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OVERTAKING AS INDICATOR OF ROAD TRAFFIC CONDITIONS

ABSTRACT

Overtaking is presented as one of the indicators of road traffic flow. The possibility of overtaking depends on the existence of an interval in the opposing traffic flow sufficient to perform overtaking. It also analyses the probability of overtaking by applying adequate equations and graphical presentations.

KEY WORDS

road traffic, overtaking, traffic flow, traffic safety, traffic capacity

1. INTRODUCTION

On two-way and two-lane roads, overtaking usually requires the use of the opposing traffic lane. In case of two-way traffic, the slow-moving vehicles create a gap between the vehicles that can be used for overtaking, and depending on the length of this gap, it also provides the opposing vehicles with the possibility of overtaking. Therefore, vehicle movement during congested traffic flow on two-way and two-lane roads oscillates between creation of platoons with gaps between them, and partial filling up of these gaps stipulated by overtaking.

Studies have shown that in evenly distributed traffic flows regarding directions, the vehicle actions are limited to the flow of 1,000 passenger vehicles in each direction. On the other hand, when almost the whole traffic moves in one direction, the given traffic lane can constantly provide the possibility of overtaking. The capacity under such conditions is limited to the number of vehicles that may travel in one traffic lane, since the other traffic lane has to be reserved for the opposing vehicles.

2. OVERTAKING AS INDICATOR OF ROAD TRAFFIC FLOW CONDITIONS

For the complex evaluation of the road traffic flow conditions, especially on two-lane two-way roads, the vehicle overtaking issue plays a very important role. Traffic safety and vehicle moving speed depend to a great extent on the possibilities of vehicle manoeuvring on the road. This logically implies the need to explain the issue of overtaking in the best possible way. In order to define the appropriate theoretical basis necessary for the analysis of the set of issues regarding overtaking, the following sections deal with the analysis based on the application of the mass service method.

2.1. Probability of overtaking

Overtaking demand is proportional to the passing capacity of the considered traffic stream. The possibility of overtaking depends on the gaps sufficiently long to allow overtaking in the opposing traffic lane.

The following diagram (Figure 1) shows the functional dependence of the dynamic vehicle dimensions or virtual gap between vehicles on the vehicle velocity and type.

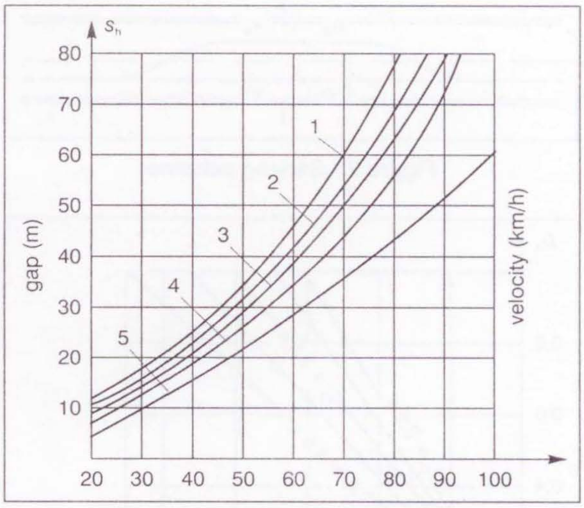

Figure 1 - Functional dependence of the dynamic vehicle dimension on vehicle velocity and type

Overtaking occurs in case following concurrent situations:

a) When the gap between the preceding vehicle moving at velocity V1 and the succeeding vehicle moving at velocity V>V1 in a stream, becomes equal or less than the minimum headway (the so-called dynamic dimensions, i.e. virtual gap).

b) When there is a gap in the opposing traffic stream sufficient for overtaking.

The probability of fulfilling the conditions under a) can be marked as p_a, and p_b marks the probability of fulfilling the condition under b). Since situations under a) and b) occur independently, the probability of concurrence i.e. the probability of overtaking equals the product of probability of the situations under a) and b). Therefore, the overtaking probability p_o equals:

$$p_0 = p_a \times p_b$$

where:

p_a – is the probability of the overtaking need. Overtaking need results from the driver's tendency to reach the destination as soon as possible. Higher speeds result in approaching closer to the preceding vehicle to a minimal safety gap, resulting subsequently in the overtaking need.

p_b – is the probability of the overtaking possibility. Situation b) can occur also in those cases when there is no overtaking need. It is this fact, namely, which contains the independence of the occurrence of the situation a) compared to situation b).

In order to calculate the probability of the need to overtake a vehicle in the given direction, a serving scheme is used (cross-section I-I) in Figure 2.

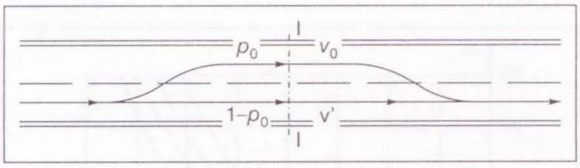

Figure 2 - Serving scheme

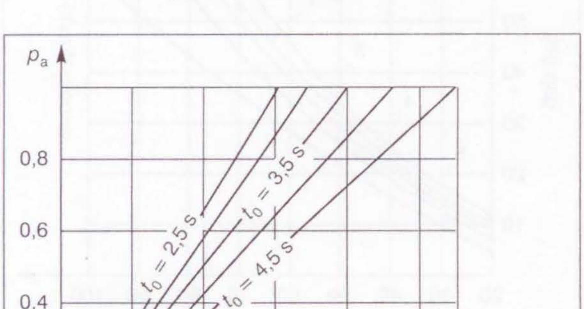

Figure 3 - The probability of the overtaking need

The probability p_o is that the vehicle from the considered direction approaching serving will arrive at the cross-section (I-I) at the moment at which it is passed by the so-called dynamic dimension (virtual gap) of the preceding vehicle.

Practically, should such a situation occur, then the driver of the succeeding vehicle has to overtake the preceding vehicle in order to maintain the speed of free movement.

The following graphic presentation provides the dependence of the probability of the overtaking need (p_a) on the flow volume in the observed direction (Figure 3).

The mean time of the cross-section (I-I) occupancy of the passage of the so-called dynamic vehicle dimension (passage time of length $S_{h(sig)}$) equals:

$$t_0 = \frac{S_{h(sig)}}{V_0}$$

The following graphical presentation (Figure 4) shows the probability of the overtaking possibility p_b depending on the opposite traffic flow volume q_1:

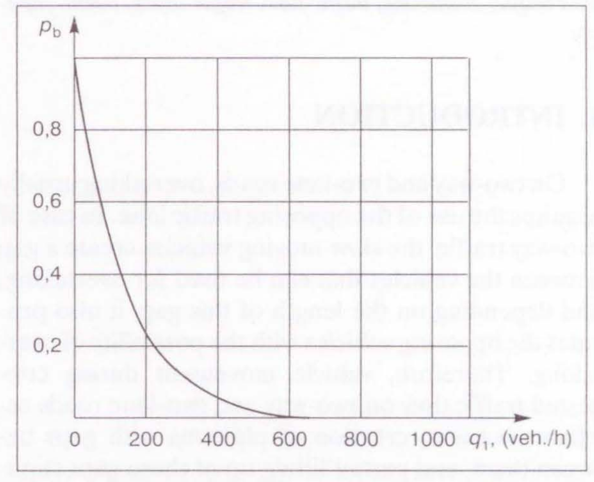

Figure 4 - The probability of the overtaking possibility

where:

V_0 – is the mean speed of vehicle free movement along the considered vehicle movement direction,

$S_{h(sig)}$ – is the mean value of the so-called dynamic vehicle dimension of the input flow.

For the considered direction of the traffic flow q_d, the mean time of cross-section (I-I) occupancy by the so-called dynamic dimensions equals:

$$q_d \cdot t_0$$

Compared to one hour the mentioned mean time of cross-section (I-I) occupancy amounts to:

$$\alpha = \frac{q_d \cdot t_0}{3600} = \lambda_d \cdot t_0$$

Relatively (compared to one hour = 3,600 sec.) the mean time of cross-section (I-I) occupancy by the so-called dynamic dimension is the probability of the overtaking need:

$$p_a = \lambda_d \cdot t_0$$

that is:

$$p_a = \frac{q_d \cdot t_0}{3600}$$

Figure 4 represents the probability graph of the overtaking need.

The probability of the overtaking possibility, as explained previously, is the probability that there is headway $t_h > t_{h0}$ in the opposing traffic flow where:

t_{h0} – is the headway of the opposing traffic flow required for overtaking

According to the studies carried out by I.V.Begma, the duration of overtaking ranges between $\theta = 10 \div 15$ sec.

Thus, it may be considered that $t_{h0} = 2 \cdot \theta$ ranges between 20 and 30 sec.

The following graph (Figure 5) shows the probability of overtaking p_0 noticed at cross-section (I-I) depending on the volume of flow q_d.

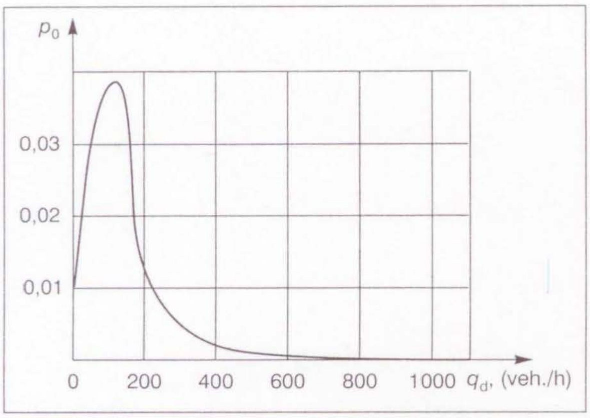

Figure 5 - Overtaking probability depending on the stream volume

It is well-known that the mean time headway values for low density flows (that are subjected to Poisson's distribution of probability) are high, and that the time headway distribution density adheres to the exponential law of distribution which is:

$$f(t_h) = \lambda \cdot e^{-\lambda t_h}$$

The probability that there is time headway $t_h > t_{h0}$ in the opposing flow is:

$$p_b = p(t_h > t_{h_0}) = \int_{t_{h_0}}^{\infty} \lambda_1 \cdot e^{-\lambda t_h} \cdot dt_h = e^{-\lambda_1 t_{h_0}}$$

$$p_b = e^{-\lambda_1 t_{h_0}}; \text{ where: } \lambda_1 = \frac{q_1}{3600}$$

therefore:

$$p_b = e^{-\frac{q_1}{3600} \cdot t_{h_0}}$$

Taking into consideration the probabilities p_a and p_b, the overtaking probability equals:

$$p_0 = p_a \cdot p_b; \; p_0 = \frac{q_d \cdot t_0}{3600} e^{-\frac{q_1}{3600} \cdot t_{h_0}}$$

The probability p_0 graph is given in Figure 5.

Therefore, if we consider individually every vehicle, the probability that it will be overtaking when approaching the cross-section (I-I) equals:

$$p_0 = \frac{q_d \cdot t_0}{3600} e^{-\frac{q_1 \cdot t_{h_0}}{3600}}$$

it also means that out of the overall flow q_d in the overtaking status there will be $q_d \times p_0$ vehicles. The total flow in the considered direction q_d is distributed along the observed road section in the length of s (km). Within a period of one hour there will be n_0 overtakings on one kilometre, and the form for n_0 equals:

$$n_0 = \frac{q^3 \cdot t_0}{3600\, s} e^{-\frac{q_1 \cdot t_{h_0}}{3600}}$$

(overtaking in one hour on 1 km of the observed road section)

Since the probability p_a of overtaking is greater with the greater flow, and the probability of overtaking possibility p_b is greater with the lower flow, this means that assuming the flows are symmetric, the flow volume at which the maximum number of overtaking takes place can be determined. This value can be determined from the following condition:

$$\frac{\partial n_0}{\partial q} = 0$$

that is, solving by q the following is obtained:

$$\frac{3q^2 t_0}{3600\, s} e^{-\frac{q \cdot t_{h_0}}{3600}} - \frac{q^3 t_0}{3600\, s} \frac{t_{h_0}}{3600} e^{-\frac{q \cdot t_{h_0}}{3600}} = 0$$

$$3 - \frac{q \cdot t_{h_0}}{3600} = 0; \quad q = \frac{10800}{t_{h_0}}$$

3. CONCLUSION

Overtaking on two-lane, two-way roads plays a significant role in the traffic flow conditions, traffic safety and throughput capacity. By applying the method of mass service it is possible to determine appropriate theoretical basics necessary to analyse the series of issues related to overtaking.

SAŽETAK

PRETJECANJE KAO POKAZATELJ UVJETA ODVIJANJA PROMETA NA CESTAMA

Prikazano je pretjecanje kao jedan od pokazatelja odvijanja prometa na cestama. Mogućnost pretjecanja ovisi o postojanju intervala dovoljnog za pretjecanje u prometnom toku suprotnog smjera. Također, analizirana je vjerojatnost izvršenja pretjecanja primjenom odgovarajućih jednadžbi i grafičkih prikaza.

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