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USING ERGONOMIC ANALYSIS AND EVALUATION OF WORKLOADS TO OPTIMIZE WORKSTATIONS THAT REQUIRE PHYSICAL WORK

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Abstract:
Without any doubt, we are living in a very modern, sophisticated, and computerized world, in which a great part of the activities done in the past by workers, are now carried out by machines or intelligent devices, capable to communicate with the environment and to make decisions according to the information received from there. The ergonomics science adapted during the time, introducing in its area of study the effects of the human-computer interaction, the new forms of stress, and the new factors which are affecting the work at the workstations. However, there are still workplaces where physical work is prevalent and where it is necessary to analyze the work conditions to improve them and to avoid injuries during the work.
This study is based on the research which has used ergonomic analysis, namely the LEST method for the optimization of the work of handler workers at a Romanian company with several working points in different regions of the country. The working points are equipped with different endowments depending on the period when they operate. The study reveals that the handlers are facing different problems at their workstations depending on the technical level of the equipment they use and the organization of the work. The same tasks lead to different perceptions and different levels of fatigue for the workers.
The ergonomic analysis offers the possibility to identify the stress factors for each workstation and optimize them to provide optimum work conditions in which the worker can perform in the best way.

Key words: physical work, ergonomic analysis, and evaluation, workstation, handler

JEL classification: M 540, M 590

1. INTRODUCTION

Nowadays, the activity of employees faces challenges from different directions, which lead to complex and specialized workplaces which must be designed according to the requirements of social and economic efficiency. A workstation is a place where a worker operates several hours per day in specific conditions with a definite purpose. To reach the goal it is necessary to exist a balance of adaptation between the workstation and the worker, which means that the workplace should be operated by different workers with a certain knowledge and skills background. The balance of adaptation consists in finding the right employee for every workstation and this is a human resource management problem. The ergonomic analysis and evaluation is used to design the workstations in accordance with the goal of work, but, at the same time, with the workers' capabilities and skills.

The ergonomic analysis of work tasks was performed for the first time at the beginning of the XX century by Frederick Taylor and the by Frank and Lilian Gilbreth which introduced the scientific study of work (Manolescu, 2010). The real development of the ergonomic analysis and the use of the results for the workstation design has begun in years '50 of the previous century, concurrent with the development of industry and with the huge request of the workforce in this area. Helander (2006) gives big importance to the ergonomic analysis, considering it a fundamental method for gathering information from the workstation and using it for the improvement of the workplace itself. He described a continuous process of ergonomic design of workstations based on the ergonomic analysis and evaluation.

The ergonomic analysis has been enriched with new methods and tools, both for physical and intellectual work with general application or specific for a certain workplace: methods for workplace analysis and workplace risks, methods for effort evaluation, musculoskeletal disorders, muscle fatigue, different types of questionnaires elaborated for specific workstations, checklists, protocols, focus groups and many other (Stanton et al, 2005). In ergonomics, there is a real symbiosis between scientific research and application in practice. It means that there are methods, tools, and other information developed through an application in practice which were confirmed and improved by scientific research and vice-versa, the results of theoretical studies developed in scientific research were applied in practice and the results contributed to the improvement of the research.

In the ergonomic analysis, there is not a mandatory number of participants, the analysis is applied for a specific workstation and/or for all the employees who work at that workplace or in the same conditions. It is possible to perform an ergonomic analysis and evaluation for one workplace if the goal is its improvement. Due to this fact, the ergonomic analysis can't be generalized, it is valid only for the workstation and conditions for which the process was conducted.

In our work, we used the LEST method for analysis and evaluation of the work tasks applied for the handler position. The method offers scientific support for the description of the present situation for the analyzed workplace, identifying the activities/conditions/ factors which need to be improved.

2. PHYSICAL WORK – GENERAL APPROACH

From the beginning of his existence man has carried out conscious activities with well-defined purposes, known as work. The first form of work was the physical work, in which the workers have to do actions as handling and moving objects, pushing or pulling, ample physical movements for the whole body or important parts of it. Today, although in many situations, the physical work of employees has been replaced by machines or robots, there are still many activities that require physical effort. In the developed countries, where the number of physical jobs has decreased, the physical work faces another challenge: the work became more static, stationary, and asymmetrical, stresses which are, sometimes, riskier than the dynamic effort. In developing countries, physical jobs are still representing an important part of the workplaces. Some physical tasks are risky and can lead to musculoskeletal disorders. This is the reason for which the workplaces must be designed and monitored continuously from at least two points of view:

- regarding the ergonomic work environment, responsible with the design of working conditions and working tasks for each workstation;
- regarding the occupational health and safety of each employee.

The preoccupations for a correct design of the workstations which involves physical work led to a big number of international studies and, subsequently, a set of norms, standards, and guides which provide recommendations, methods, and techniques very useful in this complex process of adapting the workplace to the worker.

According to the Office Industrial Relations, Workplace Health, and Safety Queensland, (2021) there were defined five situations that characterized the physical work:

- physical work that requires high muscular effort;
- manual handling of objects/materials;
- static work;
- repetitive work
- work affected by vibrations

In all these situations the human body is directly affected and it is necessary to have appropriate occupational health management to avoid injuries and chronic fatigue. The core elements which define the physical work are the type of effort – dynamic or static and the strength or amount of muscular effort required to complete a particular task.

Physical work that requires high muscular effort refers to a wide range of activities related to agriculture, forestry, constructions industry, metallurgical industry, or mining in which the workers lift heavy weights, are working for a long time in awkward positions, at extreme temperatures, have to push or to pull heavy loads or working in an unstable balance.

Manual handling of objects/materials is a very common activity carried out in different fields of work like: logistics, warehousing, and transportation, nursery, supermarkets and shops, tourism, labs or food industry, in offices, in maintenance and repairs operations. For these activities, there are legally established limits that take into consideration the age and the sex of the worker. According to the Romanian legislation, in table 1 are summarized these limits for manual handling of objects/materials.

Table 1. Maximum permissible limits for manual handling of masses (in kg)

Types of handling	Frequency of operations	Men			Women		
		Age (years)			Age (years)		
		16-19	19-45	over 45	16-19	19-45	over 45
Lifting	rare	35	55	40	13	15	13
	frequent	25	30	25	9	10	9
	very frequent	20	25	20	8	9	8
Carrying	rare	30	50	40	13	15	13
	frequent	20	30	25	9	10	9
	very frequent	15	20	15	8	10	8
Pulling	rare	15			10		
	frequent	10			7		
Pushing	rare	16			11		
	frequent	11			7,5		

Source: own elaboration with information from Ministry of Labor and Social Solidarity and Ministry of Health and Family, (2002) "General norms of labor protection", Art.168, available at https://www.iprotectiamuncii.ro/norme/norme-generale-protectia-muncii.pdf

Regarding the frequency of operations, the same document defines rare the situation in which the manual handling represents less than 5% of the shift, frequent if these operations represent from 5 to 10% of the shift and very frequently the situation in which the manual handling of materials represents more then 10% from the shift.

Static work is defined as any position where the load on the musculoskeletal system is maintained for more than 4 seconds (Suszyński, Butlewski, and Stempowska, 2017). Due to the automation and computer utilization in more and more fields, a lot of activities became static: writing, computer work, lab work, jobs from the textile industry, control panel monitoring, activities from health systems as surgery, ophthalmology are only some examples of static work.

Repetitive work consists of a succession of activities that are carried out in the same way over and over again during the shift. In the major part of situations, the repetitive work is done by arms or arms and fingers, both with right and left part or only with one part. The ergonomic evaluation has established the level of risks for the repetitive work according to the number of motion patterns repeated during the work (Table 2).

Table 2. Similar motion pattern repeated by the arm and hand

Number of motions	Level of risk
10 times per minute or less	Low level of risk
11–20 times per minute	Medium level of risk
more than 20 times per minute	High level of risk

Source: own elaboration with information from Health and Safety Executive, *Assessment of repetitive tasks of the upper limbs (the ART tool)*, available at https://www.hse.gov.uk/pubns/indg438.pdf

The repetitive work is present in the food industry, in wood processing, in the electronic industry, in mechanical and maintenance work, in office computer work, and others.

Work affected by vibrations is another form of physical work; the vibrations can affect the whole body or only a part of it, usually, we talk about hand-arm vibrations and whole-body vibrations. The first situation is specific to the workers which are using grinders, clipping hammers, plate vibrators, rock drills, etc. and the whole-body vibrations are present when workers are near heavy machinery which produces vibration while operating or themselves are working with forest machines, graders, tractors, military vehicles, etc. According to the European Directive (2002/44/EC), the daily exposure limit at vibrations is calculated based on a standardized eight-hour reference period and has the following values:

Table 3. Action values and exposure limit for workers affected by vibration, calculated for an eight-hour period

	Hand-arm vibrations	Whole-body vibrations
Action value	2.5 m/s^2	0.5 m/s^2
Exposure limit	5 m/s^2	1.15 m/s^2

Source: own elaboration with information from International Social Security Association (2010), *Guide for Risk Assessment in Small and Medium Enterprises. Hazards arising from whole-body and hand-arm vibrations*, available at https://ww1.issa.int/sites/default/files/documents/prevention/2Vibrations_en-36313.pdf

The ergonomic evaluation for workstations with physical work aims to evaluate the type of muscular contractions (static, dynamic), the intensity of the contraction, and the individual characteristics. According to the results of the ergonomic evaluation, it is possible to design correct the workstations so that the worker not be overloaded, meaning the muscular effort doesn't exceed the worker's physical capacities. In this case, the body is able to adapt to the load and recovery is quick when the worker stops.

3. ENERGY CONSUMPTION ASSOCIATED WITH PHYSICAL WORK

For a person to be able to move and work, he needs a daily supply of energy. When a person works harder or makes an effort for a longer period, the need for energy increases, and a series of effects inevitably occur in his body. Specifically, the rhythm of breathing will be faster and deeper to increase oxygen supply, and the heart rate will increase with the activation of automatic biochemical and nervous control systems of the body. Through the blood, more oxygen will be transported from the lungs, and the excess heat from the area of the muscles that contract as a result of the effort will be transported throughout the body, causing an increase in its temperature.

To avoid endangering the health of workers, different methods and techniques are used to measure physical work and express the magnitude of energy consumption in calories per hour or minute for various physical activities or work intensities. For normal work activities, the heart rate should not increase by more than 40 beats per minute above the rest value, and the body temperature should not increase by more than 1°C above the rest temperature (World Health Organization, 1992). The energetic need for physical work is calculated taking into account the following factors: the sex of the worker and the intensity of the physical effort. All the energetic needs of the body are fulfilled through food intake. Table no. 4 presents the recommended values for three levels of physical work intensity.

Table 4. The need for food energy depending on the physical work intensity

	Daily energetic need [kcal/day]		
	Light work	**Moderate work**	**Hard work**
Men, 1.71 m high			
minimum acceptable weight - 54 kg	2335	2682	3164

maximum acceptable weight - 73 kg	2786	3199	3775
Woman, 1.59 m high			
minimum acceptable weight - 47 kg	1846	1941	2154
maximum acceptable weight - 63 kg	2223	2337	2594

Source: own elaboration with information from Naghiu A., Apostu S., (2009) *Alimente şi alimentaţie în mileniul III. (II) Necesartul şi consumul de energie alimentară*, Agricultura Journal, Vol 71, No 3-4 (2009), available at https://journals.usamvcluj.ro/index.php/agricultura/article/view/3599/3336 [accessed on the 1st of September 2021]

The values from the table above show a high energetic need for physical work, a well-known fact in ergonomic science. One of the goals of ergonomic research and analysis is the design of workstations in such a way that to reduce the physical effort for the workers and to improve their work conditions and environment. Some recommendations accessible for the managers are (Office Industrial Relations, Workplace Health, and Safety Queensland, 2021):

- purchasing goods in small loads for easier manual handling or in large loads for handling with specific devices;
- reduction of the size or weight of the loads;
- use of hooks or tools to pull the loads;
- use of pallet trucks or forklifts to move large or heavy objects;
- use of conveyor belts where the transport distance is long and the storage place is the same.

Applying these measures, as well as others specific to the workplace, will lead to a reduction in energy consumption, and exposure to prolonged physical exertion. At the same time, these measures will protect the workers' health, prevent muscular overload, and will avoid musculoskeletal diseases.

4. RESEARCH METHODOLOGY

4.1. SHORT PRESENTATION OF LEST METHOD

As was mentioned previously, I have carried out an ergonomic analysis based on the LEST method for the handler workplace. The method was developed by the Laboratory of Ergonomics and Sociology of Work from France and it is recommended for workplaces with a low level of qualification. The analysis takes into consideration the influence factors of the workstation, divided into five areas (Manolescu, Lefter, Deaconu, 2013):

- physical environment
- physical effort
- mental stress
- psychosocial factors
- work time

For each area the influence factors are explicitly identified (16 in total for all five areas) and, for each factor, the method recommends a number of parameters to evaluate during the research. This is the flexible part of the method application because gives the possibility to select only the parameters which characterize the analyzed workplace. The workers have to evaluate each parameter with a 10-level evaluation grid in which (Manolescu, Lefter, Deaconu, 2013):

- the values 0, 1, and 2 are given if the parameter doesn't cause fatigue;
- the values 3, 4, and 5 are given if the parameter causes slight fatigue;
- the values 6 and 7 are given if the parameter leads to medium fatigue;
- the values 8 and 9 are given if the parameter leads to significant fatigue;
- the value 10 corresponds to the employee overload.

The LEST method has both an objective and subjective character; the objective character is given by the quantitative variable analyzed during the evaluation process and the subjective character is represented by the opinions of the workers regarding the work they perform. An advantage of applying this method is that its implementation does not require expertise and is designed in such a way that all staff involved participate in all phases of the evaluation process (Diego-Mas, 2015).

4.2. RESEARCH DESIGN AND APPLICATION

The research was carried out at the Marelvi SRL Company active in the field of distribution and commercialization of household electrical appliances: refrigerators, freezers, washing machines, stoves, televisions, IT products, kitchen appliances, boilers, vacuum cleaners, ovens, hobs, and air conditioners. The activity has started in 1995 as a local, family business and had a continuous development being now a national-level company. The headquarter is situated in Radauti (Suceava County, Romania) with two more offices and warehouses in Bucharest and Deva. The main customers of the company are represented by the big supermarket networks such as Carrefour, Auchan, Dedeman, Altex, E-mag, Media Galaxy, Flanco, Cora, where the distribution is ensured only for the brands for which the company has the title of the sole importer.

The distribution activity carried out by Marelvi Company requires a very good organization and a sufficient number of staff in the warehouses to load and unload the goods from the cars, as well as to store them in the warehouse space. In the company's three warehouses, the majority of the staff is represented by handlers and this is the reason I have focused my research on handlers' perceptions about their work conditions. The total number of handlers, participants at the research was 15, of which 6 are working at Radauti warehouse, 4 in Deva, and 5 at the Bucharest warehouse.

The research was designed with the following steps:

- studying the conditions in which the activity is carried out and selecting the specific parameters from the list recommended by the LEST method for each influencing factor;
- formulating the research hypotheses;
- preparation of the questionnaire specific to LEST method for data gathering;
- application of the questionnaire to all handlers from all three warehouses;
- data processing both at the company level and for each warehouse;
- conclusions and recommendations for the improvement of the handler workstation.

After the study of the specific work condition for the handler job, I have formulated two hypotheses:

H1. The perception of the handlers about the working conditions will be similar or very near, no matter the warehouse where they are working.

H2. The technical endowments influence the perception of the handler regarding the working conditions.

After the application of the questionnaires, the data were centralized and used for the calculation of the impact degree of each factor on working conditions. First, it was calculated the arithmetic mean for each parameter and all handlers from all warehouses, then it was calculated the mean of the means for each influence factor taking into consideration the parameters associated with each factor. The same calculus was made for the five areas defined by the LEST method.

This logical approach was applied again for each warehouse separately to compare the perceptions of the handlers from different locations.

5. CONCLUSIONS

5.1. THE RESULTS OF THE ERGONOMIC ANALYSIS FOR HANDLER POSITION

The application of the LEST method leads to interesting results regarding the organization and work conditions for handlers. The results of the calculations described above were used to plot the workplace histogram which allows a rapid conclusion on the most stressing factors. Figure no.1 represents the histogram for the handler workplace in Marelvi Company.

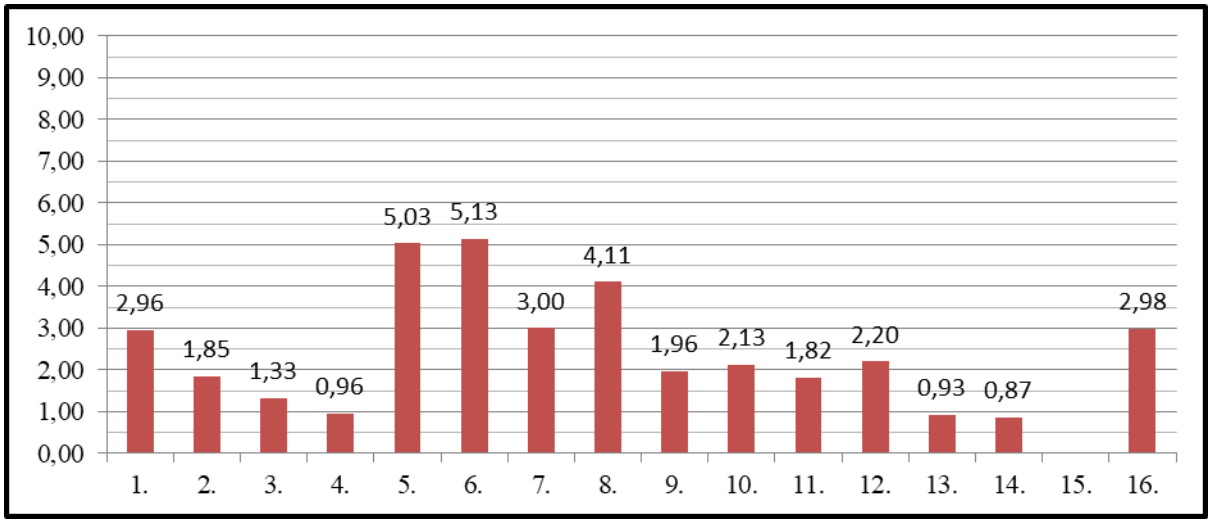

Fig. no.1. Histogram for handler workplace

Source: own elaboration with data from research

Legend			
1. Thermal ambiance	5. Static effort	9. Attention	13. Communication possibilities
2. Noise	6. Dynamic effort	10. Degree of detail	14. Cooperation
3. Lighting	7. Working time pressure	11. Initiative	15. Checking the products made
4. Vibrations	8. Complexity, speed	12. Professional training	16. Working time

For a significant ergonomic analysis, there were considered only the factors which contribute to at least a slight fatigue, meaning the factors with values bigger than 3. The first conclusion from the workplace histogram regards the level of fatigues caused by the influence factors; the highest values were obtained for static effort (5.03) and dynamic effort (5.13), which means that they induce a slight to medium fatigue to the handlers. The main factors which lead to this fatigue are standing posture and its prolonged duration, as well as significant energy consumption during the handling of goods. We consider it is a normal result, taking into consideration that these factors are specific to the handler's work. The next value from the histogram is 4.11 obtained for the factor complexity and speed. It suggests that the handler work is not a standardized one, it depends on the volume, dimensions, and weight of the boxes they have to handle and store in the warehouse. Sometimes the movements have to be rapid and precise, which will put extra pressure on the worker. The last factor analyzed is the working time pressure, which registered an average value of 3. The concrete parameters included in this factor and scored by the handler are the actual working time, the number and duration of breaks, time for surveillance, and how they are paid for the work. From these, the actual working time and the payment are considered more stressful, than the other two, being scored with values over 4. We can conclude that the handlers sometimes have to do extra work and are not very pleased with their payment; on the other hand, there are no problems with the breaks, they can take a break when they need it.

All the other factors included in the LEST method are scored with values less than 3, which means they are not perceived as factors that cause fatigue. For these factors, it is necessary to be monitored from time to time to see their evolution.

5.2. SAME TASKS, DIFFERENT PERCEPTIONS

The general results presented above are not enough to make decisions regarding the improvement of the work conditions for the handler position at Marelvi SRL Company. It is necessary a detailed analysis at each warehouse, especially because there are big differences between the scores given by handlers from different location for the same parameter of LEST method. The analysis for each warehouse will allow the identification of the best solution for the factors that hinder the daily activities for each region. For example, in the case of the factor that defines the thermal environment, more specifically, the parameter of temperature differences between seasons, it registers different values in the Rădăuți area, compared to the one in the Bucharest area, where the climate is milder.

Based on the data centralized after the application of the LEST questionnaire, I drew the histogram for each warehouse and compared the scores for the same factor. In the following figures, there are represented in a compared form, the histograms for the three working points, grouped according to the areas defined by the LEST method.

The first area is the physical environment in which are working the handlers; it includes the thermal environment, the noise, the lighting, and the vibrations. According to the scores given by the handlers, only the thermal environment has values of more than 3, the other factors are between 0.67 and 1.95 which indicates that they are not causing fatigue during the work. From the three warehouses, the best situation is in Bucharest, with a score of 2.77, and the worst in Deva, with a score of 3.08. These scores are due to the physical effort and the duration of physical effort which are the main causes for the workers' fatigue. The most tired are the handlers from the Radauti warehouse, the oldest one, and the least automated of all three.

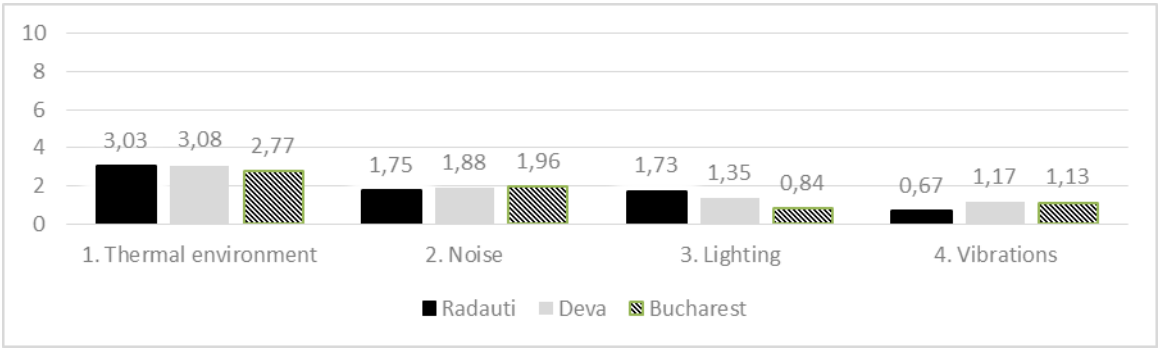

Fig. no.2. The histogram for the Physical environment

Source: own elaboration with data from research

The second area defined by the LEST method is the physical effort which has two factors: static effort (or demands) and dynamic effort. It is obvious that these are characterizing the main activities carried out by the handlers and are causing fatigue during a working day. Although the tasks are similar for all handlers from the three warehouses, the perceptions are different, we can say very different, as are shown in the histogram below.

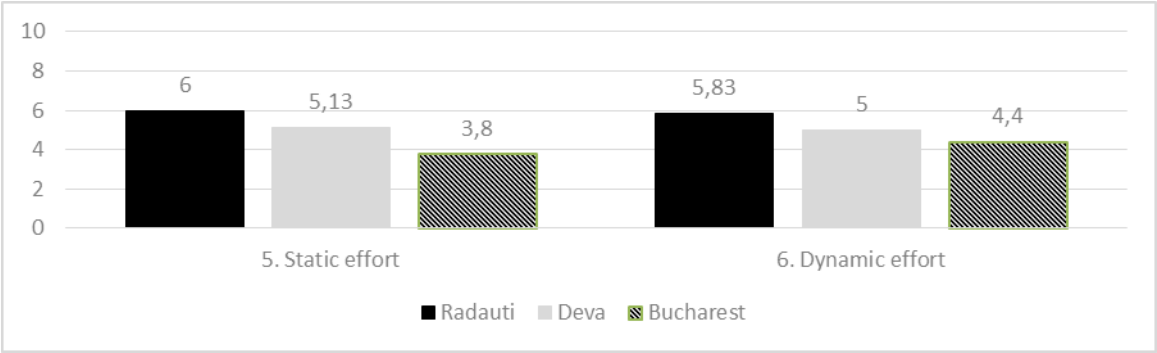

Fig. no.3. The histogram for Physical effort
Source: own elaboration with data from research

Indeed, these two factors have a big impact on the fatigue perception for the handlers, more than the previous ones. The maximum value is 6 for static effort, given for the handler from Radauti warehouse which are feeling medium fatigue during their work, compared with their colleagues from Bucharest warehouse, which score this factor with 3.8 (slight fatigue). The situation in the Deva warehouse is nearer to Radauti, the difference between the two values being small. In the case of dynamic effort, the hierarchy is the same, but the values are not so different. The explanation of this result refers to the technical endowments of each warehouse. The oldest is the one from Radauti, which has a different design, is less accessible, and with fewer machinery. The newest is the Bucharest warehouse, with more loading and unloading ramps, and more accessible and better compartmentalization of the warehouse by product areas. The management should pay attention to these two factors to harmonize the working conditions of the handlers of all company warehouses.

The third area defined by the LEST method is mental stress with three factors: working time pressure, complexity, speed, and attention. As we noticed from the general histogram of the workstation for the company, here there are activities that lead to fatigue during the work.

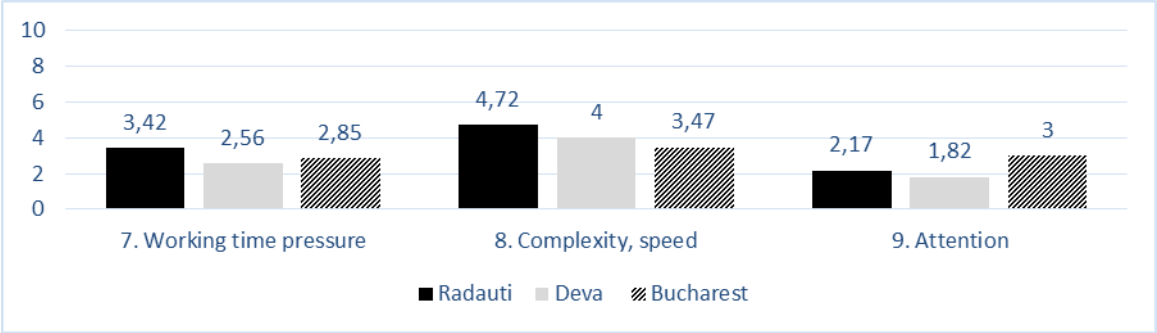

Fig. no. 4. The histogram for Mental stress
Source: own elaboration with data from research

The factor with the biggest impact on the fatigue perception is the complexity of handling activities and the speed of acting, which causes slight fatigue at Bucharest (value 3,47), but with 36% bigger in Radauti. This difference is caused by the fact that Radauti warehouse is the central one, with a more complex activity and a bigger work volume. Regarding the working time pressure, only in Radauti the factor the value exceeds the limit of 3 for slight fatigue, the explanation being connected to the role of the central warehouse of this location. The third factor – attention – doesn't cause fatigue but we can notice again big differences between the perception or workers from different location; the value scored for the Bucharest warehouse is the biggest, with 40% bigger than the smallest value scored for Deva warehouse. The parameters included in the Attention factor refer to the level of attention required by the handling operations, the level of the frequency of risks associated with the work. The value scored by the handlers show that the more complex the means of work used, the more attention is required and the risk of accidents increases.

The next area analyzed refers to the psycho-social factors and includes: how fine is the work, initiatives, professional level, communication, and collaboration between colleagues. All the values scored by the handlers are below 3, some of them below 1 which show that these factors are not causing stress or fatigue during work. Indeed, the handlers can have initiatives in organizing their work, usually communicate and collaborate with each other in their activity. The work doesn't require a high level of professional preparation and it is not fine (detailed) work. The results of the investigation are presented in figure no. 5.

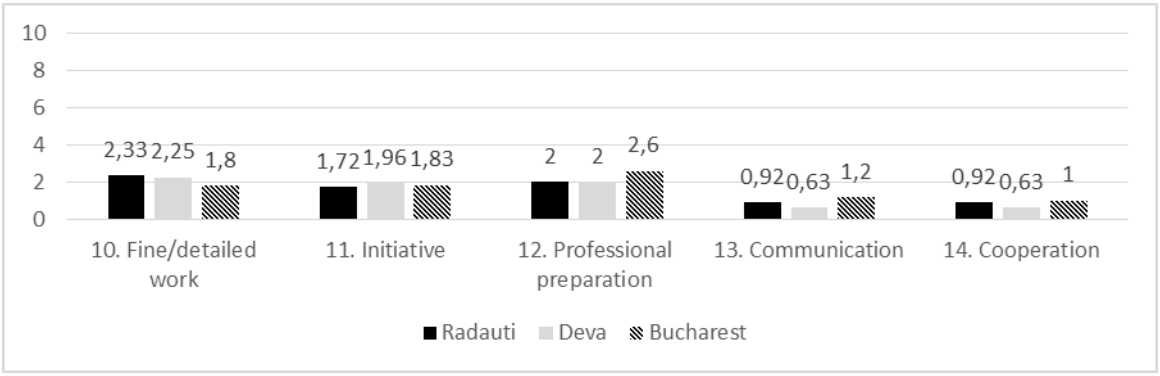

Fig. no.5. Histogram for psychosocial factors
Source: own elaboration with data from research

A final remark is about the professional background of the handlers: the results show a direct connection between the technical level of the warehouse endowments and the professional requirements. In Bucharest, where are used modern and more complex technical systems, the workers must have a higher professional level and this fact is perceived as a stress factor.

The last area analyzed in our research is the work time which includes the daily schedule, the duration of the work week, and how much time need the workers to arrive from home to work point.

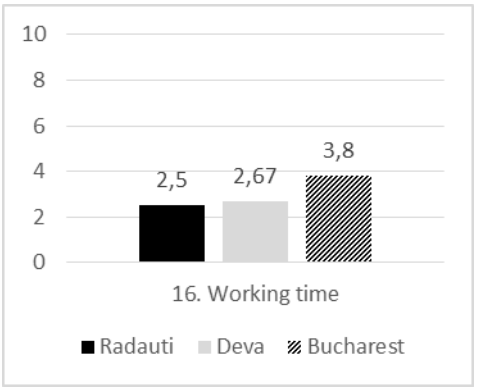

Fig. no. 6 Histogram for Working time
Source: own elaboration with data from research

From the graph, we notice more intense fatigue perceived by the handlers from the Bucharest warehouse compared with the other locations. The daily schedule and the duration of the work week are the same for all the warehouses, so the parameter which induces the difference is the transport time from house to work. In Bucharest, the warehouse is situated outside the city and it takes a lot of time to arrive from home to work, which causes extra fatigue to the workers. It is a difficult problemme for the management and very hard to solve since the handlers are living in different parts of the city.

5.3. SUGGESTIONS FOR THE IMPROVEMENT OF THE WORKSTATION

The goal of the application of the LEST method was the improvement of the work conditions based on the handlers' perceptions regarding the factor which cause fatigue. The analysis highlighted the main workspace parameters and their contribution to the general fatigue perceived by the employee. Consequently, we can formulate a set of proposals for the improvement of handlers' work from Marelvi SRL Company:

- better insulation of the Radauti warehouse to reduce the temperature differences between seasons and to assure a more constant inside temperature;

- the modernization of the technical endowments at the same warehouse, taking into consideration that it is the central one, with a bigger volume of activity, but the oldest machines;
- regarding the static and dynamic effort, which is bigger in the Radauti warehouse, we propose the organization of work in two shifts to avoid the pick of activity that demand sustained effort over a long period from the handlers.

Analyzing the results of the research correlated with the two hypotheses we can conclude that the first hypothesis is partially confirmed because we found a big number of parameters from the work environment which induce different levels of fatigue although is the same company and the same job. The second hypothesis is confirmed, the technical endowments have a positive effect on the perceived level of fatigue, the handlers from Bucharest warehouse being the least tired due to the modern work point where they are working.

The ergonomic analysis is an effective and detailed research tool, able to offer a big volume of real and detailed information about the organization of the work and about the perception of the employee regarding the stress parameters which are causing fatigue.

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