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Dynamic Homogeneity and Functional Dependence on the Number of Traffic Accidents, the Role in Urban Planning

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Abstract

This paper presents certain research of some roads in the Republic of Macedonia, with the purpose to express the functional dependence of the dynamic homogeneity on the number of road accidents in the urban area. The paper presents a relationship between the medium quadrat deviation and the medium velocity in a free traffic flow. The dynamic homogeneity is obtained as on the basis of the construction of the velocity in a free traffic flow, on which the adequate diagrams were construed, depending on the designed geometric elements on the alignment of the road in the plan and the profile. Furthermore, pursuant to the parameter of the dynamic homogeneity it is possible to numerically evaluate the success of the alignment solution and a numeric comparison of the variants in the pre-design stage, or in the stage of an preliminary design. This research can serve as an analysis of the alignment of the road as referring to the newly designed and the already constructed roads.

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Keywords: urban planning, dynamic homogeneity, geometric homogeneity, free traffic flow, traffic accidents, organization and planning, municipal facilities

1. Introduction

The Republic of Macedonia disposes of 13,040 kilometres of road, 957 kilometres of which are national roads; 3677 km are country roads, and 8406 are local roads.

In the course of the year over 2000 road accidents happen, leaving hard consequences (casualties, injuries and

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with high material damages). The basic reasons for the road accidents are: the speed unadjusted to the road conditions and traffic, driving under the influence of alcohol, the disrespect of the right of way, poor psychological and physical conditions, incorrect overtaking, the disrespect towards the road signs, all these reasons representing over 67% of the total number of road accidents. But, it must be pointed out that the incurrence of road accidents is mainly connected with the speed of driving.

It is obvious that, in many cases, when the accidents happen on the inadequately constructed sections of the road, the mistakes are assigned to the driver who has failed to adjust his driving to the road and traffic conditions. Thereby, it is neglected that all road inconveniences can cause an accident.

The research, carried out in many countries, lead to the conclusion that the geometric elements of the road in the plan and the profile, are in many cases the reason for accidents. But, the numerous research also lead to the conclusion that the designed speed which is the basis for the determination of the limit values in plan and profile is not constant, but a variable along the road or the section in both directions. The variable speed, which can also be addressed to as calculated speed in the conditions of a free traffic flow of a certain vehicle, can in the course of the designing, serve as a basis for obtaining the adequate values of the elements of the road. The closer these elements are to one another, the more homogenous and safer the road is. Due to these reasons, the construction elements of the road should be dimensioned and adjusted to the dynamism of driving, that is, according to the variable driving velocity, which is obtained in a free traffic flow as the resultant of the simultaneous influence of the applied constructional elements of the road, the vehicle type and the human factor of the driver upon the feeling of complete security [1-5].

2. Influence of the road elements on the number of accidents

The research on the influence of the road on the number of traffic accidents has been carried out through a long period of time, and consists of the contemplation and noting of the road accidents (N) of certain road sections, or on a certain location, and are expressed through a relative number of traffic accidents (Nr) and through their absolute number of traffic accidents (Ng) and in function of the average annual daily traffic (and the length of the section).

N- Number of the traffic accidents upon the number of the vehicles PGDS on the length L of the section.

PGDS – average annual daily traffic (vehicles per day)

$$N_r = \frac{10^6 \cdot N}{365 \cdot PGDS \cdot L} \quad \text{[accidents/mil.vehicles.year]} \tag{1}$$

$$N_g = \frac{365 \cdot PGDS \cdot N_r}{10^6} \quad \text{[accidents/km year]} \tag{2}$$

But, a realistic estimation is possible only if we take into consideration the overall influence of all elements of the road as it happened [1].

Research have been carried out on the overall influence of the road elements on the velocity of a free flow and, on the basis of those research, a computer program has been construed for the construction of the profile of the velocity upon a free flow [2, 3]. The following Fig. 1 presents the overall diagram of the influence of the road elements upon the velocity of a free flow.

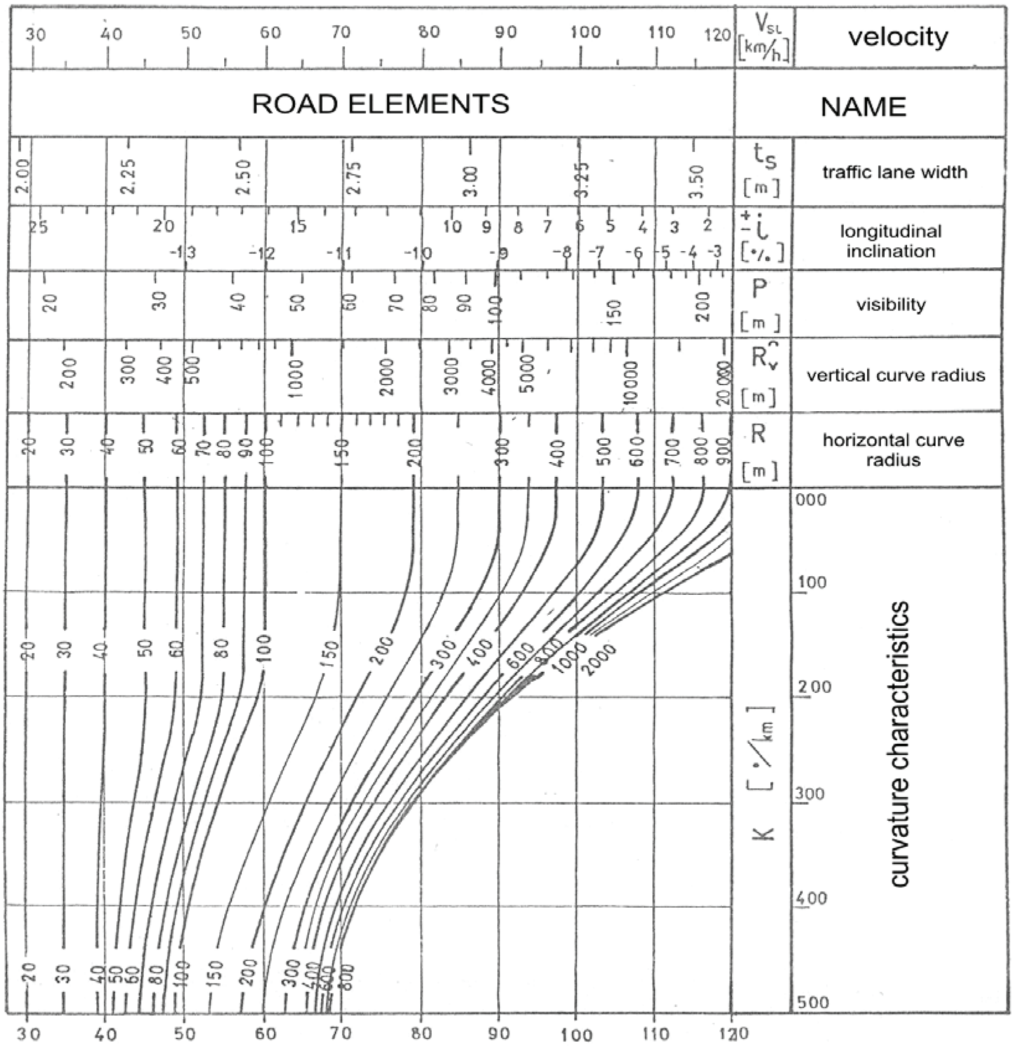

Fig 1. Overall diagram on the influence of the road elements on the velocity of a free flow

The overall influence of all road elements on the number of traffic accidents can be implicitly expressed through the hesitation of the velocity in a free flow, as this velocity depends on the size and the spatial distribution of exactly these elements, and of course, the number of vehicles as a factor hampering the free flow. This is logical because all traffic accidents happen while the vehicles are in motion and are due to the untimely lowering of the vehicle or the failure to stop, which is again conditioned by the road elements and by the traffic condition. The velocity hesitation is expressed by the coefficient of variation of the velocity of the passenger vehicles in a free flow, referred to as a coefficient of dynamic homogeneity (Dh).

$$D_h = \frac{100 \cdot S}{\bar{V}_p} \quad [\%] \tag{3}$$

D_h - coefficient of dynamic homogeneity
S - average quadrat deviation defined by the following expression:

$$S = \sqrt{\frac{\sum_{i=1}^{i=n}\left(V_{pi} - \overline{V}_p\right)^2 \cdot X_i}{\sum_{i=1}^{i=n} X_i}} \; [km/h] \; ; \quad \overline{V}_p = \frac{\sum_{i=1}^{i=n} V_{pi} \cdot X_i}{\sum_{i=1}^{i=n} X_i} \; [km/h]$$

V_p - average value of the calculation velocity on the section of a certain length
V_{pi} – a constant value of the calculation velocity on the elementary section of the road,
X_i - elementary length of the road with a constant value of the calculation velocity,

The practical check-up of this thesis was carried out as on the basis of three-year analyses on 16 sections of the road network in the Republic of Macedonia with the total length of 109.27 km [4]. The collected data are shown in Table 1, where N_s is the number of lethal accidents, N_p is the number of accidents with injured people and N_m is the number of accidents with material damage.

According to the data on the table, the multiple regression was obtained, having the form as follows:

$$N_r = 0.237 + \frac{6499}{PGDS^{1.3}} + 0.0645 \cdot e^{0.12 \cdot D_h} \tag{4}$$

where the standard deviation from the regression is: S_N=0.49

Table 1. Number of accidents on certain sections in Macedonia

No	Road section	Section length [km]	Period: 2010-2011-2012 PGDS [veh./day]	N_s	N_p	N_m	N_g $\left[\frac{\text{accidents}}{\text{km} \cdot \text{year}}\right]$	N_r $\left[\frac{\text{accidents}}{\text{mil.veh.km}}\right]$	D_h [%]
1	Veles-Stip	7.87	1705	-	4	3	0.30	0.48	12.14
2	Veles-Stip	3.65	1705	-	5	4	0.82	1.32	17.00
3	Veles-Stip	6.54	1705	-	14	10	1.22	1.96	16.08
4	Stip-Kocani	7.84	3038	-	4	2	0.25	0.23	7.69
5	Stip-Kocani	2.67	3470	1	2	5	1.12	0.89	6.08
6	Stip-Kocani	6.10	3470	-	4	6	0.55	0.43	11.16
7	Gradsko-Negotino	1.93	6538	2	-	1	0.52	0.22	1.02
8	Gradsko-Negotino	4.20	6538	-	4	5	0.71	0.30	9.66
9	Gradsko-Prilep	4.12	2272	1	7	9	1.38	1.66	6.76
10	Gradsko-Prilep	5.97	2272	2	2	6	0.56	0.67	5.41
11	Gradsko-Prilep	16.24	2402	1	2	9	0.25	0.28	14.83
12	Berovo-Obozna	3.14	657	-	3	1	0.42	1.77	15.40

13	Berovo-Obozna	4.20	657	-	3	4	0.56	2.31	20.21
14	Berovo-Obozna	7.00	657	1	5	4	0.48	1.98	16.44
15	Kumanovo-Sv. Nikole	17.94	1337	-	13	6	0.35	0.72	12.92
16	Strumica-Kostulino	9.91	672	1	11	6	0.60	2.46	15.85
$\sum$		109.27		9	84	81			

On the basis of the above multiple regression equation, it is possible to write an expression for the forecast of the number of accidents referring to a road with a L length, within the planned period of N years, on the average annual daily traffic and on the annual increase of p.

$$\sum_{t=1}^{t=n} N = PGDS_0 \cdot L \cdot \left\{ \frac{86.51}{10^6} \cdot \left[\frac{(1+p)^n}{\ln(1+p)} \right] + \frac{2.372}{PGDS_0^{1.3}} \cdot \frac{\left[\frac{1+p}{(1+p)^{1.3}} \right]^n - 1}{\ln\left[\frac{1+p}{(1+p)^{1.3}} \right]} + \frac{23.54 \cdot e^{0.12 \cdot D_h}}{10^6} \cdot \left[\frac{(1+p)^n - 1}{\ln(1+p)} \right] \right\} \quad (5)$$

For example, for a PGDS of 3000 vehicles/day, p= 4% and n= 20 years and Dh = 18,52% which leads to $\sum$N = 33.85 accidents in the course of 20 years

3. Construction of the velocity profile in a free traffic flow

There is an elaborated methodological procedure and a software, DIP (Dynamism research of the road) exists for the construction of the profile of the calculation velocity and for the adjustment of the road elements to that velocity.

Data were taken from the Ministry of Internal Affairs – Safety, Control and Regulation of the traffic Service, referring to the number of traffic accidents and the dangerous points and the dangerous sections of one part of the road network in the Republic of Macedonia were identified. Sections long 109,27 kilometres were analysed which represents a small portion of the total length of the road network, but these research was sufficient to lead to a certain conclusion, but also to initiate further research in this direction (Tab. 1).

The number of traffic accidents occurring on those sections was 174. By the DIP program, the velocity profile in both directions was constructed (example on Fig. 2). On the basis of this diagram, the dangerous points, that is, the dangerous sections can also be identified. These points are those when the diagram shows a braking with the leg black (double line).

By using the DIP program, and the analyses carried out on the number of traffic accidents on part of the road in the Republic of Macedonia, the dependence was obtained of the dynamic homogeneity in function of the traffic accidents. The dynamic homogeneity was determined as for a velocity in free flow of both direction of driving (calculation velocity).

On the basis of the analyses of the reasons for the incurring of the traffic accidents, it was concluded that the basic reason is the geometric discrepancy of the construction elements in plan and profile, as are: the big curve difference, the discrepancy in the neighboring elements of the horizontal curves, the insufficient friction coefficient of the pavement**,** big longitudinal inclinations, sections with inadequate view and short overtaking space, inadequate transversal inclinations as per direction and scope and the existence of such combination of elements in a situation and longitudinal profile which, due to deformed perspective images seem discontinued and in out of harmony and influence the psychological and the physical condition of the driver.

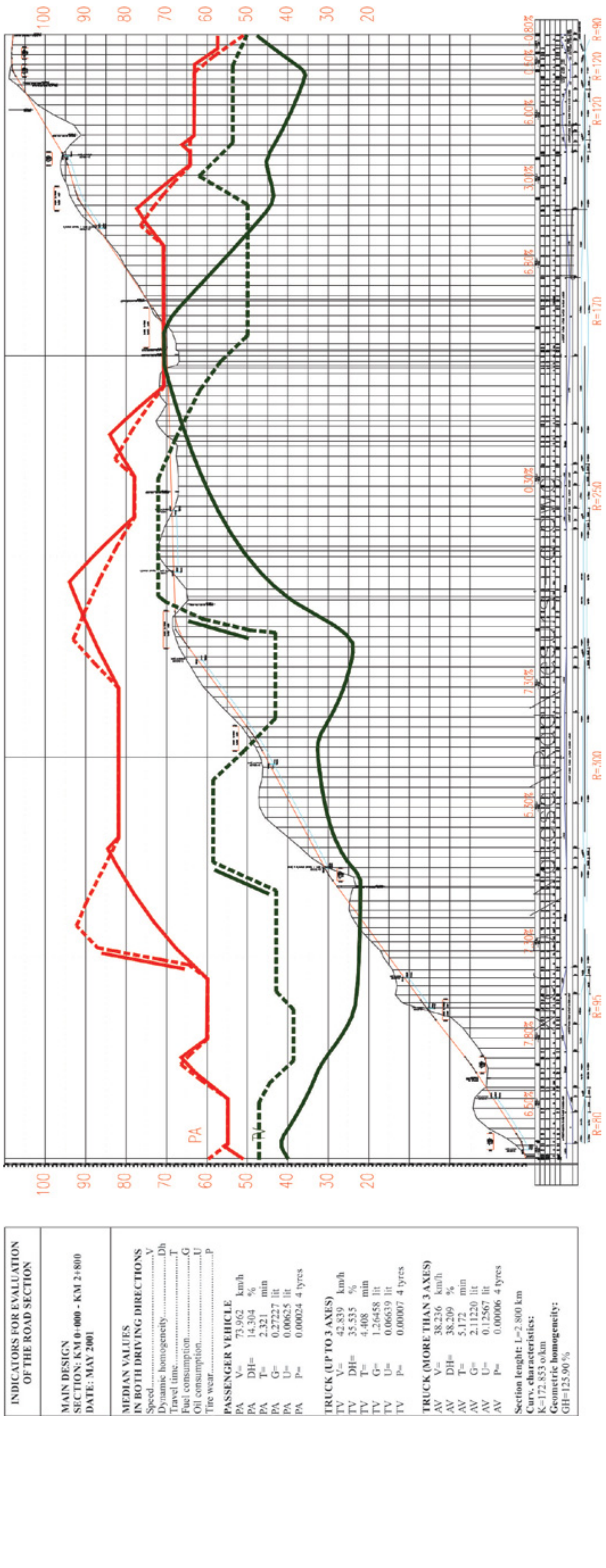
INDICATORS FOR EVALUATION OF THE ROAD SECTION
MAIN DESIGN
SECTION: KM 0+000 - KM 2+800
DATE: MAY 2001
MEDIAN VALUES
IN BOTH DRIVING DIRECTIONS
Speed....V
Dynamic homogeneity....Dh
Travel time....T
Fuel consumption....G
Oil consumption....U
Tire wear....P
PASSENGER VEHICLE
PA V= 73.962 km/h
PA DH= 14.304 %
PA T= 2.321 min
PA G= 0.27227 lit
PA U= 0.00625 lit
PA P= 0.00024 4 tyres
TRUCK (UP TO 3 AXES)
TV V= 42.839 km/h
TV DH= 35.535 %
TV T= 4.408 min
TV G= 1.26458 lit
TV U= 0.06639 lit
TV P= 0.00007 4 tyres
TRUCK (MORE THAN 3 AXES)
AV V= 38.236 km/h
AV DH= 38.209 %
AV T= 5.172 min
AV G= 2.11220 lit
AV U= 0.12567 lit
AV P= 0.00006 4 tyres
Section lenght: L=2.800 km
Curv. characteristics:
K=172.853 o/km
Geometric homogeneity:
GH=125.90 %
PA
TV

Fig. 2. Speed profile in the free flow (DIP software)

4. Functional dependence of the coefficient of dynamic homogeneity on the number of traffic accidents

On the sections where a certain number of traffic accidents have been detected, the diagram of the calculation velocity in a free flow in both directions and the dynamic homogeneity (Dh) was determined, indispensable for the evaluation of the level of security of the traffic and for the identification of the potentially dangerous spots. The analyses carried out on the sections lead to the conclusion that the coefficient of the dynamic homogeneity varies in scope, but that this scope is more prominent where the non-harmonized geometric elements are present. Thus, on the blask spot sections or on sections evidenced as dangerous and on spots where the braking is done by the leg, the velocity diagram indicates a high coefficient of dynamic homogeneity leading to the conclusion that, the non-homogenized geometric elements lead to road accidents. Using the data on the relative degree of accidents on the observed sections (Tab. 1) and the determined coefficient of dynamic homogeneity, an original diagram was constructed referring to the dependence between the Dh coefficient and the degree of accidents Nr expressed as number of accidents on one million of vehicles per kilometre (Fig. 4).

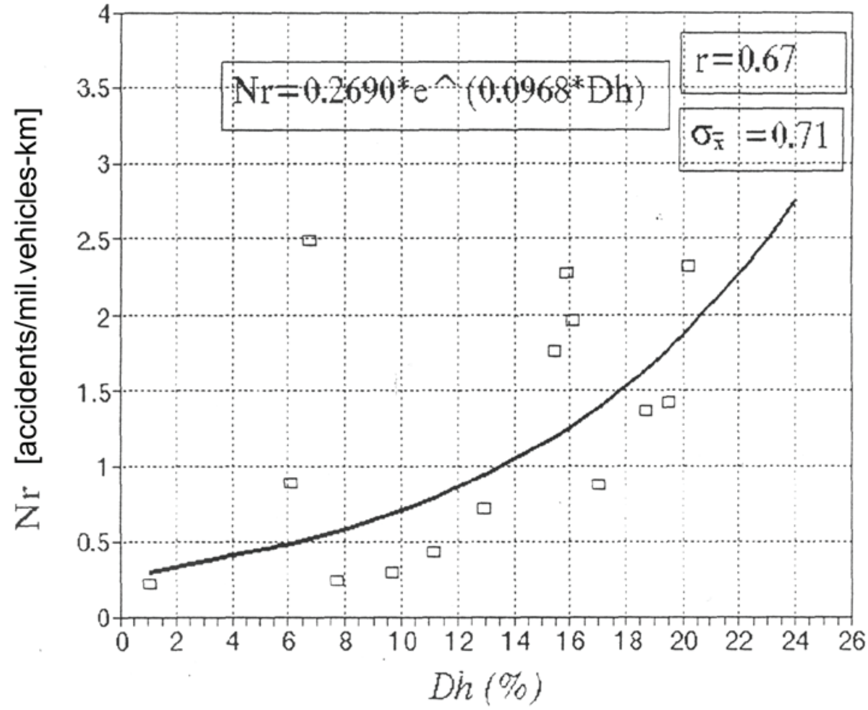

Fig. 3. Dependence of the degree of accidents on the dynamic homogeneity

On the basis of the existing data, the coefficient of the correlation demonstrates that the correlation is good with r = 0,67, which expresses the dependence of exponential type. Although the quantity of data is small, it can be concluded that the degree of danger increases with the increase of the Dh coefficient. It is not possible to give any normed value connected with the degree of accidents, due to the small number of data, but these research can contribute to further investigations in this direction. However, by this parameter, it is possible to numerically value the success of the lining solution and to numerically compare the variants in order to select the optimal one.

5. Conclusion

The above presentation leads to the following conclusions:

1.The simultaneous influence of all elements of the road on the forecast number of accidents can be replaced with high degree of certitude by the coefficient of the variation of the speed in a free flow under the influence of those elements of the road under the term of dynamic homogeneity (Dh).

2.The dynamic homogeneity is obtained by the profile of the speed in a free flow (calculation) by which, in the course of designing, it is possible to have an insight into the general traffic security for the whole road stretching as well to locate the potentially dangerous spots on the line, which make it possible to timely correct the line of the road.

3. The prevention in the security of the traffic in the process of designing can be achieved by the dimensioning and harmonisation of the road elements as pursuant to the realistically expected variable (calculation) velocity of movement and the behaviour of the driver in the traffic.

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