ISSN 1822-296 X

KAUNO TECHNOLOGIJOS UNIVERSITETAS

TRANSPORT MEANS

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE

ISSN 1822-296 X

KAUNAS UNIVERSITY OF TECHNOLOGY
IFTOMM NATIONAL COMMITTEE OF LITHUANIA
SAE LITHUANIAN BRANCH
THE DIVISION OF TECHNICAL SCIENCES
OF LITHUANIAN ACADEMY OF SCIENCES
KLAIPĖDA UNIVERSITY
VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

TRANSPORT MEANS 2009

PROCEEDINGS OF THE 13th INTERNATIONAL CONFERENCE

October 22 – 23, 2009
Kaunas University of Technology, Lithuania

KAUNAS•TECHNOLOGIJA•2009

Proceedings of 13th International Conference. Transport Means. 2009

Analysis of Uncontrolled Crossing Passage Time

A. Ragauskaitė*, V. Bagdonas, A. Sladkowski*****

**Kaunas University of Technology, Studentų 48, 51367, Kaunas, Lithuania, E-mail: agnrag@yahoo.com*
***Kaunas University of Technology, Studentų 48, 51367, Kaunas, Lithuania, E-mail: vaclovas.bagdonas@ktu.lt*
***Silesian *University of Technology, Krasinski str. 8, PL-40019, Poland, E-mail: aleksander.sladkovski@polsl.pl*

Abstract

There are proposed the analytical model of two streets uncontrollable crossing passage time, which is founded on safe interval D_1 between vehicles with espousal condition and assumption, when vehicles flow is simplest off interval D_1 ranges. There are given probability formulas of vehicle stopping by crossing, formulas of middle time, whom vehicle delays letting comming automobiles from right go first, and condition formula of traffic jam formation.
KEY WORDS: *uncontrollable crossing, passage time, analysis*

1. Introduction

By way of regularizing parameters of city traffic flows and of fraffic infrastructure it‘s needed to solve problems of two types:

1) to conform streets and crossing throughputs to traffic regular flows intensities;
2) expeditiously to redistribute (correct) traffic flows intensities, if parameters of fraffic infrastructure (repair works, accidents and etc.) are temporarily varied.

Problems of first type are solving on statistical characteristics of traffic flows (source-purpose matrixes, actual intensities) grounds chosen number of outside lanes, installing traffic-light modes of „green wave“, regulating duration of traffic-light phases and etc. Now these problems are successfully solving.

To solve problems of second type it‘s needed to know actual passage times of streets and crossings, expeditiously solve problem of traffic flow distribution in real time and to be able to realize founded results, that is expeditiously to divert vehicles for actuality in optimal routs. It is technically and theoretically complicated problem. The system structural scheme, which is needful to solve complicated problem, is affinity described in literature [1]. One of the basic subsystem of discussed system – dynamic (expeditiously renewable) database of street crossing passage time, which is backed up on ground of dimensional and prognosis data. Exactly for this pupose herein is needful under consideration analytical model of crossing passage time.

In this artical is restricted to analytical model of one lane crossing passage time of two streets (there are unvalueded cases of turning to left or right or round).

2. Models of traffic flows basic characteristics

Researches of crossing passage time are founded on formula (proposed in literature [1]) of safe interval D_1 between front bumpers of adjacent and going along vehicles:

$$D_1 = L(t) + l = 1{,}8v_{n+1}(t) + l. \tag{1}$$

Here:
$L(t)$ – distance on time t between back bumper of previous vehicle and front bumper of follow-up vehicle [m];
l – average length of vehicle [m];
$v_{n+1}(t)$ – velocity of follow-up vehicle [m/s] on time t;
1,8 – coefficient containing time (seconds) dimension.

In analytical researches of traffic flows often are supposed that vehicles flow is simplest: stationary, ordinary and without interaction [2]. However, in reality such model is not completely adequate. It‘s due to the fact that vehicles flow is not flow without interaction: automobiles can not to come near one by other closer than safe distance D_1 (Fig1).

Probability density function $\rho(x)$ of interval between adjacent and going along vehicles can be expressed by formula [3]:

$$\rho(x) = \begin{cases} 0 & \text{, when} \quad -D < x < 0; \\ \lambda e^{-\lambda x} & \text{, when} \quad x \ge 0; \end{cases} \tag{2}$$

If *N*- density of vehicles (number of vehicles in one road kilometre), then medium interval Δ between next-door automobiles in traffic flow is:

$$\Delta = D_1 + \int_0^\infty x\rho(x)dx = D_1 + \int_0^\infty x\lambda e^{-\lambda x}dx = D_1 + \frac{1}{\lambda} = \frac{1}{N}. \quad (3)$$

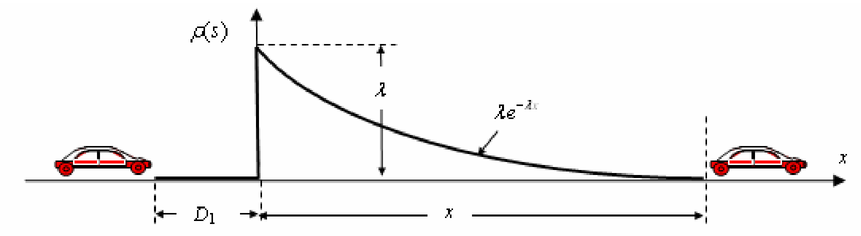

Fig. 1. Probability density function of interval between adjacent and going along vehicles

Scheme of uncontrollable crossing of two streets with equal same traffic intensities is shown in Fig.2.

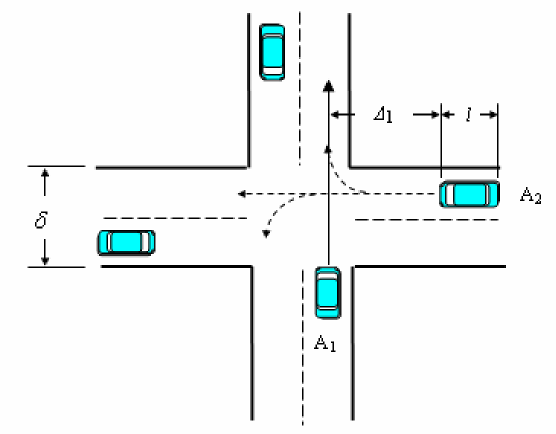

Fig. 2. Scheme of uncontrollable crossing of two streets with equal same traffic intensities

First of all is discussed state, when traffic is not intensive and there are no lines by crossing.
Then, when automobile A_1 (figure 2) comes to crossing, it‘s possible two situations:
1) obstacle from right (automobilis A_2) is enough far away and A_1 can safely go by crossing;
2) automobile A_2 is near and A_1 must stop and let automobile A_2 go first.
In both situations must be separated two cases:
2-1) when A_2 is going directly or turning to left;
2-2) when A_2 is turning to right.

When automobile A_2 is enough far away, it must obtain specification:

$$\Delta_1 \geq D_1 + \delta + l \text{, on case 2-1,}$$
$$\Delta_1 \geq 2D_1 - \delta + l \text{, on case 2-2.} \quad (4)$$

This specification means that while automobile A_1 will go through crossing, A_2 will not come closer than safe distance D_1.

Suppose that automobile A_2 is near, when

$$\Delta_1 < D_1 + \delta + l \text{, on case 2-1,}$$
$$\Delta_1 < 2D_1 - \delta + l \text{, on case 2-2.} \quad (5)$$

This event probability

$$P_{st} = \frac{\Delta_1}{\Delta} \quad (6)$$

Middle crossing passage time

Middle crossing passage time t_{1L} , whom automobile A_1 will delay letting comming automobile from right go first.

When it‘s searching for this important characteristic, it‘s possible to talk about t_{1L} unconditional and conditional values.

Unconditional t_{1L-b} value includes all events, whereas and these, when automobile A_1 passes the crossing immediately (don‘t need to let any go first).

Conditional t_{1L-s} value is counted only for such situations, when automobile A_1 must stop and let automobile A_2 go first, because otherwise condition (2) or (4) will be not supplyed.

$$t_{1L-b} = P_{tk}\,(t_{1L-D_1-tk} + t_{1L-\overline{D_1}-tk}) + P_d\,(t_{1L-D_1-d} + t_{1L-\overline{D_1}-d}) + P_{st}\,\frac{v_1}{a}\,. \tag{7}$$

Here:

a – stop and speed-up accelerations of automobile (it’s supposed that these accelerations are equal in absolute value), and component $P_{st}\,\frac{v_1}{a}$ is time, whom automobile delays in stopping and running up;

P_{tk} – probability, that automobile coming from right purposes to go directly or turn to left;

P_d – probability, that automobile coming from right purposes to turn to right.

If vehicles flows distribute equally, then (without rotation events), P_{tk} = 2/3; P_d = 1/3;

t_{1L-D_1-tk} and $t_{1L-\overline{D_1}-tk}$ – middle time, whom A_1 will delay letting comming automobile from right go first, but with condition that the automobile goes directly or turns to left and when it‘s remaining to crossing further (t_{1L-D_1-tk}) or near ($t_{1L-\overline{D_1}-tk}$) than $\Delta_1 - D_1$;

t_{1L-D_1-d} ir $t_{1L-\overline{D_1}-d}$ – middle time, whom A_1 will delay letting comming automobile from right go first, but with condition that the automobile turns to right and when it‘s remaining to crossing further (t_{1L-D_1-d}) or near ($t_{1L-\overline{D_1}-d}$) than $\Delta_1 - D_1$.

$$\begin{aligned} t_{1L-D_1-tk} &= \frac{1}{v_1}\int_{-D_1}^{0}\left(\int_{0}^{(D_1+\delta+l)+x}(y-x)\lambda e^{-\lambda y}dy\right)Ndx + P_{st}\,\frac{v_1}{a} = \\ &= \frac{ND_1}{\lambda v_1} + \frac{ND_1^2}{2v_1} + N(D_1+\delta+l)e^{-\lambda(D_1+\delta+l)}\frac{1}{\lambda v_1}\left(1-e^{\lambda D_1}\right) + \frac{N}{\lambda^2 v_1}e^{-\lambda(D_1+\delta+l)}\left(1-e^{\lambda D_1}\right)\,. \end{aligned} \tag{8}$$

$$t_{1L-\overline{D_1}-tk} = \frac{1}{v_1}\int_{0}^{\frac{1}{N}-D_1}\left(\int_{x}^{(D_1+\delta+l)+x}(y-x)\lambda e^{-\lambda y}dy\right)Ndx + P_{st}\,\frac{v_1}{a} = \frac{1-e^{-1}}{\lambda v_1}\left(\frac{N}{\lambda} - \left(N(D_1+\delta+l)+\frac{N}{\lambda}\right)e^{-\lambda(D_1+\delta+l)}\right)\,. \tag{9}$$

$$\begin{aligned} t_{1L-D_1-d} &= \frac{1}{v_1}\int_{-D_1}^{0}\left(\int_{0}^{(2D_1-\delta+l)+x}(y-x)\lambda e^{-\lambda y}dy\right)Ndx + P_{st}\,\frac{v_1}{a} = \\ &= \frac{ND_1}{\lambda v_1} + \frac{ND_1^2}{2v_1} + N(2D_1-\delta+l)e^{-\lambda(2D_1-\delta+l)}\frac{1}{\lambda v_1}\left(1-e^{\lambda D_1}\right) + \frac{N}{\lambda^2 v_1}e^{-\lambda(2D_1-\delta+l)}\left(1-e^{\lambda D_1}\right)\,. \end{aligned} \tag{10}$$

$$t_{1L-\overline{D_1}-d} = \frac{1}{v_1}\int_{0}^{\frac{1}{N}-D_1}\left(\int_{x}^{(2D_1-\delta+l)+x}(y-x)\lambda e^{-\lambda y}dy\right)Ndx + P_{st}\,\frac{v_1}{a} = \frac{1-e^{-1}}{\lambda v_1}\left(\frac{N}{\lambda} - \left(N(2D_1-\delta+l)+\frac{N}{\lambda}\right)e^{-\lambda(2D_1-\delta+l)}\right). \tag{11}$$

Conditional probability density $\rho(x|_{let\_go\_first})$, expressives of probability density of distance x to first automobile coming from right with condition that $x \le \Delta_1$, can be expressed with formula:

$$\rho(x|_{reikia\_praleisti}) = \rho(x|_{RP}) = \begin{cases} 0 & \text{kai} \quad -D_1 < x < 0; \\ \dfrac{\lambda e^{-\lambda x}}{1-e^{-\lambda \Delta_1}} & \text{kai} \quad x \ge 0. \end{cases} \tag{12}$$

Conditional value of middle crossing passage time t_{1L-s} is computable by the same method as t_{1L-b}, but instead probability density function (2) is using function of conditional probability density (12). Then:

$$t_{1L-s} = P_{tk} \frac{1}{1-e^{-\lambda(D_1+\delta+l)}} (t_{1L-D_1-tk} + t_{1L-\overline{D_1}-tk}) + P_d \frac{1}{1-e^{-\lambda(2D_1-\delta+l)}} (t_{1L-D_1-d} + t_{1L-\overline{D_1}-d}) + \frac{v_1}{a} . \quad (13)$$

Very important characteristic of traffic flow is middle time t_L, whom automobile A_1 after stop delays waiting chance to go through crossing. This time is expressed by formula:

$$t_L = t_{1L-s} + \sum_{j=1}^{\infty} (P_{sk})^j t_v . \quad (14)$$

Here

P_{sk} – probability, that when ordinary (k) vehicle passes from right, automobile A_1 will have no chance (because of ordinary automobile coming from right) to go through crossing;

t_v – middle value of time, measured between passage moments of previous and follow-up vehicles.

First component in formula (14) means middle time, whom automobile A_1 approached crossig will delay letting automobile A_2 coming from right go first.

Every next component in formula (14) means, that automobile A_1 will have wait till one more automobile will pass on contrariwise traffic line.

On the ground of formula (1) and distribution law (2), probability P_{sk} can be expressed by formula:

$$P_{sk} = 1 - e^{-\lambda S_{sto}}, \qquad S_{sto} = v_1 \sqrt{\frac{2(\delta + l)}{a}} \quad (15)$$

Time t_v is topical for automobile, which can not go through crossing even when it lets automobile coming from right go first. That‘s why it‘s needed just conditional value of this time, wherefore function of conditional probability density $\rho(x|_{NL})$ is using in formulas.

$$t_v = \frac{D_1}{v_1} + \frac{1}{v_1(1-e^{-\lambda S_{sto}})} \int_0^{S_{sto}} x\lambda e^{-\lambda x} dx = \frac{D_1}{v_1} + \frac{1-e^{-\lambda S_{sto}}\left(1+\lambda S_{sto}\right)}{\lambda v_1 (1-e^{-\lambda S_{sto}})} . \quad (16)$$

By means of sum formula of members of infinite descending geometrical progression and sumed up (15), formula (14) assumes easier form for counts:

$$t_L = t_{1L-s} + \frac{t_v}{1-P_{sk}} = t_{1L-s} + t_v \left(e^{\lambda S_{sto}} - 1\right). \quad (17)$$

The middle time Σt_L, whom first by crossing stopped automobile delays going through it, is expressed by formula:

$$\Sigma t_L = P_{st} t_L . \quad (18)$$

It‘s no trouble to count that (if traffic intensity is $I = Nv_1$ [tp/s] in research direction) further $Nv_1 t_L$ vehicles will approach crossing during time t_L.

Thus if

$$Nv_1 t_L > 1, \quad (19)$$

then jam of automobiles develops by crossing.

3. Conclusions

Analytical models of crossing passage time make assumptions to solve problems of street passage time.

When velocity of traffic flow is reducing, then crossing middle passage time is shortening.

References

1. **Daunoras J., Bagdonas V., Gargasas V.,** City Transport Monitoring and Routes Optimal Management System // *Transport*, Vilnius: Technika, 2008, 23 (2): 144-149.
2. **Vandaele N., Van Woensel T.,; Verbruggen A.,** A Queueing based Traffic Flow Model. Transportation Research – D: Transport and environment. January 2000, vol. 5 nr 2, pp 121-135.
3. **Petrauskaitė E.,** Simulation of Car Passing Processes in one Lane Street // *Electrical and Control Technologies – 2009* : papers of the international conference, 7-8 May 2009, Kaunas, Lithuania. p. 9-12.

Contents