## TRANSPORT MEANS

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE

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

## TRANSPORT MEANS 2009

PROCEEDINGS OF THE $13^{\text {th }}$ INTERNATIONAL CONFERENCE

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

## Proceedings of $13^{\text {th }}$ International Conference. Transport Means. 2009

# Analysis of Uncontrolled Crossing Passage Time 

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#### 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:

$$
\begin{equation*}
D_{1}=L(t)+l=1,8 v_{n+1}(t)+l . \tag{1}
\end{equation*}
$$

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 [ $\mathrm{m} / \mathrm{s}$ ] 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]:

$$
\rho(x)=\left\{\begin{array}{cr}
0, \text { when } & -D<x<0  \tag{2}\\
\lambda e^{-\lambda x}, \text { when } & x \geq 0
\end{array}\right.
$$

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

$$
\begin{equation*}
\Delta=D_{1}+\int_{0}^{\infty} x \rho(x) d x=D_{1}+\int_{0}^{\infty} x \lambda e^{-\lambda x} d x=D_{1}+\frac{1}{\lambda}=\frac{1}{N} \tag{3}
\end{equation*}
$$



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 $\mathrm{A}_{1}$ (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:

$$
\begin{align*}
& \Delta_{1} \geq D_{1}+\delta+l, \text { on case } 2-1, \\
& \Delta_{1} \geq 2 D_{1}-\delta+l, \text { on case } 2-2 . \tag{4}
\end{align*}
$$

This specification means that while automobile $\mathrm{A}_{1}$ will go through crossing, $\mathrm{A}_{2}$ will not come closer than safe distance $D_{1}$.

Suppose that automobile $\mathrm{A}_{2}$ is near, when

$$
\begin{align*}
& \Delta_{1}<D_{1}+\delta+l, \text { on case } 2-1, \\
& \Delta_{1}<2 D_{1}-\delta+l, \text { on case } 2-2 . \tag{5}
\end{align*}
$$

This event probability

$$
\begin{equation*}
P_{s t}=\frac{\Delta_{1}}{\Delta} \tag{6}
\end{equation*}
$$

Middle crossing passage time

Middle crossing passage time $t_{1 L}$, whom automobile $\mathrm{A}_{1}$ will delay letting comming automobile from right go first.

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

Unconditional $t_{1 L-b}$ value includes all events, whereas and these, when automobile $\mathrm{A}_{1}$ passes the crossing immediately (don't need to let any go first).

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

$$
\begin{equation*}
t_{1 L-b}=P_{t k}\left(t_{1 L-D_{1}-t k}+t_{1 L-\overline{D_{1}}-t k}\right)+P_{d}\left(t_{1 L-D_{1}-d}+t_{1 L-\overline{D_{1}}-d}\right)+P_{s t} \frac{v_{1}}{a} . \tag{7}
\end{equation*}
$$

Here:
$a$ - stop and speed-up accelerations of automobile (it's supposed that these accelerations are equal in absolute value), and component $P_{s t} \frac{v_{1}}{a}$ is time, whom automobile delays in stopping and running up;
$P_{t k}$ - 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), $P_{t k}=2 / 3 ; P_{d}=1 / 3$;
$t_{1 L-D_{1}-t k}$ and $t_{1 L-\overline{D_{1}}-t k}$ - middle time, whom $\mathrm{A}_{1}$ 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 ( $t_{1 L-D_{1}-t k}$ ) or near ( $t_{1 L-\overline{D_{1}}-t k}$ ) than $\Delta_{1}-D_{1}$;
$t_{1 L-D_{1}-d}$ ir $t_{1 L-\overline{D_{1}}-d}$ - middle time, whom $\mathrm{A}_{1}$ 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 ( $t_{1 L-D_{1}-d}$ ) or near ( $t_{1 L-\overline{D_{1}-d}}$ ) than $\Delta_{1}-D_{1}$.

$$
\begin{gather*}
t_{1 L-D_{1}-t k}=\frac{1}{v_{1}} \int_{-D_{1}}^{0}\left(\int_{0}^{\left(D_{1}+\delta+l\right)+x}(y-x) \lambda e^{-\lambda y} d y\right) N d x+P_{s t} \frac{v_{1}}{a}=  \tag{8}\\
=\frac{N D_{1}}{\lambda v_{1}}+\frac{N D_{1}^{2}}{2 v_{1}}+N\left(D_{1}+\delta+l\right) e^{-\lambda\left(D_{1}+\delta+l\right)} \frac{1}{\lambda v_{1}}\left(1-e^{\lambda D_{1}}\right)+\frac{N}{\lambda^{2} v_{1}} e^{-\lambda\left(D_{1}+\delta+l\right)}\left(1-e^{\lambda D_{1}}\right) . \\
t_{1 L-\overline{D_{1}-t k}}=\frac{1}{v_{1}} \int_{0}^{\frac{1}{N}-D_{1}}\left(\int_{x}^{\left(D_{1}+\delta+l\right)+x}(y-x) \lambda e^{-\lambda y} d y\right) N d x+P_{s t} \frac{v_{1}}{a}=\frac{1-e^{-1}}{\lambda v_{1}}\left(\frac{N}{\lambda}-\left(N\left(D_{1}+\delta+l\right)+\frac{N}{\lambda}\right) e^{-\lambda\left(D_{1}+\delta+l\right)}\right) .  \tag{9}\\
=\frac{N D_{1}}{\lambda v_{1}}+\frac{N D_{1}^{2}}{2 v_{1}}+N\left(2 D_{1}-\delta+l\right) e^{-\lambda\left(2 D_{1}-\delta+l\right)} \frac{1}{\lambda v_{1}}\left(1-e^{\lambda D_{1}}\right)+\frac{N}{\lambda^{2} v_{1}} e^{-\lambda\left(2 D_{1}-\delta+l\right)}\left(1-e^{\lambda D_{1}}\right) .  \tag{10}\\
t_{1 L-D_{1}-d}= \\
t_{1}^{v_{1}} \int_{0}^{\frac{1}{N}-D_{1}}\left(\int_{x}^{\left(2 D_{1}-\delta+l\right)+x}(y-x) \lambda e^{-\lambda y} d y\right) N d x+P_{s t} \frac{v_{1}}{a}=\frac{1-e^{-1}}{\lambda v_{1}}\left(\frac{N}{\lambda}-\left(N\left(2 D_{1}-\delta+l\right)+\frac{N}{\lambda}\right) e^{-\lambda\left(2 D_{1}-\delta+l\right)}\right) . \tag{11}
\end{gather*}
$$

Conditional probability density $\rho\left(\left.x\right|_{\text {let_go_first }}\right)$, expressives of probability density of distance $x$ to first automobile coming from right with condition that $x \leq \Delta_{1}$, can be expressed with formula:

$$
\rho\left(\left.x\right|_{\text {reikia_pralesti }}\right)=\rho\left(\left.x\right|_{R P}\right)=\left\{\begin{array}{ccc}
0 & \text { kai } & -D_{1}<x<0 ;  \tag{12}\\
\frac{\lambda e^{-\lambda x}}{1-e^{-\lambda \Lambda_{1}}} & \text { kai } & x \geq 0 .
\end{array}\right.
$$

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

$$
\begin{equation*}
t_{1 L-s}=P_{t k} \frac{1}{1-e^{-\lambda\left(D_{1}+\delta+1\right)}}\left(t_{1 L-D_{1}-k k}+t_{1 L-\overline{D_{1}-k}}\right)+P_{d} \frac{1}{1-e^{-\lambda\left(2 D_{1}-\delta+l\right)}}\left(t_{1 L-D_{1}-d}+t_{1 L-\overline{D_{1}-d}}\right)+\frac{v_{1}}{a} . \tag{13}
\end{equation*}
$$

Very important characteristic of traffic flow is middle time $t_{L}$, whom automobile $\mathrm{A}_{1}$ after stop delays waiting chance to go through crossing. This time is expressed by formula:

$$
\begin{equation*}
t_{L}=t_{1 L-s}+\sum_{j=1}^{\infty}\left(P_{s k}\right)^{j} t_{v} . \tag{14}
\end{equation*}
$$

Here
$P_{s k}$ - probability, that when ordinary (k) vehicle passes from right, automobile $\mathrm{A}_{1}$ 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 $\mathrm{A}_{1}$ approached crossig will delay letting automobile $\mathrm{A}_{2}$ coming from right go first.

Every next component in formula (14) means, that automobile $\mathrm{A}_{1}$ will have wait till one more automobile will pass on contrariwise traffic line.

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

$$
\begin{equation*}
P_{s k}=1-e^{-\lambda S_{s t o}}, \quad S_{s t o}=v_{1} \sqrt{\frac{2(\delta+l)}{a}} \tag{15}
\end{equation*}
$$

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 $\rho\left(\left.x\right|_{N L}\right)$ is using in formulas.

$$
\begin{equation*}
t_{v}=\frac{D_{1}}{v_{1}}+\frac{1}{v_{1}\left(1-e^{-\lambda S_{s o s}}\right)} \int_{0}^{S_{v o}} x \lambda e^{-\lambda x} d x=\frac{D_{1}}{v_{1}}+\frac{1-e^{-\lambda S_{s o t}}\left(1+\lambda S_{s t o}\right)}{\lambda v_{1}\left(1-e^{-\lambda S_{s o t}}\right)} . \tag{16}
\end{equation*}
$$

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

$$
\begin{equation*}
t_{L}=t_{1 L-s}+\frac{t_{v}}{1-P_{s k}}=t_{1 L-s}+t_{v}\left(e^{\lambda_{s s o}}-1\right) . \tag{17}
\end{equation*}
$$

The middle time $\Sigma t_{L}$, whom first by crossing stopped automobile delays going through it, is expressed by formula:

$$
\begin{equation*}
\Sigma t_{L}=P_{s t} t_{L} . \tag{18}
\end{equation*}
$$

It's no trouble to count that (if traffic intensity is $I=N v_{1}[t p / s]$ in research direction) further $N v_{1} t_{L}$ vehicles will approach crossing during time $t_{L}$.

Thus if

$$
\begin{equation*}
N v_{1} t_{L}>1, \tag{19}
\end{equation*}
$$

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. Petrauskaitè 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.

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