Optimization of traffic at intersection of streets of Republic and Melnikayte in city Tyumen

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Abstract. The organisation of safe traffic is the priority objective for any modern city. At the present level of motorization there’s a need to create safe conditions for the movement of every road user: cars and pedestrians. Considering separate intersections and junctions with a fair amount of traffic intensity, both transport and pedestrian ones, it is advisable to separate pedestrians and passengers in the circulation space. This task has been elaborated in the present work. There are suggested several variants of pedestrian crossing in different levels at one of the busy intersections of the city of Tyumen. Based on the technical and economic comparison, an over-head pedestrian crossing of the "rhomboid" type is proposed for implementation. The implementation of the chosen option on this transport hub will ensure the necessary road safety and unhindered traffic interruption as a part of the creation of a highway for continuous traffic in the city of Tyumen.

1. Introduction
In the current conditions of the development of the street and road network, the city of Tyumen can not be imagined without the availability of conditions for the safe and comfortable movement of all traffic participants. According to the magazine "Russian Reporter" Tyumen was recognized the best major city in Russia [1]. In addition, in 2017, like two years ago, Tyumen took the first place in the rating of the quality of roads, which was compiled by the All-Russian Popular Front [2]. The natural increase of population, including due to migration from other regions of the Russian Federation, causes a continuous increase in the population of the city (Figure 1). The consequence of this fact is an increase in the level of motorization of the regional capital, which currently occupies the fourth place among the cities of the Russian Federation (RF) [3-10].

Herewith, a straightforward dependence of the increase in the number of population and congestion of the city's largest 'arteries' - the main streets of the regulated traffic is evidently visible.

A key aspect is the safety of traffic, both cars and pedestrians. So, for the period from 01.01.2015 to 01.12.2017 in the regional capital, 1122 road accidents were established, qualified as a run on a pedestrian [11]. By eliminating the movement of traffic flows and pedestrians in one level, the safety of the transport hub will be significantly increased.

This trend predetermined the need for a more detailed elaboration of the main transport hubs of street and road network in Tyumen with the calculation of numerical values of traffic intensity on them.
The results of the calculation showed that currently the main intersections have the levels of congestion B and D in accordance with the current normative literature [12] (Figure 2).

In the course of the work, unacceptable levels of loading of such traffic intersections as Melnikayte - the Republic, 50 years of October - Profsoyuznaya street and the Republic - Maurice Thorez were marked. On the basis of the analysis of calculated data, the intersection of the streets of the Republic and Melnikayte is selected for a detailed study, which according to full-scale measurement is the busiest transport hub in the city of Tyumen [13].

According to the fulfilled calculations, the daily traffic intensity in all directions at the intersection under consideration, which was obtained on the basis of the Lobanov technique, is 76,462 vehicles / day or 4248 vehicles / hour [14]. At the same time, according to the normative indexes, the intensity per lane is 500 cars / hour with a driving lane width of 3.5 m.

2. Analysis of the intersection of the streets of the Republic and Melnikayte
The daily traffic intensity of vehicles along the Republic Street in both directions is 39535 vehicles / day; on the Melnikayte street -36927 vehicles / day. Daily in the direction of the bus station on the main street of Tyumen are passing 20708 vehicles, towards the railway station - 18827, along the

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**Figure 1.** Dynamics of changes in the level of motorization and population of the city.

**Figure 2.** Daily traffic intensity at intersections of streets.
street Melnikayte, in the direction of "Regional Clinical Hospital number 2" - 22591, in the part of the city where the main shopping centers are concentrated – 14336 vehicles.

Moreover, in the process of collecting data on the existing situation, considerable fluctuations in the intensity of traffic during the day are noted at the intersection (Figure 3).

Figure 3. Diagram of traffic intensity during the day at the intersection of the Republic – Melnikayte.

The constructed graph of the change in the traffic intensity during the day clearly demonstrates the unacceptable loading of transport hub under consideration by vehicles at peak times, the maximum throughput in the evening hours is particularly shown, which entails the appearance of traffic jams and a decrease in the level of traffic safety [15].

An integral part of any transport hub within inhabited locality is pedestrian traffic, which also significantly hinders the traffic of vehicles and reduces the overall level of safety for all road users. The pedestrian crossing is on the same level with the road-way, which does not allow you to give up on the traffic signal regulation. Based on the natural measurements, the pedestrian traffic was 1672 people / hour, which implies the presence of a large amount of public transport. As a result, this transport hub is crossed by 23 bus routes and 9 route taxis.

Based on the analysis of the above information, it follows that at the intersection of the streets of the Republic and Melnikayte, the need to optimize traffic and pedestrians is evident.

3. Constructive solutions for improving the intersection of streets

For increasing the level of safety and comfort of all participants of traffic, it is predetermined that the traffic signal regulation at the intersection under consideration is needed to be abandoned in order to take measures for the cardinal reorganization of the transport hub.

The selection of typical junctions for this area is complicated by the immediate proximity of buildings and structures. On the basis of a thorough analysis, it was determined that none of the types of standard junctions are suitable for cross-roads characteristics. As a consequence, there is a need to develop an individual transport interchange project [16].

A three-level, ring-type transport interchange with two straight courses was developed at the intersection of the streets of the Republic and Melnikayte (Figure 4).

The proposed structure is compact and has the following parameters: the radius of the road ring is 25 m; the maximum height of the structure, depending on the type of pedestrian crossing, is 13.5 m; the maximum length of the strokes will be 250 m. The dimensions of the traffic junction do not foresee the changes in the city’s development line in the road junction under consideration. It is also worth noting that the presence of two direct strokes in different levels will avoid traffic lights and move the streets into the main line of continuous traffic.
In the process of developing an individual design for transport interchange project, the traffic of pedestrians on this structure is taken into account. The presence of two straight strokes implies an increase in the speed of cars, therefore, the construction of a pedestrian crossing on one level with the roadway is fraught with a decrease in the level of safety for all participants of traffic and transport speeds, which, according to the basic postulates of the theory of transport flows, will cause congestion on the considered intersection. To prevent the appearance of the aforementioned difficulties, it is necessary to arrange pedestrian crossings in different levels. To ensure maximum safety for all participants of traffic, there are three variants of pedestrian crossing:

The first variant – pedestrian undercrossing (Figure 5);
An underground pedestrian crossing is a typical rectangular shape construction. The movement of pedestrians in this crossing is similar to the movement on the ground pedestrian crossing, which facilitates the orientation of the residents and visitors of the city. In addition, this pedestrian crossing will allow separating traffic and pedestrian flows not in time but in space, which in turn will create the possibility of continuous pedestrian traffic. This design solution will not affect the architectural and planning picture in this transport hub.

The second variant – a crucial ground pedestrian crossing (Figure 6);

![Figure 6. A crucial ground pedestrian crossing plan (variant 2).](image)

The construction of this crossing is a crucial kind, which makes it possible to significantly reduce the time of pedestrians moving through the considered arterial streets. This construction intends an increase in the height of the entire construction of the junction by 2.5 meters, due to the need to raise the road ring and implement a pedestrian crossing between transport levels. The impossibility of increasing the height of the pedestrian tier is due to the difficulty of moving citizens with disabilities. The walls of the structure of the crossing are planned to be made of a polymer transparent material to save energy spent on lighting the crossing.

The third variant – a rhomboid ground pedestrian crossing (Figure 7).

The configuration of this crossing implies the movement of pedestrians within the road ring in condition of providing the appropriate level of pedestrian safety. At the same time, a decrease in the parametric measure of the crossing will reduce its cost in comparison with competing options. The design of the rhomboid pedestrian crossing does not foresee a change in the dimensions of the design of the road interchange, which, as a consequence, will not lead to an increase in the cost of the entire structure as a whole. The presence of walls made of light-transmissive material, similar to the second option, is provided for reducing electricity costs during daylight hours.
Figure 7. A rhomboid ground pedestrian crossing plan (variant 3).

4. Results
In order to select the optimal option of pedestrian crossing for these conditions, an analysis of all the developed variants on a significant number of criteria was carried out, the main ones being: the length of the crossing, both in the direct and diagonal directions, the time of pedestrian passage of the transport hub, the throughput of the proposed engineering solutions, economics indexes of their implementation. The main results of the calculation of the parameters are presented in Table 1.

| Parameter                                           | Ground crossing (existing) | Underground crossing (variant 1) | Ground crossing (variant 2) | Ground crossing (variant 3) |
|-----------------------------------------------------|-----------------------------|---------------------------------|-----------------------------|-----------------------------|
| Crossing length, m                                  |                             |                                 |                             |                             |
| - impact stroke                                     | 31,1                        | 80                              | 64,1                        | 53,7                        |
| - diagonal stroke                                   | 74,6                        | 132                             | 64,1                        | 78,2                        |
| Passage time, seconds                               |                             |                                 |                             |                             |
| - impact stroke                                     | 69,1                        | 79                              | 67,4                        | 59,9                        |
| - diagonal stroke                                   | 117,3                       | 124,6                           | 67,4                        | 77,6                        |
| Throughput, people / hour                           | 4200                        | 12000                           |                             |                             |
| Changing in the overall dimensions of the transport structure | -                           | Not needed                      | Needed for 2,5              | Not needed                  |
| Need for lighting, W / h                            | -                           | 1740                            | 920                         | 680                         |
| Costs for the construction of a pedestrian crossing (million rubles) | -                           | 89,72                           | 31,21                       | 26,01                       |
The key aspect for the construction of a pedestrian intersection is security. All three developed options correspond to this aspect and will allow increasing the level of safety. However, an important factor is the time interval spent on crossing the street diagonally, and in this case the overhead pedestrian crossing, represented in the work as the second option - 64.1 seconds, is in the lead. Taking into account the anticipation in the case of traffic light regulation under the current situation, the calculated indexes are lower than the current one by 1.15 times, which will speed up the movement of pedestrian flows. All three pedestrian crossings have the same throughput, which is especially important during active hours of the city.

The arrangement of the second variant provides for changing the construction of the road interchange (an increase in the height of the structure by 2.5 m), which directly increases the material consumption and the cost of construction work, which is extremely unprofitable for the interchange project.

In terms of the ecological aspect, underground crossing (option 1) provides for a round-the-clock need for lighting, which entails greater costs than the costs of lighting in overhead pedestrian crossings that require lighting only in the dark. According to the results of the calculation, the third option requires less energy for lighting than the second version - 25500 lm (680 W / h) [17]. Estimating the cost of construction of the proposed options, the third option is also leading, as the cost of its construction is much lower than the first and second - 26.01 million rubles. Based on the analysis of the parameters presented in the table, it can be concluded that option three is most beneficial from the point of view of the comparison parameters.

5. Conclusion

Each of the three developed options for pedestrian crossings has their own special characteristics. So the variant with the underground pedestrian crossing does not create problems for the architectural appearance of the city, and the variants with an overhead pedestrian crossing look more attractive from the point of view of the technological performance and the material intensity of the construction of these crossings.

For people with disabilities, special conditions will be created for the ascent to the pedestrian crossing.

In addition, the installation of solar panels on the walls of the pedestrian crossing will reduce the cost of lighting for the structure by 80%. The amount of electricity that will be consumed by the proposed types of overhead crossings will save on electricity consumption of about 50% than the cost of lighting an underground pedestrian crossing, since the design of the transitions involves the construction of walls made of polymer material.

Based on the analysis of the work performed, it can be concluded that the construction of a road junction on this district will significantly improve the safety of traffic of cars and pedestrians. Based on the results of elaborating the proposed options, a rhomboid overhead pedestrian crossing (option 3) was chosen as the optimal one for this transport hub, since this structure is the most profitable for most indicators. In the future, it is planned to carry out a more detailed feasibility study for the developed version of the pedestrian crossing.

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