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UNCERTAINTY OF ROAD TRAFFIC SAFETY MEASUREMENTS

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Abstract − Road traffic has important part for the every days life. Traffic accidents are related to the vehicles technical side and to the traffic surveillance from authorities and police. Environment is damaged mainly through vehicles exhaust gases, noise and vibration. This study work deals with road traffic safety measurements uncertainties. Damages can be minimised if uncertainties of the measurements are estimated and taken into account by above areas. In this work will be given models of uncertainty estimation for the vehicles technical conditions measurements, environment safety measurements and authorities surveillance measurements. Estimated and validated are concrete values of the uncertainties for various situations using measurement comparison data.

Keywords: road traffic, measurement, uncertainty

1. BASIC INFORMATION

Road traffic has important part in the every days activity and has great influence as economical factor. For the road traffics one of the most important factor is safety assurance. Safety is related as coming up from the accidents with vehicles and on the other hand as a environmental hazard. Accidents are linked to the vehicles technical part and to the traffic surveillance from authorities and police. Environment is damaged directly through vehicles exhaust gases, noise and vibration.

Now-a-days task is to have concrete steps to maximise the safety of the road traffic. Safety can by increased if surveillance is on a high and stabilized level. Surveillance involve large scale of measurements and inspections. The base for better safety is also to have more quality and higher accuracy of measurements. One of the advantage steps to have higher accuracy is minimise the uncertainties of measurements which are used by road safety assurance. Such minimisation shall be realistic. To achieve realistic minimisation there shall be used practical experience data of measurements.

This study work deals with the road traffic safety measurements and its uncertainties. In this work for the road safety measurements were initially estimated theoretical uncertainty factors and its values and presented calculation models. Models correctness and suitability were controlled using data of practical measurements in Estonia. Uncertainties were controlled through comparison schemes on measurements through few years. Comparisons schemes were carried out for measurements of the vehicles braking parameters, for measurements of the environmental hazardous gases O_2, CO, CO_2 and CH content and for measurements of the vehicles noise level by its standing.

Used were also data for the surveillance measurements which were gathered through practical measurements by the authorities and police in Estonia.

2. ROAD TRAFFIC SAFETY MEASUREMENTS

Measurements on the road traffic safety area can be categorised as the three main classes: measurements of the vehicles parameters during technical inspections, environmental protection measurements and measurements used by inspection and surveillance of the road traffic by authorities and police.

Road vehicles periodical technical inspection involves next measurements - brakes efficiency and braking force measurements, dimensional including clearance measurements and lights and windows correctness measurements. Environmental protection measurements involve vehicles exhaust gases O_2, CO, CO_2, CH_x and NO_x content and smoke concentration measurements and noise and vibration level measurements.

Authorities and police use mainly speed, dimensional and mass measurements. High importance has measurements of alcohol content in the drivers blood or drugs influence. Under control is also drivers working hours but this area is not dealt in this work.

Road traffic safety measurements methods are not standardised internationally. Exist well known measurement principles and they shall be used for method writing. Measurements are carried out in hard conditions on site and the measurement instruments working conditions are often complicated. Practical measurement process is visually easy to carry out, but in real conditions rather complicated. Above is reason that by measurements and by the uncertainty estimation shall be taken account large quantity of influence factors. Particularity for those measurements is fact that remarkable influence has measured object.

As example is vehicles exhaust gases measurements. Influence factors are given as follows. First group of factors are linked to the vehicles engines condition, before and during the time of measurements like a value of engines

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temperature and speed and engines working conditions roughness directly before measurements.

Second group of moments is related to the gas analyser and its appliances conditions and environment – hoses and filters clearness and temperature and ventilation capability of rooms.

Last group is linked to the measurements person competence – how strictly and smoothly they carry out measurement actions.

An other aspect is that safety measurement shall not also harm persons who are under accusation. Legally the measurement uncertainty area is the grey zone where real measurement result may only situate. So measurements assurance shall involve internationally accepted principles like using accreditation according EN ISO IEC 17025 requirements.

2.1. Vehicles technical inspection measurements

Road vehicles technical inspection is carried out regularly and inspected parameters are set up by EU directives. During technical inspection are involved next main measurements - brakes efficiency and braking force measurements, dimensional including clearance measurement, correctness of lights and transparency of window glasses. In the Table 1 are shown summarily vehicles parameters measured by periodical technical inspection. Measurements models are given and theoretical expanded uncertainty U was estimated in [1]. Expanded uncertainty is given taking into account measuring instruments calibration data.

Table 1. Vehicles safety parameters controlled by technical inspection and its uncertainty

Measured parameter	Measurement range	Expanded uncertainty U, 95 % probability level
Braking force and vehicles mass	0,1 kN ÷ 40 kN 100 kg ÷ 15 t	10 % for 1 force measurement 10 % for force difference 3 % for mass
Geometrical measures	0,5 mm ÷ 30 m	0,5 % from the measurement result (MR)
Window glasses transparency	(5 ÷ 60) % (60 ÷ 100) %	15 % from the MR 10 % from the MR

Most complicated is braking parameters measurements which involve various influence factors as speed, smooth and stability of braking force application and vehicles braking system condition during the measurements. Braking system involve especially brakes discs and system working conditions like temperature and dryness and the tires clearness. Next group of influence factors is related to the roller bench and the weighing instrument conditions – roughness and dryness of the rollers surface and vehicles exact localization on the rollers.

2.2 Environment protection measurements

Road vehicles parameters which are related to the environment protection, involve for the gasoline engines, exhaust gases O_2, CO, CO_2, CH_x and NO_x content measurements and for the diesel engines smoke concentration measurements.

Separate area is vehicles noise level and vibration measurements. Both areas are measured directly by measuring devices. The noise level and vibration measurement methods are standardized.

In the Table 2 are shown summarily vehicles parameters values linked to the environment protection.

Measurements models are given and expanded uncertainty U was estimated in [2], excluding noise level measurement. Expanded uncertainty is given taking into account measuring instruments calibration data.

Table 2. Vehicles parameters in environmental protection area and its uncertainties

Parameter	Measurement range	Expanded uncertainty U, 95 % probability level
Exhaust gases	CO content (0,03÷10) vol % CO_2 content (0,5 ÷ 18) vol % CH content (5÷9999) vol ppm O_2 content (0,1 ÷ 22) vol % λ-number (0,8 ÷ 1,2)	0,1 vol% or 10 % from the measurement result (MR) 1,0 vol % or 10 % from MR 12 vol ppm or 10 % from MR 0,3 vol % or 10 % from MR 0,3 % from calculated value
Diesel engines gases smoke	(0,5 ÷5) m^{-1}	0,5 m^{-1} or 10 % from MR
Non-moving vehicles noise level	(30÷130) dB	3 % from MR

By those measurements is important to have influence factors on required level. Influence factors list is given in art 2 of this work.

Noise level is measured directly by sound level meter, but shall be assured absent of external noises.

2.3 Road traffic surveillance measurements

By traffics surveillance authorities are used mainly speed, dimensional and mass measurements of the road vehicles and drivers conditions measurements.

Drivers conditions measurements involves alcohol content in blood, drugs influence and working hours quantity. In the Table 3 are shown summarily surveillance measurements values and its theoretical uncertainties.

Table 3. Road traffic surveillance measurements with measurement range and uncertainty

Parameter	Measurement range	Expanded uncertainty U, 95 % probability level
Vehicles speed	(30 ÷ 200) km/h	3 km/h or 3 % from the measurement result
Vehicles mass	100 kg ÷ 15 t	3 % from the measurement result
Geometrical measures	0,5 mm ÷ 30 m	3 % from the measurement result
Alcohol content in blood	(0,050 ÷ 3,00) mg/L	Various

Values are measured directly using specific well recognised measuring instruments. Problem is lack of standardised measurement methods, especially for the speed and the alcohol content measurements. Special value has alcohol content measurements metrological assurance [3].

3. UNCERTAINTY OF ROAD TRAFFIC SAFETY MEASUREMENTS

For this study work were used GUM principles for the estimation of the uncertainty components. Components estimation was carried out using concrete measuring equipment data, methods and specific conditions.

For those measurement is particularity, that great number of the influence factors exist. Reason for this is, the measurements are carried out mainly in the field conditions and measurement object has essential influence. Some of influence factors can give exaggerated uncertainty if were not correctly analysed and taken into account. Summary quantity of the influence factors which have importance can reach up to 6 – 8 for one type of measurement.

By road vehicles technical inspection measurements have importance next influence factors:

- measuring instruments calibration uncertainty;
- temperature and cleanness of the working environment;
- testing persons competence to carry out on a similar way procedures;
- a speed and stability of braking force application;
- the vehicles braking system and brakes discs working conditions;
- the tires clearness;
- brake tester rollers surface roughness and dryness;
- weighing bridges stability;
- vehicles wheels place variation on rollers and on load receptors.

Theoretically the measurement uncertainty should be 3 up to 5 times more than measuring device uncertainty. Taking into account that the braking measurements procedure is complicated can be assumed that expanded uncertainty for one measurement (force or mass measurement) can be on the level (1 up to 3) % from the measuring instrument indication.

For the vehicles environment protection measurements importance have next influence factors:

- measuring instruments calibration uncertainty;
- idle speed and working stability of engine;
- vehicles exhaust gases systems working conditions;
- gas inlet hose correct length and unbrokeness;
- gas inlet hose cleanness from the previous measurements;
- nearby environment purity from exhaust gases;
- temperature and general cleanness;
- testing persons competence to carry out on a similar way procedures.

Can be assumed that expanded uncertainty for one measurement should be on the level up to 10 % from the measuring instrument indication taking into account measuring instrument calibration data.

For the traffic surveillance measurements have importance next influence factors:

- measuring instruments calibration uncertainty;
- environment conditions;
- measured object particularities;
- measurement persons competence to carry out on a similar way procedures.

Each of above influence factors give uncertainty component u_i.

Combined uncertainty u is found by equation:

$$u = \sqrt{\sum \xi^2 u_i^2} \qquad (1)$$

where ξ is sensitivity coefficient.

General problems is how to estimate right sensitivity coefficients ξ for the uncertainties components. There is not direct calculation equations.

4. PRACTICAL COMPARISONS TO CONFIRM UNCERTAINTY COMPONENTS VALUES

Rightness of the theoretical results can be controlled properly through practical measurements comparisons. For proficiency scheme shall be used ISO Guide 43 principles to assure the comparison results. Required are competent organizer of scheme, stabile object for measurements and determined measurement conditions. The road vehicles inspection stations are suitable participants for the road vehicles parameters measurement comparison scheme.

Taking into account above in Estonian were organised comparison schemes for vehicles inspection stations for the next parameters:

- braking force, braking efficiency and vehicles mass;
- exhaust gases CO, CO_2, CH and O_2 content and λ-number;
- non-moving vehicles noise level.

Braking parameters measurements comparison scheme involve 45 inspection stations. More exact data were given in [1]. Braking parameters measurement comparison summary results are given in Table 4. Measurement objects were 4 road vehicles and those parameters stability was estimated analysing results of participants. Big quantity of measurements allows use statistical calculation of results.

Table 4 Braking parameters measurement comparison summary results

Vehicles No	Force difference, F			Mass	Efficiency, E_B	
	Front axle	Rear axle	Par-king	M	Sum-mary	Par-king
	%	%	%	kg	%	%
Estimated deviation on probability level P=95 %						
1	11	11	16	120	8	6
2	10	17	25	80	11	12
3	14	18	42	170	10	8
4	12	12	16	125	14	6
Realistic average for 4 vehicles	12	17	25	130	13	10
Theoretical	10	10	10	75	15	10

Force difference F is presented as relative percentage from measurement result of forces influenced on wheels of the same axle. Results in the Table 4 show that theoretical uncertainty estimation is a bit better than practical measurements gave. Above means that the measurement uncertainty is better to estimate (5÷6) times bigger than the measuring device uncertainty, especially in the case of force difference measurements.

Exhaust gases concentration comparison scheme involves 45 inspection stations. More exact data are given in [2]. Exhaust gases concentration measurement comparison summary results are given in Table 5. Measurement objects were 3 various vehicles with gasoline engines. Measured deviation is shown as average standard deviation multiplied by factor 2 giving probability level 95 %. Results in the Table 5 show that theoretical uncertainty estimation is a bit lower than practical measurements gave. Above means that the measurement uncertainty is suitable to estimate 3 times bigger than the measuring device uncertainty.

Table 5 Exhaust gases concentration measurement comparison summary results

Vehicle	Idle	Measured deviations in practice				
		CO	CO_2	O_2	CH	λ
		%v/v	%v/v	%v/v	ppm	v/v
1	Min	0,037	0,650	0,19	15	0,008
1	Fast	0,050	0,550	0,12	13	0,006
2	Min	0,015	2,200	0,10	13	0,004
2	Fast	0,010	2,100	0,07	12	0,002
3	Min	0,010	1,100	0,40	40	0,040
3	Fast	0,025	1,100	0,80	40	0,039
Realistic average deviation for 3 vehicles, *P*=95 %						
		0,030	1,500	0,20	20	0,010
Theoretical expanded uncertainty, *P*=95 %						
		0,300	2,500	0,50	60	0,015

Non-moving vehicles noise level measurement comparison scheme involves 52 vehicles inspection stations. Noise level measurement comparison summary results are given in Table 6. Measurement object was noise generator which gives noise with frequency 20 Hz (characteristic for engines working in idle) and with changing frequency from 20 Hz up to 100 Hz (characteristic for engines working in various speed).

Table 6 Non-moving vehicles noise level measurement comparison summary results

Noise level by 20 Hz		Changing noise level (20-100) Hz		Environment	
Average dB	Measured deviation	Average dB	Measured deviation	Average, dB	Measured deviation
52,3	±2 %	84,5	±1,6 %	79,2	±1,6 %
Theoretical expanded uncertainty, *P*=95 %					
	±2 %		±2 %		±2 %

Results in the Table 6 show that theoretical uncertainty estimation is approximately the same that practical measurements gave. Comparison conditions in this case were ideal. In the real measurements by vehicles inspection station uncertainty can be assumed to be bigger. Above means that the measurement uncertainty of measurement is better to estimate (3÷4) times bigger than measuring instrument uncertainty.

To carry out authorities surveillance measurement comparisons was difficult by reason that to obtain suitable reference object (vehicles speed measurements, alcohol content in blood) is impossible or participants quantity is small (mass measurements on road conditions).

Authorities surveillance measurements uncertainty was estimated initially theoretically using the measuring instrument data, the measurement method and on site measurement condition analyse. This uncertainty was corrected using results achieved during 5 year period by estimation its measurements reliability in practice.

For example, vehicles speed measurement expanded uncertainty was estimated initially for 100 km/h ±3 km/h. Uncertainty value ±3 km/h for 100 km/h is used in the various European countries. Estonian practice shows, taking account gathered more data that this uncertainty is better to be up to ±5 km/h. There was initially lack of information about influence factors.

5. PRACTICAL USE OF UNCERTAINTY VALUES

Above is essential if inspection personnel makes conformity decision. There shall be involved uncertainty. Measurement process result is only estimate of the true value and the interval where true value may be situated gives uncertainty. Safety requirements demand that the accepted result shall be less normative value minus uncertainty. But legal requirements allow to accuse person under control only if the measured value is properly assured. Shall be taken into account that uncertainty interval is not properly assured and so it shall be used as suitable for a person under sanction i.e. measurement result may overrun normative value by uncertainty.

6. CONCLUSIONS

Given models of measurements uncertainty and assured values of road traffic safety measurements help to achieve higher quality of surveillance and inspection operations.

Estimated theoretical values can be controlled by comparison results and some correction were needed.

Results of this study work were used in Estonian legal acts for the better control of traffic. In Estonia can be seen tendency to less road accident in last years.

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