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# Software development for Qualimetrical ergonomics of a workplace

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**Abstract.** Ergonomics is the science investigating the person and the activity within the process management aiming at improvements of labor conditions and labor process at workplace. The microelement analysis as part of ergonomics allows in quantitative measures estimate time that is expended and to analyse effective use of time, as one of the major indicators. Along with an indicator of time it is necessary to consider and other indicators influencing man during commission of labor process which can be presented in the quantitative form, using science a qualimetry. The aim of the research is to analyze scientific literature on qualimetrical ergonomics of a workplace and develop software for practical evaluation of qualimetrical ergonomics. At the crossroads of a qualimetry and ergonomics the system of the microelement analysis was discovered. The research provides approach in software development for the microelement norm-fixing at the beginning of process automation.

**Key words:** ergonomics, qualimetry, microelement analysis, workplaces.

## INTRODUCTION

The investigations carried out on society labour activities and finding the solution for design problems of the workplaces proves that primary elements of production systems functioning are regulated by the conventional principles of international law.

Among the scientific directions of labour economics essential value is gained by ergonomics. Ergonomics is the science investigating human and his or her activity in conditions of operations management with the purpose of improvement of tools, conditions and work process. Ergonomics development has long history (George & Jones, 2004) and as science discipline it developed since 1949 (Eldholm & Murrell, 1973; Kuorinka, 2000). The term 'ergonomics' was accepted in England in 1949 when the group of English scientists established organization 'The Ergonomic society'. The International Ergonomics Association emphasizes ergonomics intervention which is aimed at appropriate workstations, equipment, production process and design of the product, may occur at different levels, which are determined by ergonomics types of the organisation: micro-ergonomics and macro-ergonomics (Drury, 1995). Ergonomics nowadays is multidisciplinary branch of science, which studies relationship between a human and work, conducts theoretical and practical studies of interrelation between a human and work environment (production technologies, machines, instruments, etc.) at micro- and macro-ergonomic level, and, on the basis of these studies, works out methods, which optimise work conditions corresponding to human's physical and mental abilities (Kalkis, 2014; IEA, 2016).

In the EU countries basically the term Ergonomics at Work is used, in the US, most commonly the synonym – Human Factors & Work Design is applied (Kalkis, 2014). In Russia in the first part of the XX century it was offered (Bogdanov, A.A.) the term 'ergologiya' and now in practice it is accepted the English term 'ergonomics'.

The ergonomics is interconnected with real parameters of technological development of system 'man-machine', and problems of coordination of a design of machinery with performance data of the person. Now there were insufficient private recommendations of psychophysiology and occupational health. In total there was a need of coordination of local recommendations in order to coordinate holistic system of requirements of various type of work and conditions (Hendrick, 2002).

In order to go beyond tightly engineering approach with considered ergonomic problem, it is important to set the task differently and see not only 'the man and the machine" principle, but also what is happening inside the machine – objectification of intrinsic forces of human. From there derives the term 'qualimetry' were needs of nature attract to problems of ergonomics and quantitative measurement of the quality comes into measurement system. Proceeding from such postulate the research is focused on software development that includes qualimetrical ergonomics principles of a workplace.

The aim of the research is to analyze the available literature on the topic of ergonomics and qualimetrical ergonomics and develop computer software with microelement norm-fixing principles.

## MATERIALS AND METHODS

Taylor and Gilbret's method according to the microelement analysis of labor movements of a human body in labour processes called by system of the Methods Time Measurement (MTM), and its various modifications (Schmid, 1957; Maynard et al., 2012; Miller, 2013) and practical receptions became one of methodical forms of association of research problems and design of labor processes in real workplaces (Freivalds & Niebel, 2009). The motions are assigned to fundamental principles and groups of motions that are not precisely evaluated with ordinary watch time study procedures. It is also the result of the studying a large sample of various processes with a time measurement device capable to capture very short elements – microelements of the movements (Heizer & Render, 2011). The system of the microelement analysis reached considerable perfection, however, there is an essential shortcoming.

The micro-elemental rate fixing is one of the most perspective and developing methods of the organization of unity of labour norms, increase of their quality and possibility of research by drawing up computer programs (for example, TiCon3, ProKondigital, TiCon MTMergonomics, TaskMaster 2000) for justification and calculation of labour input of performance of a certain type of works (Orefkov & Perevoschikov, 2005; Maksimov, 2014). One of the main advantages of microelemental norm-fixing is that it allows to create in short terms standards without carrying out time consuming researches.

The system of the microelement analysis has reached considerable perfection. However, it has a shortcoming too.

The MTM (De Almeida & Ferreira, 2015) and BSM method (the Russian option of MTM) dismembering labor process on ‘microelement’, fixes only duration of time of each element. However, it doesn't consider ergonomic parameters of the performed work, the static moments creating static intensity of muscular system of the person, logical (information) sequence of the analysis of objects of attention in labor process outside the analysis (Orefkov & Perevoschikov, 2005).

Partial association of these methods is that BSM is more focused on the universality to rationing in various industries, also it is the classification considering the quantitative and qualitative parameters influencing time of performance of microcells that are developed. But the shortcoming is that this system differs in complicated coding system. Therefore at the biomechanical description of process of work the system of MTM was used.

Taking into account the above described shortcomings, the new method of micro-elemental rate fixing with inclusion of additional parameters of the labor movements including the biomechanical description and tables of their ergonomic indicators is presented in this research.

On the basis of the obtained data the algorithm of calculation of required parameters with use of the developed software is presented.

## RESULTS AND DISCUSSION

The computer software has been developed that takes into account several scientific methodologies.

The problem faced by the researchers observing or planning the working process lies in recording or planning time of each movement while the algorithm is being realized.

In order to develop software for qualimetrical ergonomics of a workplace, authors used the logical diagram of labor process algorithm consists of several steps (Perevoschikov, 2015):

1. Observation is carried out for the purpose of taking in and handle basic procedures and transitions.
2. All initial data are filled in the analytical chart.
3. The workplace planning is filled.
4. Analytical results of operations are entered on the reverse side of the chart with the description and left-hand movements singly. At first the content of procedure is written down.
5. After entering each microelement, the researcher must ask: Is the transition not a problem to performer of the work to next movement? If transition to the next microelement is linked with the choice of one or several ways or necessity of a logical action is placed.
6. All actions of the whole cycle of work connected with machining labor object in given workplace are entered in the logical diagram of algorithm, that is, all actions involving calculation of per-piece time, excluding time for rest and natural reasons.

Before starting creation of the computer software it was required to carry out interrelation of the various parameters that are influencing each other. The IDEF0

(Integration definition for function modeling) functional modeling method was applied for representation of all structure in this software development work. The function is a set to the interconnected and interacting operations (actions) which will transform from input to output.

Accordingly to the functional modeling methodology the ‘Calculate Labour Intensity’ of a process is presented in software development context diagram (Fig. 1).

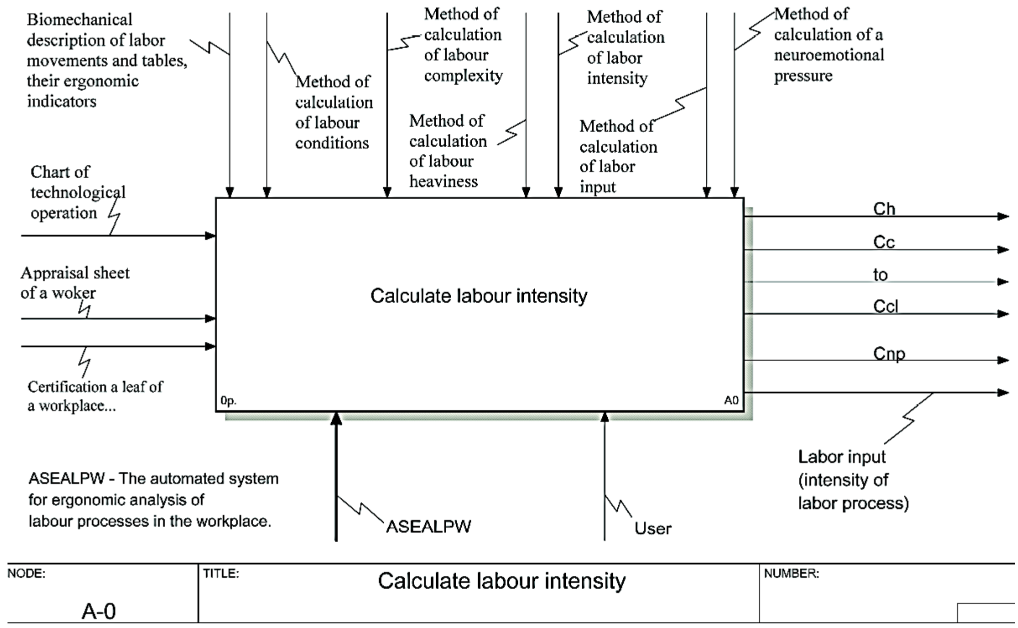


**Figure 1.** Software development context diagram.

As input of this process is the chart of technological operation (operation is characterized by a rigidity of processed product, workplace, and workers.). It is an appraisal form of a worker and certification page for workplace under the terms of performed work.

The calculation mechanism of labour intensity process performance consists of such elements:

– the developed system of calculation of intensity of labour process;
– the engineer-economist who is the direct user of system.

As process control consists of such steps:

– method of calculation labour conditions;
– method of calculation of labour complexity (intellectual strain (mental labor));
– method of calculation of labour heaviness (physical strain (physical labor));
– method of calculation of labor input;
– method of calculation of labor intensity;
– biomechanical description of labor movements and tables, their ergonomic indicators;
– method of calculation of a neuroemotional pressure.

The main function, in turn, may be divided into nine specific functions which are presented on decomposition diagram ‘Calculate labour intensity’ (Fig. 2).

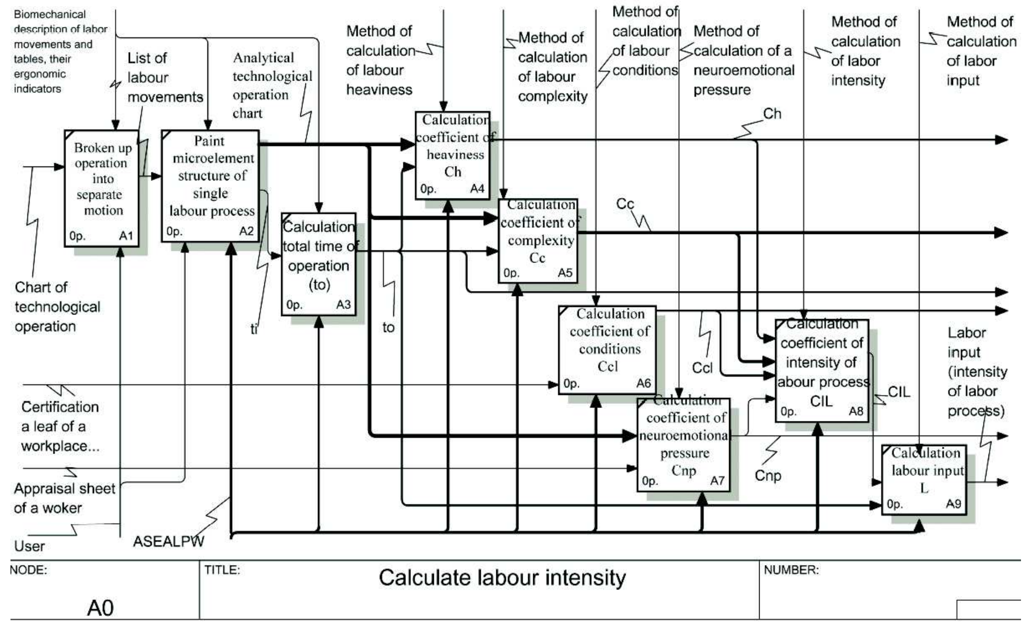


**Figure 2.** Diagram of decomposition ‘Calculate labour intensity’.

A decomposition diagram serves as representation of the main function and it is possible to model detailed functionality of the developed system.

On the presented decomposition diagram (Fig. 2) it is shown that after the correct input data of functions the calculations are carried out. Hence participation of the engineer and system in the course of calculations is also important and visually presented.

At this development stage of the software tasks of processes A1, A2, A3, A4, A5 are solved and partially solved processes of A8, A9 (Fig. 2).

As next step in software development it will be considered decomposition of function of A4 ‘Calculate coefficient of labour heaviness’ (Fig. 3). This diagram provides possibility to obtain the necessary parameters for calculation of heaviness coefficient, for instance:

- static moment;
- performed mechanical work;
- total physical activity;
- residual calculation of energy;
- heaviness of labor process.

Heaviness of labor process is the part of working capacity connected with physical activity and quantitatively reflects operations ability of work element which changes in time.

Labour heaviness and coefficient of labour heaviness can be calculated on the basis of the following formulas:

a) Heaviness of labor process

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

where: $H$ – heaviness of technological operation under research, size dimensionless (relative); $A$ – mechanical power of locomotorium, J min$^{-1}$; $M_{ave}$ – average statistical moment for operation, Hm; to – total time of operation, sec.; $\Delta E_o$ – internal energy expenditure residual of an organism, cal;

b) Coefficient of heaviness

$$K_{\text{T}} = e^{0.125 \cdot (1-H)} \quad (2)$$

Change in value of labor duration without changing the very essence of the process leads to increase or decrease of heaviness of labor process. But change of duration value gives rise to change in movement speed of system of man-labor implement-labor object. Therefore, mechanical work performed by a man in a unit of time increases or decreases. The latter conjures up changes in coefficient of heaviness.

On the diagram (Fig. 3) are shown the necessary parameters in determination process of coefficient of heaviness.

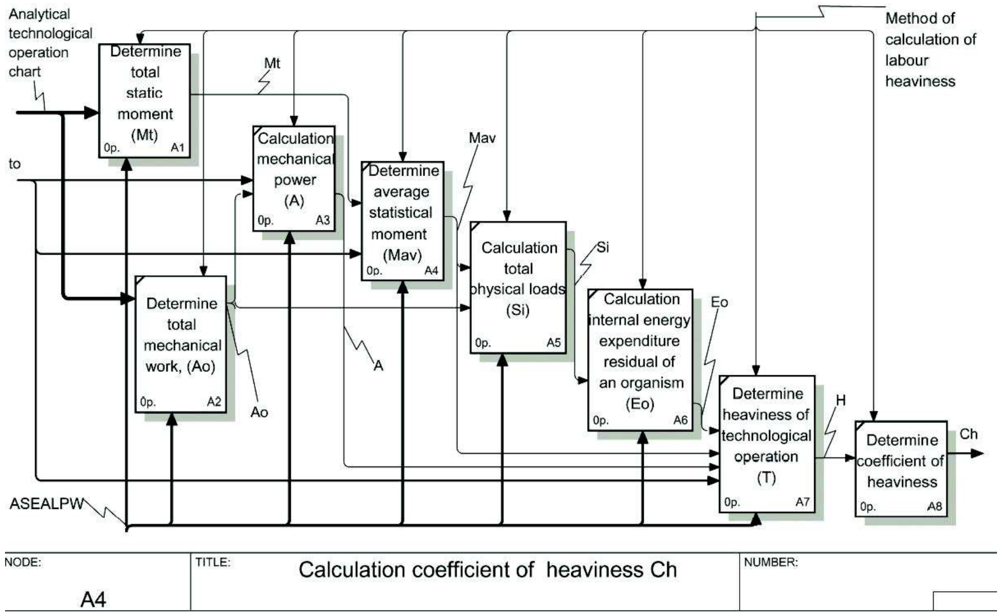


**Figure 3.** Diagram of decomposition 'Calculating coefficient of labour heaviness'.

Calculation of the total static moment can be presented more in detail. Decomposition of a function A4.1 'Calculate total static moment' (Fig. 4) visually represents the demanded operations for finding the total static moment.

As shown in Fig. 4, calculation is made automatically on the basis of already known data from analytical operation chart.

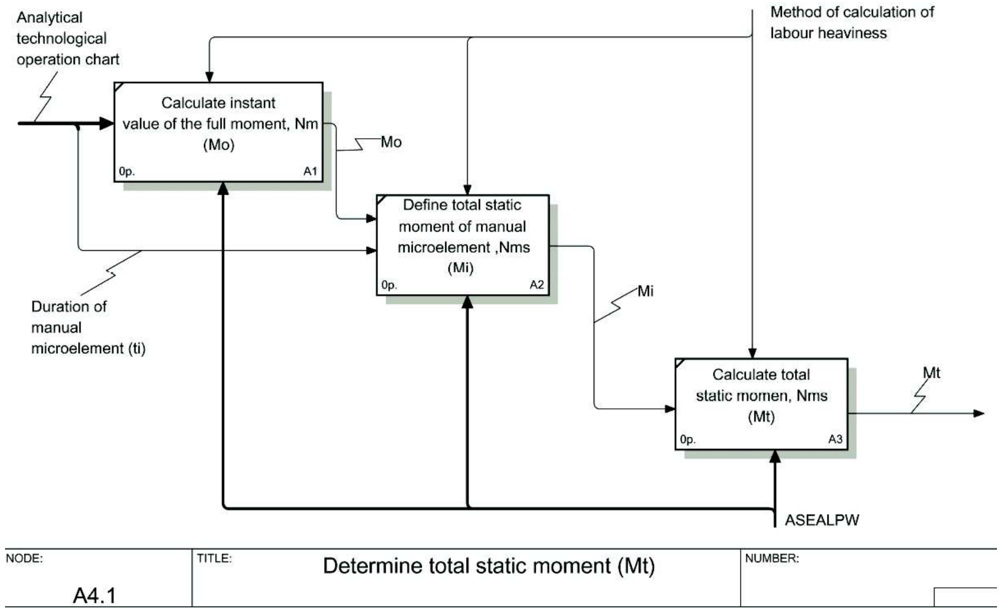


**Figure 4.** Decomposition diagram 'Calculate total static moment'.

As next step it is important to understand decomposition of a function A5 'Calculate coefficient of complexity' (Fig. 5). This chart represents processes that are calculated on the basis of the following formula:

$$C_c = \frac{\ln(N_0 - \propto \cdot N_б)}{e^{\left(1 - \frac{\alpha \cdot N_б}{N}\right)}} \cdot \left(\frac{\delta}{\delta_o}\right) \tag{3}$$

where: $N$ – total number of algorithmic members in the labor process under research, pcs.; $N_o$ – quantity of operands in algorithm of labor process, psc.; $N_b$ – number of logical conditions in algorithm of labor process, psc.; $\alpha$ – coefficient of logical conditions variety; $\delta$ – intensity of processing information in the labor process under research; $\delta_o$ – intensity of processing information in base labour process (optimum intensity of information processing).

On examining labor process in the informational aspect, the extent of the subject's contribution to labor complexity must be clear.

Every labor subject is strictly. Personal habits, cognition and skill give concrete expression to his stature as an individual – labor subject. At this stage of research the technique of complexity determination of single labor process demands further research. At the moment the outcome is rather subjective, depending on the researcher who is carrying out the analysis of labor operation.

It should be noted that in the presented software outcome the complexity of single labor process is considered from two parties: information load and intellectual strain of an organism.

As reflected in Fig. 5, several parameters are used for coefficient of complexity calculation. Decomposition of process A5.5 'Calculate the relative level of calculate intensity of information processing by the performer' (Fig. 6) shows necessary indicators for calculation of a relative level of information processing intensity by the process performer.

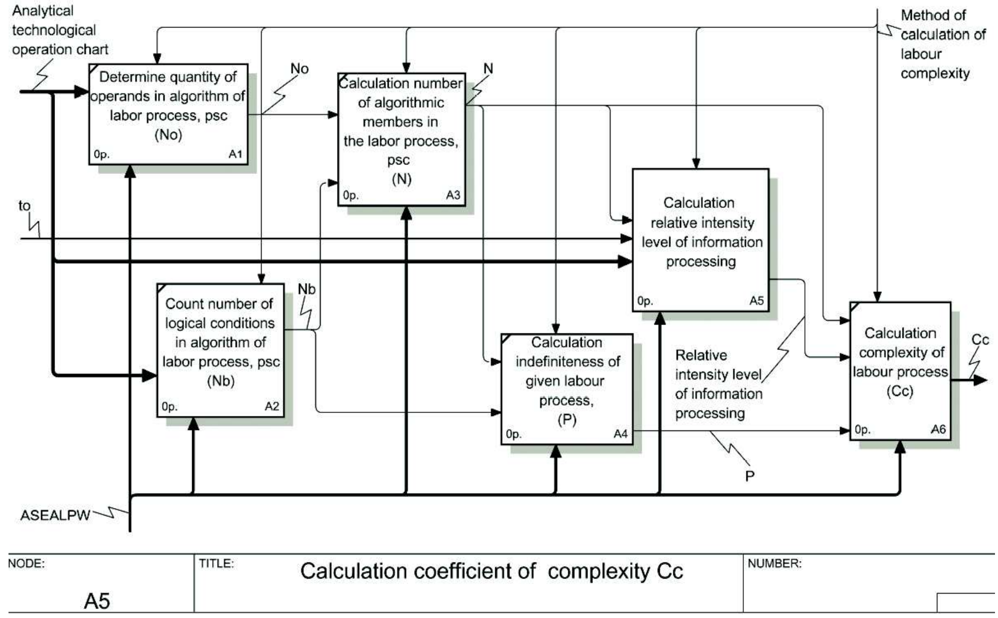


**Figure 5.** Decomposition diagram 'Calculate coefficient of complexity'.

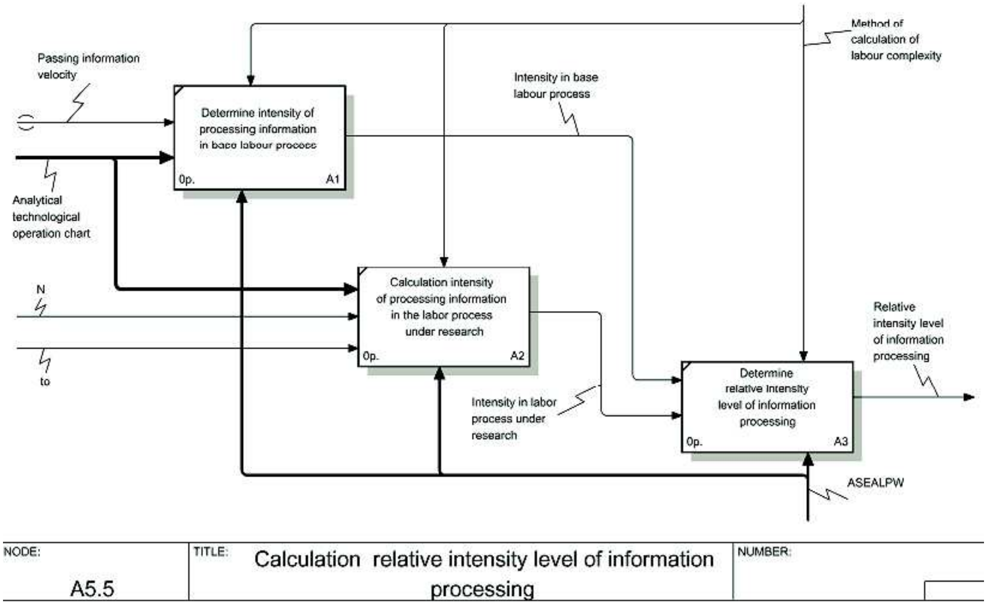


**Figure 6.** Decomposition diagram 'Calculate the relative level of calculate intensity of information processing by the performer'.

Determination of all parameters is carried out on the basis of the data presented in analysis of the labor process chart that is filled at the very beginning of all necessary work tasks.

The calculation of intensity of labour process is carried out in such order:

1. analysis of technological operation under research;
2. calculation of coefficient of heaviness ($C_h$);
3. calculation of coefficient of complexity ($C_c$);
4. calculation of coefficient of conditions ($C_{cl}$);
5. calculation of coefficient of neuroemotional pressure ($C_{np}$);
6. calculation of coefficient of intensity of labour process.

$$CIL = C_h \cdot C_c \cdot C_{cl} \cdot C_{np} \tag{4}$$

7. calculation of intensity of labour process:

$$I_{lp} = L = CIL \cdot t_o \tag{5}$$

where: $L$ – labour input, work·h$^{-1}$; $t_o$ – total time of operation, h.

According to the presented concept and the management of a database for ergonomic parameters calculations at the workplaces the computer software was developed. At current stage of development of the software a main objective is to test the program algorithm and find defects in the applied system of work microelement rationing. It is in accordance with other researches that still question remains about the validity of adding specific predetermined times to determine elemential times, since the motion times can change if the sequence is changed (Freivalds & Niebels, 2009). Also researchers constantly have tried to find out the ways to improve MTM methods (Karger & Walton, 1982; Sellie, 1992; Freivalds & Yun, 1994) and one of the most simplified approaches was developed by Zandin (1980) and originally applied at Saab-Scania manufacturing plant in Sweden in 1967 (Zundin, 1980). From this stage the Maynard operation sequence technique (MOST) derived (Maynard, 2001). The topicality to use the predetermined time systems have not decreased. Such systems can be used in many contemporary manufacturing plants, and it can be beneficial only if the people are using these systems right. Each application should involve careful analysis and understanding of the system and its use in proper manner. Authors suggest that special training is necessary for the correct and practical application of these techniques. Today scientists and practitioners can obtain the motion study methods from more than 50 different systems of established predetermined time. Each system provides its own unique predetermined time systems and have various sets of motion-time tables with application rules for using the motion time values. Therefore in further research authors will try to implement various motion patterns with its complexity and characteristics in order to improve software development.

## CONCLUSION

At the current stage of work rationing software development the main effort is to create and use various program versions that can help to develop microelement system standards including earlier standards and integrate them all into one general automated control system. Such software will allow to quantify the workload of operators in various kind of manufacturing processes. Future research is necessary to integrate also mental workload and its interaction with physical workload investigation possibilities in the software.

## REFERENCES


De Almeida, D. & Ferreira, J.C. 2015. Analysis of the Method Time Measurement (MTM) Methodology through its Application in Manufacturing Companies. *Flexible Automation and Intelligent Manufacturing* **1**, 2–9.

Drury, C.G. 1995. Ergonomics and Quality. In Proceedings of the IEA World Conference (ABERGO), Brazil, 16–20 p.

Eldholm, O.G. & Murrell, K.F.H. 1973. *The Ergonomics Society: A History 1949–1970*, London: Research Society, London, 80 p.

Freivalds, A. & Niebel, B. 2009. Niebel`s Methods, Standards & Work Design, 12th Ed. New York: Mc-Graw Hill, 736 p.

Freivalds, A. & Yun, M.H. 1994. Productivity and Health Issues in the Automation of T-Shirt Turning. *International Journal of Industrial Engineering* **1**(2), 103–108.

George, J. & Jones, G. 2004. Understanding and Managing Organizational Behaviour. 4th Edition. Prentice Hall, 696 p.

Heizer, J. & Render, B. 2011. *Operations Management*, 10th Ed. USA: Prentice Hall, 888 p.

Hendrick, H.W. 2002. An Overview of Macroergonomics. In H.W. Hendrick, B.M. Kleiner (Eds.): *Macroergonomics: Theory, Methods and Applications*, Lawrence Erlbaum, New Jersey, pp. 1–23.

IEA, International Ergonomics Association, *www.iea.cc,* accessed 15.01.2016.

ILO, International Labour Organization, *http://www.ilo.org/global/about-the-ilo.* Accessed 10.01.2016.

Integration definition for function modeling (IDEF0). 1993. Draft Federal information processing standards publication **183**.

Kalkis, H. 2014. *Business Ergonomics Management*. Gutenbergs Druka, 155 p. (in Latvian)

Karger, D.W. & Walton, M.H. 1962. *Advanced Work Measurement.* McGrew-Hill, New York, 632 pp.

Kuorinka, I. 2000. *History of the Ergonomics Association: The First Quarter of Century.* IEA Press, Santa Monica, 696 pp.

Maksimov, D.G. 2014. Emergence and development of microelement norm-fixing. *Bulletin of Udmurt University, Economics & Law* **1**, 68–71.

Maynard, H.B., Schwab, J.L. & Stegemerten, G.J. 2012. *Methods Time Measurement*. Literary Licensing, USA, 302 pp.

Maynard, H.B. 2001. MOST, H.B., Eight Parkway Center, *www.hbmaynard.com.* Accessed 10.01.2016.

Miller, D. 2013. *Towards Sustainable Labour costing in UK Fashion Retail.* Capturing the Gains. The University of Manchester, 45 pp.

Orefkov, V.V. & Perevoschikov, Y.S. 2005. Ergonomics rate fixing of labor. M. Publishing House VCUZh, Izhevsk: UDSU Publishing House, 934 pp. (in Russian).

Perevoschikov, Y.S. 2015. Labor process (engineering-economic research into working standards). – Izhevsk: Publishing house ‘Udmurt university’, 331 pp. (In Russian).
Records management function and information models. The Department of Defense. 1995 (In USA) *http://www.archives.gov/era/pdf/rmsc-19951006-dod-rm-function-and-information-models.pdf*. Accessed 12.12.2015.
Schmid, R.O. 1957. *An analysis of predetermined time system*. Newark, New Jersey, 200 pp.
Sellie, C.N. 1992. Predetermined Motion –Time Systems and the Development and Use of Standart Data. In Salvendy G (ed.): *Industrial Engineering.* John Wiley & Sons, New York, pp. 1639–1698.
System of standard on basic movement (BSM-1), Moscow: Economics, 1989, 123 pp.
Zandin, B. 1980. *MOST Work Measurement Systems*. Marcel Dekker, New York, 204 pp.