Agronomy Research **16**(4), 1762–1770, 2018
https://doi.org/10.15159/AR.18.169

Ergonomic modelling parameters and the influence of ergonomics on planning workplaces

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Abstract. Modern economic research divides all economics into structural levels: mega-economics, macroeconomics, meso-economics, micro-economics, and nano-economics. From the point of such traditional divisions, the research is topical in the primary economic structure of society – nano-economics – and thanks to this work operations can be subdivided into workplaces in the form of transformation processes. The aim of the research is to develop ergonomic modelling parameters and to discover the influence of ergonomics on the planning of workplaces based on a case study. The research involved a study of workplace ergonomic planning methods and principles. Solutions for a series of problems which are related to the improvement of workplace ergonomics may be discovered in the following ways: improving work organisation in every workplace by using work process-related micro-elemental methods and a determination of work expenditure, the levels of physical strenuousness involved in the work, the complexity of the work, and the social importance of the workplace. These parameters will allow the workplace quantity characteristics to be discovered, such as in terms of a generalised parameter which conforms to the requirements which describe a workplace, and in terms of operational management via the condition of workplaces and the salary systems being utilised. The research provides a case study in which ergonomic modelling parameters are developed and concrete workplace interventions are introduced.

Key words: human factors, work, workplace, case study, intervention.

INTRODUCTION

The term ‘workplace’ has many interpretations which have a lot in common. The founders of scientific management had no clarity when it came to precisely what constituted a ‘workplace’. They assumed it was an intuitive term, a place in which working activities were carried out (Taylor, 1919; Gastev, 1972; Gastev, 2011).

Over time it became necessary to standardise the term ‘workplace’. In 1943, the American Society of Mechanical Engineers (ASME) focused on the unification of the term ‘workplace’. As a consequence of discussions, the ASME came to the conclusion that the term ‘workplace’ was part of a production space in which an employee carries out their duties.

The International Labour Organisation explains the term ‘workplace’ as including all places in which workers need to be to carry out their duties or from which they need to be followed in connection with their work where they are directly or indirectly under the direction of their employer (ILO, 2018).

In GOST 12.1.005 (1989), the term ‘workplace’ is given the following definition: ‘a place involving a permanent or temporary stay when working during the course of carrying out one’s working activities’. Hence researchers provide several definitions for the term ‘workplace’, and it may be concluded that in most studies it is a place which is equipped with the necessary technical means so that an employee can carry out any working activity.

In order to further expand the concept of the ‘workplace‘ and move onto the concept of ‘ergonomic workplace passport‘ with the concept of ‘the working activities of an individual’ which are common to sociology, economics and engineering, with: ‘the workplace being an elementary part of the production space in which the allocated means of work, equipment which is required for that work, and the object of the work itself are interrelated with the implementation of individual work processes in accordance with the function of obtaining the product of the work’. The primary scheme for a system in which workplace elements interrelate in accordance with the previously stated definition is shown in Fig. 1.

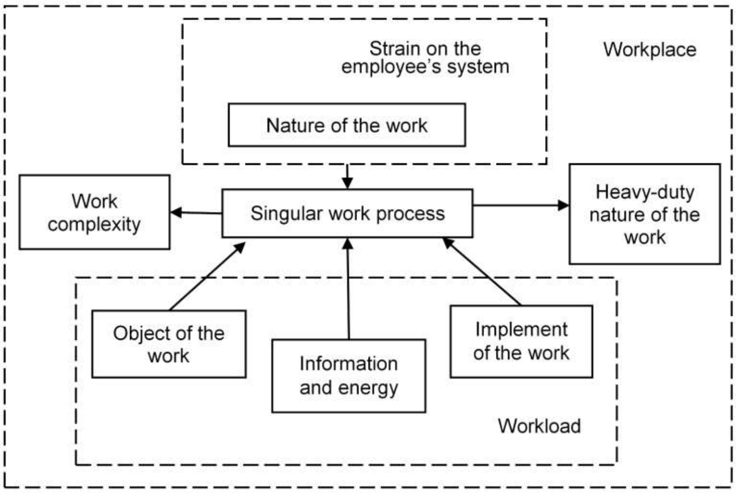

Figure 1. Structural scheme for the workplace (short version).

Successfully implemented and modelled ergonomics for workplaces are very important in terms of the continuous process of improvement, and can result in the optimum functioning of the socio-technical system, one which ensures employee safety at work, psycho-social comfort, improvements in life quality, and providing an influence on one’s motivation for the work (Kalkis & Roja, 2016). Hence the implementation of ergonomic modelling parameters which require careful planning and influence analysis.

An ergonomic evaluation of the workplace has been carried out across quite a long period of time because the layout of the workplace is the primary value when creating a physical workplace (Bhattachary, & McGlothlin, 2012). To measure the quality of the workplace the methodology presented in Perevoshchikov (1974; 2015) and Orefkova's work (1990; 2005) were both utilised.

The combination of qualitative, quantitative, emotional, and sanitary-hygienic parameters form the concept, 'the ergonomic workplace passport'.

MATERIALS AND METHODS

All workplaces and all places which must be visited during the course of one's everyday life must have a detailed passport. This has to take the form of an official document. To achieve these objectives, the term 'ergonomic workplace passport' is introduced. This takes into account the qualitative and quantitative characteristics of the workplace and the time spent at work.

Currently, the study focuses on engineering production, and the methodology entitled 'the ergonometric workplace passport' has been developed. Such a methodology provides legal implementation as an integral part of a collective agreement.

The development of methodology entitled 'ergonometric workplace passport' involves various elements that need to be analysed, including the following:

1. The parameters of the object of the work;
2. A list of operations in the workplace;
3. The workplace layout and its ergonomic parameters, including a 3D model creation of the workplace;
4. Work process analysis in the workplace using predetermined motion time systems (PMTS);
5. Calculations for the coefficient levels of physical strenuousness involved in the work , the complexity coefficient, the working conditions coefficient, and the neuro-emotional pressure coefficient in the workplace;
6. The characteristics of the social and production status in the workplace.

In order to be able to determine the quantitative characteristics, the best system to use is one which involves a microelement analysis of time. Microelement standards have their own development processes, and a large number of predetermined motion-time data systems have been developed (known as PMTS). The most prominent of these are as follows:

1. The method time measurement, or MTM (Karger & Walton, 1982; Maynard et al., 2012; De Almeida & Ferreira, 2015);
2. The 'most work measurement time system', or MOST (Zandin, 2002; Deshpande, 2007);
3. MODAPTS (Heyde, 1983; Sullivan et al., 2001).

Perevoshchikova & Orefkova's methods (2005) and unpublished work by the authors was developed on the basis of the MTM and BSM systems, and these are used here to calculate the microelement norms. The methodology includes three additional parameters: mechanical power, the static moment, and logical action.

Currently, on the basis of methods which involve trace elements, an automated system which calculates time allowances has been developed (Genaidy, 1990; Alkan et al., 2016). But these systems only determine the duration of the work process, without affecting the mental characteristics of the work.

In this research, task creation is considered in relation to the 'ergonometric workplace passport'. This is based on a qualitative assessment of working hours in a specific workplace. In order to determine the qualitative and quantitative parameters, the methodology presented by Perevoshchikov (1974; 2015) and Orefkova (1990; 2005) was utilised.

A new method of work measurement system was used, based on findings from a physical performance quantitative assessment, a biomechanical analysis of human work movements, and a work process improvement with an engineering-economic introduction to working standards (Korenev, 1977; BSM, 1989; Orefkov & Perevoschikov, 2005;). Russian copyright registration certificates were obtained which confirmed the existence of software products and their ownership (Maksimov & Perevoschikov, 2014; Maksimov et al., 2015).

The new computer software was developed on the basis of the methodology presented in the article by Maksimov & Kalkis (2016).

RESULTS AND DISCUSSION

Every concrete work process has its own qualitative certainty. This is expressed by a combination of properties, attributes, and parameters which determine the given work process as such. For example, any technological operation is a qualitative manifestation of a single work process.

Therefore the qualitative certainty of work is expressed in a specific individual work process, with multiple processes combining within the scale of a company to define the quality of production.

For practical purposes, the method of dividing jobs and professions into light, moderate, hard, very hard, and heavy-duty categories (Mantoye et al., 1996) is based on physiological, sanitary, and hygienic studies and serves to generalise the practical demands of individual organisations, and it has been used for a relatively long time. At present, when it is required in each concrete case, a scientifically profound approach is required in practically every technological operation which involves the standardisation and organisation of various aspects of the work process. Production requires more precise, detailed standards and methods when it comes to analysing any work process.

The nature of and results from a variety of scientific investigations that have been reported in the press and which link up to aspects of the levels of physical strenuousness involved in the work, along with work strain, and work intensity, if they do not deal with social aspects, may be summarised as follows:

1) the characteristics of work in the physiological aspect is a form of work-related strenuousness;

2) the characteristics of work in terms of the impact imposed by the production environment on the human nervous system are classed as being strain;

3) the value both of the levels of physical strenuousness involved in the work and the work complexity depends upon the material factors and environmental conditions in which the work process is taking place.

In order to be able to study the physiological aspects of an individual in the work process means taking some consideration of the physiological reaction of an individual as a response to competing factors in the work process, such as the object of the work and the instruments being used for that work. Hence it is necessary to analyse and understand the physiology of an organism as a complete system in terms of physiological abstraction and its subordination to the general laws of nature, and it will allow knowledge of the functioning of the human body to be developed in terms of working processes.

The quantitative assessment of categories for the levels of physical strenuousness involved in the work is an holistic process which includes an analysis of interacting physical forces. Several physical conditions of the surrounding environment are then taken into account when carrying out any analysis of the levels of physical strenuousness involved in the work such as, for example, temperature, velocity, air humidity, the chemical composition of air, the level of aerosols in the atmosphere, illumination, noise, vibration, and radiation. By having a huge number of experiments being conducted to measure the energy-related metabolism of an individual in terms of various types of work, a total can be calculated in relation to mechanical work and, as a result of generalisations, a formula can be obtained by which the coefficient of the work can later be determined without resorting to measuring the exchange of human energy. One should take into consideration the fact that the laws of mechanics can be used to calculate external mechanical work.

The process which involves the levels of physical strenuousness involved in the work can be calculated as shown in Formula 1 (Orefkov & Perevoschikov, 2005).

$$H = 0.476 \cdot \left(\frac{A}{4{,}189} + \frac{M_{ave}}{442} + \frac{0.06 \cdot \Delta E_o}{t_0}\right) \quad (1)$$

where H – the strenuous nature of any technological operation which is currently under research, without size dimensions (relative); A – the mechanical power of the body's locomotor apparatus, J min^{-1}; M_{ave} – the average statistical moment for operation, Hm; t_o – the total time of the work operation, in seconds; ΔE_o – internal energy expenditure residual for an organism, cal.

For the practical use of the proposed formula, specific methods and guidelines (a manual) were prepared.

The use of the calculation method which involves the levels of physical strenuousness involved in the work and the predetermined motion-time data system allows for an accurate mathematical calculation to be determined in relation to the category of strenuousness involved in the work. Such an approach can confirm the intuitive feelings of individuals when it comes to any imperfections which may exist in the existing formal methods for the evaluation of the levels of physical strenuousness involved in the work.

In the performance of a given type of work, a significant factor is the complexity of the work, something that characterises the intellectual strain of the subject who is involved in carrying out that work. In the research, intellectual strain is understood as being the process of information perception. Work complexity levels serve to influence the speed at which information change is transformed. Information obstacles within the process of perception are objects of attention. An object of attention is a perceived object's specific parameters, and the subject who is involved in carrying out the work establishes continuous contact with it.

In order to quantify any submission of work complexity, the following mathematical formula is used:

$$C_c = \frac{\ln(N_0 - \propto \cdot N_b)}{e^{\left(1 - \frac{\alpha \cdot N_b}{N}\right)}} \cdot \left(\frac{\delta}{\delta_o}\right) \quad (2)$$

where N – is the total number of algorithmic members in the work process under research, pcs; N_0 – is the quantity of operands in the algorithm for the work process, psc; N_b – the number of logical conditions in the algorithm for the work process, psc; α – the coefficient for the variety of logical conditions; δ – the intensity at which information is processed in the work process which is being researched; δ_o – the intensity at which information is processed in the core work process (the optimum intensity of information processing).

The quantitative evaluation of work complexity is evidenced by the results from the calculation. The calculation of the work expended which takes into account quantitative and qualitative indicators is presented in the following formula:

$$I_{lp} = L = C_h \cdot C_c \cdot C_{cl} \cdot C_{np} \cdot t_o \qquad (3)$$

where L – is work input; work·h^{-1}; t_o – is the total time of the work operation, h; C_h – is the coefficient for the levels of strenuousness; C_c – is the complexity coefficient; C_{cl} – is the coefficient for conditions; C_{np} – is the coefficient for neuro-emotional pressure.

The next step in the research was to design the scheme for the system (Fig. 2). The system's operational diagram in Fig. 2 shows the main algorithm which includes the C# programming language and the Visual Studio Community 2017 interactive development environment for modelling software. Firebird (a database server) was chosen to design the database. It is simple to use and makes it possible to create the server.

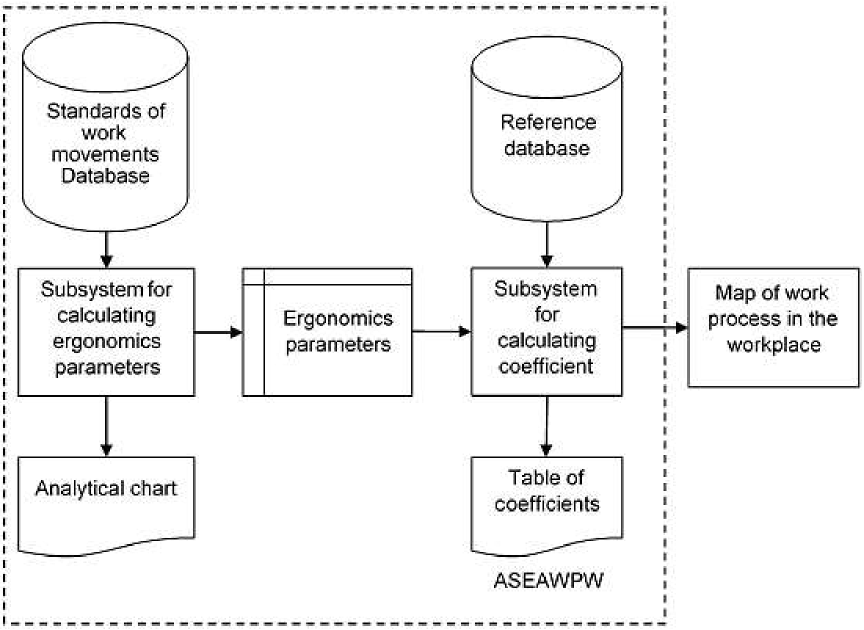

Figure 2. Data showing the ASEAWPW representation (ASEAWPW being the automated system for an ergonomic analysis of work processes in the workplace).

The software product, ‘The automated system of ergonomic analysis for work processes in the workplace’, was used for calculating the complex of work indicators for the work process in conjunction with a database that includes all of the ergonomic dependencies involved in work-related task movements.

The calculations for the computer software were carried out in the following order: (1) the type of work in the workplace is determined. Information is taken from the product’s technological map; (2) gather together information on the method being used to carry out the operation. Information is taken from the product’s technological map; (3) an analysis of primary data; (4) an analysis of basic procedures and transitions; (5) divide transitions into movements and objects of attention; (6) the work process analysis card is filled in. Based on the selected method for trace elements; (7) the work strenuousness coefficient, work complexity coefficient, work conditions coefficient, and neuro-emotional pressure coefficient were determined. The coefficient is determined on the basis of formulae 1 and 2, and with the methodology developed by Orefkov & Perevoschikov (2005); (8) the calculation for the intensity of the work process was carried out. This is a coefficient that is determined on the basis of formula 3.

The main software window is shown in Fig. 3.

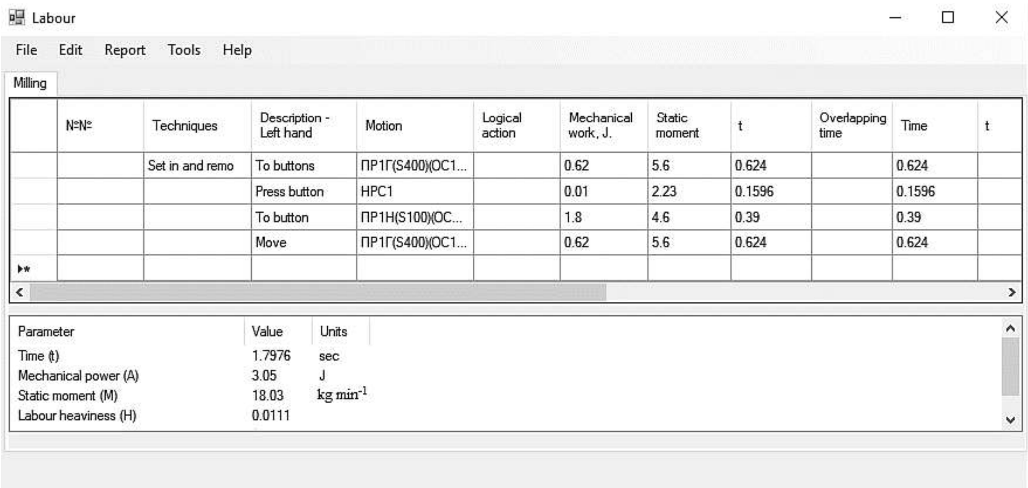

Figure 3. The main program window.

The following table shows some operations that were calculated with the help of the software (Table 1).

Table 1. Work input

Operation	t, time (seconds)	C_h	C_c	L, working hours
Surface grinding of a bracket	28.2	0.71	1.26	0.00698
Milling	27.8	1.03	1.15	0.0091
Boiler diagnosis	29.7	0.58	4.19	0.02005
Milling	17.35	1.21	1.25	0.00729
Machining	99.67	1.22	1.2	0.04053
Turning operation	216	1.2	1.3	0.0936

An analysis of the production operation was carried out using computer software and it gained the results shown below:

1. Operation: milling. information is taken from the product's technological map;
2. Processing a low-speed shaft with a weight of 14.4 kg. Information from a detailed drawing;
3. An analysis of the operation;
4. An analysis of basic procedures and transitions;
5. Cut-up transitions into movements and objects of attention;
6. The data is entered into the program (Fig. 3). Based on the selected trace elements method;
7. Results (the bottom half of fig. 3): total operating time t = 27.8 s; total mechanical work a_0 = 45.54 j; total static moment m_t = 641.9 nms;
8. The coefficient of work strenuousness – C_h = 1.03 (formula 1). The coefficient of work complexity – C_c = 1.15 (formula 2);
9. The coefficient of conditions – $C_{cl} = 1$. The coefficient for neuro-emotional pressure – C_{np} = 1. These factors are not included in the software. A full study should be undertaken of their impact upon the work process;
10. T = 1.03·1.15·1·1·0.0077 = 0.0092 working hours (formula 3).

The data received has been entered into a database and can be used to design an ergonomic passport for a workplace.

The parameters obtained are only a small part of compiling an ergonomic workplace passport, since it is necessary to graphically represent the workplace in question and its interaction with the base of the given labour processes for the company being analysed under specific production conditions.

CONCLUSIONS

The developed methodology, entitled the 'ergonometric workplace passport' can be used in other research and in practical applications in relation to work organisation preventive measures. At the current stage of designing the ergonomic workplace passport, only the first stage is being implemented, involving the option to be able to use computer software when it comes to measuring the quantitative and qualitative parameters of the workplace. It is planned to further refine the basic movement system to determine the energy costs, and to refine the software package for better evaluation results. The most difficult, and most important step, will be to refine the definition of the intellectual complexity of the work being carried out.

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