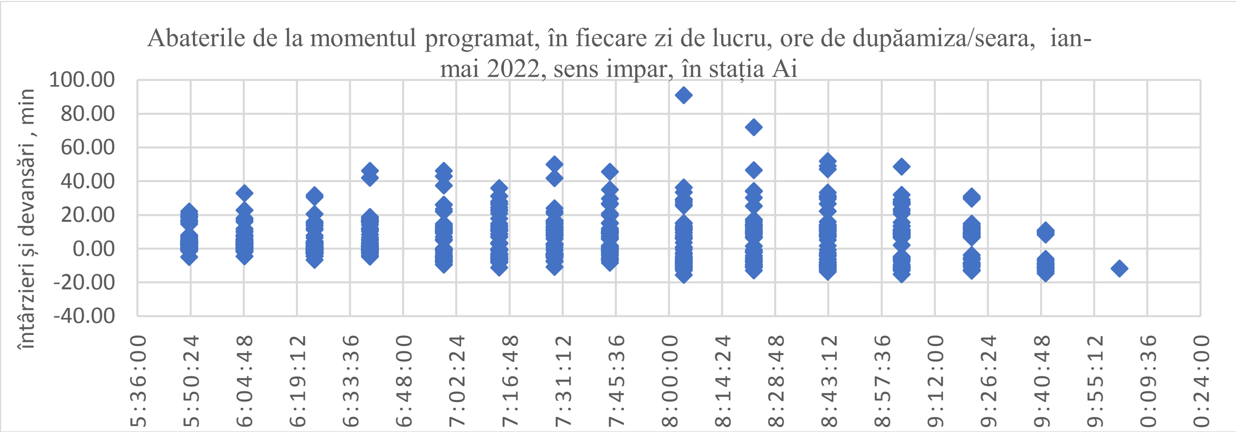

Figure 5. 6. Deviations from the scheduled time, on working days, between January and May 2022, impar sense, station Ai

The frequency of deviations indicates the low level of interest in respecting the scheduled time, because as represented below, in Figure 5.23, it is observed that only 193 deviations from the schedule out of all 684 records are in the range of values declared in the literature as accepted of delay (from the operators), illustrated in green.

Many delays approx. 180 (ie approx. 26% of delays are longer than 11 min., only in the afternoon hours considered, while roughly, delays of more than 2 minutes are just as numerous. Waiting at the station is extended also due to advances from the announced program.

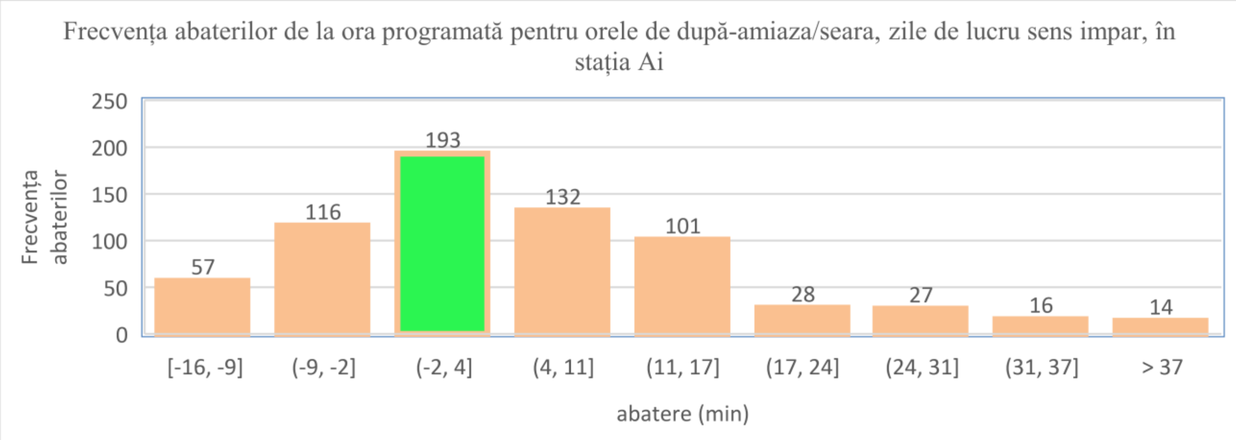

Figure 5.7. The frequency of deviations from the scheduled hours for circulation on working days, for impar sense, in station Ai, period ian-mai 2022

For weekend days, Saturdays and Sundays, the deviations for each scheduled traffic hour are represented in the Figures below (Fig. 5.24), where a high variation is observed, but the advances from the schedule are smaller, due to the effects that they produce suspended runs.

An analysis of the frequency of violations (non-observance) of scheduled traffic hours on Saturdays and Sundays (Fig. 5.25) reveals that only 80 of the 245 traffic data records fall within the accepted range, the remaining approximately 67% of the total delays exceeding the value of 5 min.

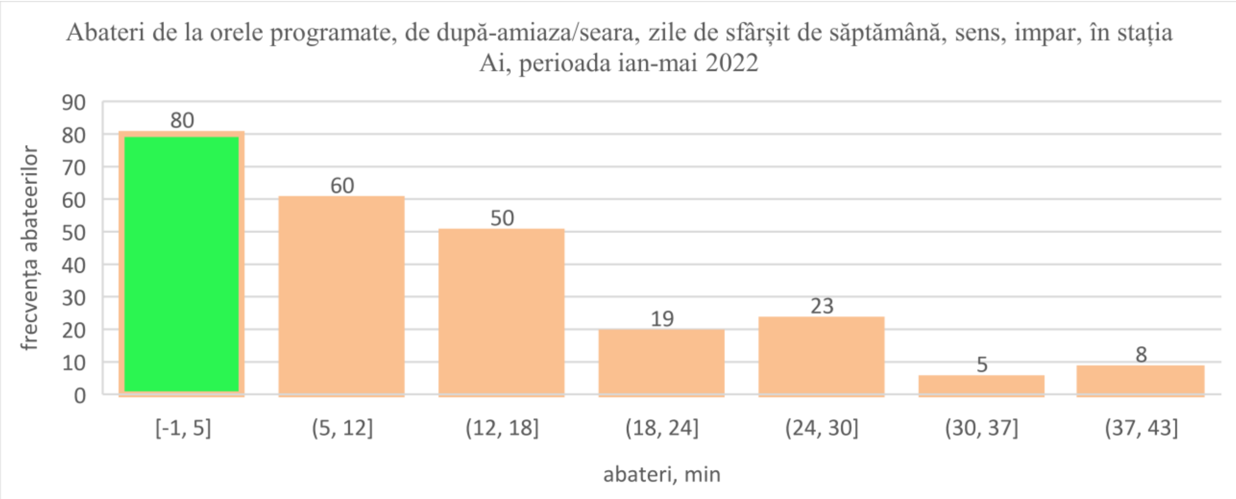

Figure 5. 8. Frequency of deviations from the scheduled time, in the afternoon/evening interval, for Saturdays and Sundays, impar sense, in station Ai, period ian-mai 2022

For the par sens, the analyzes are similar, they show the same wide dispersion of the data recorded for bus traffic. Some of these analyzes are used throughout the following sections.

5.3.1.2 Waiting times at the station

Waiting at the station, as described in the section dedicated to its calculation, is different from traffic delay or advance, the traveler waiting until the arrival of a ride, which is closest to the scheduled time for traffic, chosen for endogenous reasons.

For all the recordings made during the operating days of May 2022, the deviations from the schedule as well as the expectations in each of the selected stations per traffic direction are shown in figures 5.26 and 5.27, respectively.

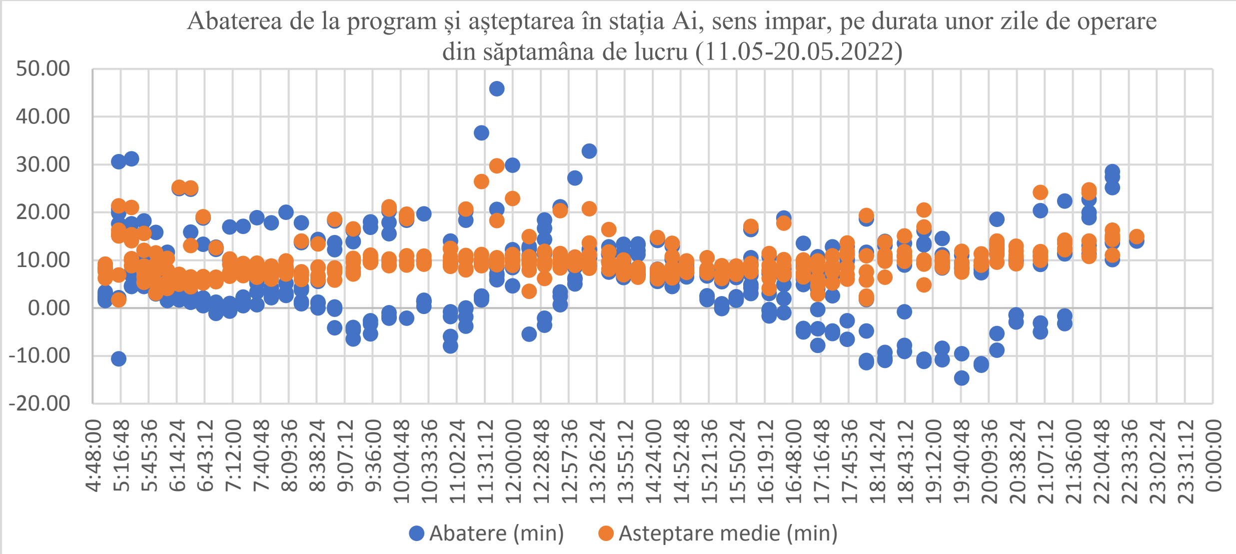

Figure 5.9. Deviations from the schedule and expectations of the operating days of May 2022, sens impar

High waiting times at the station are observed in a few cases, explained by two and three suspended trains, in the operation interval outside the traffic peak, i.e. after 10:30. It should be noted that the operator does not announce the suspension of any journey either on the website or through the passenger information system, in stations where it exists. It should be noted that the departures from the schedule are denser in the evening period, when fewer passengers use the bus line to return to their homes located in the suburbs.

For the par sense, the sense of operation, from the periphery to the center, the schedule advances are significant especially in the morning, and the suspensions of the trains occur even earlier in the morning (after 9:00), but they also occur during the afternoon and evening.

Due to deviations from the schedule, whether they are late or early, the traveler waits for more than half of the value of the scheduled succession interval, a "standard" value, resulting from accepting the assumption that users arrive at the station at a constant rate, immediately after the departure of the previous journey and until the arrival of the intended journey, which is not delayed. The deviations are greater as the delays and advances are greater, reaching values of up to 30 min.

5.3.2 Statistical distribution of deviations from the schedule

The accepted punctuality (adherence to the schedule) of traffic through the station is defined in the literature by the interval (-2, 5), that is, early traffic from -2 min to delayed traffic by +5 min, and it can be shown that the probability density of deviations from this interval follows a normal distribution law.

From the statistical analysis of the recorded deviations from the traffic schedule, we find that the deviation is a random variable for which we can obtain the mean μ and the standard deviation, σ.

The accepted punctuality (observance of the schedule) of traffic through the station is defined in the literature by the interval (-2, 5), that is, early traffic from -2 min to delayed traffic by +5 min, and it can be shown that the probability density of deviations from this interval follows a normal distribution law.

From the statistical analysis of the recorded deviations from the traffic schedule, we find that the deviation is a random variable for which we can obtain the mean μ and the standard deviation, σ.

If by hypothesis (which remains to be verified) we consider that this random variable X follows a normal distribution law n (x; μ ;σ), and the distribution function of the random variable is:

$$F(x) = P(X < x) = \int_{-\infty}^{x} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(y-\mu)^2}{2\sigma^2}} dy$$

Considering the wanted range of variation defined by the two values, x_1, the smallest and x_2 the biggest, and the difference between these being a=$x_2 - x_1$, the area of the probability density can be constructed so that the punctuality is maximum, i.e. the circulation through the station of interest is included in the interval a. Thus,

$$A(x_2) = F(x_2) - F(x_2 - c) = \int_{x_2-a}^{x_2} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(y-\mu)^2}{2\sigma^2}} dy$$

To find the maximum of the expression, we derive and equate to 0, and obtain:

$$A'(x_2) = -\frac{x_2-\mu}{\sqrt{2\pi}\sigma^3} e^{-\frac{(x_2-\mu)^2}{2\sigma^2}} + \frac{x_2-a-\mu}{\sqrt{2\pi}\sigma^3} e^{-\frac{(x_2-a-\mu)^2}{2\sigma^2}} = 0$$

which leads to

$$x_2 - \mu = \frac{a}{2}$$

Bearing in mind that the second-order derivative at point $x_2 = \mu + \frac{a}{2}$, adică

$$A''\left(x_2 = \mu + \frac{a}{2}\right) = -\frac{a}{\sqrt{2\pi}\sigma^3} e^{-\frac{a^2}{8\sigma^2}} < 0,$$

it follows that the area A(x) is maximum when $x_2 = \mu + \frac{a}{2}$, or that the probability density area of the range of deviations from the traffic schedule is maximum (the probability that the deviations are between x_1 și x_2) when the two benchmarks are located on either side of the average value of the deviations from the schedule (Cevallos 2011).

More simply, it can be said that the statistical average of the deviations should be:

$$\mu = \frac{x_1+x_2}{2},$$

in order to identify the punctuality area in which the deviations from the traffic schedule through the station fall.

For example, if meeting the schedule (punctuality) is considered when the advance from the planned schedule is a maximum of 2 min (-2), and the delays must not exceed more than 4 min (+4).

It follows that the adjustment of the schedule should be made with the average value of the punctuality domain, μ_{aj}:

$$\mu_{aj} = \frac{-2+4}{2} = 1 \text{ min}$$

to advanced values (if the deviations are generally of the nature of advances compared to the schedule) or to delayed values (in the case of recorded data of the actual circulation compared to the schedule).

The correction made to the circulation times through the Ap station of interest must meet the following conditions:

- either small in size so that the travel habits of travelers are not significantly affected,
- not to be applied repeatedly within a year, but only once or at most twice a year, seasonally, for the same reason of maintaining travelers' confidence in the constant provision of the service,
- the adjustment value of the timetable programmed in a station to be analyzed in correlation with the necessity or maintenance of the same timetable in neighboring stations
- the size of the adjustment should be included in the accepted range that defines punctuality. This represents the fact that, when the level of demand is high (the scope of punctuality is reduced, for example - 1, + 3 min), the adjustments applied to the timetable are smaller, than in the opposite case

5.4 Analysis of the traffic data of a tram line

5.4.1. Methodology and study area

A tram line with a dedicated track was selected for the study. Trams serving this line are monitored along the route using AVL technology as they pass through the waiting stations. (Șerban 2021)[3]

The tram line takes an average of 34,000 passengers daily, along the route there are several transfer nodes to other transport lines, both surface and underground.

5.4.2 Characteristics of the studied line

Table 5. 3. Line indicators

	Work day	Zi de sfârșit de săptămână
Average speed	14.51 km/h	14.92 km/h
Average speed during peak periods	13.30 km/h	13.64 km/h
Average passenger volume	1791 călători/h	1531 passengers/h
Capacity utilization rate maximă	2241 călători/h	1915 passengers/h

The biggest deviations are registration in three connecting stations with other transport lines.

5.4.3 Adjustments of the planned traffic schedule with the method of genetic algorithms

The parameters of the genetic algorithm used are as follows: population size Pop_{dim}= 60 (the same for every day).

The objective function is:

[3]Șerban, M.A., (2021) The use of the genetic algorithms for optimizingpublic transport schedules in congested urbanareas, IOP Conference Series: Materials Science and Engineering, https://iopscience.iop.org/article/10.1088/1757-899X/1037/1/012062

minim {M $[\sum_{n=1}^{60} |x_{n,j_1}|, |x_{n,j_2}|, \dots, |x_{n,j_{23}}|]$; W$[\sum_{n=1}^{60} |x_{n,j_1}|, |x_{n,j_2}|, \dots, |x_{n,j_{23}}|]$; F$[\sum_{n=1}^{60} |x_{n,j_1}|, |x_{n,j_2}|, \dots, |x_{n,j_{23}}|]$}

where:

x_{n,j_i} – deviation on day n and station j_i ;

i = $\overline{1,\ 23}$, n = $\overline{1,\ 60}$

M – Monday, W – Wednesday, F - Friday

The initial population was created as follows: a chromosome was considered as the string formed by the values obtained by the difference between the planned time and the actual time of passage through each station, being a total of 23 stations, meaning the string will have a length of 23 bits represented by real positive and negative values.

The population comprises 60 chromosomes, each corresponding to a day of Monday/Wednesday/Friday/Sunday, during 60 weeks, starting with 01.04.2019.

Following the evaluation, the best individual was determined as C_9, and the weakest as C_{33} – for Mondays; C_{21} – the best and C_{34} the weakest for Wednesdays; C_{35} – the best and C_{30} the weakest for Fridays; C_{46} – the best and C_{23} the weakest for Sundays.

P_{t+1} = {C_1, C_2, ..., C_{60}}

For Mondays, given the values of the fitness function, we condition that the value of the function f(x) be less than 66, so that 14 chromosomes will be removed before the crossover operation.

The blue color indicates the minimum deviation value in that chromosome (value string) and the yellow color indicates the maximum value.

Table 5. 4. Initial population of deviations obtained for Mondays

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	S_{17}	S_{18}	S_{19}	S_{20}	S_{21}	S_{22}	S_{23}
C_1 F(x)=109.06	-1.41	-0.68	-0.14	-2.37	-3.84	-3.57	-3.97	-5.26	-5.12	-5.74	-5.56	-5.22	-5.42	-6.28	-7.05	-7.88	-8.12	-8.17	-8.71	-9.70	-8.18	-8.03	-5.22
C_2 F(x)=49.75	-1.38	-.2.21	-1.76	-2.14	-3.44	-3.02	-2.62	-2.13	-2.67	-1.96	-2.06	-1.64	-2.57	-2.76	-2.66	-2.02	-1.85	-1.79	-1.12	-4.07	-2.42	-2.57	-2.05
C_3 F(x)=111.33	-1.59	-1.20	-0.71	-2.74	-5.58	-5.04	-4.48	-5.01	-5.14	-6.56	-6.48	-7.07	-6.90	-7.41	-7.40	-7.20	-7.37	-7.14	-7.67	-7.77	-6.30	-5.15	-4.31
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
C_{58} F(x)=20.38	0.02	0.47	1.19	1.63	0.06	0.34	0.68	0.51	0.60	0.36	0.57	0.96	1.20	1.49	1.47	1.72	1.80	1.80	1.34	-2.13	-0.33	1.75	1.01
C_{59} F(x)=23.31	-2.09	-1.81	-0.97	-0.30	-1.21	-0.96	-0.38	0.07	0.36	-0.36	-0.03	0.49	0.73	0.07	0.47	0.50	0.61	0.81	1.31	1.98	3.38	3.28	2.91
C_{60} F(x)=15.78	-1.08	-0.63	-0.19	0.61	0.12	0.48	0.85	0.12	0.03	0.58	0.69	0.99	0.50	1.14	1.39	1.05	1.18	1.30	-1.46	-2.05	-0.87	0.58	0.41

For Mondays, given the values of the fitness function, we condition that the value of the function f(x) be less than 66, so that 14 chromosomes will be removed before the crossover operation.

The blue color indicates the minimum deviation value in that chromosome (value string) and the yellow color indicates the maximum value.

The fitness function value for each chromosome in the initial population is calculated as follows:

Each chromosome consists of a series of deviation values recorded in each station, from that day to the planned time, initially established. We total these values, the negative ones being added in the following way:

F(x) for C_1 is $\sum |x_{1,j_1}|, |x_{1,j_2}|, \ldots, |x_{1,j_{23}}|$ = 1.41 + 0.68 + … + 5.22 = 109.6

F(x) for C_{60} is $\sum |x_{60,j_1}|, |x_{60,j_2}|, \ldots, |x_{60,j_{23}}|$=1.08 + 0.63 + … + 0.41 = 15.78

The procedure is generative. It uses 3 main operators: reproduction, crossover and mutation. Each generation of a genetic algorithm consists of a new population produced from the previous generation.

For Mondays, given the values of the fitness function, we condition that F(x) is not greater than 66, so that 14 chromosomes will be removed before the crossover operation.

For Wednesdays, given the values of the fitness function, we condition that F(x) is not greater than 66, so that 13 chromosomes will be removed before the crossover operation.

For Fridays, given the values of the fitness function, we condition that F(x) is not greater than 66, so that 21 chromosomes will be removed before the crossover operation.

For Sundays, given the values of the fitness function, we condition that F(x) is not greater than 88, so that 29 chromosomes will be removed before the crossover operation.

In the Tables below I have centralized (for working days) the results obtained by crossing the selected chromosomes (two by two) from the initial population of solutions generated by the function: f(x) =$X_{scheduled}$ - X_{real},

the new populations being composed of 23 chromosomes (Mondays), 23 chromosomes (Wednesdays), 19 chromosomes (Fridays)

The fitness function value for each crossover result can be found in the first column of the tables, the next chromosomes will be chosen for the crossover operation.

The crossover operation was performed as follows: the elements of the parent chromosome were compared and the lowest value of a bit was selected. (if $|x_{1,j_1}|$<$|x_{2,j_1}|$, choose x_{1,j_1})

5.5. Traffic schedule adjustment solutions for robust operation

Robust operation is, in this paper, the movement of buses without delays/advances beyond the proposed (agreed) margin against the displayed schedule. The interval proposed in the previous section of (-2 min; +5 min) is the one announced by several urban public transport management operators/agencies, but can be set with different values depending on local conditions and the objectives of the public administration responsible for ensuring the right to mobility for citizens.

A range established solely on the basis of statistical analyzes at one station of interest, even if it is the most important among several other stations on a line, cannot lead to a correct and viable adjustment for the whole of the line(s) it serves . The analysis should include the study of the distribution of schedule deviations at least in the next few stations that are requested by important passenger flows.

Thus in this section, I propose a methodology for adjusting the traffic schedules for the public transport service network at the level of an area/portion/or the entire network of public transport lines that have a schedule displayed (physically in the station and/or on the web page of the operator).

The methodology can be included in a larger program to modernize the monitoring of the quality of the public transport services offered, in which case it can be extended, by modernizing the vehicle fleet with the addition of the passenger boarding/disembarking monitoring module at each station on the route.

The stages of the methodology specifying the periodicity of their fulfillment are briefly described in table 5.5:

Table 5. 5. Proposal for a management plan for adherence with traffic schedules

Etapa	Denumire și activități componente	Periodicity
I	*Consolidarea Bazei de Date pentru analiza circulației și ajustarea programului*	
	- Definirea bazei de date (structură, dimensiuni, relații între câmpuri, algoritmi de verificare etc.)	annual
	-”Încărcarea” bazei de date cu informațiile legate de programul de circulație programat,	annual or biannual
	- Colectarea datelor de circulație înregistrate de sistemul AVL pentru liniile de inters și pentru toate stațiile de pe traseu,	monthly
	-Identificarea anomaliilor, erorilor, cauzelor acelor anomalii,	monthly
	-Corectarea informațiilor înregistrate de sistemul AVL; alcătuirea unui ”registru” al corecturilor la baza de date,	monthly
	-Consolidarea bazei de date pentru analiză.	During one year of operation
II	*Analiza abaterilor de la program și calculul ajustărilor necesare*	
	Determinări ale dimensiunii și caracteristicilor distribuției abaterilor de la program în stațiile de capăt de linie,	monthly
	Determinări ale legilor statistice de distribuție ale abaterilor de la program în stațiile liniilor și calculul ajustărilor necesare,	monthly
	Identificarea stațiilor în care sunt necesare ajustări la program,	monthly
	Soluții de ajustare a programului și validarea programului ajustat prin simulări ale circulației cu abaterile identificate în timpul unui an de operare	annual
III.	*Calculul așteptărilor medii suplimentare în stație*	annual
IV	*Consolidarea unui program managerial pentru monitorizarea abaterilor sistematice de la programul de circulație*, folosind înregistrări AVL	
	Determinarea anomaliilor (curse neefectuate accidental, vehicule defecte la plecare, vehicule defectate în parcurs etc),	monthly
	Determinări și raportări ale cauzelor producerii abaterilor de la program la nivel de stație, linie și pe zone ale rețelei de servicii	monthly
V	*Proiectarea și realizarea unei anchete pentru identificarea indicelui de satisfacție la nivelul fiecărei linii și ansamblului rețelei de servicii.*	anual

Chapter 6. IMPROVING INCLUSIVE URBAN PUBLIC TRANSPORTATION SERVICES FOR TRAVELERS

6.1 Introduction

An inclusive public transport system is essential for disabled people's access to education, jobs and healthcare, as well as maintaining social life with family and friends. The ability to move and travel independently is fundamental to lessening the limitation to a normal life for people with physical disabilities.

In this chapter, we have proposed some solutions for improving the degree of inclusion of public bus transport services for people with physical disabilities and we evaluate their impact on the local public operator and general users.

In the next section, the investigation method is described (**Şerban 2022**)[4]. The third section is dedicated to the description of the actual adaptation of the regular bus from the fleet owned by several transport operators and also to the description of the adjustment of the transport service on a selected bus line.

6.2.3 Selection of an urban public passenger transport line for adaptation to an inclusive service

To observe the impact of the implementation of the proposed solutions for an inclusive transport service on regular users, a relatively long bus line was selected. It provides access to many important functional areas (it has 30 stops) such as parks, markets, medical centers, shopping mall, train station.

6.3 Solutions for improving inclusive public bus transport services

6.3.1 Adaption the manual ramp to an electro-hydraulic ramp

The electro-hydraulic drive ramp consists of the main structural components and the secondary elements for the movement of the three structural elements. This pump will allow the manual ramp to be converted into an electro-hydraulic actuation ramp (Figure 6.10), which is called an automatic ramp for easier differentiation from the manual ramp.

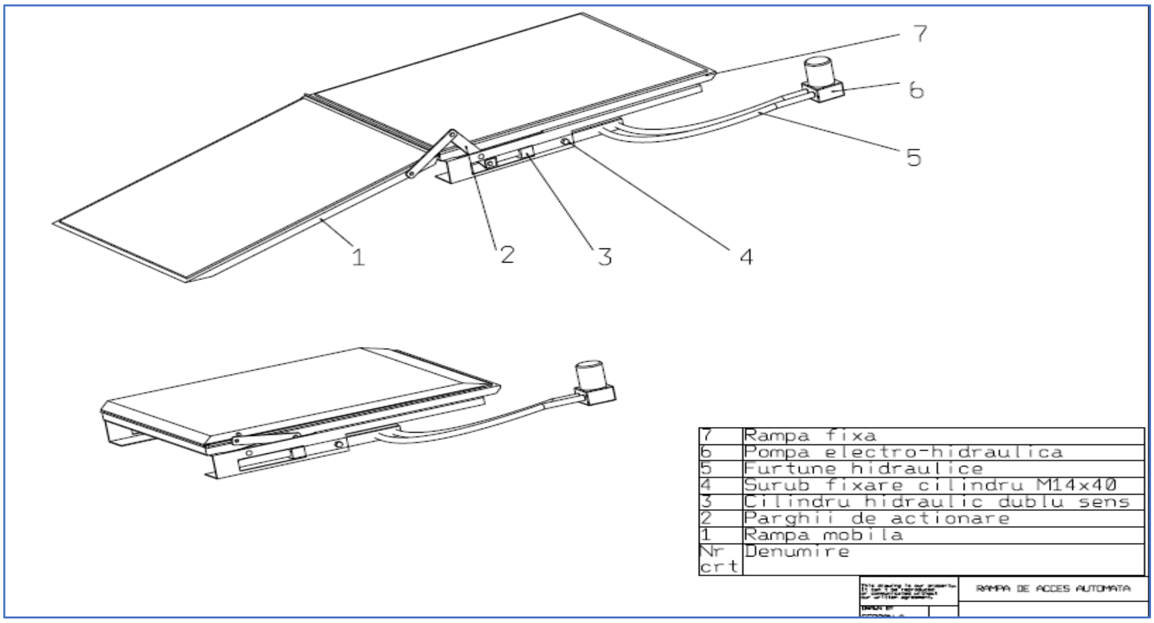

Figure 6.1. Automatic folding ramp - 3D view

The bi-directional hydraulic pump, electrically controlled, actuates the two hydraulic cylinders, mounted on either side of the boom, which begin to push the two pairs of levers. These levers (marked with 2) connected by bolts, execute the rotation movement of the plate 1, embedded in the floor of the bus. At a speed controlled by the pump, in order to meet the preset opening time of eight seconds, plate 1 touches the pavement surface, after completing the rotational movement

[4]Şerban, M.A., (2022) Impact of inclusive services of urban bus transportation on users and operator, Scientific Bulletin, Series D, Issue 3, 207-2018

and subsequently the translational movement by a height of 2 cm, to align plate 1 with the floor of the bus .

The hydraulic pump is controlled by two relays, which actuate the hydraulic pump in opposite directions for travel and storage functions (powering the double-acting hydraulic cylinders). No electronics or sensors are required for ramp operation.

6.3.2 Adapting the interior space of the bus to provide additional seats for people with physical disabilities

Figure 6.12 a) I represented a simplified sketch of the main arrangements in a regular reference bus of the public transport fleet in Romania's big cities. By removing six seats for ordinary passengers, the two additional spaces for the physically disabled are obtained.

a)

b)

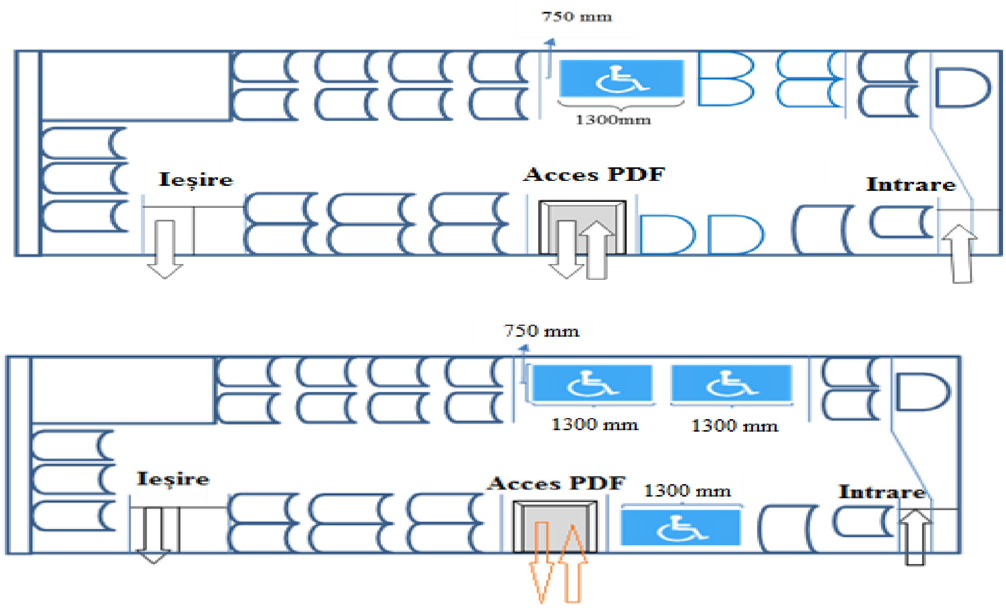

Figure 6.2. a) Urban bus with a length of 12m (27 seats and 1 seat for people with physical disabilities), b) three-seater adapted bus for people with physical disabilities

6.3.3 Adaptarea serviciului de transport cu autobuzul

The automatic ramp has an estimated opening/closing time of 8 seconds, so a full duty cycle is approximately 16 seconds.

The other estimated times are mentioned in Figure 6.3 below, where the exit of three physically disabled persons is considered first, and then three other successive entries. It is not necessary that the time the bus is standing at the station also includes the time for locking the wheelchair (mooring).

Total access time in buses equipped with electro-hydraulic ramp:

$T_{raeh} = T_{or} + T_{ib1,2,3} + T_{evinter} + T_{ab1,2,3}$ = 16 s + 20 s + 5 s + 20 s = 61 s

where: T_{or}= time for operating the electro-hydraulic ramp;

- $T_{ab1,2,3}$ = time for the successive descent of three physically disabled persons;
- $T_{evinter}$ = time required to avoid interaction between two physically disabled persons descending and ascending;
- $T_{ib1,2,3}$ = time for the ascent of three physically disabled persons.

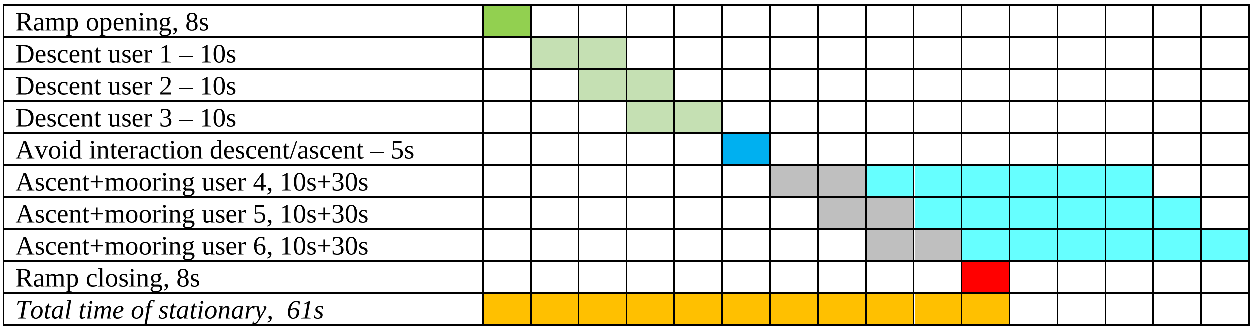

Figure 6. 3. Time required for physically disabled access using an automatic ramp

In order to identify the effect of the introduction of equipment for the automatic handling of the ramp for people with disabilities, the total duration of use of a manual ramp is calculated.

Total access time on buses equipped with manually operated ramp:

$$T_{rm} = T_{aa} + T_{ic} + T_{drm} + T_{ab1,2,3} + T_{evinter} + T_{i1,2,3} + T_{îrm} + T_{rc} = 190 \text{ s}$$

where: T_{aa} = the time required to secure the bus;

The choice of three departures of an urban bus line was made so as not to affect/influence public transport at peak times. In the table below, the three routes of the bus line, in one direction between origin and destination, are presented, where it was highlighted the timetable adapted for the circulation of the specially adapted bus (italic font, bold). In the modified timetable, additional standing time for people with physical disabilities (T_{raeh}), is included, in a few stations (points of interest) selected along the route of the bus line..

6.4 Estimation of the impact of the proposed adaptations for a more inclusive urban passenger transport

6.4.1 The impact of bus adaptation on the operator and regular users

The total costs for adapting the two buses on the line include:

- The cost of the automatic ramp with electrohydraulic actuation: 7000 RON for all the equipment;
- The labor cost related to mounting on the bus (approximately 10 hours of work): 10 hours x 200 RON/hour = 2000 RON/automatic ramp mounted and connected, in operating condition;
- The cost of adapting the interior space of the bus to ensure wheelchairs (approximately 5 hours of work and additional parts/elements needed for anchoring): 5 hours x 200 RON/hour + 1000 RON parts needed = 2000 RON/adapted bus.

Therefore, the total cost for adapting two buses for more inclusive transport services:

2 x 11000 RON/bus = 22000 RON.

6.4.2 The impact of increased time due to an inclusive transport service on regular users

For the one-way inclusive service, there are seven selected bus stops, where the additional time required for three successive descents of physically disabled persons and then three further ascents takes approximately one minute for each stop.

The maximum estimated time is seven minutes for the inclusive one-way service. If all regular users of the inclusive bus (about 100 users) travel from one end of the bus line to the other end, we estimate the total amount of time lost along that journey.

For this estimation we use a simplified methodology (Popa 2000), (Ortuzar 2022) for the estimation of the value of travel time (VTC), which is based on the average income of travelers in the study area. Thus, the average net salary in the analyzed area was approximately 3217 RON in 2020.

The value of travel time is considered to be approximately 25% of the average net salary per time unit, i.e. VTC = 0.25x3217 RON/month: 22 working days/month: 8 hours/day: 60 min/hour = 0.076 RON/minute.

Thus, we can conclude that, in the worst case, when the inclusive bus carries all approximately 100 regular passengers on a one-way trip, the total cost of traveling on an inclusive bus with the physically disabled, when the additional time is approximately 7 minutes: 7 min x 100 passengers x 0.076 RON/min. = 53.20 RON for one-way travel. The hidden cost (non-monetary) for each traveler is only 0.53 RON for a trip on an inclusive bus, which is actually the price of every regular citizen to live in an inclusive environment.

Chapter 7. CONCLUSIONS, CONTRIBUTIONS AND FUTURE RESEARCH DIRECTIONS

7.1 Final conclusions

1. From the research and synthesis of a wider literature than that specified in the bibliography of the work, several essential elements result that make the topic necessary and timely, namely:

- the city that is based on motorized mobility and road transport becomes no longer economically efficient, in addition to the aggressions on the natural environment that the development of the road traffic infrastructure generates.

- public passenger transport is an obligation of local, regional or central public authorities to ensure the "right to mobility" of the inhabitants, and it is also the main tool at the authority's disposal for sustainable urban development solutions.

-in the case of cities that did not invest early in traffic decongestion measures (lack of investment both in the public transport system and in an infrastructure favorable to public transport and pedestrians), the degree of motorization of the inhabitants increased, transport in common becoming uncompetitive and ineffective in the absence of policies for its development.

- urban traffic oversaturated with personal vehicles does not allow a sustainable evolution of the city, many areas being deprived of easy access to the main points of interest of an urban settlement.

- the implementation of "mobility as a service" solutions integrated with quality public transport services, as a basic element, can lead to the attraction of individual car transport users towards sustainable social mobility.

The necessity of the research topic led to the formulation of some research questions that oriented the analysis, synthesis and research effort to identify solutions to improve the quality of public urban passenger transport services.

2. For conceptual clarifications and differentiations of the notion of quality used in various fields, such as the field of production of material goods, the field of service provision, and among these, the provision of public services, and then even more narrowly, for public passenger transport services from the urban environment, we analyzed and synthesized the various

meanings, definitions, treatments in a distinct chapter, and the most important conclusions are as follows

- in the literature, service quality, in general, is a different concept from product quality, with material representation, although some similarities may exist, especially due to the precedence of research related to the development of manufacturing quality assurance systems.

- for services, the quality perceived by the user is the element, which, if it reaches high levels, through appropriate solutions, positively influences, further, the quality achieved by the operator of the transport service, which can become a virtuous circle of sustainable mobility.

- the quality of public transport services in a certain area of analysis depends on the strategic, tactical and operative decisions to which both the public authority and the administrations of different categories contribute, as well as the user communities through their level of demand.

- in the evaluation of the quality, quantitative indicators can be used that assess properties of the public transport service, observed directly, or/and qualitative indicators, which estimate the perceptions of passengers.

- the public transport service is one belonging to the sphere of regulated services, and the regulations and directives at national and European level must be properly implemented in the current practice of the provider, the authority and the users.

- for more precise determinations of the achieved quality of the urban public transport service, information technologies make available the traffic tracking system (Automated vehicle location - AVL).

3. The collection of data for the evaluation of the quality level of the transport services is still a completely unclear subject, on which we carried out research in the specialized literature, which further supported the practical research approach undertaken. Some of the most important conclusions of the theoretical investigations are as follows:

- the main data collection techniques for surveys and surveys regarding the quality of public transport are similar to statistical research with other different transport purposes, differentiated by some particularities, related to the types of surveys, types of questions – observed preference and/or preference declared, types of allowed answers, sample size, evaluation scales.

- essential differences result mainly from the need to help the respondent in revealing impressions/perception of the trips made (to observe travel habits).

- there is no need to adapt the questionnaires and the way of carrying out the surveys to provide support in the correct understanding of the questions

7.2 Own contributions

In a list of my main contributions in the PhD thesis, I can state at least the following as follows:

1. Synthesis of the literature to determine the need to develop the thesis, revealing the difficulties encountered in mobility and transport in large cities and the support that quality urban public transport can provide to those responsible for urban planning.

2. Conceptual clarifications and differentiations of the notion of quality used in various fields, such as the field of production of material goods, the field of service provision, and among these, the provision of public services and, more narrowly, for public passenger transport services in the urban environment I analyzed and synthesized the various meanings, definitions, treatments.

3. Synthesis of data collection methods and techniques for assessing the level of quality of transport services, which are differentiated by various particularities from the techniques used in other fields.

4. Designing, carrying out the survey in the pilot phase, and then creating the databases and analyzing the results for two types of surveys:

a. the first survey, which is intended to determine the factors that relevantly influence travelers' perception (degree of satisfaction) regarding the quality of public transport services,

b. the second survey, which aims to identify the importance of knowing/displaying the traffic schedule in each waiting station for public bus transport, for a transport line from the periphery, also called a collection transport line/" feeder" for high-capacity and high-speed transit services (tram with dedicated track or subway).

5. Realization of a methodology for adjusting the traffic schedule for two categories of public passenger transport services in the urban environment, following the analyzes of a database made up of records with the AVL system. Statistical analysis of schedule deviations for:

a- a "feeder" bus line from the periphery, to other "collector" lines of the public urban passenger transport network,

b- a tram line with a circular route, with the role of a "collection" route.

6. Design and implementation of the database for analysis and calculation of traffic schedule adjustments for robust operation.

7. Statistical description of systematic deviations from the schedule to identify the schedule adjustment value in the stations of interest and with the highest passenger flow.

8. A solution for adjusting the planned traffic schedule with the method of genetic algorithms for a tram line with a dedicated track.

9. Designing a solution to automate the actuation of the access ramp that is found in the equipment of the bus fleet but the actuation is manual, as well as estimating the costs of modernizing a bus

10. Solution for adapting the interior of buses intended for more inclusive public transport by widening, as well as estimating the adaptation costs.

11. Identification of services/rides intended for inclusive transport and estimation of the impact on other users due to prolonged waiting in stations for the access of persons with physical disabilities.

7.3 Future research directions

The doctoral thesis discusses, once again, the quality that a public transport service should offer, adapted to the need for flexibility and integration/intermodality that citizens in dense urban environments have.

The research undertaken in the thesis has the major limitation of some data recorded only in a few months from January to May 2022, when economic and social activities were resumed after major restrictions of physical interaction.

a. So, the database for the analysis of the annual (or seasonal) adjustment of the traffic schedule must be extended to consider a stable behavior for both the operator and the users.
b. A direction of study should mainly address non-users of public transport services. It will be possible to identify in detail what non-users want/preferences to change their car addiction behavior.
c. The solutions identified for adapting some bus transport services to the needs of people with physical disabilities and calculating monetary costs for operators and non-monetary/hidden costs for general users can be extended for other categories of people with disabilities/reduced spatial accessibility.
d. For greater spatial coverage of a robust, inclusive public transport network, further research is needed to establish bus and trolley lines and the proportion of each operator's fleet adapted to the special needs of people with physical disabilities.
e. Carrying out "in-depth" surveys with representatives of local public authorities to identify the availability of municipalities to support free public transport.

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