Nexo Revista Científica
Vol. 36, No. 06, pp. 1793-1799/Diciembre 2021

ISSN-E 1995-9516
Universidad Nacional de Ingeniería

http://revistas.uni.edu.ni/index.php/Nexo
https://doi.org/10.5377/nexo.v34i06.13160

Organization of coordinated functioning of various types of passenger transport in transport-interchange hubs

Organización del funcionamiento coordinado de distintos tipos de transporte de pasajeros en centros transporte-intercambio

Oleg Moskvichev*, Svetlana Leonova

Samara State Transport University. Samara, Russia.
*Corresponding author E-mail: oleg.moskvichev@internet.ru

(recibido/received: 28-octubre-2021; aceptado/accepted: 07-diciembre-2021)

ABSTRACT

The article deals with the organization of high-quality interaction of various types of passenger transport in the transport- interchange hub. Urban and regional interchange hubs are being studied. A methodology based on the use of quantitative methods and implemented with the help of software products (the developed program "Effective transfers" and the well-known simulation modeling programs PTV Visum, AnyLogic) is suggested. This method is applicable for any city and includes 3 stages. At the first stage, the number of passengers in the transport-interchange hubs who transfer from one type of urban public transport to another is predicted; the direction of passenger traffic is determined; urban routes that require schedule approval are chosen. At the second stage, the number of passengers who use the considered transport-interchange hub to transfer from suburban, intercity transport to urban modes of transport is predicted. At the third stage, the schedule of all types of transport is coordinated; the need for rolling stock is determined; passenger traffic is modeled and studied at the hub in order to rationally organize the planning structure of the transport-interchange hub. The obtained scientific results can be used in the design of a system of transport and transfer hubs and planning the placement of transport and social facilities on the territory of the transport-interchange hub.

Keywords: Railway transport; Suburban transport; Transport-interchange hub, Urban transport.

RESUMEN

El artículo trata de la organización de la interacción de alta calidad de varios tipos de transporte de pasajeros en el centro de intercambio de transporte. Se están estudiando centros de intercambio urbanos y regionales. Se sugiere una metodología basada en el uso de métodos cuantitativos e implementada con la ayuda de productos de software (el programa desarrollado "Transferencias efectivas" y los conocidos programas de modelado de simulación PTV Visum, AnyLogic). Este método es aplicable a cualquier ciudad e incluye 3 etapas. En la primera etapa, se predice el número de pasajeros en los centros de intercambio de transporte que se transfieren de un tipo de transporte público urbano a otro; se determina la dirección del tráfico de pasajeros; Se eligen rutas urbanas que requieran aprobación de horario. En la segunda etapa, se predice el número de pasajeros que utilizan el centro de intercambio de transporte considerado para trasladarse desde el transporte interurbano suburbano a los modos de transporte urbano; se determina la dirección del tráfico de pasajeros; la elección de tales rutas urbanas, cuyo horario debe coordinarse con el horario de las rutas de transporte suburbano e interurbano. En la tercera etapa, se coordina el horario de todos los tipos de transporte; se determina la necesidad de material rodante; el tráfico de pasajeros se modela y estudia en el centro con el fin de organizar racionalmente la estructura de planificación del centro de intercambio de transporte. Los resultados científicos obtenidos se pueden utilizar en el diseño de un sistema de centros de transporte y transferencia y en la planificación de la ubicación de las instalaciones sociales y de transporte en el territorio del centro de intercambio de transporte.

Palabras claves: Transporte ferroviario; Transporte suburbano; Centro de intercambio de transporte, Transporte urbano.

1. INTRODUCTION

One of the main directions of the development of the railway transport complex in Russia is to increase the transport mobility of the population within and between agglomerations in order to ensure the spatial development of the country, the expansion of the network of high-speed highways and the development of high-speed traffic (Institute for Natural Monopoly Problems, 2019). All this is impossible without a system of transport interchange hubs, which are key elements of the transport infrastructure (Kristersson, 2012; Monzón *et al*., 2016; Vlasov, 2017). The rational planning structure of the hub provides for the availability of transport and social facilities for a quick, comfortable and safe transfer from one type of transport to another, as well as for the provision of a number of additional services. The creation of the transport-interchange hub contributes to the development of urban mobility and improvement of the quality of the urban environment through the rational structure of the hub and the creation of public spaces on the territory of the transport-interchange hub. It is also important to determine the availability of transport-interchange hubs (Sun *et al*., 2018).

The transport interchange hub is the center of attraction for passenger traffic. The passenger, having the opportunity to transfer from one mode of transport to another in the transport-interchange hub or another node/stop, will choose a transport-interchange hub, since this transfer will be quik (usually no more than 3 minutes) and convenient, while there is the possibility of additional social services.

The main difference between the transport-interchange hubs from other transfer hubs is the provision of a consistent schedule for all vehicles that intersect at the hub. Given the fact that all types of urban, suburban and intercity transport can intersect at an interchange hub, it is very difficult to agree on the schedule of all vehicles, taking into account supply and demand. In this regard, there is a need to model and manage the system of transport-interchange hubs, which will solve the problem of high-quality interaction of transport modes in the transport-interchange hub and plan a rational planning structure of the hub.

2. MATERIALS AND METHODS

Modeling of the system of transport-interchange hubs provides for the possibility of rational choice for placing transport-interchange hubs, forecasting the amount of passenger traffic, drawing up an agreed schedule for all vehicles, determining the need for rolling stock, linking urban public transport routes with each other, with suburban and intercity routes. The most difficult is the predicting of passenger traffic in the transport-interchange hub and the coordination of the schedule of all modes of transport. Here it is important to schedule the movement of urban modes of transport so that the time spent on transfers between urban routes and the time spent on transfers from the main mode of transport (rail) to urban modes of transport are minimal.

In order to solve the problem of organizing high-quality interaction of various modes of transport in the transport-interchange hubs, it is necessary:

- make a rational choice on the transport-interchange hub placing,

- collect and analyze passenger traffic data, determine their size and direction of travel,
- agree on the schedule of urban public transport routes, depending on supply and demand,
- agree on the schedule of urban and suburban routes, intercity transport, depending on supply and demand,
- implement passenger traffic modeling in the transport-interchange hubs,
- determine the rational planning structure of the hub, create the necessary functional zones and ensure the development of public space.

The choice of locations for transport hubs is directly related to the passenger traffic and the already defined network of urban passenger transport, with the routes of urban public transport and routes of suburban, intercity transport (Fan *et al.*, 2018; Ludan *et al.*, 2018; Monzón *et al.*, 2016). On the urban passenger transport network, it is possible to distinguish urban transport-interchange hubs and regional transport-interchange hubs (Figure 1). In urban transport-interchange hubs, the routes of urban public transport intersect. In regional transport-interchange hubs are urban, suburban and intercity routes. In regional hubs, the main mode of transport is usually rail.

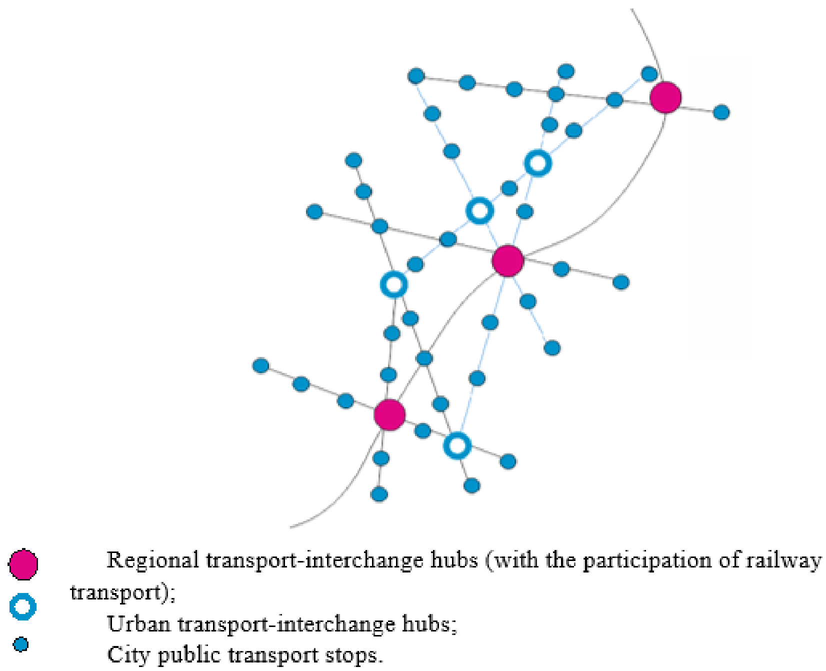

Figure 1. Urban and regional transport-interchange hubs on the urban public transport network.

The choice of locations for urban transport hubs is based on the use of quantitative methods, with the main criterion being the average time per trip (Kalyuzhnyi and Losin, 2018; Leonova, 2019a, 2019b; Moskvichev and Leonova, 2020). The forecast value of the number of passengers who will use a particular transport-interchange hub as a departure point, destination or transfer point is estimated.

The choice of locations for regional transport hubs is based on the principle of interaction between the main mode of transport (usually rail) and the "supply" modes of transport (urban) (Shagimuratova, 2016; Sherbina *et al.*, 2015).

The collection and analysis of data on urban passenger traffic is carried out using survey data and questionnaires, data from the transport model of the city.

Data on suburban and intercity passenger traffic is collected and analyzed based on the number of tickets sold and the number of passengers transported by rail, suburban and intercity buses.

To coordinate the movement schedule of all vehicles in the transport-interchange hub, to model passenger traffic and to plan the space of the hub, it is proposed to use a number of software products that will ensure high-quality interaction of transport networks of various types of transport in the hub, will make it possible to predict and manage passenger traffic in any period of time, to determine the rational planning structure of the hub.

To solve the problem of organizing high-quality interaction of various modes of transport in the transport-interchange hub, a method is proposed that includes three stages (Figure 2).

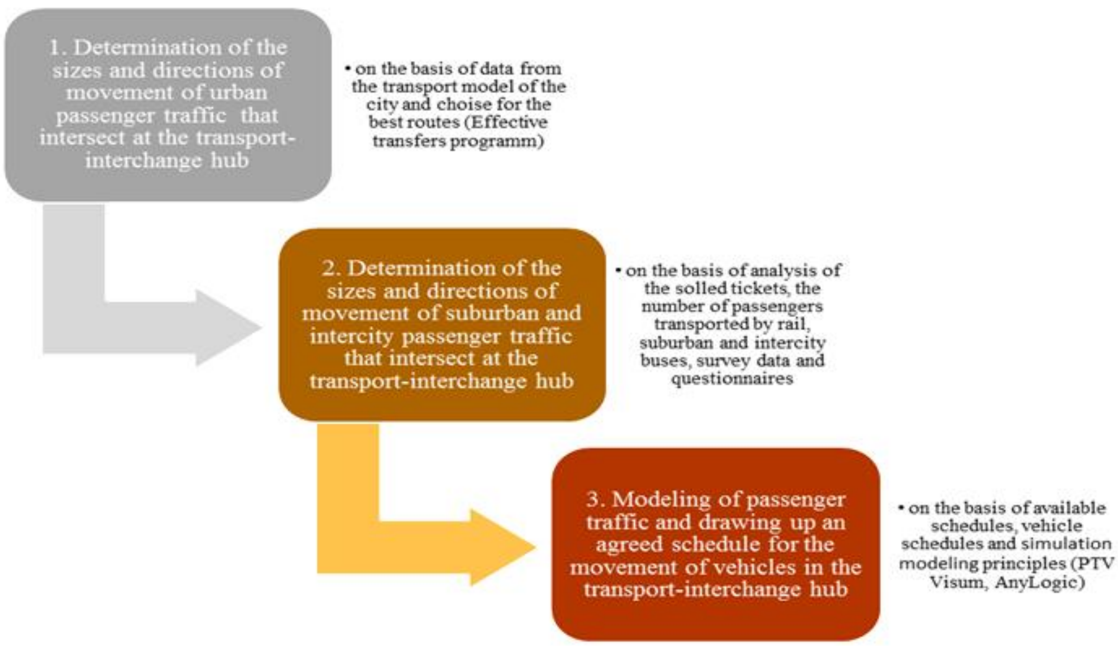

Figure 2. The proposed methodology for solving the problem of organizing high-quality interaction of various types of transport in the transport-interchange hub.

3. RESULTS AND DISCUSSION

The method suggested in the article is based on the use of quantitative methods and is implemented using software products (the developed program "Effective transfers" and the well-known simulation modeling programs PTV Visum, AnyLogic). This method is applicable for any city, but it is indispensable for cities with a developed system of urban land transport (in cities where most of the city area is subject to transport services, tram, bus and trolleybus routes cover the entire city).

At the **first stage**, it is carried out:

- predicting the number of passengers who use the transport-interchange hub as a transfer hub in the urban passenger transport system,

- determining the direction of passenger traffic,

- selecting city routes that require a consistent schedule to ensure fast transfers.

At this stage, based on the data obtained from the city's transport model, a matrix of inter-stop correspondences on the city's public transport networks is compiled. With the help of the developed program "Effective transfers" (in C#), the optimal routes from point *i* to point *j* are selected according to the criterion of the minimum travel time. Direct and transfer routes are defined. Firstly, direct routes are assigned, then routes with one transfer, with two transfers, and so on. The result is a set of transfer nodes for the urban passenger transport network and the amount of passenger traffic in each of them (Table 1).

Table 1. Selection of passenger routes in the urban public transport system with the help of the program “Effective transfers”.

From where (*i*)	To where (*j*)	Number of passengers, pass.	Direct (non-transfer) route	The numbers of the transport-interchange hubs where the transfer is carried out (for routes with transfers)	City public transport route number
1	2	11	Non-transfer		7, 21
1	3	20		8, 51	from 21 to 47, from 7 to 51
1	4	45	Non-transfer		54
1	5	7		43	from 8 to 30, from 8 to 43

Using a special algorithm in the program "Effective transfers" , you can get data not only on the number of passengers who use the considered transport-interchange hub as a departure point, destination and transfer point, but also on the routes that passengers use during the changing at this hub (Table 1).

Next, a list of all transport-interchange hubs on the urban passenger transport network is compiled, indicating the projected amount of passenger traffic at the hub, intersecting routes that require an agreed schedule of vehicles in the urban public transport system (Table 2).

Table 2. Characteristics of urban transport-interchange hubs.

Transport-interchange hub number	The numbers of all routes that pass through the transport-interchange hubs	Route numbers that require a consistent schedule to ensure a quick transfer	Passenger traffic, pass.
8	3, 5, 7, 21, 47, 51, 57	21 → 47 7 → 51	12000
51	5, 7, 21, 47, 51, 12, 71, 95	21 → 47 7 → 51 5 → 12	34000

At the **second** stage, it is carried out:

- predicting the number of passengers who use the considered transport-interchange hub to transfer from suburban, intercity transport to urban modes of transport,

- determining the direction of passenger traffic,

- the choice of such urban routes, the schedule of which should be coordinated with the schedule of suburban and intercity transport routes.

At this stage, it is important to enter data on suburban passenger traffic into the existing transport model of the city. Here, the points of passenger traffic emergence are suburban localities, and the points of repayment are points *j* on the urban transport network. Passengers departing from suburban localities arrive at regional transport hubs (Figure 1) and transfer from railway transport (suburban, intercity transport) to other types of urban public transport. The size of passenger traffic can be judged on the basis of the analysis of sold tickets, survey data, questionnaires, data on the place of residence of large enterprises employees and organizations when considering "labor" correspondence. Urban and suburban routes are identified that require an agreed schedule of vehicles to ensure a quick, safe and comfortable transfer at the hub (Table 3).

Table 3. Urban and suburban transport routes that require an agreed schedule.

Transport-interchange hub number	Suburban trains	Suburban buses	City route numbers
8	6504, 6578	420, 101, 544	21, 12, 47, 14, 7
230	6530, 6572, 6586	102, 380	51, 13, 62, 6

At the **third** stage, it is carried out:

- coordination of the schedule of all transport modes,

- determining the need for rolling stock,

- modeling and research of passenger traffic in the hub for the purpose of rational organization of the planning structure of the transport-interchange hub.

Using data on passenger traffic and on the routes of urban and suburban transport that intersect at the transport- interchange hub and require an agreed schedule, it is possible to ensure high-quality interaction of different types of transport, to calculate the need for rolling stock.

Simulation of passenger traffic in the transport-interchange hub, taking into account the time of day, is possible in simulation modeling programs (PTV Visum, AnyLogic). Knowing the schedule of vehicles, the density of passenger traffic in the simulated space of the hub is determined in order to identify "barrier" places and organize a rational planning structure. At this stage, it is also planned to organize public spaces and social infrastructure facilities.

4. CONCLUSION

The methodology suggested in the article allows organizing high-quality interaction of passenger transport systems in the transport-interchange hub by collecting and analyzing data on the sizes and direction of passenger traffic, choosing optimal routes, and modeling passenger traffic at the transport interchange hub. At the same time, the coordination of vehicles schedule in the system of urban public transport, the schedule of urban and suburban routes, intercity transport are ensured, passenger traffic is modeled, the need for rolling stock is calculated, the rational planning structure of the hub is determined, the necessary functional zones are created and the development of public space is ensured.

REFERENCES

Fan, B., Yang, Y. and Li, L. (2018). Integrated optimization of urban agglomeration passenger transport hub location and network design. EURASIP Journal on Wireless Communications and Networking, 2018 (1), 168.

Institute for Natural Monopoly Problems. (2019). Analytical report "Railway transport of Russia: Challenges until 2025". Proceedings of the Conference “National Forum for Sustainable Development”, May 22, 2019, Moscow, Russia. Retrieved March 21, 2021, from http://ipem.ru/files/files/research/20190405_rail_2025_report.pdf

Kalyuzhnyi, N. and Losin, L. (2018). A method of mathematical modeling for transfer hub establishment in Saint Petersburg. Transportation Research Procedia, 36, 245-251.

Kristersson, P. (2012). The role of public transport interchanges in regional planning. Regions Magazinen, 285 (1), 16-17.

Leonova, S. (2019a). On the formation of the system of transport and transfer hubs of the Samara City district. Railway Transport, 8, 58-61.

Leonova, S. (2019b). The choice of locations of transport-interchange hubs of the urban passenger transport network. Transport of the Ural, 4 (63), 101-105.

Ludan, I., Maiorov, E., Santana, J. and Saprykin, O. (2018). Integrated approach to building a microscopic city model. In: Proceedings of the 5th International Young Scientists Conference on Information Technologies, Telecommunications and Control Systems (vol. 2298, p. 8). Aachen, Germany: CEUR.

Monzón, A., Hernández, S. and Di Ciommo, F. (2016). Efficient urban interchanges: The city-HUB model. Transportation Research Procedia, 14, 1124-1133.

Moskvichev, O. and Leonova, S. (2020). Methods of selection of transport interchange hubs location based on optimization mathematical model. World of Transport and Transportation, 18 (2), 198-213.

Shagimuratova, A. (2016). System analysis in determining the priority directions of development of transport and interchange nodes of railway transport. Urban Planning, 2 (42), 63-71.

Sherbina, E., Danilina, N. and Vlasov, D. (2015). City planning issues for sustainable development. International Journal of Applied Engineering Research, 10 (22), 43131-43138.

Sun, C., Chen, X., Zhang, H. M. and Huang, Z. (2018). An evaluation method of urban public transport facilities resource supply based on accessibility. Hindawi Journal of Advanced Transportation, 2018, 1-11.

Vlasov, D. (2017). Transport and interchange nodes: Monograph (2nd ed.). Moscow, Russia: MGSU.