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POPULATION GEOGRAPHY

How Express Trains from Moscow Affect Population Mobility

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Abstract—The paper is devoted to assessing the impact of passenger railway transport increasing speed on change in the conditions of commuting. The role of commuting in the composition of settlement relationships is considered on the example of transport directions from Moscow to Tver, Nizhny Novgorod, Orel, Belgorod, and Kursk, on which projects for a significant speed increase of railway traffic were implemented in the 2010s. The data on the dynamics of passenger traffic for different types of trains and the results of sociological surveys of regional express trains' passengers in the selected directions serve as the informational base for assessing the conditions for the transformation of settlement systems through changes in the railway transport. The improved accessibility to transport between Moscow and several regional centers due to the launch of express trains has affected the spatial behavior of residents of these regions in different ways. Conclusions are made on the effect of the technical and economic parameters of the speed increase in rail transport, the established settlement system, and other geographical parameters of the territory on the transformation of rail links. Due to these factors, the effects of speed increase have manifested themselves unequally in the considered directions. It is shown that they are observed most clearly in the territories where the increasing speed has made it possible to implement the potential of intra-agglomeration mobility (Tver) and less noticeably on routes of medium length involving inter-agglomeration (Nizhny Novgorod) links. Some cities (Orel, Kursk, and Belgorod) are characterized by a restrained effect of the speed increase in rail transport on the change in the commuting, which is sensitive to the distance from the capital and to the potential of migration.

Keywords: regional express trains, commuting, passenger traffic, transport accessibility, railway transport speed increase, settlement system, railway transport

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INTRODUCTION AND PROBLEM STATEMENT

The increasing speed of railway transport is related to the emergence of the set of socioeconomic effects that affect the settlement system: spatial concentration; agglomeration effect; and economic, functional, and planned modernization of populated areas [2, 6, 19].

Transport is playing a key role in the formation of new settlement systems and evolution of existing ones. The agglomerations' radii are expanding, the interaction of large cities and local settlement systems is intensifying, their structural diversification and space polarization are taking place, urbanized corridors are being formed, which usually coincide with transport corridors, based on which the framework of the territorial structure of the economy and settlement is formed [13, 16]. The spatial mobility of the population is the most important component of modern settlement relationships. The intensification of commuting as a result of improved transport connectivity leads to a slowdown in the contraction of the socioeconomic space and over-concentration in large centers due to the increased availability of labor markets outside these centers.

Since 2009, projects for launching speed suburban and intercity communication have been annually implemented in Russia, surveys have been carried out to build the first express trains in the country, which makes it relevant to assess the effects of speed increase. The world experience of their assessment and forecasting suggests that taking the settlement's characteristics into consideration can reveal additional economic effects both within the framework of an assessment of a single project and for the economy of the territory as a whole. This makes studying the current experience of launching regional express trains and their impact on the spatial connections that are formed by the population's migrations a relevant task.

This study makes an attempt to expand the range of indirect methods for studying settlement relationships. Sociological methods for studying the structure of passenger traffic under the changing conditions of interregional transport connectivity are used to assess the impact of speed increase on the transformation of settlement systems. The sample of implemented proj-

ects allows analyzing the effects for both the intra- and inter-agglomeration mobility of the population.

REVIEW OF PREVIOUS STUDIES

The introduction of speed communication in the world clearly indicates the presence of a wide range of effects on the territories that have improved the transport links with areas of population and economy concentration [24, 27, 28]. In addition to direct and indirect economic effects, which are widely covered in the Russian and foreign scientific publications, the increased mobility of the population is related to significant social effects: retaining and developing social ties, overcoming barriers to moving to a new place of residence, and increasing the radius of comfortable daily commuting [7, 22, 23, 26]. For the population this allows achieving professional and personal goals that could not have been attained in the original place of permanent residence. This results in a growth of scale of commuting for better job prospects and a significant improvement in wages that compensates the commuting costs.

Providing a high level of transport services is a prerequisite for the integration of territories of any size into a single economic space [2, 5], and accelerating the traffic is one of the key mechanisms to achieve this [17, 18]. However, today Russia is lagging the main technological trends that determine the priorities for the development of the transport infrastructure in the next decades, especially in the development of speed transport communication [4]. In Russia, express trains include those that travel faster than 91 km/h and which move at a speed of 141–200 km/h in some sections of the route; trains with a higher speed are classified as high-speed transport [3].

All over the world, speed and high-speed traffic is being launched on routes with the highest demand, and Russia is no exception: most of the implemented and planned projects on the speed increase of passenger traffic connect Moscow with the nearest large centers of settlement system.

The theoretical base of the work is made up of two opposing areas of modern scientific research, which are close to the topic under consideration. One of them concerns the issues of delimitation of urban agglomerations, which consider transport accessibility as a prerequisite, and not as a transforming condition. The second area is applied research devoted to assessing the socioeconomic effects of changes in the parameters of transport accessibility.

The processes of intensive integration are confirmed by numerous scientific studies concerning the delimitation of the Moscow agglomeration. Many assessments agree that its border long ago spread to the territory of Tver oblast, having included its administrative center in the radius of regular commuting and dacha suburbanization [10, 11]. The urban agglomerations of Moscow and Nizhny Novgorod form the upper echelon of the framework of settlements; however, the speed increase of communication lines has not ensured the overlapping of the zones of their influence and their unification into a superagglomeration structure [1]. At distances of more than 300–400 km from the capital, return labor migrations are usually considered as processes of temporary labor migration (*otkhodnichestvo*) over short distances [11, 15].

Today, any decision on the construction or modernization of transport infrastructure is accompanied by the calculation of the potential socioeconomic effects from the implementation of the project; however, the spatial component in the methods of their assessment usually yields to the budgetary component. This can be seen in scientific publications that cover mainly the technical and economic side of speed increase projects [14]. Studies on the impact of transport speed increase on the socioeconomic space touch upon the issues of settlement only in a number of cases and are usually limited to describing the consequences at a qualitative level [6, 13]. The actual data on the number of trips made are mainly used in the methods for forecasting passenger traffic, which leave the structure of passenger traffic and the cause-and-effect relationships outside the scope of the study [12, 21, 22]. The narrow variability of methods for assessing the effects on settlement is due to the lack of publicly available statistical data in choosing any of the assessment methods. Such studies can be based on mass sociological surveys, which is reflected in foreign works on the impact of transport increasing speed on population mobility [25]. Modern scientific research on spatial mobility increasingly relies on big data [20]. The parameters of the initial data of mobile operators allow them to be used to identify dependences between the volumes of migration flows and transport accessibility at any time and in any territorial level [8, 9, 11]; however, they are the most inaccessible source of information.

MATERIALS AND METHODS

In this study, the statistical data on the volumes and dynamics of passenger traffic were supported by the results of sociological surveys that illustrated the structure of the migration flow. This made it possible to more objectively assess changes in the spatial behavior of the population due to the increasing traffic speed.

The following sources of primary data became the informational base for the study:

—Mass sociological surveys of express trains passengers, which were conducted by the Infrastructure Economics Centre (IEC). The total sample included more than 2300 people. The survey was conducted in the period of October 20–29 2016 on weekdays and weekends, which made it possible to trace the weekly

commuting cycles. The survey was carried out using the method of interviews in trains traveling in both directions: Moscow–Tver (Lastochka train), Moscow–Orel (Lastochka train), Moscow–Nizhny Novgorod (Lastochka and Strizh trains), and Moscow–Belgorod (express train no. 715V). The sample included only passengers that traveled between the final points of the routes.

—Data from OJSC RZhD (Directorate of High-Speed Communications, Federal Passenger Company, Moscow–Tver Suburban Passenger Company) on the volume of passenger traffic on railway lines for 2009–2018, and data on the number of tickets sold for all types of trains in 2009–2018.

The processing of the sociological survey data required the use of statistical analysis methods to group sociological information and analyze the structure of passenger traffic according to the sociodemographic data of the respondents and the characteristics of their migratory behavior. Methods of mathematical statistics were also used to analyze the databases of railway carriers in terms of the dynamic and structural analysis of changes in passenger traffic. The observation interval chosen for the study is important for evaluating the effects, since it was at this time that all the existing projects on the increasing of speed of traffic from the capital region were implemented (Fig. 1):

—Lastochka train (launched in 2015) to Tver;

—Sapsan (2009) and Lastochka (2019) trains to St. Petersburg;[1]

—Lastochka train (2014) to Orel and Kursk;

—Lastochka train (2014) to Smolensk;

—Sapsan (2010), Lastochka (2013), and Strizh (2015) trains to Nizhny Novgorod.

An express train runs between Moscow and Belgorod; it does not have the formal status of a express train but provides speed increase comparable to that of the Lastochka trains.

By 2016, express trains had been regularly running in the directions chosen for the study for several years, which means that they had managed to transform the spatial connections formed by the commuters under the new conditions of transport accessibility. Today, this makes it possible to track the most noticeable changes in spatial mobility at the stage of the appearance of the effects of speed increase.

RESULTS AND DISCUSSION

The launch of an express service has affected spatial mobility on the routes under consideration in different ways. This has been influenced both by the peculiarities of settlement, which are reflected in the established pattern of migration mobility, and the frequency of traffic, which partly predetermined the demand for express trains.

The Moscow–Tver Direction

On the Moscow–Tver section, passenger transportation is carried out not only by suburban trains but also by express long-distance trains: in addition to Sapsan, the Lastochka electric train also frequently travels in this direction. In the first calendar year of operation, they took over up to 90% of the passenger traffic, completely replacing the Moscow–Tver express train and partly replacing the traditional (low-speed) suburban trains (Fig. 2). Moreover, the observed switching cannot be considered forced, since the launch of Lastochka train did not radically change the existing schedule. Throughout the day, express electric trains alternate with normal trains, which permits passengers to choose the most suitable travel options. However, the workload of low-speed trains during the peak morning and evening hours is lower despite the price being cheaper by a factor of about 1.5.

The passenger traffic on Sapsan trains in 2014–2015 amounted to approximately 95 000 passengers over one year (5–7%); as soon as Lastochka trains were launched, Sapsan's share of the traffic between Tver and the capital decreased by a third due to the uncompetitive prices on the suburban route. Note that the launch of Sapsan trains did not lead to an increase in the mobility of Tver's residents, as happened after the launch of Lastochka trains.

In 2015–2018, passenger traffic on the route increased by almost one-and-a-half times: from 1.8 to 2.6 mln people per annum. The increase was almost entirely due to the Lastochka trains not only reducing the travel time between Tver and Moscow from 3 h to 1 h 40 min but also being noticeably more comfortable for passengers. This contributed to the acceleration of the integration of labor markets: even more residents of Tver and the Tver oblast became part of the daily labor commuting, and local settlement systems were included in the radius of the agglomeration, which also improved the accessibility of transport to Moscow. The survey revealed the emergence of isolated (so far) but regular migration links between Moscow and settlements outside the 1.5-h isochrone of transport accessibility from Moscow: in the Spirovsky, Torzhoksky, and Staritsky districts.

The age structure of passengers on all express trains has shifted towards the working-age population. On all the routes considered, the gender structure of passenger traffic is dominated by women; however, the difference in the percentage of men and women is minimal for trains to Tver and Nizhny Novgorod. This bias may be due to the less-than-optimal departure times for the surveyed trains, which could have led to distortions in the sample.

[1] The Moscow–St. Petersburg route is not considered in the article.

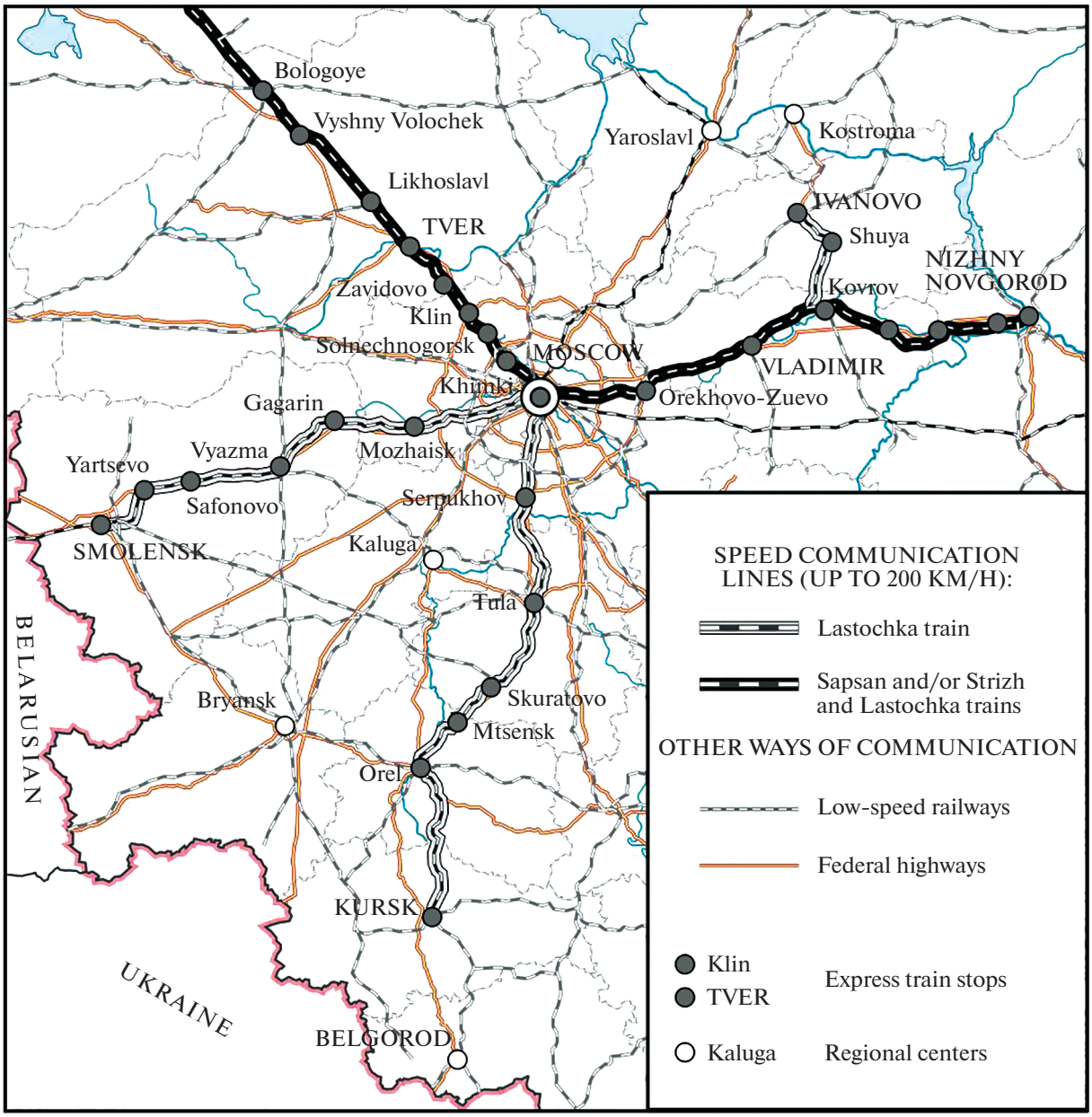

Fig. 1. Existing routes of express railway traffic from the Moscow transport node, 2020. Compiled by the author.

The presence of stable center–peripheral connections that are characteristic of agglomerations is confirmed by the frequency of travel, as illustrated by the sociological surveys. More than 20% of the respondents surveyed on the Moscow–Tver train travel this route daily. Passengers from Tver and the Tver oblast increased the frequency of their trips to the capital most of all among all the considered routes: half of the respondents began to travel more often than before the launch of the Lastochka trains despite the spatial mobility being high even before the introduction of fast trains on this route. Among them, the largest share is accounted for by labor migrants, which indicates the involvement of Tver in the orbit of intra-agglomeration connections (Figs. 3, 4).

The tariff is one of the factors of mobility. It acts as a significant limitation for both the nonworking population and labor migrants who have a high share of transport costs in the structure of their regular personal expenses. Due to the involvement of both categories in the return migration on the Moscow–Tver line, more than half of the passengers consider the high ticket price to be the main disadvantage of the express train. For the rest of the respondents with less

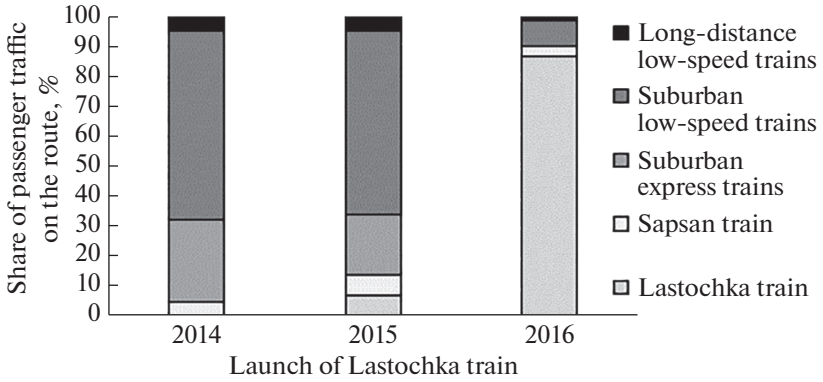

Fig. 2. The structure of passenger traffic for trains of different types on the Moscow–Tver route, 2014–2016. Compiled by the author.

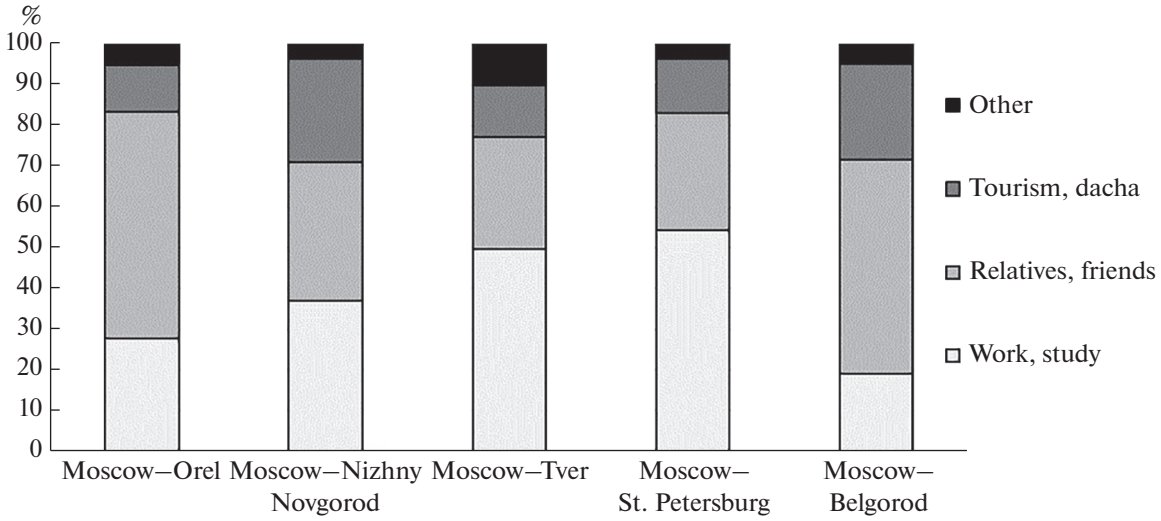

Fig. 3. The structure of passenger traffic for express trains according to purpose of travel, 2016. Compiled by the author.

intensive connections with the capital, the factor limiting the number of trips was not the tariff but the low frequency and the high load of the trains.

The effects of a compression of space have also been felt by the residents of Moscow region. The travel time to Klin, which is the last main stop on the territory of Moscow oblast, has decreased by a factor of 2.5 to 40 minutes. In 2016, 70% of the passenger traffic to Klin, which amounted to almost 1 mln passengers per annum, was using the Lastochka trains.

The Moscow–Nizhny Novgorod Direction

Over the past ten years, the passenger traffic has slowly but steadily grown from 1.4 mln in 2009 to 2.3 mln in 2018. The launch of Sapsan, Lastochka, and Strizh trains did not lead to as sharp an increase in the passenger traffic as the one observed in Tver due to the increasing speed of rail traffic with the capital; however, since their appearance, they have played a dominant role in the structure of railway traffic. The Sapsan train, which ran on this route from 2010 to 2015, was replaced by the Strizh train, which also retained its leading position in the structure of passenger traffic and even attracted passengers from Lastochka train and other types of trains (Fig. 5). Since 2018, Sapsan train has started to run between Moscow and Nizhny Novgorod again, and the express trains completely replaced the segment of slow coach trains on the route.

The popularity of the Strizh trains in this direction can be explained by their more convenient schedules and slightly shorter travel time (saving approximately 20 min) at a ticket price that is comparable to the Lastochka train. The launch of Strizh train in this direction proved to be the most competitive not only

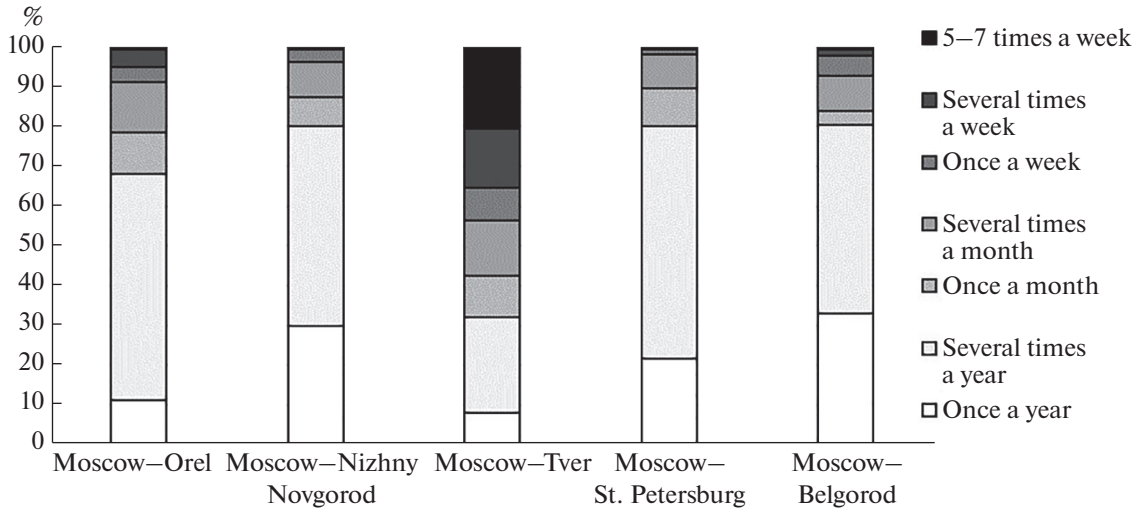

Fig. 4. The structure of passenger traffic for express trains according to frequency of trips, 2016. Compiled by the author.

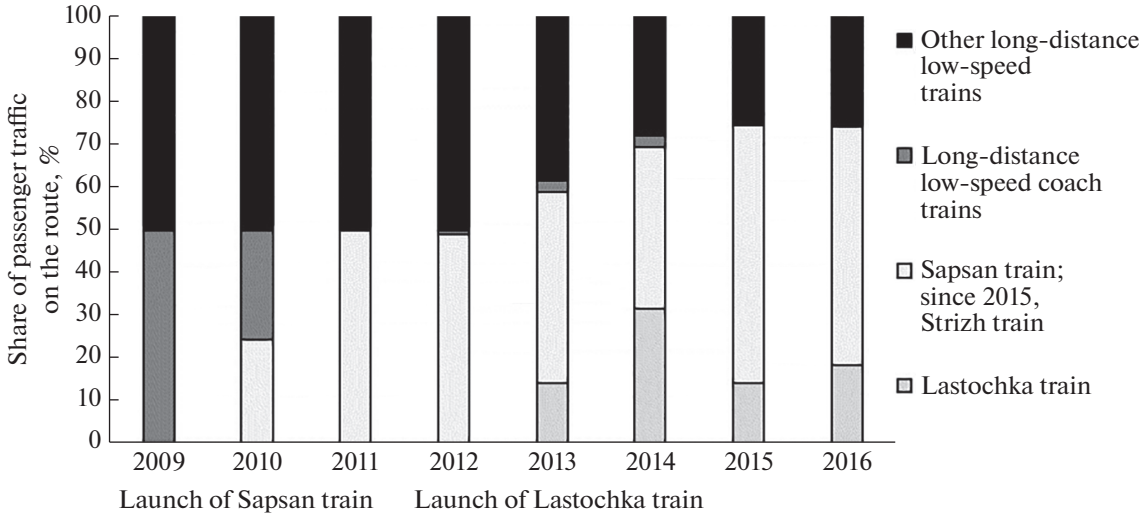

Fig. 5. The structure of passenger traffic for trains of different types on the Moscow–Nizhny Novgorod route, 2009–2016. Compiled by the author.

in comparison with land transport but also with air transport: the total time spent on the route from the center of Moscow to Nizhny Novgorod in the case of air transportation is on average longer than the time spent traveling on express train,[2] which has increased it competitive advantages.

The age structure of passengers has also shifted towards the working age. For women, this peak is less smoothed; the percentage of passengers over working age is higher. The share of the working population on the Moscow–Nizhny Novgorod route is 90%, which is an indicator of the effectiveness of speed communication for the potential growth of regular migration flows.

The potential effects of speed increase in this direction influence not only the intra-agglomeration mobility of residents of the eastern sector of the Moscow agglomeration but also inter-agglomeration flows; however, the increase is not enough for the formation of stable supra-agglomeration structures. Speed increase has not lead to the overlap of the radii of the comfortable commuting migration of both

[2] The travel time by air is 4 h 30 min, and the travel time on a speed train is 3 h 48 min (+15 min on the fastest type of transport from the city center). The travel time by was calculated making allowance for the average daily time of travel from the city center to the airport and the time required to pass through all registration procedures before a flight (on average 1.5 h).

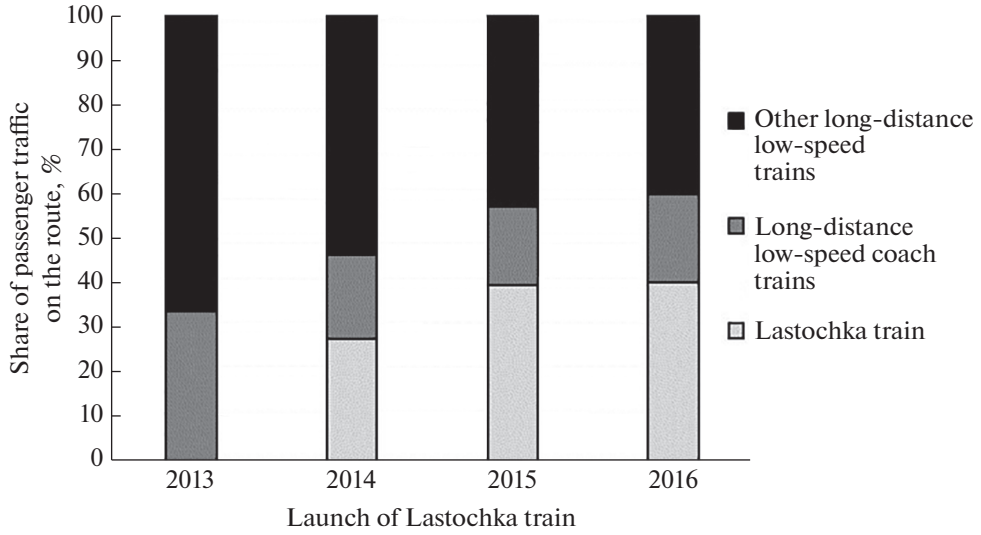

Fig. 6. The structure of passenger traffic for trains of different types on the Moscow–Orel route, 2013–2016. Compiled by the author.

agglomerations or an increase in regular commuting between them. However, there is steady growth in demand exclusively for express trains, which indicates that there are prerequisites for the integration of the Moscow and Nizhny Novgorod agglomerations as a result of their transport convergence into urbanized areas, which are similar to European and American megalopolises.

The Moscow–Orel Direction

This route differs from the remaining ones by the almost complete absence of passenger traffic dynamics. Over the past ten years, it has varied between 650 000–730 000 passengers per annum. The launch of express trains did not ensure the switching of passenger flows and, judging from the statistics, it did not affect passenger volumes in any way (see Fig. 6). This is due to the almost complete lack of time savings compared to slower trains, the newer trains travel on this route only twice a day, and their inconvenient schedule. With its late arrival in Moscow (11:10 a.m.) and inconvenient departure time (5:55 p.m.), a migrant who works in the capital on the standard schedule could not use the Lastochka train when it was launched.

On the Moscow–Orel route, the gender imbalance is most noticeable: less than half as many men travel as women. At the same time, the age structure of the males and females has shifted towards the working age and retirement age, respectively. This route also has the largest gender differences in terms of the frequency and purpose of travel. More than half the men surveyed travel on this route at least once a month, while 44% of them travel for work, which may be an indicator of the processes of the development of labor migration (*otkhodnichestvo*) for short distances, which are within 300–400 km from the capital [15]. This distance allows such temporal labor migrants (*otkhodnik*s) to return home relatively regularly without an excessive transport costs relative to their personal budget. Women are much less mobile: 80% of the respondents travel on average once a year for personal purposes. The Orel oblast belongs to the regions in which *otkhodnichestvo* of women has also become widespread: women's work trips are of the same nature as those of men but their places of employment are focused more on older categories (nannies, nurses, etc.), which was also reflected in the age-sex structure of the passengers.

The Moscow–Kursk Direction

Speed traffic has become even less popular on the Moscow–Kursk route (Fig. 7). This is because of the alternative to the Lastochka trains on this route offered by the express trains to Belgorod, which are faster at a comparable ticket price and level of service. Approximately 860000 passengers travelled between Moscow and Kursk in 2018, of whom only 14% travelled on express trains.

The effects of the launch of the Lastochka trains in the Kursk direction are regulated by the technical parameters of the traffic: the speed traffic did not lead to an increase in migration activity or significant changes in the spatial behavior of residents of Orel and Kursk. This is due to the insignificant gain in travel time and the low frequency of traffic, which has not helped draw them into the gravity zone of the Moscow agglomeration or led to the appearance of regular settlement connections as Moscow remains remote.

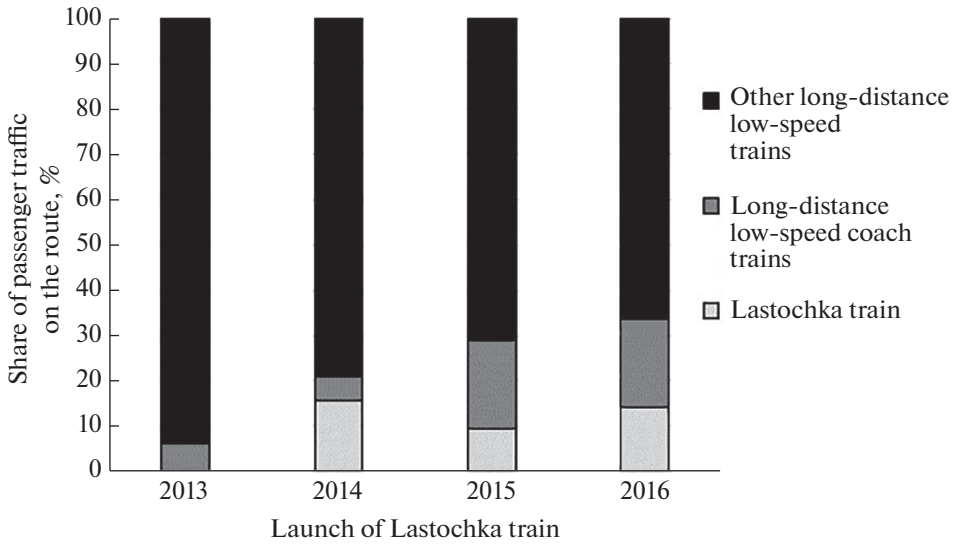

Fig. 7. The structure of passenger traffic for trains of different types on the Moscow–Kursk route, 2013–2016. Compiled by the author.

The Moscow–Belgorod Direction

Kursk is the last stop of the express train in this direction; however, the express Moscow–Belgorod trains provide a significant speed increase, with comparable effects to the Lastochka trains. It is possible to get from the capital to Belgorod in an express train in 5 h, compared to least 7 h on a common long-distance train; however, this increase has not led to an increase in the number of trips to Moscow.

The main purpose of Belgorod residents' trips is to visit friends and relatives several times a year. In addition, this direction is notable for a large share of recreational trips made with the same regularity. However, the final destination points, Kursk and Tula, are the nearest large centers only for less than half of them. It is this category of passengers (more than 80% of the passenger traffic in total) that was most strongly affected by the increasing speed of railway traffic.

A mass sociological survey on the route was carried out on the Moscow–Belgorod train no. 715V. The age structure of passengers has most strongly shifted towards the older working age and retirement age for both genders, which is correlated to the purpose of their journey. Residents of both Belgorod and Orel use express trains with Moscow for business travels to the minimum extent. More than 90% of the surveyed passengers work in the settlements of their residence and use trains only for one-off business trips extremely rarely.

The launch of express trains from Orel, Kursk, and Belgorod has had the greatest impact on the migration activity of the residents in these directions: almost 20% of the respondents had never traveled by train to Moscow and other settlements along the route before the appearance of faster rail transport. Another 20% noted that they had begun to travel much more often. For 33% of the surveyed respondents, the train has become an incentive to travel for purposes other than the main one. As a result of the faster rail transport, stable migration links have not been formed between the centers of regional settlement systems due to the small scale of the centers. The return migration between Kursk, Orel and Belgorod is of an episodic nature and the purpose of travel is different from those of workers: most of the respondents work in the same settlement where they live.

The increasing speed of railway traffic in these areas has not in any way affected the integration of the regional settlement systems with the Moscow agglomeration. This is due to the same reasons: the low frequency of fast rail traffic, less than optimal schedules, and the geographic distance from the capital, which still does not justify travelling to Moscow regularly even after taking the faster trains into consideration.

CONCLUSIONS

Most of the projects increasing speed of railway traffic in Russia are confined to the Moscow transport node and connect it to the nearest major regional centers.

There are two groups of factors in the settlement connections transformation affected by the increasing speed in the rail transport. The first group consists of the geographical parameters of the territory: the physical distance between settlements, their size and population, which in general terms expresses the level of socioeconomic development of the territories, and the presence of spatial connections between them. The second group consists of the technical and economic

parameters of the increasing speed of traffic: traffic intensity, speed, and tariffs. The regulation of technical and economic conditions leads to an increase in labor mobility, which is simultaneously sensitive to the distance and potential of migration. This is observed most clearly in the territories integrated into the Moscow agglomeration due to the traffic increasing speed and is less noticeable for medium-length routes with the distance of the commuting radius from Moscow of more than 300 km.

Speed communication with Tver has made it possible to fully implement the potential of intra-agglomeration mobility, ensuring its position as a focal point of the Moscow urban agglomeration. The total passenger traffic on the route increased over the period from 2015 to 2018 from 1.8 to 2.6 mln passengers per annum, and almost all of the increase was accounted for by the Lastochka trains. The growth rate of the Moscow agglomeration is significantly ahead of the rate of development of its infrastructure equipment. This was one of the reasons for the rapid growth in the popularity of speed routes, which eliminate the infrastructure barrier hindering the integration of the capital with the centers in the peripheral territories of the agglomeration.

The reduction in travel time between major cities is an incentive for their integration into supra-agglomeration structures. All types of express trains that exist in Russia run between Moscow and Nizhny Novgorod, which indicates the great demand for the traffic increasing speed between them; however, due to the technical parameters, they have not provided sufficient transport links for comfortable regular labor migration. The key role in changing mobility in this direction is played by the size of settlement centers, which has an effect despite the significant geographic distance.

In the other cases considered (Orel, Kursk, and Belgorod), the effect of increasing speed of train traffic was quite measured. The moderate size of these centers combined with the critical distance from the capital and an infrequent express train schedule have prevented the migration ties with Moscow from growing significantly.

CONFLICT OF INTEREST

The author declares that she has no conflict of interest.

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