Methodology of assessing traffic service level at intersections of feeding focal points

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Abstract. The article presents the methodology of assessing the level of traffic service during the operation, conversion or creation of new focal points in urban areas. The presented methodology of assessing the level of traffic service within the context of traffic performance of uncontrolled intersections allows assessing the degree of influence of focal points on the adjacent street-and-road network. The methodology contains nine consecutive steps and results in assessment of the level of traffic service. The distinctive feature of the methodology is the need to distribute the intensity of traffic flows at the entrance or exit to/from the territory in question when there are several feeding intersections. The result of distribution of transport flows is a matrix that relies on the intensity of the transit flow. If the intensity of conflicting traffic flows exceeds the limit values recommended by the national regulatory standards, the traffic must be controlled by traffic lights. An integrated mathematical model is presented; it allows assessing the load factor of traffic on the basis of open source data, for example, geometric parameters of feeding intersections, the area of the focal point and its remoteness from the city center. Such data can be obtained using GIS technologies. The unique character of the integrated model is that it involves parameters reflecting both the transport demand and traffic performance of the feeding intersection. The model includes the boundary intervals of vehicles driving in the main flow and the intervals of movement in the minor flow. The sequence of calculation of the transport demand converted into the influence of traffic flow intensity on the street-and-road network and traffic load factor is shown. Recommendations on how to choose a traffic management pattern for uncontrolled intersections are given.

1. Introduction
Traffic performance of the street-and-road network (SRN) depends mainly on the following geometric characteristics of roads and streets: the number of lanes and their width, width of the roadside and its existence, density of intersections, left and right turns, road markings, parameters of grade lines and cross-sections as well as other properties. In addition, the traffic performance of SRN is influenced by such factors as speed limit, guardrails, channeling of traffic flows, and others [2]. When assessing the capacity of separate elements of SRN, especially grade crossings, the ratio of intensities in conflicting directions should be paid attention to, as it will be a decisive factor in determining the capacity value at the uncontrolled intersections [5-6]. Ultimately, the intersections are the elements of SRN which significantly reduce its traffic performance. As a rule, when organizing transportation to focal points (FP), the feeding intersections are located at the same grade with the adjacent SRN. Therefore, the transport demand for entry and, especially, for exit, will influence the capacity of both the feeding intersection and the adjacent SRN significantly.
2. Methodology of Assessing the Level of Traffic Service

The methodology is based on mathematical models of assessing the load factor, their key feature is using open source data. The main goal of the proposed methodology is a consistent description of actions (steps) while determining the level of traffic service at intersection(s) feeding the FPs. Figure 1 shows the road map of this methodology.

Figure 1. Road Map of Methodology of Managing Road Traffic at Intersections Feeding FPs

2.1 The first step of assessment

The first step of this methodology involves creating a sketch of planning FP indicating the adjacent transport infrastructure; the location of roads of all categories passing through FP or in close proximity to it should be taken into account. Besides, one should not overlook the areas of the adjacent territory, which can be used for entering FP or leaving it. When assessing the level of traffic service at FP, its sketch should be created taking into account the existing conditions of traffic services for visitors using private transport (PT) at most. An example of a sketch is shown in Figure 2. When sketching, the organization of traffic at feeding intersections must be particularly important; one should take into account the number of lanes and their width, channeling, traffic signs location, acceleration and deceleration lanes, since these elements can significantly influence traffic performance and, consequently, the level of traffic service.

2.2 The second step of assessment

The second step of the methodology involves determining the number of feeding intersections. In the case of assessing the level of traffic service of the existing FP one should consider all functioning intersections. The intersections for entry/exit of official, freight and other transport may be excluded as passing them is carried out in a special mode. If the level of traffic service is assessed for a designed FP at the first iteration, one feeding intersection may be set out, and only if the service level is low at the second and subsequent iterations (step 9), additional feeding intersections should be considered.
Figure 2. A sketch of FP with two feeding intersections – at the top; the management of the road traffic: on the left – feeding intersection №1; on the right – feeding intersection №2

2.3 The third step of assessment

If there are two or more intersections feeding the FP, the intensity of the traffic flow (visitors using PT) should be distributed between these intersections; it is the third step of the methodology. If there are two feeding intersections, it is necessary to assess the possibility of organizing only entry at one intersection and, accordingly, only exit at the other one. Such organization of traffic will allow channeling the traffic
flows not only at feeding intersections, but also in the parking area of the FP. The distribution of the traffic flow intensity upon arrival (entrance to the FP territory) should be proportional to the total intensity of the transit flow which can enter the FP territory according to the existing traffic management at the feeding intersection. The distribution of the intensity of leaving traffic flow (exit from the PT territory) should be proportional to the traffic performance of the accesses (groups of lanes) responsible for the exit from the FP territory.

2.4 The fourth step of assessment

At this step the case of the intensity distribution between two feeding intersections can be considered; it is presented in Figure 2. The total intensity of entry per maximum hour was 580 cars/h and of exit – 520 cars/h. For the first intersection the total intensity of transit traffic was 1400 cars/h in the directions leading to the territory of the FP (in both directions of the main flow), and for the second intersection it was 600 cars/h (only in one direction of the main flow). Therefore, the total intensity at the entrance to the FP should be distributed in proportion to these intensities (proportionality factor (1400/(1400+600)=0.7) and it will be 580*0.7=406 cars/h for the first intersection, and 580*0.30=174 cars/h - for the second intersection).

The intensity of leaving traffic flow (exit from the FP territory) is distributed in proportion to the traffic performance of the groups of lanes. For example, at the first intersection the capacity of the lane with two directions can be determined according to the methodological recommendations for assessing the traffic performance [3]: it will be 236 cars/h for the first intersection taking into account the traffic management at the first intersection (turns to the left and to the right are allowed). Thus, the intensity distribution should be calculated in proportion to the capacity of the traffic directions to the exit from the FP. For the second intersection it will be 448 cars/h taking into account the traffic management (Figure 2). Consequently, the total intensity at the exit from the FP is distributed in proportion to these capacities (proportionality factor (236/(236+448)=0.34) and it will be 520*0.34=177 cars/h for the first intersection, and 520*0.66=343 cars/h for the second intersection. Within the context of the calculated intensities of traffic flows at feeding intersections it is possible to carry out the fourth step of the methodology – generation of an intensity matrix (Tables 1 and 2).

**Table 1. Matrix of Traffic Flows Intensity at Intersection 1**

| Departure | N   | S   | W   | O   | Total |
|-----------|-----|-----|-----|-----|-------|
| N         |     | 600 |     | 231 | 600   |
| S         | 800 |     |     | 175 | 1206  |
| W         |     |     |     |     |       |
| O         | 117 | 60  |     |     | 177   |
| Total     | 917 | 660 |     | 406 | 1983  |

**Table 2. Matrix of Traffic Flows Intensity at Intersection 2**

| Departure | N   | S   | W   | O   | Total |
|-----------|-----|-----|-----|-----|-------|
| N         |     |     | 343 |     | 343   |
| S         |     |     |     |     |       |
| W         |     |     |     |     |       |
| O         | 174 |     | 600 |     | 774   |
| Total     | 174 |     | 943 |     |       |
2.5 The fifth and sixth steps of assessment

At the fifth step the type of intersection is selected on the basis of GOST technical documents on the traffic management and methodological guidelines on assessment of the traffic performance [1, 3] which rely on conflicting intensities of transport and pedestrian flows and the number of road traffic accidents that occurred during the year. When assessing the current level of traffic service, the fifth and sixth steps of the methodology are disregarded.

2.6 The seventh step of assessment

When the type of intersection is chosen, the parameters of the intersection functioning must be calculated – Step Seven. In fact, the basic parameters calculation is based on the calculation of the intersection traffic performance carried out at the third step of the methodology. The calculation of the load factor is produced by Expression 1.

\[
z = \sum_{i=1}^{n} \frac{E_{FP} \cdot d_{it} \cdot k_{di} \cdot k_{di}}{P_{it}}
\]

where \( N_a \) – intensity of the \( i \)-th direction of the traffic flow in the traffic group, cars/h; \( E_{FP} \) – transport demand at the center of a focal point, corr./day; \( d_{it} \) – share of visitors using PT during the hour in question; \( P_{it} \) – average number of people in PT, people; \( k_{di} \) – coefficient of daily irregularity for the hour in question; \( q_a \) – intensity of the traffic flow of the first rank conflicting with the traffic direction in question, cars/h; \( k_d \) – coefficient of the traffic flow proportion distributed between intersections of the given FP; \( k_{dep} \) – coefficient of daily irregularity on departure; \( n \) – number of traffic flows in the traffic group; \( t_f \) – average boundary zone, sec.; \( t_l \) – average following distance, sec.; \( N_{02j} \) – intensity of the transport flow of the second rank conflicting with the traffic direction in question, cars/h (disregarded if absent); \( N_{03j} \) – intensity of a third-rank traffic flow conflicting with the traffic direction in question, cars/h (disregarded if absent); \( m \) – number of traffic flows of the second and third ranks, respectively, conflicting with the traffic direction in question.

According to Expression 1:

\[
z = \left( \begin{array}{c}
13050 \cdot 0.45 \\
1.68 \cdot 0.15 \cdot 0.66
\end{array} \right) \cdot \left( \begin{array}{c}
3600 \\
3.7 \cdot e^{-600/2} \cdot 6.5 \cdot 1.7 \cdot 2
\end{array} \right) \cdot \left( \begin{array}{c}
13050 \cdot 0.45 \\
1.68 \cdot 0.15 \cdot 0.66
\end{array} \right) \cdot \left( \begin{array}{c}
3600 \\
3.8 \cdot e^{-600/2} \cdot 6.6 \cdot 3.8 \cdot 2
\end{array} \right) \cdot \left( \begin{array}{c}
1 - 231 \\
561
\end{array} \right) \cdot \left( \begin{array}{c}
1 - 231 \\
561
\end{array} \right) =
\]

\[
= 0.2624 + 0.6768 = 0.94.
\]

According to the table presented in [3], the calculated load factors allowed determining the level of traffic service as \( E \). At this stage the eighth step of the methodology (Figure 1) can be considered complete. The load factor for the second intersection is calculated in the same way:
\[ z = \left( \frac{13050 \cdot 0.45}{1.68} \cdot 0.15 \cdot 0.66 \right) \left( \frac{3600}{3.7} \right) e^{\frac{600/2}{3600 \cdot 6.5 \cdot 3.7}} \cdot (1) \cdot (1) = 0.51 \]

The level of traffic service at the first intersection is \( E \), and for the second intersection – \( C \), which suggests that the first intersection needs to be reconstructed.

3. Findings
The calculations show that the presented methodology and model (1) require only those input data that are open to public, for example, geometric parameters of feeding intersections, the area of FP and its remoteness from the city center. These data can be obtained using GIS technologies. Besides, it should be noted that data on the share of visitors using PT and the average number of people in one PT arriving at FP, the coefficients of daily irregularity can be found in reference books and scientific publications [7, 8, 9] as well as in other works of the authors.

4. Conclusion
The presented methodology of assessing the traffic service allows for assessment of influence of all-purpose FPs on the adjacent street-and-road network by means of assessing uncontrolled intersections feeding these FPs. It is important to note that the input data are data that are open to public. Besides, the methodology makes it possible both to assess the level of traffic service of existing FPs and to predict it for the designed FPs. The methodology will be of practical interest for design companies working in the field of transport and urban planning and in transport departments.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the data used.

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