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ANALYSIS OF THE EFFICIENCY OF SUBURBAN PASSENGER TRANSPORTATION ON THE LVIV RAILWAY SECTIONS

Summary. A developed transport system ensures the population's needs in safe movement and guarantees stable functioning and development of the production sphere. Despite being consistently unprofitable, suburban transportation by railway remains attractive for many population categories. The developed railway network, the low cost of transportation, and the capacity reserve of most sections partially compensate for the existing shortcomings and contribute to further development and open new prospects for attracting additional users of transport services. The main problems of suburban passenger transport, which worsen the quality of the services provided and affect the competitiveness of railway suburban transport compared to other modes of transport, are examined in this article. During the analysis of the schedule of suburban trains departing and arriving at the Lviv station, irrational management decisions were found that left room for improvement. In addition, the load factor of rolling stock on the routes Lviv-Sambir-Sianky and Sianky-Sambir-Lviv was determined, and it dropped to 40 % during the follow-up, which indicates inefficient use of rolling stock. The ratio of the time the train stays at the stops to the total duration of the route in suburban traffic is also calculated. The time on the road for the Sambir- Stryi route was 69 %, and the technical speed was only 21.7 km/h. The results obtained in the article are also typical for many other monitoring areas, indicating this problem's repeatability.

The positive experience of European countries in solving similar problems allows us to react correctly to the situation and take short-term measures to change the dynamics to a positive one without additional time losses. It is also worth noting that a set of measures to improve the services provided to passengers must be carried out according to the requirements of the Technical Specifications for Interoperability, which must be ensured upon joining the European Union. Further investigations should analyze the flow of passengers at all stations and stopping points to identify the main points of creating passenger flow on researching routes.

Keywords: suburban transportation, passenger rail transportation, problems of suburban passenger transportation.

1. INTRODUCTION

The requirements for suburban passenger transportation are increasing from year to year. In the conditions of fierce competition, railway transport begins to lose passengers due to the increase in requirements for the quality of the services provided. Outdated rolling stock, low transportation speed and long intervals between trains make commuter rail transport less attractive to potential users.

The demand for suburban passenger transportation by rail depends on many factors. They include [1, 2]:

- the number of the population of the state and the dynamics of changes;

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- location of large production enterprises, educational institutions, and medical institutions by administrative-territorial units;
- level of development of other types of passenger transport;
- rates of population`s urbanization;
- improving the quality of services provided to passengers;
- introduction of preferential tariffs for specific categories of passengers;

According to the plans of the "Suburban Passenger Company" branch, measures will be taken to reduce the carrier's costs [3]. Optimization, unification, repair, and operational work standardization are planned to achieve the goal. Therefore, there is a need for further research aimed at optimizing suburban railway connections.

2. RESEARCH STATEMENT

In Ukraine, a significant share of passenger transportation is railway transportation. Moreover, 70 % of passengers are on suburban transportation [4]. Despite such a large share of the total number of passengers, this type of transportation is the most unprofitable, with significant organizational and technical problems. According to data provided by Ukrzaliznytsia [3, 5, 6], from 2010 to 2020, suburban passenger transportation caused company losses of approximately UAH 40 billion. Statistics by years are presented in Fig. 1. The company spends approximately 20 % of its profits from freight transportation to cover costs for such transportation.

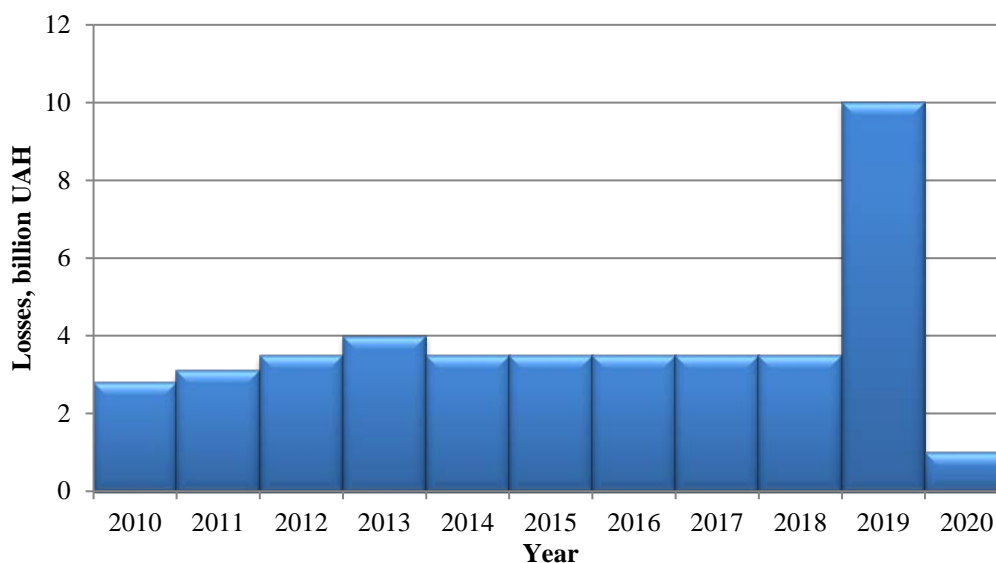


Fig. 1. Unprofitability of suburban passenger transportation by rail in the period from 2010 to 2020

In addition, the following “chronic” problems are characteristic of passenger suburban rail transport [7]:

- wear and tear of rolling stock;
- low transport speed;
- insufficient frequency of trains to ensure that the traffic schedule is close to similar car routes;
- low organization of interaction with other types of urban transport.

Moreover, passenger transportation is organized according to old Soviet templates and requires new comprehensive solutions. Transportation by high-volume trains with long intervals does not provide the opportunity to compete equally with automobiles despite the lesser transportation costs.

The experience of European countries can be used to solve the problems mentioned above, particularly those of Germany, Great Britain, France, Sweden, etc. These countries comply with the

Technical Specifications for Interoperability (TSI) requirements, the implementation of which must be ensured by Ukraine upon joining the European Union. In the conditions of increased passenger demands for the quality of service, carriers had to apply the latest approaches and practices to the organization of suburban traffic. In particular [8, 9]:

- acceptable intervals of movement between trains;
- high speed of movement on the section;
- construction of the rolling stock composition, which depends on the demand for transportation;
- providing a dynamic traffic schedule, which can change in a short time based on the results of an analysis of passenger flows in real-time.

Implementing such changes requires modern methods of monitoring the number of passengers to select rolling stock with a capacity that meets the needs. The general concept is a small interval between trains with a small passenger capacity [9–11]. As an example, we can cite [12] the train schedule of the Swedish company SL (Storstockholms Lokaltrafik) on the section Stockholm City – Nynäshamn (Table 1).

Table 1

The schedule of suburban passenger trains on the section Stockholm City – Nynäshamn

Monday – Friday													
Hours	Minutes						Hours	Minutes					
04	36	51e					15	06e	14c	21e	36e	44c	51e
05	06	21e	36	51e			16	06e	14c	21e	36e	44c	51e
06	06	21e	36e	44c	51e		17	06e	14c	21e	36e	44c	51e
07	06e	14c	21e	36e	44c	51e	18	06e	14c	21e	36e	46c	51e
08	06e	14c	21e	36e	44c	51e	19	06e	16c	21e	36e	46c	51e
09	06e	14c	21e	36e	46c	51e	20	06e	16c	21e	36e	46c	51e
10	06e	16c	21e	36e	46c	51e	21	06e	21	36e	51e		
11	06e	16c	21e	36e	46c	51e	22	06e	21	36e	51e		
12	06e	16c	21e	36e	46c	51e	23	06e	21	36e	51e		
13	06e	16c	21e	36e	46c	51e	00	06e	21	36de			
14	06e	16c	21e	36e	44c	51e	01	06de	36d				

The schedule is presented without a weekend. The longest route is 130 km. Markings in the schedule: e – follows only to the station Västerhaninge; c – does not stop at the section Trångsund – Vega; d – rides only on Friday.

For a visual representation, the scheme of movement of suburban trains in Stockholm is presented in Fig. 2.



Fig. 2. Stockholm suburban train traffic scheme [13]

Analysis of the schedule shows a large number of train pairs. There are also periods when the train follows certain sections without stops, and in some cases, the train route is shortened.

It should be added that trains run on sections, the composition of which contains from two to eight carriages, mainly 2 to 4 carriages are used. To a certain extent, the routes are also duplicated by road transport. The technical speed of the Stockholm City – Nynäshamn train for different variations of the route is shown in Table 2.

Table 2

Technical train speed Stockholm City – Nynäshamn for different route variations

Route	Total duration of the trip, min/h	The total length of the route, km	Technical speed, km/h
1	51/0.85	62	72.9
2	53/0.88	62	70.5
3	57/0.95	62	65.3
4	61/1.02	62	60.8

It is also possible to consider suburban rail transport, which is carried out in the London agglomeration. The scheme of London's main trains is presented in Fig.3.



Fig. 3. London suburban train traffic scheme [14]

As we can see, suburban trains have a relatively extensive network of routes, mainly outside the city. One of the routes, Watford Junction – Euston Station, with a total length of about 30 km daily, provides transportation of passengers from 05:38 to 23:58, observing a constant interval of 15 minutes. Transportation is carried out by rolling stock of 2–4 wagons.

Given this density of trains, there is a need to optimize the composition of the rolling stock for transportation and constantly monitor each route's demand for the possibility of making operational changes.

In the scientific work [1], the problems of the passenger transportation market were considered, and methods of increasing the competitiveness of railway transportation were proposed. The article [15] describes the improvement of the existing system of suburban passenger transportation through more efficient transport service of passenger flows. Among the publications, it is also worth noting works [16], [17, 18] and others.

The relevance of the research topic is the need to increase the speed of following suburban trains, improve the efficiency of rolling stock, and increase the quality of the provided transport services. The study of suburban rail transport will be conducted using the Lviv-Sianky and Stryi – Sambir routes. The results obtained will be compared with those of similar European routes. The purpose of the work is to obtain conclusions regarding the implementation of short-term and long-term changes aimed at the development and improvement of suburban railway transportation, taking into account the experience of European countries.

3. PRESENTATION OF THE BASIC MATERIAL

According to the source [2], the volume of transported passengers in suburban traffic largely depends on the time of day and the season. For example, from 6:00 to 9:00 and from 17:00 to 19:00, approximately 70 % of the daily passenger traffic is accounted for. Analyzing the composition of suburban rolling stock, it can be noted that it does not depend on the number of passengers using rail transport services at a specific time.

For a more detailed analysis, the direction Lviv-Sambir-Sianky was chosen. The route of this section is in demand among passengers. Suburban transportation here is carried out according to the schedule [19] presented in Table 3.

Table 3

The schedule of suburban passenger trains on the section Lviv – Sambir – Sianky in both directions

Direction	
Lviv – Sambir – Sianky	Sianky – Sambir – Lviv
09:30–11:23–13:53	02:40–05:03–07:12
17:40–19:44–22:49 (except Saturday)	05:00–07:30–09:58 (except Saturday)
20:43–22:39–01:20	14:46–17:07–19:23

The total length of the route is 160 km. Time on the road is from 4 hours 23 minutes (47 minutes are due to train stops, which is 17.9 % of the total duration of the route) to 5 hours 09 minutes (80 minutes are due to train stops, 25.9 %).

Using statistical data on tickets sold for each station, we will create a diagram of the rolling stock occupancy in the section Lviv – Sambir – Sianky (Fig. 4) та Sianky – Sambir – Lviv (Fig. 5). We will understand the relationship between the actual number of passengers and the number of seats as occupancy. We have chosen transportation carried out under standard conditions to construct the diagram.

Lviv		70/90
Sknyliv		73/93
Obroshyno-Mistky		75/95
Velykyi Liubin-Porichchia		70/90
Komarno-s.p.39		60/80
Rudky-63km		55/75
Sambir-Sozan		50/70
Stryi Sambir - s.p.Luzhok		40/60
Strilky - Yavora		37/57
Turka - s.p. Benkove		less than 40%
Sianky		less than 40%
		100%
		monday - thursday, saturday-sunday(in the numerator)
		friday(in the denominator)

Fig. 4. Rolling stock load on the section Lviv – Sambir — Sianky

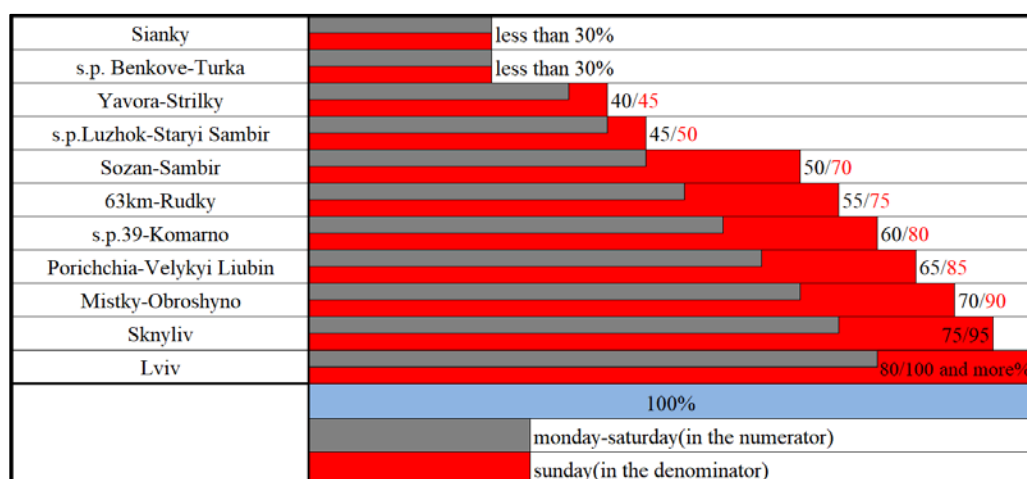


Fig. 5. Rolling stock load on the section Sianky – Sambir – Lviv

Unfortunately, a significant proportion of discount tickets are not sold through ticket offices. In addition, there is a certain number of ticketless passengers. Moreover, some passengers pay for a ticket that does not correspond to their point of departure or destination. Such factors significantly influence the construction of the above graphs. However, it is observed that the rolling stock is used inefficiently in the sections Stryi Sambir – Sianky and Sianky – Stryi Sambir. This is about 70 km (44 % of the total length of the route); that is, during movement, 40–60 % of the passenger capacity of the rolling stock is not used. It indicates a low organization of the transportation process, which leads to suboptimal operation and, accordingly, to an increase in the wear and tear of the rolling stock and rail, inefficient planning of the working hours of railway workers, and other negative consequences.

The Stryi-Sambir trip, with a total of 63 km, has been partially analyzed. The fastest trip lasts 2 hours 10 minutes, and the longest route is 2 hours 54 minutes. The technical speed of the trip with the longest duration is 21.7 km/h, which is extremely low. According to statistical data on the indicated route for December 2023, 5,500 passengers used the railway services in both directions, including 1,000 passengers of preferential categories. The total number of seats in one train is 420. It is possible to transport 2,480 passengers in both directions per day and 74,400 passengers per month, respectively. The average monthly load is less than 8 %. We will also calculate the ratio of the time spent by the train at the stops to the total duration of the trip as a percentage. The results of the calculations are presented in Table 4.

Table 4

The ratio of the time a train spends at stops to the total duration of the trip on the section Stryi – Sambir in both directions

Route/Train schedule	The total duration of the trip, min	The total duration of stops, min	Share attributable to train movement, %	Share attributable to stops, %
Stryi – Sambir 05:25–07:52	147	34	76.9	23.1
Stryi – Sambir 11:36–13:45	128	16	87.5	12.5
Stryi – Sambir 17:58–20:12	134	23	82.8	17.2
Sambir – Stryi 04:35–07:29	174	54	69.0	31.0
Sambir – Stryi 08:14–10:39	145	31	78.6	21.4
Sambir – Stryi 17:15–19:25	130	27	79.0	21.0

The ratio of the time the train stays at the stops to the total duration of the trip for trains departing from or arriving at the suburban station of Lviv station is summarized in the graph presented in Fig. 6.

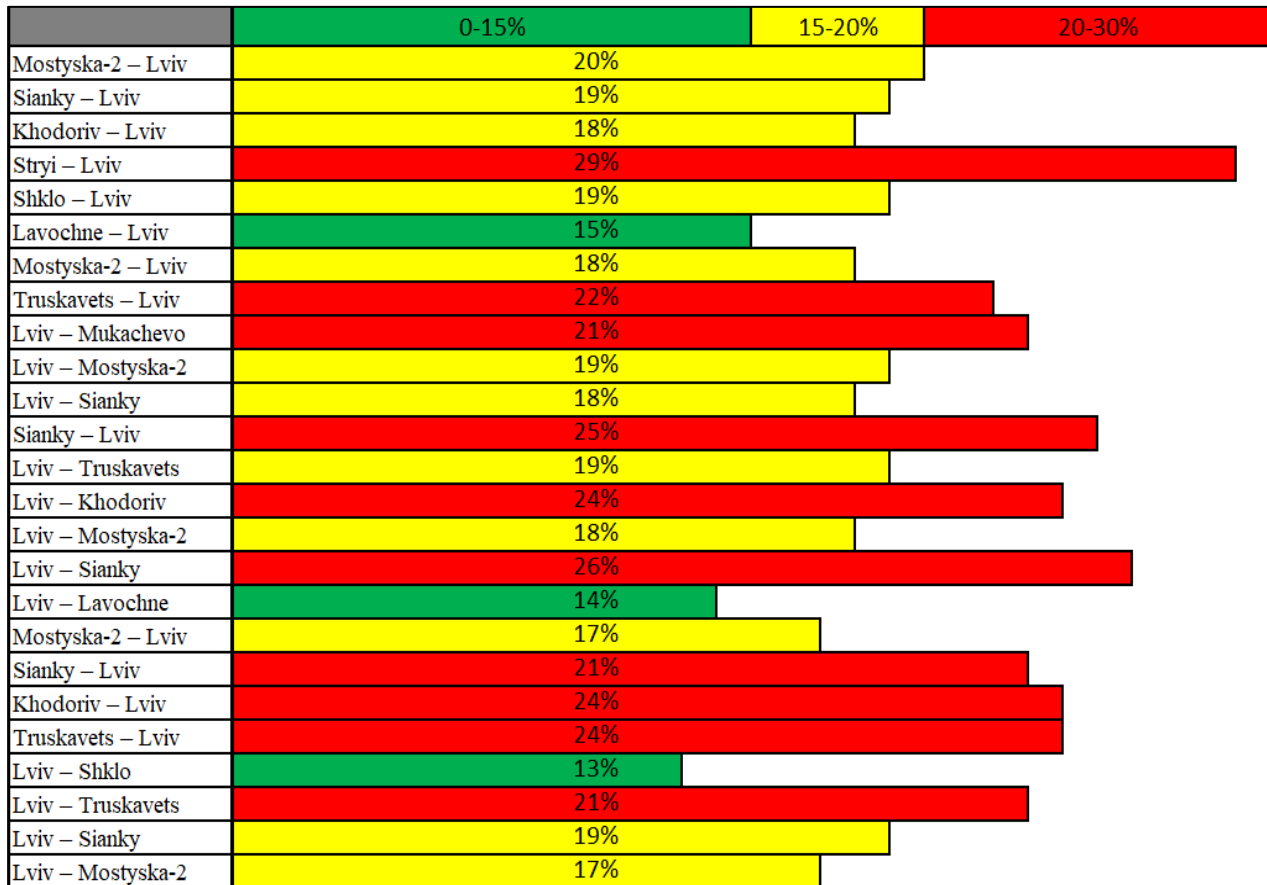


Fig. 6. The ratio of the time a train spends at stops to the total duration of the trip

The technical speed of trains departing or arriving at the suburban station house of Lviv station is summarized in Table 5. We will use the current train schedule for the calculation [19].

Table 5

The technical speed of trains departing or arriving at the suburban station house of Lviv station

Route/ Train schedule	Total duration of the trip, min/h	The total duration of stops, min	The total length of the route, km	Technical speed, km/h
1	2	3	4	5
Mostyska-2 – Lviv 04:17–06:43	146/2.43	29	78.3	32.2
Sianky – Lviv 02:40–07:12	272/4.53	52	167.4	36.9
Khodoriv – Lviv 05:05–07:22	137/2.28	25	62.8	27.5
Stryi – Lviv 05:35–07:27	112/1.87	32	75.0	40.1
Shklo – Lviv 05:56–07:40	104/1.73	20	44.4	25.7
Lavochne – Lviv 04:30–07:50	200/3.33	30	147.6	44.3
Mostyska-2 – Lviv 05:58–07:59	121/2.02	22	78.3	38.8

Continuation of Table 5

1	2	3	4	5
Truskavets – Lviv 05:45–08:27	162/2.70	36	114.0	42.2
Lviv – Mukachevo 09:01–15:04	363/6.05	78	216.5	35.8
Lviv – Mostyska-2 09:01–11:03	122/2.03	23	78.3	38.6
Lviv – Sianky 09:30–13:53	263/4.38	47	167.4	38.2
Sianky – Lviv 05:00–09:58	298/4.97	75	167.4	33.7
Lviv – Truskavets 14:00–16:39	159/2.65	31	114.0	43.0
Lviv – Khodoriv 17:39– 0:07	148/2.47	36	62.8	25.4
Lviv – Mostyska-2 17:40–19:45	125/2.08	23	78.3	37.6
Lviv – Sianky 17:40–22:49	309/5.15	80	167.4	32.5
Lviv – Lavochno 17:49–21:17	208/3.47	30	147.6	42.5
Mostyska-2 – Lviv 17:00–19:06	126/2.10	22	78.3	37.3
Sianky – Lviv 14:46–19:23	277/4.62	57	167.4	36.2
Khodoriv – Lviv 17:14–19:34	140/2.33	34	62.8	27.0
Truskavets – Lviv 16:58–19:40	162/2.7	39	114.0	42.2
Lviv – Shklo 20:31–22:15	104/1.73	13	44.4	25.7
Lviv – Truskavets 20:22–23:05	163/2.72	35	114.0	41.9
Lviv – Sianky 20:47–01:24	277/4.62	54	167.4	36.2
Lviv – Mostyska-2 20:43–22:56	133/2.22	23	78.3	35.3

The results are related to the uneven distribution of passenger flows in suburban traffic by time of day, day of the week, and season, as well as a significant attraction to large stations.

In addition, the technical speed of a similar route by the Swedish carrier is 1.5–3 times higher than the routes we analyzed. This is explained by the optimization number of stops, the time spent at the stops, and the technical characteristics of the rolling stock.

Evaluating the above and considering all the problems and shortcomings, suburban passenger transportation on the Lviv – Sambir – Sianky and Stryi – Sambir sections has some advantages that can improve the overall situation with suburban transit. They include:

- the extensiveness of the railway network, which connects recreational areas and potentially attractive tourist facilities;
- short distance to the border crossing points;
- availability of capacity reserves in most sections.

If we consider suburban rail transportation in the country as a whole, then the following methods can be proposed to solve the mentioned problems at the expense of:

- implementation of monitoring systems at the request of passengers at sections, stations and stopping points;

- increasing the efficiency of the use of rolling stock;
- formation of new trains using rolling stock created at our production facilities;
- slight increase in tariffs;
- reducing the interval between trains;
- attraction of a larger number of regular trains on promising sections that compete with road transport;
- division of routes with a length of more than 150 km into separate routes;
- introduction of measures to prevent ticketless travel;
- testing new experimental routes.

4. CONCLUSIONS AND FUTURE RESEARCH PERSPECTIVES

Suburban passenger transportation by rail plays an essential role in Ukraine's transport complex. They cover almost all population categories and provide interconnections between the country's regions in economic, social, and other spheres. Increasing labor productivity and rational use of labor resources largely depends on the efficiency of passenger transportation. Carrying out a number of important and versatile tasks requires constant improvement and modernization. Taking into account the growth of competition and increased demands of passengers for the quality of service, the number of passengers transported by railway transport within the suburban zone is decreasing.

The main measures to increase competitiveness and maintain demand for the use of railway transport are updating the rolling stock and infrastructure, increasing the speed of transportation, reducing the intervals between trains, increasing the level of passenger service at train stations, improving the sanitary and technical condition of the rolling stock.

The results indicate a low technical speed of transportation in the range of 22–45 km/h, which is much lower than similar European routes, for which the technical speed of 70 km/h is an average indicator. In addition, it should be noted that the occupancy of the rolling stock on the train's path is sometimes reduced to 30 %, which requires optimization of the rolling stock composition or the decomposition of existing routes.

The problem of ticketless travel can be solved in the following ways: the introduction of self-service machines for buying a ticket, the introduction of an additional commission fee when buying a ticket at traveling ticket cashiers, preventing the use of one ticket by many passengers, carrying out extra checks for the presence of a ticket at separate points.

Implementing both short-term and long-term changes will increase the use of rolling stock and transport infrastructure, improve passengers' comfort and help them use their time effectively. The set of measures aimed at developing and enhancing suburban railway transportation must be implemented in compliance with the TSI requirements, which must be ensured upon joining the European Union.

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АНАЛІЗ ЕФЕКТИВНОСТІ ПРИМІСЬКИХ ПАСАЖИРСЬКИХ ПЕРЕВЕЗЕНЬ НА ДІЛЯНКАХ ЛЬВІВСЬКОЇ ЗАЛІЗНИЦІ

Анотація. Розвинена транспортна система забезпечує потреби населення в безпечному переміщенні та є запорукою стабільного функціонування та розвитку виробничої сфери. Приміські перевезення залізничним транспортом, хоч і є стабільно збитковими, але залишаються привабливими для багатьох категорій населення. Розвинена залізнична мережа, низька собівартість перевезень та резерв пропускнув спроможності більшості ділянок частково компенсують наявні недоліки та сприяють подальшому розвитку і відкривають нові перспективи щодо залучення додаткових користувачів транспортних послуг. У статті розглянуто основні проблеми приміських пасажирських перевезень, які погіршують якість наданих послуг та впливають на конкурентоспроможність залізничних приміських перевезень

порівняно з іншими видами транспорту. Під час аналізу розкладу руху приміських поїздів, що відправляються та прибувають на станцію Львів, виявлено нераціональні управлінські рішення, які можливо удосконалити. Крім цього, на маршруті Львів – Самбір – Сянки та Сянки – Самбір – Львів визначено коефіцієнт завантаження рухомого складу, який упродовж слідування опускався до позначки 40 %, що свідчить про неефективне використання рухомого складу. Також обчислено відношення часу перебування поїзда на зупинках до загальної тривалості рейсу приміського руху. Для маршруту Самбір – Стрий час перебування в русі становив 69 %, а технічна швидкість – лише 21,7 км/год. Отримані в статті результати характерні також для багатьох інших ділянок слідування, що свідчить про повторюваність цієї проблеми.

Позитивний досвід європейських країн у вирішенні схожих проблем дає змогу правильно відреагувати на ситуацію та вжити короткострокових заходів для зміни динаміки на позитивну без додаткових часових втрат. Також варто зазначити, що комплекс заходів щодо покращення наданих послуг пасажирові повинен здійснюватися відповідно до вимог TSI, імплементацію яких необхідно забезпечити для вступу до Європейського Союзу. У подальших дослідженнях варто проаналізувати потоки пасажирів на всіх станціях та пунктах зупинок для визначення основних пасажироутворювальних пунктів на досліджуваних маршрутах.

Ключові слова: приміські пасажирські перевезення, пасажирські залізничні перевезення, проблеми приміських перевезень пасажирів.