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ERGO-ASSESSMENT OF LOCOMOTIVE DRIVERS' TRAFFIC ENVIRONMENT

ABSTRACT

While operating a locomotive or a railcar the engine drivers are exposed to the action of several simultaneous factors of disturbances from the traffic environment, and therefore their reliability and safety are reduced. The human-determined physical, sensor and cognitive factors are not only the attributes of the engine driver, but also include influences from the traffic environment, due to the interaction in the "engine driver – traffic means – traffic environment" system. Traffic environment is defined in such a way that, among other things, it includes also the working environment of the drivers cab and the recent traffic situation. The action of factors of temporary subjective disturbances and/or permanent psychological and physiological changes, depend not only on the individual endurance of engine drivers, but also significantly on the type of locomotive or railcar operated by the engine driver, as well as on the fact whether the traffic is intended for the transport of passengers and/or freight, or a shunting engine is involved. The ergo-assessment based on a survey of 50 respondents yielded the final results that are almost identical to the results of ergo-assessment obtained during the formation of the methodology of cognitive ergo-assessment on a sample of 31 respondents. In both cases the surveyed respondents were engine drivers who in practice operate all types of locomotives and railcars, who have acquired engine driver secondary school qualifications and have passed vocational testing for all types of locomotives and railcars. Systemic ergo-assessment of the intensity of the overall psychophysical effort is possible by introducing the index of importance I_v which is used in case of all engine drivers to integrally and equally recognise also the influence of the percentage of occurrence of a certain factor of subjective disturbance and influence of the average assessment of the subjective disturbance intensity, thus allowing an insight into the structure of a system of simultaneous ergo-assessment factors and isolation of ten dominant ergo-assessment factors. Partial cognitive ergo-assessment and inter-comparison of the intensity of subjective disturbances

have indicated the types of locomotives and/or railcar compositions in which the maximum partial intensity of disturbance is due to the following factors regarding the working ambient of the drivers cab: visibility, intensity of the difficulty of operation, and intensity of disturbance of the audible traffic noise.

KEY WORDS

traffic environment, cognitive ergo-assessment, dominant factors of subjective disturbances, assessment parameters, safety and reliability

1. INTRODUCTION

For the "traffic means (drivers cab) – controlling persons (engine drivers) – traffic environment" system, this work presents the methodology of cognitive ergo-assessment of the harmful impact of all the simultaneous ergo-assessment factors on the drivers. This methodology is proposed by the authors as one of the measuring tools for the evaluation of the impact of the traffic and working environment on the reduction of safety and reliability of the entire traffic process due to the transport of passengers and/or cargo. The authors rationally suppose that the reduction of safety and reliability of the entire traffic process significantly depends on the reduction of safety and reliability of persons personally controlling the transport means, and is proportional to the increase in the intensity and scope of the harmful impact of the traffic and working environment on persons controlling the traffic means. The title of the work "Ergo-assessment of locomotive drivers' traffic environment" emphasises the intention of the authors to study at the level of traffic process and by using concrete parameters to evaluate the

impact of the traffic environment on the persons controlling the traffic means. The traffic environment has been defined by the authors as more comprehensive and wider than the working environment of the drivers cab itself, since it encompasses also the characteristic recent traffic situations. In the Republic of Croatia and the countries in its closer environment that have a similar railway infrastructure, there is no comparative methodology for identical evaluation of the harmful impact of the system of simultaneous factors of disturbance from the working and traffic environment on the engine drivers, with balanced recognition of the intensity of subjective disturbance and the percentage of the occurrence of the disturbance among the respondents. The past research [1] has resulted in different ranking of the factors of disturbance according to the criterion of the average intensity of individual subjective disturbance in relation to the criterion of the percentage of occurrence of individual disturbance in case of all the respondents. Due to different individual endurance, health, and psychophysical condition of the respondents, the influence of the number of respondents on the results was reduced by increasing the number of respondents from 31 from the past research [1] to 50. By comparing the results for 31 and 50 respondents the authors attempt to confirm the final methodology of cognitive ergo-assessment for the engine drivers. Which are the dominant and important factors of disturbance, and how to rank them individually in relation to all the others? The authors propose concrete parameters with numerical values to prove, structure and assess the impact of all the simultaneous factors from the traffic and working environment on the engine drivers during work.

The methodology was developed from 2007 to 2009, by partial simultaneous studies for engine drivers [1], [2] and ship crew members on inland waterways [3], [4], [5]. The research presented here was preceded by pre-study using the method of interviewing the typical representative of the target group in order to set the scientific hypotheses and to make the questionnaire [2], [3], based on the recognition of the occurrence of subjective disturbances in case of respondents mentioned in the professional and scientific literature [6], [7]. The proposed methodology is not universal for all the traffic branches. A student who works as an engine driver, and is one of the co-authors of this paper, participated in forming and testing the survey for the engine drivers.

Fifty respondents were included in the survey anonymously and on a voluntary basis with organisational assistance from the Croatian Engine Drivers Union (Sindikata strojovođa Hrvatske - SSH). Out of an average of 22.4 years of service, the respondents have been working on the average for 21 years as engine drivers. They are all citizens of the Republic of Croatia and males, employees at the HŽ Vuča vlakova

d.o.o. (Croatian Railways – Train Traction Company) owned by the Republic of Croatia, of average age of 41.3 years, average mass 93.7 kilograms and average standing height 180.4 cm. All the respondents have secondary school qualifications and have passed the vocational ability test for all types of locomotives and railcar compositions, and in practice all of them operate all types of locomotives and railcar compositions, the same as in the past research carried out on a sample of 31 respondents [1], which is a precondition for the comparison of results. The presented methodology of cognitive ergo-assessment is based on the trend of recent research of humans as subjects in traffic and study of the environment-driver interaction, which has been common in the entire world in the last 30 years [8], [9].

2. AUDIBLE TRAFFIC NOISE AS ERGO-ASSESSMENT FACTOR

Ninety per cent of 50 respondents have immediately said that they are disturbed by audible traffic noise (87.1% on a sample of 31 respondents). During the interview, 98% of 50 respondents (100% on the sample of 31 respondents) have assessed the intensity of subjective disturbances because of continuous and periodic audible traffic noise in relation to the intensity of subjective disturbances due to other factors of the provided items in *Table 4*. Thus, the respondents from the same target group, regardless of the number of respondents, are a competent research sample, since they recognised in themselves during the survey the characteristic subjective disturbances from *Tables 1, 2 and 3*, which in literature [6], [7] are related also to the possible impact of audible traffic noise. It can be seen from *Table 1* that the relative individual ranking of disturbances according to their frequency of occurrence in all respondents in relation to all the other simultaneous subjective disturbances which can be connected with the impact of audible traffic noise, does not change significantly with the increase in the number of respondents from 31 to 50, and three dominant subjective disturbances from *Table 1* with highest frequency of occurrence have kept their ranking position.

It is interesting to compare the research results [5] of sleep disturbance on the sample of 12 ship crew members who control a vessel or vessel composition during 24-hour navigation in the form of navigation B, since for these ship crew members while they are sleeping during the rest interval with the engines running during navigation, the percentage of occurrence of sleep disturbance is 91.7%. *Table 1* shows that in case of engine drivers the percentage of this same subjective disturbance - sleep disturbance during the interval of resting at home (in a quiet ambient) is only

Table 1 – Percentage share of occurrence P(%) of subjective disturbances by respondents

Subjective disturbances offered to the interviewed respondents:	P (%)	
	31 respondents	50 respondents
change in mood and/or occurrence of a feeling (Table 3)	100	98
sleep disturbance during resting interval at home (Table 2)	83.9	76
psychical fatigue and/or overwork	71.0	70
difficult communication with colleagues (voice raising)	48.4	52
poorer audibility of the colleagues' speaking and of audio signals and messages	51.6	50
sleep disturbance in 8-hour resting interval in turnaround (Table 2)	41.9	42
partial loss of hearing after leaving the workplace	29.0	34
reduced concentration in carrying out the work tasks	38.7	30
headache	32.3	30
prolonged response time	12.9	16
impossibility of performing working tasks	0	4
disorientation in working ambient	0	2
none of the above	0	2

Source: Expanded and amended results of past research [1]

slightly lower both for 31 and for 50 respondents in relation to the ship crew members. It is surprising that for the engine drivers, which is again confirmed in Table 1 in case of a greater number of respondents, the subjective disturbance - sleep disturbance in resting interval at home, regarding the frequency of occurrence is ranked higher than the subjective disturbance - sleep disturbance in 8-hour interval of resting in turnaround, with as much as twice the frequency of occurrence both in case of 31 and 50 respondents, despite the fact that the engine drivers in turnaround rest in the resting rooms that are part of the railway stations and in the immission zone of intensive audible traffic noise. Obviously, it is not necessary for the engine drivers to sleep near the source of audible traffic noise (like the ship crew members on the vessel and with the engines running) in order to have a high percentage of occurrence of the sleeping disturbance, these subjective disturbances are prolonged in a high percentage of occurrence also to the resting interval in the quietness of home after work. This proves the existence of a system of ergo-assessment factors: subjective disturbance of sleep disturbance in case of engine drivers is not a consequence of being exposed only to the factor audible traffic noise.

Table 2 shows the comparison of the occurrence percentage of five provided characteristic subjective disturbances of sleep disturbance for engine drivers on a sample of 50 and 31 respondents, ranked from the highest to the lowest percentage of occurrence in case of 50 engine drivers. These results were compared with the results obtained through research [5] on a sample of 12 ship crew members who manage a vessel and who sleep during navigation of the vessel with the engines running in the form of navigation B. During the study of the sleep disturbance of ship

crew members the subjective disturbance - "I don't sleep long" - was not offered as optional answer in the questionnaire; however, at the respondents' request in trial testing of the questionnaire, this subjective disturbance was offered to the engine drivers as a possible answer. It was to be expected that on a sample of 12 ship crew members who sleep on the vessel during continuous 24-hour navigation with the engines emitting high audible noise the highest occurrence of 66.7% is for the subjective disturbance - "I wake up often", since the results of 1979 Vernet research [10] show that the percentage of waking up of people who live in the vicinity of railway lines is increased if the level of noise jump is greater than 52dB(A) when the trains pass, and the effect is identical for the ship crew members when during sleeping on a vessel in the resting interval there occurs an intense jump of the audible noise level emitted by the engines, due to a concrete traffic manoeuvre of the vessel or the pushed composition. However, surprising is the result that ship crew members who manage vessels and sleep on them with ship engines running, and the engine drivers who, unlike ship crew members sleep at home and in the quiet, have almost equal percentages of occurrence for the subjective disturbances - "I have troubled sleep" and "I get no rest". It is completely clear and expected that in case of engine drivers there has been no habituation or adaption of the central nervous system to frequent exposure to audible noise. Has there been possible prolongation of the action of audible traffic noise to the resting interval in the quiet of one's home, which is in conflict with the claims in almost all scientific literature where the majority of authors claim that subjective disturbance of sleep because of the action of audible noise is temporary and short-term, and that it disappears very quickly after the respondent

Table 2 - Frequency of occurrence P(%) of subjective disturbance of sleep disturbance

Engine drivers			Ship crew members in navigation of form B	
Subjective disturbance	P (%)		Subjective disturbance	P (%)
	31 respondent	50 respondents		12 respondents
I don't sleep long	58.1	54.0	I don't sleep long	/
I have troubled sleep	48.4	44.0	I have troubled sleep	41.7
I get no rest	48.4	42.0	I get no rest	58.3
I cannot fall asleep	38.7	40.0	I cannot fall asleep	16.7
I wake up often	38.7	32.0	I wake up often	66.7
none of the above	16.1	22.0	none of the above	9.0

Source: Expanded and amended results of past research [1], [5]

ceases to be exposed to audible noise. More probably, this is the consequence of stronger and prolonged cumulative effect of several simultaneous factors from the traffic environment with very similar subjective disturbances.

A group of subjective disturbances with the highest frequency of occurrence of 98% from Table 1 is the change in a feeling and/or change in mood, and Table 3 shows a detailed insight into its structure according to the percentage share of the occurrence in all the 50 respondents for 12 characteristic subjective disturbances ranked from the highest to the lowest percentage of occurrence. The average frequency of occurrence of individual subjective disturbances in all respondents from Table 3 was surveyed in case of engine drivers also for the interval of service, as well as for the resting interval immediately after work, and during 8-hour resting in turnaround in non-shift regime of work. The results for the engine drivers have been compared for the samples of 31 and of 50 respondents, along with the comparison also with the results

on a sample of 12 ship crew members who directly manage the vessels or vessel compositions. The ranking of subjective disturbances for engine drivers from Table 3 remained the same both for the sample of 31 and of 50 respondents with slight deviations in the percentage of occurrence.

Surprising is the result that the subjective disturbances fatigue and tension both on the sample of 31 and of 50 engine drivers occur, compared to the results from Table 3, in higher percentage of occurrence in relation to the occurrence of the same subjective disturbances in ship crew members who also work and rest on the vessel during navigation 24 hours a day in the form of navigation B. This is also confirmed by the cumulative effect due to a more complex system of simultaneous ergo-assessment factors of engine drivers compared to the ship crew members, with more intensive indirect impact of other factors on the impact of the factor audible traffic noise via relations and links in the system, but also a possible greater volume of the required activities and stronger mental fatigue of

Table 3 - Percentage of occurrence P(%) of subjective disturbances - change in mood and/or occurrence of a feeling during work and/or rest immediately upon the end of the working interval

Engine drivers			Ship crew members who control	
Subjective disturbances	P(%)		Subjective disturbances	P(%)
	31 respondents	50 respondents		12 respondents
fatigue	80.6	78.0	irritation	75.0
exhaustion	71.0	68.0	fatigue	66.7
tension	58.1	58.0	tension	50.0
sleepiness	51.6	54.0	anger	41.7
irritation	41.9	46.0	anxiety	33.3
anxiety	38.7	30.0	exhaustion	33.3
apathy	35.5	30.0	aggression	33.3
anger	29.0	28.0	sleepiness	25.0
unease	16.1	20.0	frustration	16.7
aggression	12.9	16.0	unease	0.0
frustration	9.7	14.0	apathy	0.0
fright	0.0	4.0	fright	0.0

Source: Expanded and amended results of past research [1], [5]

the engine drivers during managing the traffic means. Considering engine drivers on a sample of 50 respondents the occurrence of subjective disturbance fatigue is 78% according to *Table 3*. The same result is highly probable and matches in value the frequency of occurrence of 70% for subjective disturbance psychic fatigue and overwork, but also with the frequency of occurrence of 76% for subjective disturbance – sleep disturbance during the resting interval at home, both according to results from *Table 1*.

Traffic audible noise certainly does not independently cause all the subjective disturbances from *Tables 1, 2 and 3* due to the departure of the respondents from the natural biological rhythm, irregularity of sleep and diet, as well as simultaneous action of several related ergo-assessment factors, and all this with very similar subjective disturbances. It should be kept in mind that the audible noise as a stressor, i.e. cumulative intensifier, will contribute to increase in the intensity and/or prolongation of the time interval of occurrence of the already existing subjective disturbances or permanent psychological and physiological consequences whose basic cause is some other factor [11], which is almost impossible to analyse partially precisely because of excessive similarity of the subjective disturbances.

Past research [1] on a sample of 31 engine drivers have already confirmed the well-foundedness of the set hypothesis [2] that audible traffic noise is among the dominant ergo-assessment factors (third place regarding the value of the index of importance I_V in *Table 5*). On a sample of 50 respondents the result from *Table 6* re-confirms that the intensity of subjective disturbances due to audible traffic noise is the highest precisely in the Diesel locomotive drivers cab, and the final results of systemic ergo-assessment on a sample of 50 respondents from *Table 5* correct the result obtained for 31 respondents: continuous and periodical audible traffic noise in the working environment of the locomotive drivers cab is a dominant ergo-assessment factor of the engine drivers' traffic environment, who operate all types of locomotives and/or railcars.

Past research prove the existence of several simultaneous ergo-assessment factors along with audible traffic noise [1], but they also confirm clear time-variable relations of audible traffic noise with other simultaneous ergo-assessment factors [12], where one factor over the relations in the system changes in time the intensity of the impact of another factor from the traffic environment. The existence of the relations confirms the cumulative impact of the traffic environment on the safety and reliability of engine drivers due to several simultaneous ergo-assessment factors, so that the overall cumulative impact of all the simultaneous factors is greater than the sum of their partial impacts. Thus, also the overall impact of audible traffic noise on the humans considered in the system of simultane-

ous factors is greater than the direct partial impact of factor audible traffic noise, due to the cumulative effect. During 2007 research [12] at all locations in the passenger space of the electric railcar composition of train HŽ6-111 the reduction of average comprehensibility of the emitted logatome over the public address system was proven, due to increased running speeds, but with the concurrent increase in the measured level of traffic audible noise caused by the higher running speed. Thus, the higher running speed has increased the subjective disturbance of respondents indirectly over the relations in the system of simultaneous factors by influencing the increase in the level of audible traffic noise.

The presented research results indicate:

1. the need for complete abandonment of the partial approach to research;
2. the need for further study of the cumulative effect because of the simultaneous action of several factors, which leads to the increase in the effect of audible noise in relation to the partial action of the audible noise on the humans. Also, additional research is required regarding the action of audible traffic noise on humans, as a stressor i.e. intensifier of the subjective disturbances caused by other factors. Both increase the intensity and prolong the interval of the action of subjective disturbances, which, according to claims from technical and scientific literature [6], [7] can be connected also with the action of audible traffic noise.

3. STRUCTURE OF ERGO-ASSESSMENT FACTORS

The respondents were offered 12 characteristic items from *Table 4*: subjective disturbances, permanent physiological and psychological changes, technical and technological preconditions, driving regimes, and all other activities or events during or outside the traffic flow interval, which can be possible factors of psycho-physical effort. Items in *Table 4* have been provided in the form of subjective disturbances, or as factors that cause and/or intensify individual subjective disturbances. The respondents added and assessed 8 additional items at their own discretion*, and they graded the items with grades from 1 upwards, only for those items i.e. factors of ergo-assessment by the free choice of the respondents which they find subjectively disturbing, and the grade 1 is equivalent to the strongest subjective intensity of disturbance.

Systemic ergo-assessment of the system of ergo-assessment factors was carried out by integral ranking presented in *Table 5* using the index of importance I_V according to formula (1), which equally respects different partial ergo-assessments according to average grade \bar{o} for the intensity of subjective disturbances

Table 4 – Factors of systemic ergo-assessment of overall psycho-physical effort

Ergo-assessment factors for evaluation: - 12 offered in questionnaire, 8* added and graded by respondents	
continuous and periodical audible traffic noise in locomotive drivers cab	A
intensive psychical strain or stress in passing through a level crossing because of the possibility of traffic accident	B
intensive psychical strain or stress because of suicides	C
engine-generated exhaust gases and oil evaporation	D
dust and engine driver's head during travel outside the driver's cab of the shunting Diesel locomotive	E
switched on air-conditioning system and open window of the Diesel locomotive engine driver's cab	F
fog, rain or snow in combination with night travelling on open sections	G
fog at high speed in running or in operation with shunting Diesel locomotive	H
visibility from the Diesel locomotive engine driver's place	I
night shift starting from midnight until 5 o'clock, for non-shift operation	J
fatigue and sleepiness during night travelling in non-shift driving regime	K
professional diseases (spinal ache, haemorrhoids, gastric difficulties due to dry food, high blood pressure)	L
poor organization of traffic and big delays	M*
draught (poor insulation of the drivers cab)	N*
failure to clean the vehicle (drivers cab)	O*
lack of management's care for working conditions	P*
poor ergonomics of drivers cab of the majority of locomotives	R*
frequent dreams about work during the resting interval	S*
poor maintenance of traction vehicles (failure to comply with servicing intervals)	T*
interpersonal relations	Z*

Source: taken over from Sumpor, D., Toš, Z., Ivanković, B., 2009 [1]

for n respondents according to formula (2) and the percentage of occurrence P of individual subjective disturbances in all respondents. The index of importance I_v has been proposed as a possible solution for systemic ergo-assessment in cooperation with the co-author Ivanković B. in papers [1], [4] which preceded the development of the cognitive ergo-assessment methodology.

$$I_v = \frac{P}{100} \cdot (16 - \bar{o}) \quad (1)$$

$$\bar{o} = \frac{1}{n} \cdot \sum_{i=1}^n o \quad (2)$$

According to the past research [1], [4], since

$$\frac{\partial I_v}{\partial \bar{o}} = -P/100 < 0,$$

this reduction of the average grade \bar{o} by the increase in intensity of subjective disturbance increases the index of importance:

$$\Delta I_v = \frac{\partial I_v}{\partial \bar{o}} \cdot \Delta \bar{o} > 0.$$

The survey was analysed precisely like this: lower average grade \bar{o} represents greater intensity of subjective disturbance which is a consequence of the ergo-assessment factors offered in the survey or added by the respondents, so that the increase in the intensity of subjective disturbances increases the value of the index of importance I_v . By analogy,

$$\frac{\partial I_v}{\partial P} = \frac{1}{100} \cdot (16 - \bar{o}) > 0$$

so that the increase in the percentage of ship crew members who subjectively feel disturbance $\Delta P > 0$ yields a higher index of importance of integrated survey:

$$\Delta I_v = \frac{\partial I_v}{\partial P} \cdot \Delta P > 0.$$

It should be mentioned that ponder $(16 - \bar{o}_i)$ which is assigned to every average grade \bar{o}_i does not change the difference regarding the second average grade \bar{o}_j and its ponder since: $|\bar{o}_i - \bar{o}_j| = |16 - \bar{o}_i - (16 - \bar{o}_j)|$. Or, in simpler words, the absolute numerical value of the difference between two average grades \bar{o}_i and \bar{o}_j equals the absolute numerical amount of the difference between their related ponders.

The results from Table 5 show that the change of ponders in formula (1) and the increase in the number of respondents from 31 to 50 have not significantly influenced the grouping of ergo-assessment factors into groups of dominant, important, and negligible ones, since there have been minor changes in mutual relative ranking of factors according to the value of the index of importance I_v just within these three basic groups. The factors R*, S* and Z* can be completely neglected in future research since they do not influ-

Table 5 – Results of systemic ergo-assessment of total psycho-physical effort of the engine drivers

Factor		50 respondents				31 respondents			
		P(%)	\bar{o}	I_V	rank	P(%)	\bar{o}	I_V	rank
dominant	A	98.00%	6.10	9.702	1	100%	6.0	6.000	3
	J	82.00%	4.44	9.479	2	83.9%	4.0	6.712	1
	G	74.00%	4.65	8.399	3	71.0%	3.4	6.097	2
	H	80.00%	5.85	8.120	4	77.4%	4.8	5.573	5
	B	68.00%	4.24	7.997	5	64.5%	3.8	5.289	6
	C	62.00%	3.32	7.862	6	67.7%	3.7	5.619	4
	E	72.00%	5.83	7.322	7	71.0%	4.8	5.112	7
	D	74.00%	6.24	7.222	8	71.0%	5.6	4.544	9
	K	68.00%	5.62	7.058	9	67.7%	4.5	5.078	8
	L	68.00%	5.88	6.882	10	61.3%	6.0	3.678	10
important	T*	48.00%	7.71	3.979	11	29.0%	7.8	1.218	12
	N*	38.00%	7.95	3.059	12	9.7%	7.5	0.437	14
	I	46.00%	9.52	2.981	13	41.9%	7.8	1.760	11
	P*	30.00%	7.87	2.439	14	6.5%	10.0	0.130	16
	F	42.00%	10.29	2.398	15	32.3%	8.8	1.034	13
	M*	34.00%	9.41	2.241	16	3.2%	8.0	0.128	17
	O*	34.00%	10.82	1.761	17	6.5%	6.5	0.358	15
	R*	2.00%	10.00	0.120	18	3.2%	10.0	0.064	18
	S*	2.00%	11.00	0.100	19	3.2%	11.0	0.032	19
	Z*	2.00%	15.00	0.020	20			-	-
Expression for I_V		$I_V = P/100 \cdot (16 - \bar{o})$				$I_V = P/100 \cdot (12 - \bar{o})$			

Source: Expanded and amended results of past research [1]

ence significantly the systemic ergo-assessment of the traffic environment.

4. ERGO-ASSESSMENT OF ENGINE DRIVERS' TRAFFIC ENVIRONMENT

Table 6 shows the results of partial ergo-assessment of the drivers cab working environment obtained by grading partial intensity of subjective disturbances in drivers cabs for three dominant factors, and with inter-comparison depending on the type of locomotive or railcars, and also by comparing the research results obtained on the sample of 31 and 50 respondents.

The results of partial ergo-assessment from Table 6 on a sample of 50 respondents confirm the results of partial ergo-assessment on a sample of 31 respondents. All the locomotives and railcars are completely equally ranked on a sample of 50 respondents regarding the average grades of the intensity of subjective disturbances for all three factors, relatively one in relation to the other, and the mean arithmetic grade presented in row $\Sigma\bar{o}$ was calculated. The respondents assessed the subjective disturbance with grades from 1 to 4, grade 1 being equivalent for the maximum in-

tensity of subjective disturbance. Diesel locomotive is subjectively the noisiest, least manoeuvrable, with minimal visibility from the drivers cab, whereas the electric composition is subjectively least noisy, easiest to manoeuvre, and with best visibility from the drivers cab. Identical ranking of subjective disturbances by respondents due to the audible noise in drivers cabs on a sample of 31 and 50 engine drivers from Table 6 are additionally confirmed by research done by Lakušić, Dragčević and Rukavina from 2005, who measured [13] the maximum level of audible traffic noise along the railway line in Retkovec in Zagreb at the passage of freight trains along the Zagreb – Vinkovci railway line.

Table 7 presents final results of the systemic ergo-assessment of subjective experience of intensity of overall psycho-physical effort in respondents, respecting also the reasons of traffic operation and comparison of research results on a sample of 31 and 50 respondents. The engine drivers assessed the subjective disturbance with grades from 1 to 7, and the lowest grade 1 is equivalent to the maximum overall psycho-physical effort. The final results on the sample of 50 engine drivers show the possible negative influence of the insufficient number of respondents on different results of ergo-assessment [1] for the sample of 31 engine drivers. According to Table 7, for the sample

Table 6 – Partial ergo-assessment of the working ambient of the drivers cab for three dominant factors, \bar{o} for subjective experience of disturbance in respondents

Type of locomotive or railcars	electric-motor composition		electrical locomotive		Diesel locomotive		Diesel motor composition	
Traffic flow for sake of transport	only passengers		freight or passengers		freight or passengers		only passengers	
Sample of respondents	31	50	31	50	31	50	31	50
visibility	3.5	3.5	2.5	2.7	1.0	1.0	3.0	2,7
intensity of severity of operation	3.5	3.4	2.5	2.7	1.2	1.2	2.8	2,7
intensity of audible noise disturbance	3.6	3.7	2.5	2.6	1.1	1.1	2.8	2,6
$\Sigma\bar{o}$	3.53	3.53	2.50	2.67	1.10	1.10	2.87	2.67

Source: Expanded and amended results of past research [1]

Table 7 – Systemic ergo-assessment of subjective disturbance of intensity of overall psychophysical effort in respondents

Traffic operates for	Locomotive or railcar	\bar{o}	
		31 respondents	50 respondents
shunting	Diesel shunting locomotive	1.6	1.5
passenger transport	Diesel locomotive	4.7	2.9
freight transport	Diesel locomotive	3.1	3.1
passenger transport	Diesel engine composition	2.9	4.8
passenger transport	electric - locomotive	5.1	4.8
freight transport	electric - locomotive	5.3	5.3
passenger transport	electric - railcar	5.4	5.5

Source: Expanded and amended results of past research [1]

of 50 respondents, it is logical that the Diesel locomotive immediately following the shunting Diesel locomotive cause for the respondents the most intensive overall psycho-physical effort in relation to the electric locomotive, electric-railcar and Diesel motor composition, since according to the results from Table 6 it is significantly noisier than they are, and according to the results from Table 5 audible noise is the first and dominant ergo-assessment factor.

It is logical and to be expected that the psychophysical effort is greater when the engine driver manages a Diesel locomotive that hauls a passenger composition in relation to the case when a Diesel locomotive hauls a freight composition, due to the cumulative effect of two simultaneous dominant ergo-assessment factors: intensive audible traffic noise in case of the noisiest Diesel locomotive and intensive care for the safety of passengers. The aggravating circumstances [1] which engine drivers claim in working with the shunting Diesel locomotive for the maximum intensity of the overall psycho-physical effort are: long standing posture, work with unfamiliar manoeuvring staff, extremely poor visibility and dependence on manual signals of manoeuvring staff, care for the safety of manoeuvring staff, tension, head outside in rain and cold during winter or heat during summer, switched on air-conditioning system and open drivers cab window, dust, smell of exhaust gases, most severe conditions due to the pushed wagons, intensive audible noise.

5. CONCLUSION

The research result at the level of the traffic process is the suggested ergo-assessment methodology, as a possible systemic approach to studies and/or orientation of the partial research approach to dominant and important factors of disturbance. The research results on a sample of 50 engine drivers prove the intensive negative impact from the traffic and working environment on the engine drivers during work. The classification of factors into dominant, important and negligible ones is enabled by ranking of individual factors of disturbance relative to all the others by means of the proposed parameter I_V with numerical value. The priority for efficient elimination or substantial reduction of harmful impact of individual factors of disturbance on the total ergo-assessment is greater with greater numerical value of the index of importance I_V . By evaluating the impact of factors at the level of the traffic process and outside the working environment of the drivers cab itself, the complete system of concurrent factors from the traffic environment is included and described, as well as the factors related with characteristic repeatable traffic situations. In reality in the Republic of Croatia there is the system of concurrent factors with interrelations described in this work. The relations will cause cumulative effect due to which the effect of the entire system of concurrent factors on humans will result in greater scope and intensity of dis-

turbance than the sum of partial effects of all the concurrent individual factors. It is efficient first to eliminate or reduce the impact of the dominant factors precisely defined in this work. However, due to strong relations in the system of concurrent factors and intensified cumulative effect it would be wrong to partially study, eliminate or reduce the impact of dominant factors of ergo-assessment only from the working environment of the drivers cab, dislocated from the traffic environment and recent characteristic traffic situations. For maximum effect, the results of this ergo-assessment need to be simultaneously applied already during the introduction of ergo-assessment of the traffic environment into the formal education of all the experts of the technical profession, in forming the legal regulations for the evaluation of the impact of the traffic environment on the traffic participants who control traffic means, in construction and/or reconstruction of the drivers cab itself and/or all the traffic means, in design and introduction of traffic processes, as well as in the construction and/or reconstruction of traffic routes. This ergo-assessment confirms the needs for electrification of the major part of the railway network of the Republic of Croatia which is being used if permitted by the terrain configuration, and due to proven subjective least visibility, highest intensity of the difficulties in driving and the highest intensity of subjective disturbance due to audible traffic noise precisely in the Diesel engine driver cabs. The systemic intervention in the traffic environment (railway line electrification), will eliminate from traffic the Diesel locomotives and Diesel motor compositions, which will result in complete elimination of subjectively the least favourable working environment of Diesel locomotive driver cabs. The same is the proof that concrete interventions in nature require a harmonised cooperation of several engineers of technical professions, since the traffic means (drivers cab), the traffic route, and the traffic process are not designed by the same professional. Since the proposed methodology of cognitive ergo-assessment is based on the conversion of the percentage of occurrence of individual disturbances in case of all engine drivers and average intensity of subjective disturbance and/or permanent psychological and physiological changes in engine drivers into a technical parameter with concrete numerical value, future studies require cooperation with the professionals such as psychologists and doctors for more precise interpretation of results and correction of the methodology.

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SAŽETAK

ERGOPROSUDBA PROMETNOG OKOLIŠA STROJOVOĐA

Strojovođe su za vrijeme upravljanja lokomotivom ili motornom garniturom izloženi djelovanju više istovremenih čimbenika smetnji iz prometnog okoliša, pa su zbog toga smanjeno pouzdani i sigurni. Fizikalni, senzorni i kognitivni čimbenici određeni čovjekom nisu samo atributi strojovođa, već obuhvaćaju i utjecaje iz prometnog okoliša, a zbog interakcija u sustavu strojovođa – prometno sredstvo – prometni okoliš. Prometni okoliš je definiran na način da, između ostaloga, obuhvaća i radni okoliš upravljačnice i recentnu prometnu situaciju. Djelovanje čimbenika privremenih subjektivnih smetnji i/ili trajnih psihološko - fizioloških promjena, osim o individualnoj izdržljivosti strojovođa, bitno ovisi i o vrsti lokomotive ili motorne garniture kojom upravlja strojovođa, ali i o tome da li se promet odvija zbog transporta putnika i/ili robe, ili je u pitanju manevarska lokomotiva. Ergoprosudbom na osnovu anketiranja 50 ispitanika dobiveni su konačni rezultati gotovo identični rezultatima ergoprosudbe dobivenim tijekom formiranja metodologije kognitivne ergoprosudbe na uzorku od 31 ispitanika. U oba su slučaja anketirani ispitanici strojovođe koji u praksi voze sve tipove lokomotiva i motornih vlakova, s SSS naobrazbom strojovođe i položenim stručnim ispitom za sve tipove lokomotiva i motornih vlakova. Sustavna ergoprosudba intenziteta ukupnoga psihofizičkoga napora omogućena je uvođenjem indeksa važnosti I_v kojim se kod svih strojovođa integralno i ravnopravno uvažava i utjecaj postotka pojavnosti pojedinog čimbenika subjektivne smetnje i utjecaj prosječne ocjene intenziteta subjektivne smetnje, što omogućava uvid u strukturu sustava istovremenih čimbenika ergoprosudbe i izoliranje deset dominantnih čimbenika ergoprosudbe. Parcijalnom kognitivnom ergoprosudbom i međusobnom komparacijom intenziteta subjektivnih smetnji ukazano je na tipove lokomotiva i/ili motornih garnitura kod kojih je najveći parcijalni intenzitet smetnje zbog sljedećih čimbenika iz radnog prostora upravljačnica: vizualna preglednosti, intenzitet težine upravljanja i intenzitet smetnje čujne prometne buke.

KLJUČNE RIJEČI

prometni okoliš, kognitivna ergoprosudba, dominantni čimbenici subjektivnih smetnji, parametri za vrednovanje, sigurnost i pouzdanost

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