Justification of Structural and Technological Solutions on Junction Perfecting on Permyakova and Shirotnaya Streets Intersection in Tyumen

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Abstract. This article presents the justification of structurally-technological decisions on a junction perfecting on the intersection of Permyakova and Shirotnaya Streets in Tyumen. The authors made a comparative analysis of typical road junctions. Based on the comparison, the engineering decisions were made for an individual type of transport junctions. Several options of individual design were proposed and analyzed and three most suitable types for the road junctions were offered. On the basis of a multilateral studying and evaluation of the developed transport the article further proposed a transport junction with change-side traffic. The use of this type of intersection will increase the road junction capacity, reduce the number of accidents due to conflicting flows reduction which, in its turn, will increase the speed of cars.

1. Introduction

With the advent of car loan system in Russia, purchase of vehicle became accessible for the most people. In 2004 more than thirty banks in Moscow and other cities provided beneficial loans on car purchase (increase of lending term, fast paperwork, reduced percentage rate, etc) [1]. Currently, such programs exist in almost all Russian banks. Along with the population growth (for twenty years the population of the city of Tyumen increased by 69.6%) there is the increase in the level of motorization, already 380 cars are the share of one thousand people. [2]. Graphs of population growth and number of vehicles (especially in the period from 2004 to 2016) show that these parameters are highly correlated. It is obvious that the motorization level is directly associated with the loan program. A spike of motorization level falls on 2004 (fig. 1) [3,4].

A significant increase in the amount of cars causes essential changes in traffic system on streets of the city.
2. Object of study

In Tyumen there are a large number of "bottlenecks", elimination of which would influence both traffic safety, the cost of passenger and cargo transportation, as well as the convenience and the ease of movement for residents and guests in Tyumen.

The issues of improving the traffic network of the city and region are considered by the staff and students of the Department of roads and airfields in Tyumen Industrial University [5-21].

During a comprehensive analysis it was found out that one of the most difficult passages in the city is the Shirotnaya and Permyakova streets intersection, as this node is the intersection of two important city traffic flows.

One reason of congestion on this transport intersection is active development of the Eastern administrative district, therefore traffic is constantly increasing.

For a more detailed analysis parameters of intersection were calculated by method of "remote satellite monitoring of traffic flows "[8]. The estimated traffic for the current year is 7321 vehicles per hour on Shirotnaya street; and 2864 vehicles per hour on Permyakova street.

Traffic volume and oscillation of overall traffic during the day are significant, namely increasing number of cars at rush hour (figure 2) [8].

![Figure 1. Graphs of rising levels of motorization and population: 1 – vehicles; 2 – population.](image1)

![Figure 2. Graphs of traffic volume changes during the day: a – on Permyakova street; b – on Shirotnaya street; 1 – total intensity; 2 – forward direction; 3 – opposite direction.](image2)
pedestrian and vehicle phases [5]. This innovation had a negative impact on roads capacity as waiting time has been increased for at least 15-20 seconds by including a "pedestrian phase", which is equivalent to the passage of 8-12 cars. To optimize the operation mode according to the new requirements, it is necessary to conduct further monitoring and adjust the operation of traffic lights. The best solution would be to separate traffic and pedestrian flows by constructing underground or overhead pedestrian crossings.

The increased traffic caused the increase of noise level in the area. According to calculations, noise level is in the range from 90 to 120 dBA (the third group of noises) [9].

These values cause unpleasant feelings, often pain which can result in hearing disorder. The number of vehicles also the pollutes the environment by carbon dioxide and on Shirotnaya street its concentration is 172 mg/m3, and on Permyakova st. it is 72 mg/m3, whereas the maximum allowed value is 5 mg/m3[9].

3. Results of the study
One of the solution to increase traffic capacity is to make more traffic lanes. As today the Eastern region at the traffic node under consideration has the capital multi-storey residential development, the possibility of extending the street by moving red lines is minimized (figure 3).

According to the program proposed by JSC "Mostostroy-11" and approved by the Main administration building of the Tyumen region, it was decided to build a two level "clover leaf" intersection on this transport node. Despite the advantages of such an interchange, there are some disadvantages, for example left-turning path is changed at 270 degrees; other disadvantages are low speed on connecting manifolds and difficulties in organizing pedestrians’ movement.

![Figure 3](image)

Figure 3. The results of in-situ measurement of geometric parameters of traffic intersection.

The following types of intersection are also widespread in Russia:
• Single point urban interchange (SPUI);
• Diamond interchange;
• Roundabout interchange;
• Turbine interchange

Table 1 show types of intersections and give their comparative analysis.

| Type                        | Design | Cost MM RUB | Characteristics | The complexity |
|-----------------------------|--------|-------------|-----------------|----------------|
|                             |        | Overpass    | Exits | Overall | Overpass length | Amount of exits | Conflict points | Occupied area, ha |
| Cloverleaf interchange      |        | 357         | 499   | 856     | 100             | 8               | 16              | 7,26 | Simple            |
| Single point urban interchange (SPUI) |        | 2410        | 424   | 2835    | 300             | 4               | 8               | 7,80 | Medium            |
| Diamond interchange         |        | 1513        | 191   | 1704    | 375             | 12              | 8               | 6,35 | Simple            |
| Two level roundabout        |        | 968         | 264   | 1232    | 300             | 17              | 18              | 5,37 | Simple            |
| Turbine interchange         |        | 355         | 312   | 667     | 108             | 12              | 8               | 6,10 | Simple            |

When analyzing the traffic intersections some difficulties in their use were revealed. These difficulties occur due to the large number of conflict points, large rounding radii, and complex turns. To select the optimal type, it was decided to project the individual types of interchange (table 2) [18].

| Type                        | Design | Cost, MM RUB | Max. number of roads/Capacity | Exits  | The configuration complexity, m | Conflict points. | Area, ha |
|-----------------------------|--------|--------------|-------------------------------|--------|-------------------------------|-----------------|---------|
| Three level SPUI            |        | 1818         | 4/medium                      | 8      | medium                        | 8               | 7,8     |
| Cross type                  |        | 1172         | 4/medium                      | 4      | simple                        | 12              | 6,5     |
| Diverging diamond interchange |      | 1504         | 5/high                        | 4      | medium                        | 8               | 7,0     |
Having considered and compared three possible interchanges, we can conclude that Three-level SPUI type will have the greatest cost, since to build the tunnel it will be required to replace all the underground utilities, therefore, this type is not economically profitable.

To make a more detailed comparison of the other two types, the authors calculated the costs of basic structures (table 3).

| Type                        | Structural component                          |                  |                  |                  |
|-----------------------------|-----------------------------------------------|------------------|------------------|------------------|
|                             |                                              | Columns type     | Bearing elements construction type | Load-bearing elements of the roadway type |
|                             |                                               | Cost Thousand rub/m³ | Cost Thousand rub/tons | Cost Thousand rub/m³ |
| Cross type                  | Modular reinforced concrete elements          | 154,90           | Metal spans with a wall span of more than 33 m | 354,97 | 184,40 |
| Diverging diamond interchange| Modular-monolithic                            | 92,20            | Girder spans from conventional reinforced concrete | 253,55 | 207,45 |

Having carrying out a detailed analysis and value assessment of traffic junctions of individual type authors can offer an interchange with shift-way traffic (figure 4)

**Figure 4.** An interchange with shift-way traffic.
This interchange requires construction of three overpasses, thus providing a high capacity due to the required quantity of lanes for each possible direction with a minimum speed reduction.

4. Conclusion

This type of interchange will be a unique engineering facility for the city. The number of conflict points will be reduced due to the changing sides in the forward direction with a deviation to the left side (to allow a left-turn maneuver), and the capacity will be high. Transportation will be convenient and safe for residents and guests of the city because of overground and underground pedestrian crossings and noise screens.

References

[1] Car loans in Russia: what convenient, beneficial and how to get it? Retrieved from http://avtourist.guru/avtokreditovanie.

[2] Tyumen-Wikipedia, the free encyclopedia Retrieved from https://ru.wikipedia.org/wiki/Tyumen #. D0.9D.D0.B0.D1.81.D0.B5.D0.BB.D0.B5.D0.BD. D0 B8 D0... B5.

[3] Motorization of Tyumen-Rael. Thoughts Retrieved from http://raelrulez.livejournal.com/418011.html.

[4] The economic rationale for expansion of dealer services for the sale and servicing of automobiles on the example of LLC pole-DM Retrieved from http://refy.ru/114/355536-2-ekonomicheskoe-obosnovanie-rashshireniya-dilerskih-uslug-po-prodazhe-i-servisnomu-obsluzhivaniyu-avtomobiley-na-primere-ooo-polyus-dm.html.

[5] 2006 GOST r 52289-2004 Technical means of traffic management. Rules of road signs, markings, traffic signals, road barriers and sending devices (N 1, 2, 3) (Moscow: Standartinform) p 100

[6] Sannikov S P, Timohovetz V D and Sergienko N P 2016 Justification of the type of transport interchange at the intersection of Nikolay Fedorov-Latitude in Tyumen Bulletin of the Construction of the Tyumen region 2(76) pp 42–5

[7] Sannikov S P and Panteleyev M 2017 Substantiation of constructive-technological solutions to improve the transportation hub at the intersection of UL. 50 years of October Street. Permyakov in Tyumen Proceedings of the X international scientific-practical conference devoted to 85 anniversary of the birth of Dr Tech S Professor L Reznik pp 287–94

[8] Testeshev A A and Timohovetz V D 2017 Methodology of traffic flows remote monitoring in the Ural Federal District largest cities using satellite monitoring data AIP Conference Proceedings vol 1800 is 1 Retrieved from http://aip.scitation.org/doi/pdf/10.1063/1.4973066

[9] Skipin L N and Zakharova E V 2014 Ecology: methodological guidelines for student’s directions: 270800.62 “construction”, all forms of training (Tyumen: Rio FEDERAL HPE TjumGASU) p 52

[10] Timohovec E and Legostaeva E N 2016 Reduction of traffic noise in speed control system of traffic flows Topical architecture, construction, energy efficiency and ecology-2016 collection of materials of the int scientifically-practical Conf in three volumes. Federal State budget institution of higher education Tyumen industrial University pp 83–8

[11] Suvalays A N, Testeshev A A, Timohovec V and Sergeev A V 2013 Innovative content management technology of roads and their meteorological provision Topical questions of designing roads 4(63) pp 198–206

[12] Timohovec V D and Testeshev A A 2013 Score of economic efficiency and environmental safety of the speed control system of traffic flows in winter Ecology and scientific and technological progress. Urbanism 2 pp 410–8

[13] Kubasov D V and Sannikov S P 2012 Slicing cement-concrete reason for increasing treshhino-resistance of asphalt concrete pavements Scientific and technical bulletin of the Volga region 1 pp 183–6

[14] Suvalays A N, Kubasov D V and Sannikov S P 2013 GIPRDORNI Topical questions of
designing roads 4(63) pp 138–44

[15] Andronov R V 2007 Modelling queues at controlled intersections of highway-road network, a major city in the dense traffic (Tyumen)

[16] Andronov R V 2012 Rearrangement of controlled crossings of highway-road network, a major city on the basis of studies of traffic congestion Road-transport complex Development and building infrastructure on the basis of environmental management VII all-Russian scientific and practical Conf FEDERAL HPE Sibadi pp 35–7

[17] Testeshev A A and Legostaeva L N 2015 Determining traffic conditions on external input Tyumen road express-method Scientific and technical bulletin of the Volga region 1 pp 135–9

[18] Shcherbakova E N and Kazantseva A N 2013 Complex estimation of efficiency of real investment Management of economic systems: electronic scientific journal 6(54) p 49

[19] Andronov R V 2014 On methods of evaluation of traffic delays on a regulated intersection Scientific and technical bulletin of the Volga region 4 pp 34–7

[20] Andronov R V, El’kin B P and Gonzalez D A 2015 Concept congestion and queues forming on a regulated intersection of dense traffic flow conditions Scientific and technical bulletin of the Volga region 1 pp 39–41

[21] Andronov R V and Koptjaeva A G 2017 Assessment of the effectiveness of reconstruction and improvement of intersections of highway-road network using the software product VISSIM Organization and traffic safety Materials X international scientific-practical conference devoted to 85 anniversary of the birth of Dr tech S Professor L G Reznik pp 143–148