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IDENTIFICATION OF INCONVENIENCES AT TRANSPORT OPERATORS' WORKPLACES

Summary. This article presents the results of a pilot survey of 300 transport operators, such as drivers, train drivers, and rescue workers. The surveys were conducted online using a Google form based on the Computer-Assisted Web Interview (CAWI) method. The following research objectives were set: to identify and compare the most relevant factors affecting the health and wellbeing of transport vehicle operators and to identify the key risks associated with their work. The findings were presented using descriptive statistics and correlation and principal component analyses. Descriptive characteristics indicated which quantitative characteristics were associated with exposure and discomfort. On the other hand, the results of correlation analyses showed, among other things, that "level of rest" as a function of "fatigue" showed a decreasing relationship and that "pain in arms, legs, lower back or neck" depended on "work position," "use of excessive force," and "work severity." The results of the principal component analysis confirmed that the data cluster under the form of factors and that there are factors whose information values are insignificant. A similar conclusion applies to the input data (i.e., the answers to the test questions). The analysis showed that only the answers to 15 of 50 questions exceeded the threshold of 2% of the information entered in the test. This could lead to the conclusion that if the test could be repeated in the future, the correct result might be obtained with slightly fewer test questions.

1. INTRODUCTION

Transport is one of the most important sectors of the economy, playing a key role in the delivery of goods and services to consumers [1-3]. Efficient transport is essential to the functioning of the modern world, and its importance is increasing with the growth of international trade and globalization [4-6]. Operators of modes of transport, despite the growing autonomization technology around the world, still have a key role in the transport system and are responsible for ensuring efficient, safe transport. Unfortunately, the transport sector brings with it increasing challenges. In recent years, there have been significant changes in technology, regulations, and consumer demands on the transport service offered or the workplace of transport operators. Over the years, truck cabs have been transformed into mobile offices equipped with various devices such as mobile data terminals, document bins, or rotating writing boards. These devices, in turn, occupy internal space, creating a cramped cab environment that restricts the driver's body movements, potentially leading to injury [7-11]. The situation is similar for the work of the paramedic, who often has a dual job: driving the ambulance and carrying the casualty. Placing state-of-the-art equipment in a medical ambulance is, on the one hand,

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facilitating the paramedic's work and, on the other hand, hindering his or her movements or exposing him or her to heavy lifting. Ensuring a high degree of functionality, safety, and employee satisfaction can largely be achieved through the correct design of the workplace [12-13].

Despite evolving technology and increasing automation, many challenges remain in ensuring operator safety [14]. In recent years, much research has focused on these aspects of work. One of the key issues leading to improved working conditions is identifying nuisance factors that may affect the quality of work and safety of transport operators [15-18] and their subsequent elimination or minimization. Knowledge about the ergonomic level of workstations can be acquired using the questionnaire-expert method. Its application among operators made it possible to find out the factors determining their negative opinion on working conditions and analyze inconveniences. The current research covered selected mobile workplaces in means of transport, such as professional drivers, couriers, and train drivers as representatives of rail vehicles and paramedics. In the aforementioned cases, the workplace is the operator's cab or, additionally, the vehicle space for paramedics.

This article aimed at identifying job-related inconveniences presents the results of survey research conducted among three groups of operators. Selected research results were analyzed using descriptive statistics, correlation, and principal component analysis (PCA), providing insights into the required number of questions and the survey's structure.

2. RESEARCH METHOD

An ergonomic assessment of workstations should be preceded by several partial studies of the existing conditions and features that make up the overall assessment. This research intended to gain insights into the existing ergonomic level of non-stationary workstations (train drivers, paramedics, couriers, and professional drivers) and identify possible nuisances and hazards. Due to pandemic constraints, the research was made available on Google Forms using the computer-assisted web interviewing Computer-Assisted Web Interview method [19]. This form made it possible to collect the opinions of operators from all over Poland.

The research procedure included the following stages: preparation of the questionnaire, implementation of the research proper by distributing the questionnaire to the research sample, and preparation and conditioning of the research results to enable their analysis using statistical methods.

2.1. Questionnaire preparation

The questionnaire was prepared in both online and paper versions. It consisted of 48 questions organized into five thematic groups. The first group consisted of metric questions that allowed us to characterize the respondents based on gender, age, and height. Respondents were also asked to indicate the type of job, length of working experience, average working time per day, and type of work (permanent or casual). The second group of questions was aimed at providing knowledge on the human factor (i.e., stress levels, psychophysical condition, fatigue, rest, fear for one's own life, responsibility for the lives of others or the load being transported, and aggression faced by operators on the job, among others. The third group of questions focused on organizational conditions, such as the severity of the work, shift work, or working in difficult weather conditions. The next group of questions was centered around the technical factor and concerned questions related to nuisances at the workplace, such as working position, workspace, location of signaling and control devices, access to equipment, perceived discomfort, equipment, complaints, dynamic and static loads and the approximate weight of objects/products handled during a work shift. The fifth and final group of questions was related to factors of the material work environment (i.e., the level of perceived vibration, noise, ambient temperature, pollution, exposure to chemical contamination, and lighting).

Respondents' opinions were measured using different scales (i.e., binary nominal scales with "yes/no" answers, four- and five-point ordinal Likert scales based on a variety of single- or multiple-choice answers) and semi-open and open-ended questions. In the case of responses classified using a Likert scale, the data from the study are treated as quantitative (scalar) data. This approach can also be applied when analyzing binary "yes/no" responses with identical weight values. Subsequently, the obtained answers were categorized for open-ended responses, and then ordinal data were transformed into scalar data expressed numerically.

2.2. Questionnaire research

More than 300 A total of 328 people representing various operator groups from all over Poland participated in the survey. The survey was conducted between March 10, 2020 and June 6, 2021. Men accounted for 81.6% of the participants, while women accounted for 18.4%. This distribution is mainly due to the type of positions that were surveyed. In addition, the gender of respondents does not affect the results, and the statements of female and male respondents are equally valuable. The largest age groups were made up of people aged 25-29 (38%), 18-24 (19%), and 30-34 (19%). Age has significant importance in the work of operators since, as the years go by, on the one hand, experience and knowledge are gained and, on the other, reaction time increases and fatigue builds up.

Anonymity allowed the operators to report various nuisances and hazards occurring at their workplaces. The collected data were subjected to statistical analysis using Statistica and Matlab.

2.3. Methods of statistical analysis

The survey conducted on a sample of 300 people among drivers, and rescue workers can be considered a pilot study since the aim, among other things, was to identify the problems faced by transport operators. This preliminary information is essential for the planning of further research on a larger scale aimed at formulating guidelines to eliminate the nuisances that occur. The statistical analysis also helped answer the question of how the survey should be structured in order to obtain reliable results and minimize the number of questions.

The results obtained from the study were analyzed using statistical methods by solving the following problems (tasks):

* description of the intensity of the occurrence of defined nuisances of working conditions
* description of the intensity of ailments associated with work activities
* description of the relationship between nuisances and ailments

In addition to the primary objectives, it is possible to analyze which groups of employees complain about onerous working conditions and what this depends on.

Taking into account the various response cafeterias to solve the problems defined above, the following analysis methodology can be proposed:

* descriptive characteristics
* correlation studies
* PCA
* PCA factor analysis
* regression analysis

3. RESULTS

This article discusses selected issues in descriptive characteristics, correlation studies, PCA factor analysis, and regression analysis.

3.1. Descriptive Characterization Results

In the case of survey results, descriptive statistics usually boil down to simple characteristics of a random sample involving the determination of mean values, standard deviations, and the production of histograms. Fig. 1 shows histograms of response counts to questions from the group of metric questions: age (years), gender (female, male), height (cm), and position (driver, train driver, paramedic). Fig. 2 shows the histograms of the number of responses to questions about the nature of work (permanent, casual), length of service (months), and number of hours worked per day.

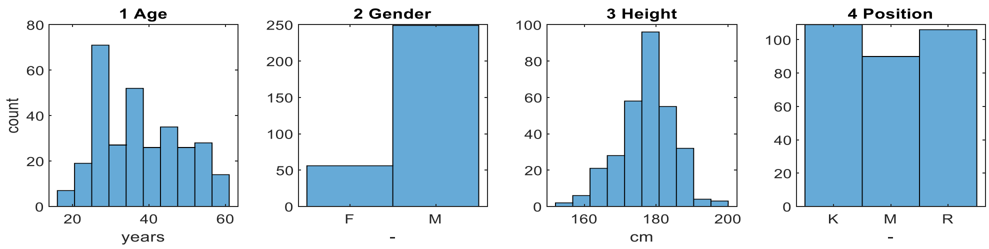

Fig. 1. Histograms of the counts of the "personal data 1-4" characteristics: 1 - Age [years], 2 - Gender [F - female, M - male], 3 - Height [cm], 4 - Position [K - driver, M - train driver, R - paramedic]

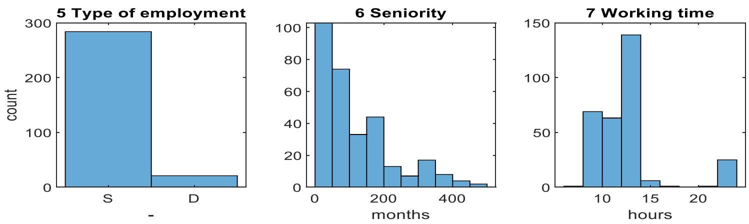

Fig. 2. Histograms of the counts of the features "personal data 5-7": 5 - type of employment [S - permanent, D - casual], 6 - Seniority [months], 7 - Working time [hours]

Based on the histograms, it can be seen that the distributions presented are not normal or not regular. The biggest difference is in gender and type of employment; most of the respondents are men, and most of those employed have permanent jobs.

Fig. 3 shows histograms of the number of responses to questions about psychophysical feelings, such as the level of perceived stress (small, medium, large, very large), psychophysical condition (I have no opinion, bad, good, very good), the level of perceived fatigue at the end of work (small, medium, large, very large). Fig. 4 shows histograms of responses to questions about the workload of a large amount of information (no, yes), feelings of fear for one's life (no, yes), and amount of rest sufficient for recovery (no, yes), monotony.

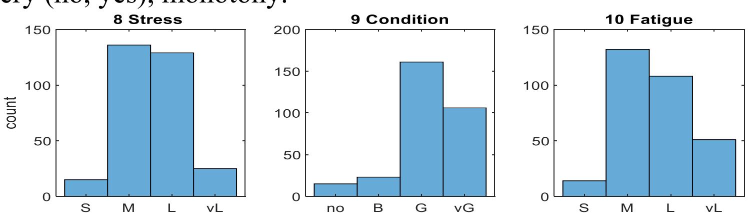

Fig. 3. Histograms of the counts of the characteristics "feelings of psychophysical fitness 8-10": 8 - level of perceived stress [S - small, M - medium, L - large, vL - very large], 9 - psychophysical condition [no - I have no opinion, B - bad, G - good, vG - very good), 10 - level of perceived fatigue at the end of work [S - small, M - medium, L - large, vL - very large]

The distributions of the described characteristics of mental and physical conditions are also not normal. Respondents indicated a medium to high burden of stress, information overload, and a lack of time for rest. On the other hand, it is positive that respondents nevertheless indicated good psychophysical conditions.

Fig. 5 shows the histograms of the number of responses to questions on the impact of the environment and surroundings on the quality of work: the pressure of the environment to be responsible for the lives of others (yes, no), the occurrence of aggression at work (no, yes), participation in training in ergonomics (no, yes). Fig. 6 shows histograms of the counts of the responses to questions about the following characteristics: time of day when work is most often performed (day, night), shift nature of work (no, yes), and a feeling of time pressure (no, yes).

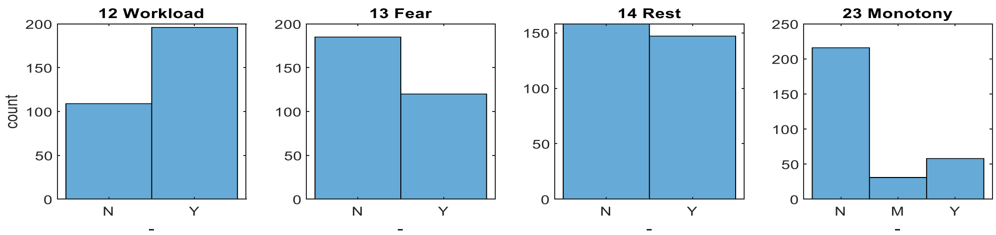

Fig. 4. Histograms of the counts of the following characteristics: "feelings of psychophysical condition 12-14": 12 - workload by a large amount of information (no, yes), 13 - Fear for one's life (no, yes) and 14 - Adequate rest for recovery (no, yes), 23 - Monotony (no, maybe, yes)

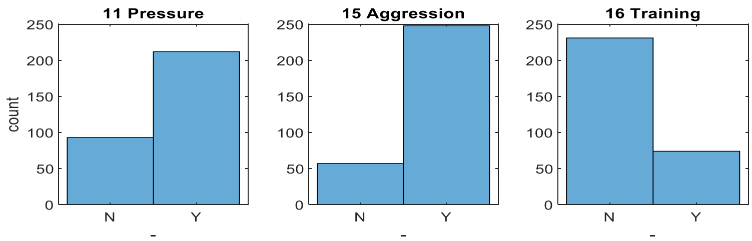

Fig. 5. Histograms of the counts of the following characteristics: 11 - environmental pressure to be responsible for other people's lives (yes, no), 15 - occurrence of aggression at work (no, yes), 16 - participation in ergonomics training (no, yes)

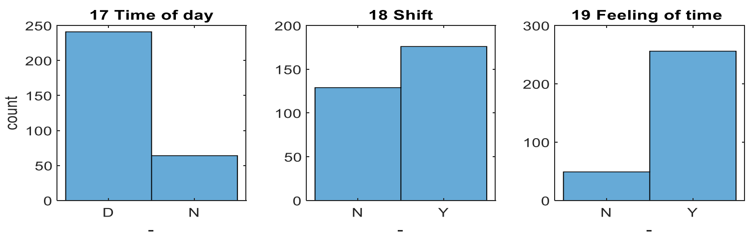

Fig. 6. Histograms of the counts of the following characteristics: 17 - time of day when work is most often performed (day, night), 18 - shift nature of work (no, yes), 19 - feeling of time pressure (no, yes)

The majority of operators feel pressure from their surroundings, have encountered aggressive behavior from others (passengers, victims), have no ergonomics training, work nine to 12 hours a day, work in harsh weather conditions, and feel they do not have enough time to do things properly.

The most important part of the study is the analysis of responses to questions about the ergonomic level of work quality. 25 such questions were formulated (with different answer options, as well as one open-ended question). Fig. 7 shows histograms of the number of answers to questions characterizing the workstation in terms of work position: forced and cumbersome (no, maybe yes, yes), safe (no, yes), comfortable (no, yes), providing proper space for performing activities (no, yes). Fig. 8 shows histograms of more detailed responses on this topic: correct adjustment of the dimensions of the workstation to the work to be performed (no, yes), easy access to control devices, easy access to other auxiliary equipment, and the occurrence of work discomfort after changing vehicles.

The majority of paramedics indicated that the position is cumbersome and uncomfortable even though the workspace allows the proper performance of activities. One-third of respondents indicated that the work position is not safe, and 132 respondents indicated that it is not comfortable. The latter two results can be considered disturbing. At the same time, the majority of respondents indicated that the dimensions of workstations and access to equipment are completely functional. These results require further detailed analysis to ensure a comfortable and safe working position.

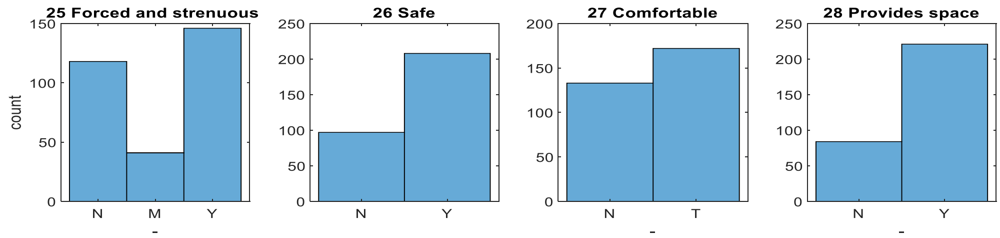

Fig. 7. Histograms of the counts of the following characteristics of the workstation position: 25 - forced and strenuous (no, maybe yes, yes), 26 - safe, 27 - comfortable, 28 - provides proper space to perform activities

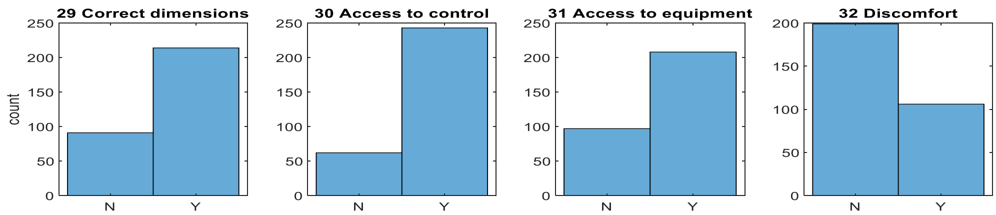

Fig. 8. Histograms of the counts of the following characteristics of the workstation position: 29 - correct adjustment of the dimensions of the workstation to the work to be performed (no, yes), 30 - easy access to control devices, 31 - easy access to devices of other auxiliary equipment, 32 - occurrence of work discomfort after changing the vehicle

Fig. 9 shows the results of the classification of responses to questions on the working conditions of limb movements and related ancillary requirements: weight handling (exposure to carrying heavy objects - no, yes), weight determination (values of the weight of the load carried during the work shift), monotypic movement (a significant number of repetitive movements of the hands, arms performed at the workstation - no, yes), applied force (the use of equipment at the workstation requires the use of excessive force - no, yes). Fig. 10 shows self-assessment responses: severity of work (very light, light, medium, heavy, heavy, very heavy), ergonomics (the workstation is ergonomic, i.e., adapted to the capabilities and needs - no, yes), severity of ailments (severity of ailments - none, small, medium, large, very large), position (holding one position for a long time - no, yes).

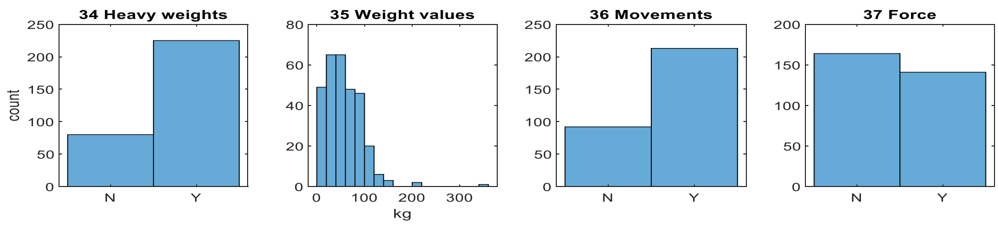

Fig. 9. Histograms of counts for responses to the following questions: 34 Weights (exposure to carrying heavy objects - no, yes), 35 weight (values of the weight of the load carried during the work shift), 36 movements (significant number of repetitive movements of hands, arms performed at the workstation - no, yes), 37 force (use of equipment at the workstation requires the use of excessive force - no, yes)

Ergonomic working conditions regarding hand movements are moderately heavy. More than 2/3 of respondents complain of having to carry heavy loads, with the indicated total weight of loads carried averaging about 50 kg. The need to maintain an uncomfortable position for long periods of time was also noted. Further responses showed the most common complaints are related to the lower back.

3.2. Correlation analysis results

Before starting the analysis, the most important relationships, the strength of whose linear relationship was planned to be determined, were extracted. These relationships were defined as "basic." The strength of the linear dependence of each relationship was described by Pearson's linear correlation coefficient.

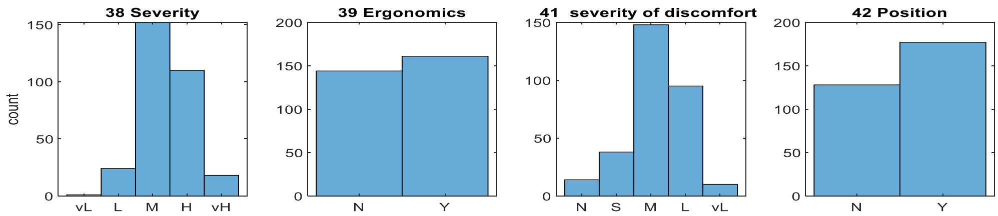

Fig. 10. Histograms of counts for responses to the following questions: 38 severity (rating of the severity of the work performed - [vL-very light, L-light, M-moderately heavy, H-heavy, vH-very heavy]), 39 ergonomics (the workstation is ergonomic, i.e. adapted to the capabilities and needs - no, yes), 41 severity of discomfort (Severity of discomfort - N-none, S-small, M-medium, L-large, vL-very large), 42 position (Holding one position for a long time - no, yes)

Table 1 gives the results of the calculations and the category labels into which we include the analyzed relationship of "basic" nature, according to the following classification: no linear relationship, weak relationship, moderate relationship, fairly strong relationship, very strong linear relationship. It can be seen that fatigue decreases with the length of rest and increases when the work position is forced. Pain complaints also depend on the working position. We classified the relationship between stress level and information load as "no linear relationship," although this result is at the limit of statistical error. In addition to the basic relationships, we analyzed the dependence of individual responses on the basic personal parameters of the respondents as defined by the test metric. Fig. 11 shows a dot plot of Pearson coefficient values (characterizing the linear relationship) of the dependence of obtained responses to the question about "feeling of stress level" on personal parameters. The strength of the linear relationship was classified as follows: no correlation ($|rho|<0.2$), weak correlation ($0.2<=|rho|<0.4$), average ($|0.4<=rho|<0.7$), strong ($0.7<=|rho|<0.9$). Note that the most statistically important dependence is the increase in the level of stress with increasing working time (variable "7"). The other correlations shown in the figure are not statistically significant, so we put them in the "no linear relationship" category, although it is possible to find a minimal dependence of stress level (with a margin of error) on location (province "1") or type of job ("4").

3.3. PCA factor analysis results

The PCA method belongs to the group of correlation studies [19-20]. Its special case is factor analysis, which makes it possible to determine regularities and hierarchies in the structure of data [22]. Undoubtedly, the advantage of the method is that it does not require initial assumptions to be made about the relationships between variables, meaning the results obtained are quite objective. In PCA, it is assumed that the information potential of the factors is assessed by means of variance (i.e., a characteristic that describes the spread). However, it can only be used for numeric type data, which requires converting all categorical or string data (described in words) into numeric values. In addition, the data must be standardized z-scores:

$$ZscData=Zscore(Data) \tag{1}$$

where: Date - survey results in numerical form, ZscData - survey results after standardization.

The PCA coefficient matrix is a pivot matrix by which the primary variables (i.e., input variables) can be brought to the factor reference system, which is expressed by the formula:

$$[Score,\ latent]=Coeff\ x\ (ZscData) \tag{2}$$

where: Score - principal component scores, Coeff - matrix of principal component coefficients, ZscData - raw data matrix, latent - percentage of explained variance in factors.

PCA converts primary (or input) variables into abstract factors using a linear transformation that minimizes variance. In factor analysis, we can determine, among other things, the stock of common variance between input variables and factors. The contribution of the variables to the factor is based on the coefficients of the PCA matrix, calculated from the formula:

$$communality = coeff^2 * 100. \quad (3)$$

Table 1

Correlation analysis results

Relationship studied	Pearson's linear correlation coefficient value	Classification result (character of the relationship)
Stress - the type of work on the job	0.17	No linear relationship
Information load - the degree of workload	0.19	No linear relationship
Fatigue - level of rest	-0.39	Moderate relationship
Fatigue - forced and strenuous position	0.26	Moderate relationship
Fatigue - the space at the workstation	-0.14	No linear relationship
Fatigue - arrangement of control devices	-0.04	No linear relationship
Position at work - complaints: pain in arms, legs, lower back, neck	0.22	Moderate relationship
Use of excessive force - pain in arms, legs, lower back, neck	0.25	Moderate relationship
Heavy workload - pain in arms, legs, lower back, neck	0.29	Moderate dependence

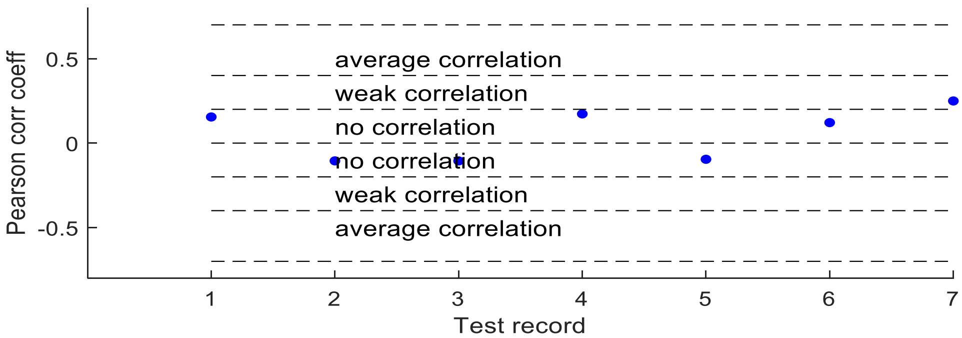

Fig. 11. Dot plot of Pearson correlation coefficient values describing the "stress level" response depending on the respondent's metric data. The labels of the metric are described as follows: 1 - province (location), 2 - gender, 3 - height, 4 - type of job, 5 - method of employment, 6 - length of service, 7 - number of hours worked per day

The result of the calculation indicates what percentage of the variation (variance) of the factor can be explained by the variation (variance) of the individual input variables. Since the contribution of the variables to the factor is normalized, we can interpret it as the weights of the contribution of the individual input variables to the factor. Thus, by multiplying the contribution by the variance of the factor described by the latent variable (describing the percentage of the explained variance in the factors), we get the contribution of the input variable to the stock of variance associated with the factor:

$$factor\ returns = communality * latent / 100. \quad (4)$$

After summing, the weights of the contribution of the variance of each input variable to the total variance are obtained:

$$variable\ validity = sum(factor\ returns). \tag{5}$$

Sorting the results of the operation yields variables ordered by share of variance. The results of the calculations shown in Table 2 are limited to the presentation of the most significant variables with the highest variance (between no. 33 and 50). The columns are marked as follows: I - the ranking position of the answer to the question according to its percentage variance (determined assuming that the sum of the variances of all answers is 100%), II - the number of the answer according to the order of the test questions, III - the percentage value of the variance of the answer to the question, IV - the group in which the answer is classified. The answer to question no. 8 at position 33 in the hierarchy of information weighting concerns the level of stress. The metric variables collectively contribute to over 19% of the variance in survey responses, with variable 8 explaining only 1.87%. Despite a perceived weak correlation between stress levels and personnel parameters, as depicted in Figure 11, utilizing a regression model holds promise for constructing a data reduction model. This model aims to elucidate the stress levels by leveraging employee data expressed through the metric variables, suggesting a potential avenue for a more nuanced understanding of the relationship.

Table 2

Weights of the shares of the variance of the input variables relative to their total variance (determining the informational significance of the input variables)

I	II	III	IV
33	8	1.8792	Feelings of condition
34	11	1.9222	Environment
35	41	1.9376	Quality
36	27	1.9571	Quality
37	16	2.0176	Environment
38	39	2.2034	Quality
39	19	2.2545	Environment
40	48	2.2906	Quality
41	15	2.4944	Environment
42	6	2.6050	Employee data
43	36	2.6355	Quality
44	4	2.6960	Employee data
45	47	2.8847	Quality
46	50	3.2537	Quality
47	32	3.2553	Quality
48	7	3.4278	Employee data
49	49	4.8916	Quality
50	5	5.6203	Employee data

3.4. Regression analysis results

Regression analysis is performed to develop a model that represents the relationship between explanatory (input) and explanatory (output) variables using an appropriately selected functional relationship, describing this relationship in the most simplified way possible. In this case, it was assumed that the input (explanatory) variables are metrics, and the output (explained) variables are stress levels. Matlab toolboxes (Regression Learner, Classification Learner) using cross-validation k_fold=6 were used to appropriately select the modeling function.

On this basis, the two best linear regression fitting methods were selected: support vector machine (SVM) and ensemble-bagged trees (EBT). Fig. 12 shows the results of estimating the stress level using linear regression with the SVM method, and Fig. 13 shows the estimates obtained using the EBT method.

Using the SVM method, we obtained a fit of 90% (number of incorrect estimates 28); using the EBT method, we obtained a fit of 97% (number of incorrect estimates: 5). We can consider these results as fully satisfactory. They will enable us to perform stress level prediction based on an employee's personal data from their metrics in the future. They represent our current belief in the dependence of the employee's stress level obtained from the research performed. If it is possible to repeat these studies in the future, the obtained models can be treated as a description of the a priori hypothesis (a description of the state of the stress level before the arrival of new data). In this way, it will be possible to check whether working conditions will improve in the future (in terms of "perceived stress levels").

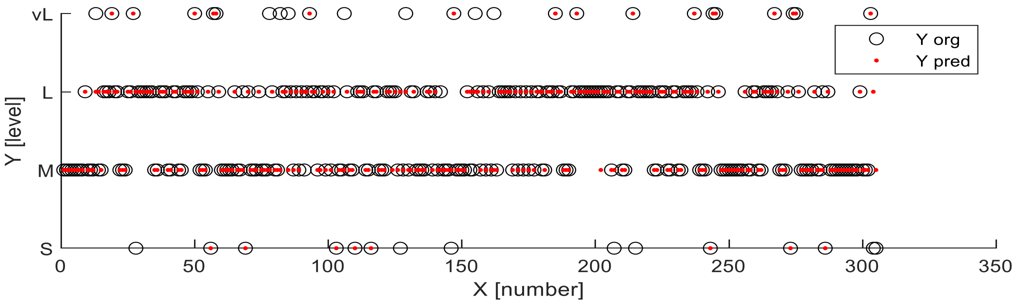

Fig. 12. Results of fitting by the SVM method with 90% fit: X- input data (employee's ordinal number), Y org - original output vari ables, Y pred - estimated output variables [S - small, M - medium, L - large, vL - very large]

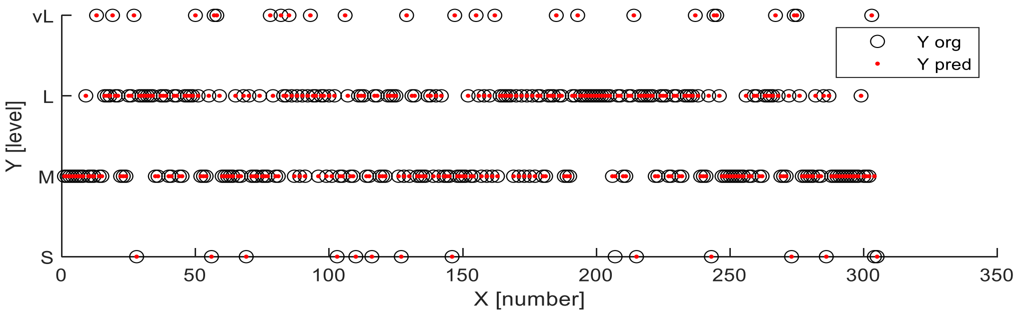

Fig. 13. Results of fitting by the EBT method with a 97% fit: X - input data (employee's ordinal number), Y org - original output variables, Y pred - estimated output variables [S - small, M - medium, L - large, vL - very large]

4. CONCLUSIONS

The statistical analysis of the survey results consisted of descriptive characteristics, correlation analysis, PCA factor analysis, and regression analysis. Descriptive characteristics indicated the quantitative characteristics related to exposures and discomfort. Among other things, it was found that the majority of transport operators feel pressure from their surroundings, have encountered aggressive behavior from victims, have had no ergonomics training, work nine to 12 hours a day in harsh weather conditions, and experience a shortage of time to perform their activities properly. In addition, the majority of respondents indicated that their position is cumbersome and uncomfortable even though the space at the workstation allows for the proper performance of activities. One-third of respondents indicated that the work position is not safe, and less than half indicated that it is not comfortable. The latter two results can be considered disturbing.

At the same time, most respondents indicated that the dimensions of the workstations and access to equipment are completely functional and that ergonomic working conditions regarding hand movements are moderately heavy. Given that most respondents had no ergonomics training, some of the responses may be inconsistent. More than two-thirds of respondents complained of having to carry heavy loads—with the indicated total weight of loads averaging about 50 kg—and of having to maintain an uncomfortable position for long periods of time.

The results serve as a prelude to further research aimed at improving the working conditions for operators. The presented histograms can serve as a basis for employers to take actions aimed at enhancing employee comfort and safety, including identifying sources of stress, providing specialized medical care, managing occupational stress, modifying workplace setups in accordance with ergonomic principles, reducing physical exertion, and providing employee training in the ergonomics of working conditions.

The results of the correlation analyses showed that "rest level," as a function of "fatigue," shows a decreasing relationship, while "pain in arms, legs, lower back or neck" depends on "work position," "use of excessive force," and "severity of work." This result indicates that "position at work," "use of excessive force," and "severity of work" are correlated. This type of correlation led to the conclusion that some of the variables can be grouped together as detected by PCA.

The results of the PCA confirmed that the data cluster under the form of factors and that there are factors whose information values are negligible. A similar conclusion applies to the input data (i.e., answers to test questions). The analysis revealed that the answers to only 15 of 50 questions exceeded the threshold of 2% information input to the test. Thus, if the survey could be repeated in the future, the correct results might be obtained with slightly fewer test questions. If the study is repeated in the future, the regression model developed that describes our previous belief in the functional dependence of the stress level could constitute a record of the "a priori hypothesis." The new test data would make it possible to verify our previous hypothesis regarding the influence of employee parameters on the level of stress experienced by the employee.

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