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Ergo-Assessment of Human Factor for Female Tram Drivers

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Abstract

The paper presents ergonomic assessment of the "tram drivers - tram - traffic environment" system in Zagreb, the capital of Croatia. The input data were collected by surveying the subjective disturbances from cognitive perception of 36 female respondents working as tram drivers. System of many simultaneous different ergo-assessment factors that affect female drivers while operating the tram may cause reduction of reliability and safety of the tram drivers' actions and increase the workload during the driving. The ergonomic assessment of subjective disturbance factors was realized by means of concrete parameters with numerical values, on the basis of which the dominant and important factors of disturbance per percentage were divided into three standard groups of factors: human factor, traffic means and traffic environment. Increased share of disturbance factors from the groups traffic means and traffic environment in relation to the share of human factor proves intense impact of traffic means and traffic environment on the female tram drivers.

Key words: female tram drivers; ergonomic assessment; disturbance factors; share of human factor

1. Introduction

The authors have studied the hypothesis that the system of simultaneous disturbance factors from the working and/or traffic environment reduces the reliability and safety of female tram drivers in Zagreb during driving, and that it is possible to estimate by means of the concrete parameters with numerical values the share of disturbance factors from groups human factor, traffic means and traffic environment. Research presented in this paper is a continuation of student research from the year 2013 [1]. According to Michon [2], there was a lagging behind in Europe in the cognitive approach in relation to the behaviouristic approach to the study of drivers' behaviour and reactions in the

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1980s. An identical situation is happening now in Croatia in all branches of transport. According to the new cognitive approach, the authors use for the input data factors of subjective disturbance from the cognitive perceptions of drivers, rather than factors i.e. input data that were obtained from in-depth studies, when, after the accident, a group of experts analyses the damaged road vehicle, as presented in Rumar's study [3]. Rumar's study is an example of the research of objective statistical risk, which is also at the same time an example of the behaviouristic approach to the research. Several authors [4] have identified the workload according to the task difficulty during driving. However, according to Fuller [4] the task difficulty and feelings of risk seem to be very highly related to each other, but feelings of risk and ratings of statistical risk are completely unrelated until a critical speed is reached (according to Fig. 1. where task demand approaches the driver's capability, and then there is the possibility of loss of control over the vehicle). Thus, risk estimates linked to risk feelings are not ongoing determinants of driver decision making.

Concrete parameters with numerical values I_V, $\bar{o}$ and $P(\%)$ have been proposed as a possible solution for systemic ergo-assessment of the driver's workload in papers [5, 6] which preceded the development of the cognitive ergo-assessment methodology. The determination of share of disturbance factors from groups human factor (H), traffic means (TM) and traffic environment (TE) has been performed according to the methodology used in the paper from 2011 [7], and using the parameter of percentage belonging to individual factor $P_{Iv}(\%)$. In the task – the capability interface model [4] by Fuller presented in Fig. 1 the group of factors human factor, dynamically and concurrently changes the capability of drivers and the task demand. Also groups of factors traffic means (vehicle) and traffic environment change the task demand.

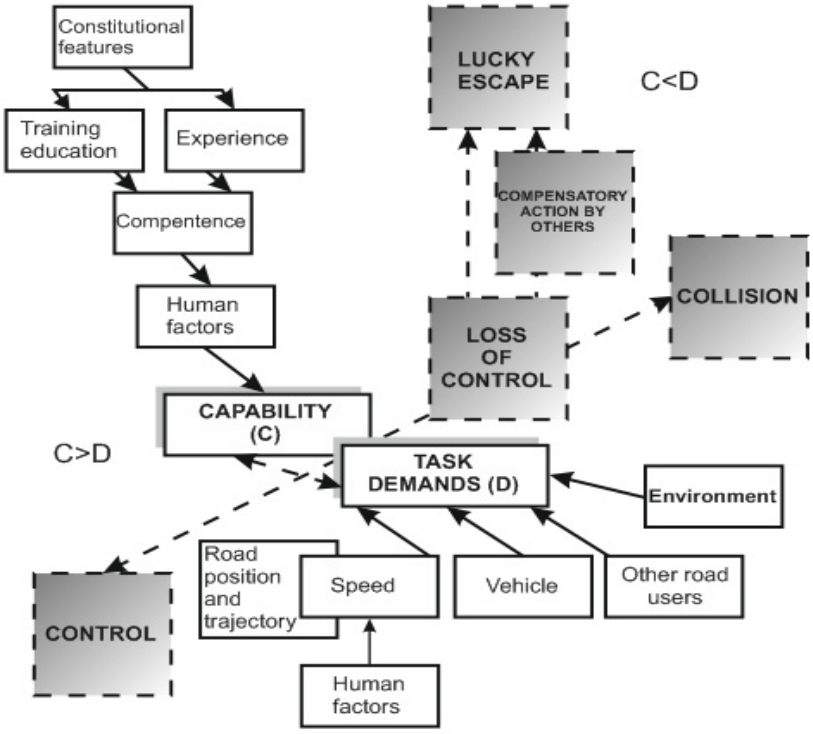

Fig. 1. Open dynamic TCI model of "task demand – driver's capability" interface.
Source: Taken over from R. Fuller, 2005 [4]

Thirty six interviewed female tram drivers of Zagreb Municipal Transit System Company (ZET) are Croatian citizens of the average age of 45.5, with the average of 18.3 years of work experience working as tram drivers, working in regular shifts, not working the night shift.

2. Ergo-assessment factors which produce workload from cognitive perception of drivers

All twenty-four factors of subjective disturbance are given in Table 1 and were offered to the respondents. They assessed only the factors that present subjective disturbance with grades from 1 upwards. Grade 1 equals the most intensive subjective intensity of disturbance.

The influence of individual factors relatively in relation to all the other simultaneous factors has been assessed in Table 2 by numerical value of index of importance I_V.

Table 1. Factors of systemic ergo assessment which cause total workload effort of female tram drivers.

Ergo-assessment factors for assessment	Mark
Lack of air conditioner and/or window in tram driver's cab	H
Non-ergonomic, uncomfortable seat without possibility to adapt to anthropometric measures of tram drivers	V
Continuous and periodical audible traffic noise in tram driver's cab	A
Visibility of traffic environment from the tram cab	K
Inaccessibility of the most frequently used manual controls in the normal arm reach	R
Professional diseases: backache, haemorrhoids, stomach disorders (brash, gastritis, duodenal ulcer), high blood pressure, ocular disorders, aches in muscles and joints, conjunctivitis…	N
Poor maintenance of vehicles (non-compliance with servicing intervals)	NJ
Lack of management's care for working conditions	T
Poor arrangement of commonly used commands for manual control or pedal control of accelerator and braking module on older models	S
Draught (poor insulation of driver's cab)	Š
Intensive stress while passing through level crossings because of the passage of the motor vehicles at red light	D
Poor organisation of transport and big delays	U
Absence of "dead man" function	Z
Intensive stress while passing through level crossings because of setting the points from tram driver's cab or manually setting the points outside of the tram driver's cab	E
Lights and other indicators outside the visual fields (without turning the head)	P
Not separated driver's cab from passenger area	O
Rain or snow in combination with late night driving until 1 a.m. or early in the morning after 4 a.m.	I
Intensive stress while working in daily peak hours	F
Rain or snow in combination with working in daily peak hours	J
Overloaded vehicles with the number of passengers	G
Intensive stress during arrival or departure from the tram platforms (and during passengers' entry and/or exit)	B
Fatigue and sleepiness while driving late at night until 1 a.m. or early in the morning after 4 a.m.	M
Intensive stress while passing through level crossings due to changes in traffic lights	C
Night call for duty at 3:30 a.m. to work in the first shift (shift starts at 4 a.m.)	L

I_V defined by expression (1) includes equally the impact of average grade $\bar{o}$ for the intensity of subjective disturbance in n respondents according to expression (2) and the impact of the percentage of occurrence $P(\%)$ of individual subjective disturbance in all the respondents. According to value I_V the subjective disturbance factors from Table 1 are in Table 2 divided into groups of dominant (from H to U), important (from Z to C) and negligible (L) ones.

Table 2. Belonging of 23 dominant and important factors of disturbance to three standard groups: H, TM and TE.

Mark of factor	Group	*P(%)*	$\bar{o}$	I_v	P_{Iv}*(%)*
H	TM	91. 70	5.76	11.224	9.56
V	TM	83.30	5.57	10.354	8.82
A	TM, H	94.40	7.41	9.997	8.51
K	TM, TE	66.70	4.38	9.085	7.74
R	TM	69.40	5.72	8.522	7.26
N	H	66.70	6.46	7.697	6.55
NJ	TM, TE	55.60	6.10	6.616	5.63
T	TE	55.60	6.30	6.505	5.54
S	TM	47.20	4.53	6.358	5.41
Š	TM	52.80	6.32	6.167	5.25
D	TE, H	36.10	6.69	4.083	3.48
U	TE	36.10	6.69	4.083	3.48
Z	TM	41.70	8.80	3.836	3.27
E	TM, TE, H	33.30	6.58	3.803	3.24
P	TM, TE	30.60	5.91	3.700	3.15
O	TM	33.30	8.33	3.220	2.74
I	TE, H	25.00	7.78	2.555	2.18
F	TE, H	25.00	7.78	2.555	2.18
J	TE	22.20	8.38	2.136	1.82
G	TM, TE	19.40	8.28	1.886	1.61
B	TM, TE, H	13.90	9.60	1.168	0.99
M	H	11.10	9.25	0.971	0.83
C	TE, H	8.30	7.33	0.886	0.75
L	H	2.80	17.00	0.028	0.024
Dominant factors (H÷U)				90.69	77.23
Important factors (Z÷C)				21.80	22.75
Negligible factors (L)				0.028	0.024
Total without negligible factors				112.49	99.98
Partial percentage belonging in individual group of factors		TM = traffic means			42.31
		TE = traffic environment			10.84
		H = Human			7.38
Overlapping of two groups of factors		TM + H			8.51
		TM + TE			18.13
		TE + H			8.58
Overlapping of three groups		TM + TE + H			4.23
Collective percentage belonging in individual group of factors, with all the overlapping		TM with all overlaps			73.18
		TE with all overlaps			41.78
		H with all overlaps			28.71

$$I_V = \frac{P}{100} \cdot \left(18 - \bar{o}\right) \tag{1}$$

$$\bar{o} = \frac{1}{n} \cdot \sum_{i=1}^{n} o \tag{2}$$

The dominant and important factors in Table 2 have been assigned the belonging to three standard groups, as in Rumar's study [3]: human factor (H), traffic means (TM) and traffic environment (TE). However, in accordance with the cognitive approach to the research, the parameter of percentage belonging of individual factor of subjective disturbance $P_{Iv}(\%)$ in Table 2 has been defined by expression (3).

$$\boldsymbol{P_{Iv} = \frac{I_{Vi}}{\sum_{i=1}^{23} I_{Vi}} \cdot 100} \tag{3}$$

A surprising result is the low ranking of factor L (Night call for duty at 3:30 a.m. to work the first shift, shift starts at 4 a.m.) in Table 2, because according to Prokop and Prokop (1955) the highest sleepiness of truck driver was registered by the surveys between 23 p.m. and 5 a.m. due to the effects of circadian biorhythm [8].

3. Research results

Ergo-assessment factors in Table 2 cause workload of respondents and among other things, the occurrence of subjective feeling of fatigue in 63.9% of female tram drivers from random sample [1]. According to Ashton and Fowler [9] the main consequences of fatigue are shown in Fig. 2.

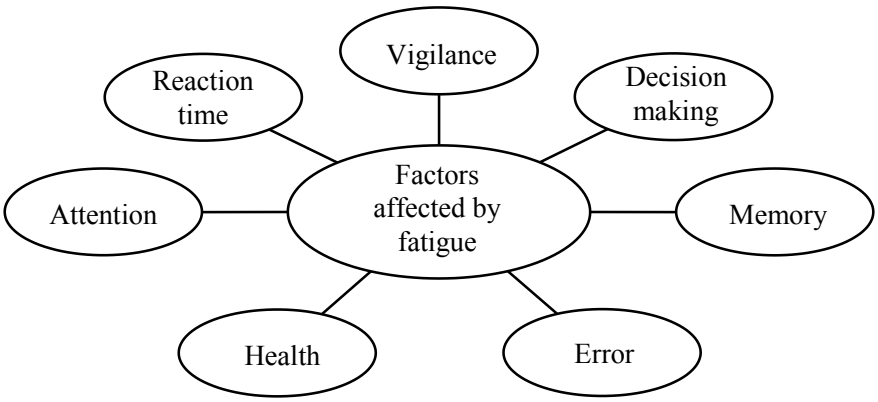

Fig. 2. Consequences of fatigue. Source: Taken over from Ashton and Fowler, 2005 [9]

If the task demand becomes larger than the driver's capability (C<D), and if there are no systems to assist the driver, in case of drivers there will be loss of control over the vehicle.

Fig. 3 presents the results expressed by P_{Iv}. The boxes below the symbol denoting the title of the group of factors in Fig. 3 contain the collective percentage share of the factors in three standard groups, with all the overlapping. According to the behaviouristic approach to the research based on the study of the statistical objective risk, the share of the human factor (H) is always extremely dominant in relation to the shares of the other two groups of factors [3]. According to the cognitive approach in this study, the lowest partial and collective percentage belonging of 28.71% for the group of factors 'human factor' (H) in this study in relation to 73.18% for the traffic means (TM) and 41.78% for the traffic environment (TE) indicate the possible non-ergonomic design of the tram drivers cab.

According to the criteria of the used methodology and the grouping factors, one of the newer proposed models is the Butterfly Flower Shower (BFS) Human Behaviour Model [10], a very similar model which describes human behaviour according to the new cognitive approach, because the key elements of the human behaviour in this model are perception, cognition and reaction. Input data in this model are: environmental factors, technological factors, organizational factors and personality factors. If the environmental factors, organizational factors and part of technological factors (infrastructure) are placed into the same group, then we are talking about the group traffic environment (TE). The second part of technological factors (vehicle) is equal with the group traffic means (TM). The personality factors are in relation with the human factors (H).

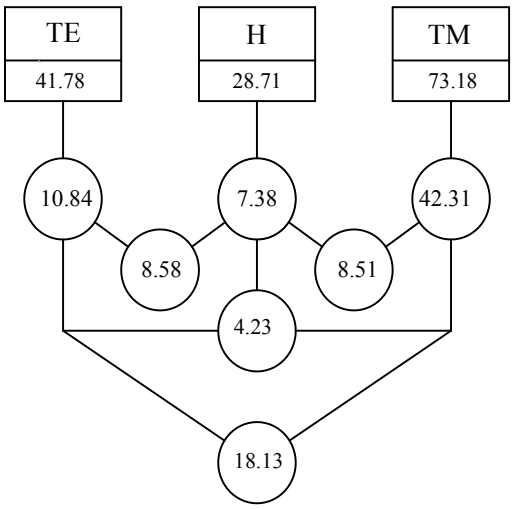

Fig. 3. Human factor (H) in tram traffic expressed by $P_{Iv}(\%)$.

Previous coauthor's study confirms the results from this study. According to Musabašić et al. [11] the most frequently used commands while operating trams in Bosnia and Herzegovina and the Republic of Croatia are: multi-purpose controller for an arm (group-related commands accelerator, brake modules and "dead man"), horn or bell, flashing light button, direction indicators, switching or blocking points, and commands for manipulation of the doors in passenger area. This study [11] confirms that the tram control panel in the new tram in Zagreb (TMK 2200 produced by Crotram consortium) is nicer in relation to Sarajevo, but the tram control panel in the new tram in Sarajevo has slightly better ergonomic solutions for the part of the frequently used and manually served commands. For example, the smaller female tram drivers in Zagreb use a pencil during manual serving commands for manipulation of the doors in passenger area. This is in accordance with the high ranking of dominant factor of subjective disturbance R from Table 2 (Inaccessibility of the most frequently used manual controls in the normal arm reach).

4. Conclusion

According to the new cognitive approach, the factors of subjective disturbance from the cognitive perceptions of drivers rather than factors of traffic accidents were used for the input data in the paper. The results are presented using the standard methodology for the area of traffic. For ergo-assessment disturbance factors from the cognitive perception of female tram drivers, using parameters with numerical values, this paper shows the shares of all dominant and important factors of subjective disturbance in three standard groups: 73.18% in group traffic means, 41.78% in group traffic environment and 28.71% in group human factor. The research results indicate that the increased share of 73.18% of the disturbance factors from the group traffic means may be connected to disadvantages in the design of the cabin and the lack of systems to assist the driver during the manual serving of the

frequently used commands on the control panel. This study also indicates the importance of collecting feedback from the cognitive perception of users - tram drivers.

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References

[1] A. Šandor, P. Zelenković, Ergo-Assessment of Female Tram Drivers' Traffic and Working Environment in Zagreb, Student work nominated for the Dean's Award, University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, 2013.

[2] J. A. Michon, A critical review of driver behavior models: What do we now, what should we do? In: Human Behavior and Traffic Safety, L. Evans and R. C. Schwing (Eds.), Plenum Press, New York, 1985, pp. 485-520.

[3] K. Rumar, The human factors in road safety, XI ARRB Conference, Australian Road Research Board Proceedings, Vol.11, Part 1, Melbourne, 1982, pp. 65-78.

[4] R. Fuller, Towards a general theory of driver behaviour, Accident Analysis and prevention 37, Issue 3, Elsevier, May 2005, pp. 461-472.

[5] D. Sumpor, Z. Toš, B. Ivanković, The System of Ergo-Assessment Factors of the Locomotive Drivers Working Environment, Proceedings of Third International Conference on Rail Human Factors, Lille, 2009, cd, 8 p.

[6] D. Sumpor, J. Jurum-Kipke, D. Petrović, Ergo-Assessment of Locomotive Drivers´ Traffic Environment, PROMET - Traffic&Transportation, Vol.22, No.6, Pardubice, Portorož, Sarajevo, Trieste, Zagreb, Žilina, 2010, pp. 439-448.

[7] J. Jurum-Kipke, D. Sumpor, N. Musabašić, Cognitive Ergo-Assessment of Human Factor During Manual Toll Collection, Proceedings of the 22nd International DAAAM Symposium, Vienna, Katalinic, B. (Ed.), Published by DAAAM International, Vienna, 2011, pp.259-260.

[8] K.H.E. Kroemer, E. Grandjean, Fitting the Task to the Human, A Textbook of Occupational Ergonomics, Fifth Edition, Published by Taylor & Francis Ltd., London, 1997.

[9] R. Ashton, A. Fowler, Human Friendly Rosters: Reducing the Risk of Fatigue, In J. Wilson et al. (Ed.) Rail Human Factors: Supporting the Integrated Railway, Chapter 19, Ashgate Publishing Limited, 2005, pp. 203-214.

[10] M. Molan, G. Molan, BFS Human Behaviour Model for Traffic Safety, PROMET - Traffic&Transportation, Vol.23, No.3, Pardubice, Portorož, Sarajevo, Trieste, Zagreb, Žilina, 2011, pp. 205-213.

[11] N. Musabašić, Z. Toš, D. Sumpor, Comparative Ergo-assessment of Control Panel for New Trams Produced in the Republic of Croatia and Bosnia and Herzegovina, Proceedings of 5th International Ergonomics Conference „Ergonomics 2013“, Mijović, B. et al. (ur.), Croatian Ergonomics Society, Zadar, 2013, pp. 175-180.