FUNCTIONAL PLANNING IN TRANSPORT INTERCHANGE HUBS: MODERNIZATION OF RAILWAY STATION ARCHITECTURE

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ABSTRACT

The purpose of the study is to explore new architectural and structural solutions that allow to modernize the existing railway stations and effectively transform them into multifunctional transport hubs. The study examines new approaches to the positioning of station buildings in cities and their equipment with infrastructure with mandatory inclusion of by-the-hour hotels. New constructive solutions providing planning, architectural, and compositional possibilities for station building design for architects are proposed. A special focus is placed on the transformation of railway stations into transport interchange hubs, which in turn can function as multifunctional complexes with a variety of functional content of the object and incorporation into their volume a transport artery to connect nearby residential areas bypassing major highways. Conclusions are drawn about the possibility of incorporating railway stations into such multifunctional complexes. The paper gives examples of design solutions for bridge and platform buildings with incorporated railway stations, which show how the architecture of railway stations can be improved by turning them into multifunctional transport interchange hubs, especially by incorporating them into the volumes of bridge or platform buildings, which significantly save construction area in cities by occupying the second level above railway tracks.

Keywords: station, multifunctional complex, transport interchange, steel reinforced concrete slab, bridge building, platform building, load-bearing floor, multi-lattice truss.

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INTRODUCTION

Railway stations are an element of the transportation network of any country, tying it into a single economic organism of the state. Today's stations have a developed typological structure, including railway stations, bus stations, river and sea stations, and airports (Gelfond, 2006). In other words, stations are present in all types of transportation by rail and road, rivers and seas, and air. Each type of station has its own characteristics, but what unites them is their direct connection with the transportation network and the nature of this transportation network (Ministry of Construction, 2020).

Historic railway station buildings

A crucial feature of historic railway stations is their location in the centers of cities. This has to do with the fact that they were erected in the 19th century when cities were significantly smaller. Today, most of the historic railway stations are situated in the central parts of urban areas due to the development of cities and the expansion of their territories (Vlasov, 2013a). For example, Moscow, Russia has nine railroad stations serving the network of mainline railroads and the network of passenger and freight rails connecting the city districts with each other and the suburbs and other cities of the country. All of them are located in the central part of the city. The railroad tracks extending from the stations are sometimes difficult for motor vehicles to traverse and thus rigidly divide the urban structure into sectors, which causes great difficulty for motor vehicles and leads to traffic congestion. This factor affects the operation of stations, as it becomes difficult to get to them by congested roads, as well as to park in the immediate vicinity of the station to drop off passengers and unload luggage (Vlasov et al., 2014). The most critical factor compromising the quality of passenger service in existing historic buildings is their insufficient capacity for ever-increasing passenger traffic. In turn, the reconstruction of such stations poses a certain challenge, because they have become architectural monuments. For instance, the Sochi railway station (Russia) designed by architect I.N. Dushkin and constructed in 1952, which stylistically belongs to the Stalinist Empire (Figure 1), is virtually impossible to rebuild.

Figure 1. The Sochi railway station. Architect I.N. Dushkin, 1952

The station is located in the center of Sochi and the territory around it is limited and difficult to reconstruct. The issue is solved in most large European and Russian cities by moving railway stations to territories adjacent to large city agglomerations. The same solution was adopted in Sochi by building one of Europe's largest railway stations with a design capacity of up to 2,000 people and a throughput capacity of between 3,000-5,000 and 20,000 passengers per hour (Figure 2), which is located in Adler on the approaches to central Sochi. The station was taken far beyond the central part of the resort and connected to the city by road and internal railway line. The same was done in Germany, where a brand new massive train station, a multilevel transport interchange hub (TIH), was built in the new territories of Berlin (Figure 3)

Figure 2. A railway station in Adler (Big Sochi)

Figure 3. A multilevel train station (TIH) in Berlin

In Astana, Kazakhstan, given the trend of the city's development and the problems arising with railway stations in city centers due to their growth, a new railway station was also placed on the outskirts of the city (Figure 4).

Figure 4. A new railway station in Astana

The second problem with outdated railway stations is their low functionality and insufficient comfort for passengers in the station building. On the one hand, railway stations provide a functional connection of the urban transport network with the railroad. On the other hand, passengers often have to stay in the station premises for a long time when they need to transfer and wait for the necessary train. The modern tendency of station building design involves a maximally developed passenger service network. This includes diverse catering, shops, pharmacies, rooms for small children with entertainment, convenient services for infants, and a wide range of entertainment options for passengers to spend their waiting times. In historic station buildings, these functions have become increasingly difficult to realize. However, the greatest drawback is the absence of hotels for temporary or hourly stays where passengers, both children and adults, could spend time in comfort while waiting for their transfer, which can take many hours, perform hygiene procedures, and get some sleep. By the hour hotels for passengers clearly need to be an indispensable part of the solution for the functional space of stations.

This article discusses the tendencies of changing architectural solutions of railway stations, which have been researched and received new solutions in the works of the Moscow State University of Civil Engineering.

METHODOLOGY

This study adopts a mixed-methods research design, combining both qualitative and quantitative approaches to comprehensively investigate the transformation of railway stations into multifunctional transport hubs. The research encompasses a review of existing literature, architectural and engineering design studies, and the analysis of case studies and real-world examples.

A thorough examination of existing literature related to railway stations, transport hubs, urban planning, and architectural innovations was conducted. The literature review was conducted through a systematic search in reputable academic databases, including Web of Science and Scopus, using specific keywords and search criteria to ensure the inclusion of relevant scholarly articles, books, reports, and other documents.

The literature review findings were analyzed thematically to identify key trends, challenges, and solutions related to the transformation of railway stations into multifunctional transport hubs.

Extensive architectural design studies were conducted to explore innovative approaches to railway station renovation and transformation. Various architectural concepts and solutions were explored to address the challenges faced by existing stations.

Engineering analysis was performed to evaluate the structural feasibility and efficiency of proposed design solutions. This involved assessing load-bearing capacities, structural integrity, and construction methods.

Real-world case studies of railway stations that have undergone transformations into transport hubs were examined.

RESULTS

Research and design at the Moscow State University of Civil Engineering has provided some proposals for hotels for the hourly stay of passengers based on the examples of three stations (Leningradsky, Yaroslavsky, and Kazansky) in Komsomolskaya Square, Moscow (Zabalueva et al., 2014a). The situation with waiting passengers at terminals such as Moscow's main railway stations is aggravated by their extremely high throughput capacity. Passenger flows are waiting for transfers to a wide variety of destinations not only by rail but also by air. Many transit passengers wait for the departure time of their trains and, in some cases, planes, using rail and bus connections to the city's airports. Moscow presents the largest TIH in the country. With nine railway stations, four airports, and a fifth airport coming soon, in Moscow, passengers often have to wait several hours or even days for a transfer. Unfortunately, hotels are mostly located relatively far from the train station, and the price of accommodation in them is high since payment is made by the day in any case. Research shows that at the current stage of development of the transport network, it is critical to have by-the-hour hotels for passengers either inside the station building or in direct proximity to them with good accessibility. In such a hotel, a room can be rented by the hour. The room has one or two bunk beds, as in a railroad car compartment, with single-use linen, a budget sanitary unit with a shower, and a minimum set of necessary furniture (Figure 5).

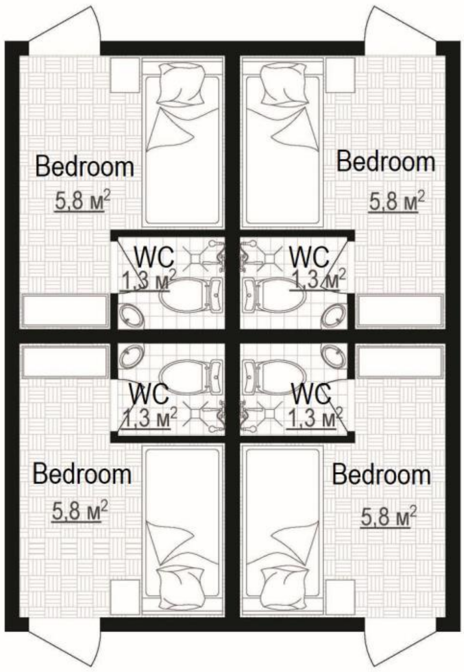


Figure 5. An example of an hourly rate hotel room

In such a room the guest can rest, tidy up, perform hygienic procedures, and feed children or put them to bed. Such a room has a reasonable price and can be rented for as many hours as the passenger needs. In the building itself, the hourly hotel provides food, entertainment, sports, stores, pharmacies, etc. Thus, passengers can not only spend time resting but also use it in accordance with their interests and needs. Capsule hotels serve the same purpose (Figure 6) (Muratov, 2013).

Figure 6. Capsule hotel

This low-cost type of hotel has recently become popular especially among young people. The adequate rest provided in such a hotel offers time to sleep and rest for the period of waiting for a connection without large expenses.

Railway stations and this

The structure of stations has recently shifted towards the organization of TIHs (Voronov & Chistiakov, 2020). A TIH assumes the transfer of passengers from one mode of transportation to another, e.g., from commuter rail to city or bus service or to and from the subway. Thus, the motion of people flows in different directions is created in the TIH.

The movement of passengers through the TIH space organized with the planning solution can improve the comfort of passengers' stay in this space, i.e., create a comfortable psychological and functional environment in the building, reducing the maximum length of passengers' movement, organizing the path of movement, and providing the necessary infrastructure (Vlasov, 2013b). Such a structure is demonstrated by the Berlin Central Station, designed in several levels (Vlasov, 2015). Figures 3 and 7 demonstrate all the levels of this complex building, with intersecting tracks in the north, south, west, and east directions and with subway tracks at the top level.

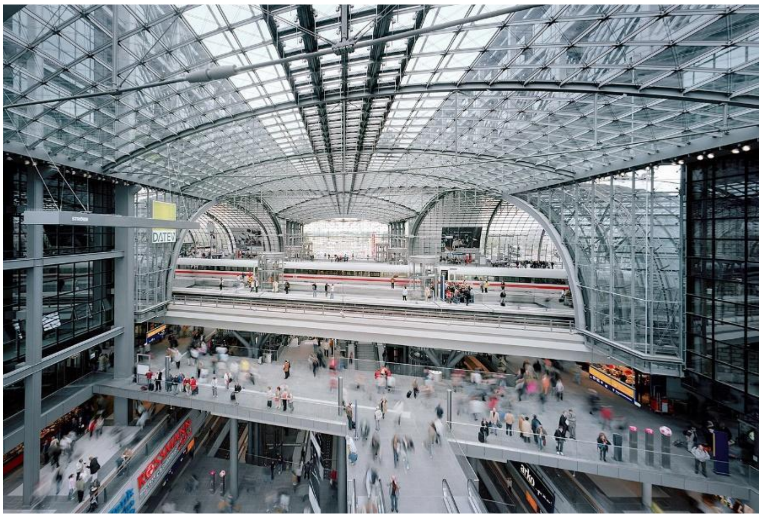


Figure 7. The main railway station in Berlin

Figure 7 gives a good view of the structure of a modern TIH. The image shows three top levels of the multi-level station building, which reaches below ground level. In the lower part, we can see platforms and cars of trains running north and south. Trains in the west and east directions go below this level. In the upper part, below the glass roof, there are fragments of the platform and trains running at the level of the city and its surrounding area. Between the described levels lies the pedestrian platform, which connects transportation platforms and hosts trading, food, accommodation, and leisure facilities for passengers waiting to board a train (or transfer). Figure 3 also shows horizontally moving walkways for passengers with luggage, escalators, and elevators linking the pedestrian and transport platforms vertically. It is also possible to transfer to the subway.

This division of railway tracks by levels significantly simplifies the task of creating ground-level tracks around the station to lead in different directions. Importantly, in addition to a multilevel structure, this railway station presents a new vision of the railway station as a TIH where passengers can transfer to a different direction or type of transport.

The functional features of TIHs are designed in accordance with the cities' needs to not only simplify and organize traffic and associated passenger movements in a particular type of transport but to ensure the movement of people from one type of transport to another in a short time. In this connection, it is proposed to design TIHs with an opportunity to transfer from rail to subway and land modes such as busses, trolleybuses, and trams. The organization of TIHs has to provide a convenient functional connection among passenger flow paths and the infrastructure of regular stations with additional functions, such as a wide trading network and various forms of public services (Zabalueva et al., 2010). An example of such a complex TIH solution is the multifunctional transport interchange complex in Vykhino, Moscow, designed in the Moscow State University of Civil Engineering (Figure 8).

Figure 8. Vykhino TIH

The Vykhino TIH has transfers from rail to subway trains and busses connecting the TIH to the city area and the suburbs. The hub has the infrastructure of both a railway station and a bus terminal. The TIH houses various parking lots, particularly intercept parking, as well as market and office areas. Thus, the complex has become not simply a transport building but a public city center. The Vykhino TIH is designed as a platform building above railway approaches. Thus, the TIH gained greater freedom in design solutions, a more flexible system of access routes for all modes of transport, and full architectural freedom. Platform buildings can simultaneously grant extra space not only inside but also on the roof level. Such large buildings can house entire neighborhoods (Barinova, 2017) (Figure 9).

Figure 9. A platform building above the marshaling yard of the Rizhsky suburban railway line at the Los station

Inside the volume of the platform goes a road passage connecting residential quarters located on the two sides of the railway, the Los station of the Rizhsky suburban railway line, and civil infrastructure, while the top level holds a park area and residential development.

Railway tracks are a source of noise and vibrations transmitted to residential development. Therefore, the sanitary standards for design envisage a significant removal of housing from railway tracks, up to 100 m. This results in significant losses of urban space. However, noise and vibration near residential buildings can be normalized by constructing platform buildings above the tracks and adjacent protected territories, which includes several floors of logistics warehouses and or/parking lots for the residents of nearby quarters, and simultaneously taking measures to isolate vibration from the railways.

It can be confidently stated that the architectural and construction design of railway stations demonstrates substantial trends toward diverse changes, determined by the current state of rail transport and the needs of the population in a variety of transport services.

However, apart from large stations that are now turning into TIHs, the railway network has a vast number of intermediate stations, which also have a system of small station buildings. They, too, need to provide for the transfer of passengers from land transport to rail and back. In this case, a modern solution for such a hub lies in the use of bridge buildings (Zabalueva et al., 2014b). In addition to serving the functions of the TIH as a station, they solve the issue of cars crossing railway tracks. This solution eliminates the problem of crossings with barriers, which accumulate a considerable amount of vehicles and turn into a constant traffic jam (Zabalueva et al., 2013). A bridge building can incorporate not only the functional zones of the TIH, but also parking lots, warehouses, shops, and other elements of civil infrastructure.

An example of this is the bridge building at the Losinoostrovskaya station above the Rizhsky suburban railway line, which was also designed by the Moscow State University of Civil Engineering as part of research related to railway transport in the urban environment. This large structure is a multifunctional complex that includes a TIH, car passage, parking, and infrastructure demanded by residents of the surrounding residential development (Figure 10).

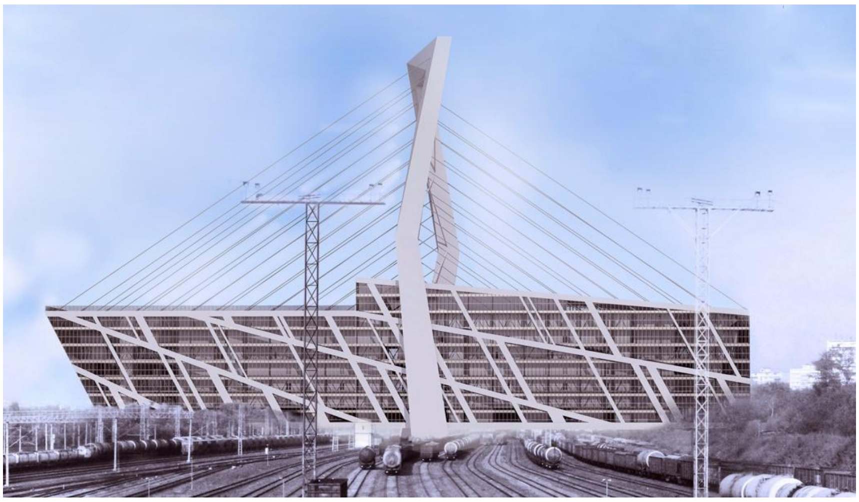


Figure 10. Bridge building with public infrastructure and a TIH at the Losinoostrovskaya station of the Rizhsky suburban railway line

Design features promoting change in railway station architecture

An influential factor changing the architecture of railway stations, which now widely transform into TIHs, is the application of new construction approaches to covering large spans with simultaneous functional filling of the long-span structure (Zakharov, 2020).

In addition to traditional options, the Moscow State University of Civil Engineering has developed new design solutions. On the one hand, they allow implementing the tasks of creating TIHs, including station functions. On the other hand, these solutions help resolve transportation problems without occupying a substantial area of land at ground level in cities where the area for construction is almost completely developed, especially in the central part. Such a fundamental solution can be bridge buildings, which are multifunctional structures and require the use of the territory only for vertical communication nodes. Among the proposed new constructions for bridge buildings, we can fundamentally distinguish three. All three solutions correspond to the length of the spans that the new structure covers. Spans of 20-25 m can use steel-reinforced concrete slabs, which are known in construction but have not been offered for these specific purposes. This construction system can likely be applied to building a smaller TIH across narrow railways to incorporate an intermediate railway station, passage for cars, and functional filling in demand in the given area of the city. Such filling can include parking lots, chain stores, areas for sports activities, etc. Ultimately, a multi-story building using steel-reinforced concrete slabs will not only provide for passengers' needs with diverse functional filling but also resolve the city's transport problems. Figure 11 presents the steel part of a steel-reinforced concrete slab block 20 m long and 1 m high with a width of 2 m. Such blocks are easily produced in factory conditions and mounted as solid flooring at the design mark of the construction site in the flooring of any width, depending on the needs of the planning solution. After installation, with the use of special anchoring, the flooring is covered with a solid concrete layer, resulting in a monolithic steel-and-concrete flooring structure.

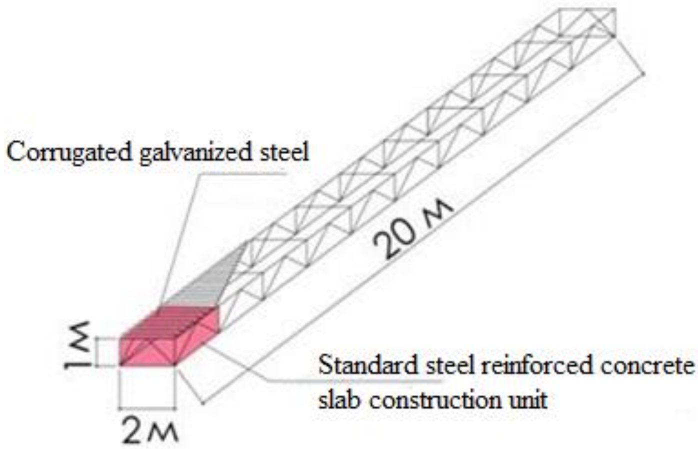
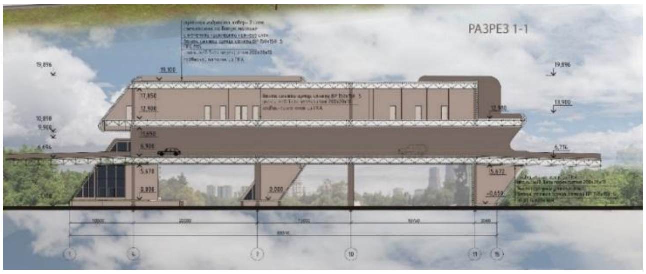


Figure 11. Steel part of a steel-reinforced concrete slab block for use in low-span bridge buildings

Figure 12 shows a complex in Butovo, Moscow, which solves the above-described problems using steel-reinforced concrete slabs that successfully cover the span over a 20 m wide railway line. The complex contains a railway station and provides a car passage connecting the city's inner streets, as well as houses and wrestling halls.

a

b



c

With the span to be covered reaching 50 m, the design scheme with a load-bearing floor can be applied. Patented and introduced into the practice of design and construction in 2016, this system presents a rigid monolithic box of the second floor based on a metal frame with internal bearing walls at short intervals, a suspended interstitial reinforced concrete floor, and a ground floor free of intermediate internal supports. This pair of interdependent floors can be repeated multiple times in the overall system of the bridge building (Figure 13).

Figure 13. A bridge building with a transport interchange over the connection of two branches of the railroad and the Varshavskoye highway

The most challenging and costly structure is a complex construction system comprised of multilattice trusses and load-bearing floors with the possible application of steel-reinforced concrete slabs. This design system can be used for large spans of 100-150 m. Figure 14 shows the lateral bearing multilattice trusses and transversal bearing floors. Thus, it is easy to form a multifunctional complex with the possibility of accommodating not only the functions of a station but also a transit road, with plenty of free space for various other functions.

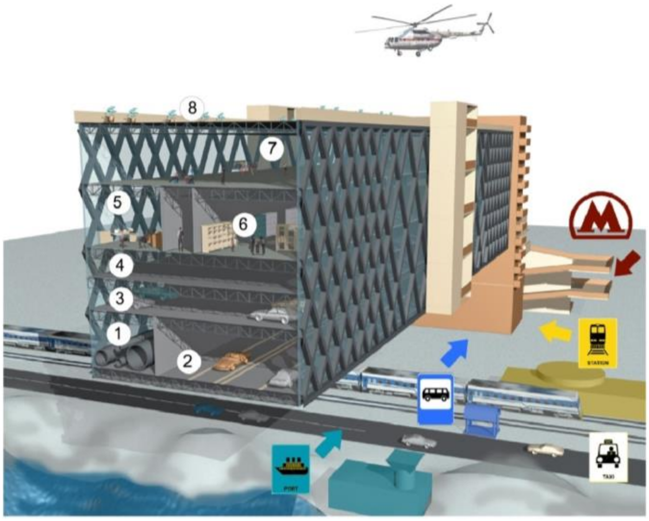


Figure 14. Cross-section of a bridge building with the functional contents of the floors: 1 – engineering communications transit, 2 – car passage, transportation links, 3 – buffer rooms: technical floor, parking lots, warehouses, etc, 5-7 – rooms of various functional purposes, 8 – operable roof (evacuation)

Traditional solutions for bridges over railway tracks or for railroads with the use of arched constructions (Figure 15) can also be transformed into new TIH constructions with a wide range of functional fillings (Kocheshkova & Zabalueva, 2009). An arched bridge made in the traditional constructive solution can be transformed, if necessary, to meet the functions of a TIH. Thus, it is possible to erect a full-fledged Kalanchevsky TIH on the Three Stations Square, Moscow.

Figure 15. Kalanchevsky overpass with a bridge over access roads to the Three Stations Square

The utilization of various modern construction solutions not only unlocks the potential of the functional filling of such buildings, but also enriches the plastics of architectural solutions (Figure 16).

Figure 16. Example of a bridge building composition solution with the possibility of various functional filling

CONCLUSIONS

The conducted research and evaluation give reason to conclude that the problems currently arising with respect to the architectural solutions of train stations include the following:

- the established locations of historic stations in the centers of large cities prevent their full use in the conditions of increasing passenger traffic;
- outdated station buildings, which have become architectural monuments, are difficult to reconstruct;
- the planning of such stations does not meet the requirements of modern passenger comfort.

Current trends in the development of railway station architecture are as follows:

- new stations are constructed away from the main urban development;
- railway stations are being transformed into multifunctional TIHs;
- platform and bridge buildings based on new design solutions are offered to house the new TIHs.

We can conclude that railway stations demand new approaches to design and construction. Such new solutions are already being partially implemented today due to life circumstances. However, specialists need to be actively engaged in this process to contribute to the renovation of station buildings in line with modern requirements for the comfort of the interior environment for passengers, ensure proper organization of human traffic in the difficult conditions of TIHs, and incorporate various functional filling in the volumes of such hubs. All these measures can be effectively carried out through the proposed advanced construction solutions.

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