AN INTEGRATED APPROACH OF QFD METHODOLOGY IN ERGONOMIC INTERVENTION

Duca Mioara[1], Valter Narcisa[2], Androniceanu Armenia[3] and Duca Iulian[4]
[1) 2) 4)] *University Politehnica of Bucharest, Romania*
[3)] *Bucharest University of Economic Studies, Romania*
E-mail: mioara_duca@yahoo.com; E-mail: narcisa.valter@yahoo.com
E-mail: armenia.androniceanu@man.ase.ro; E-mail: duca_iulian@yahoo.fr

Abstract
Every company is preoccupied with attracting and keeping employees. In doing so, each company has to solve the ergonomic problems encountered, as they have a major impact on employees. In this paper, the authors aim at presenting a new application of the QFD methodology (specific method of Quality Management) in the ergonomic intervention, so that the intervention becomes clearer and more concise and gives precise results. The authors propose four Houses of Quality in cascade designed to solve an ergonomic intervention taken as a case study to illustrate the successful use of QFD in the study. The authors believe that using the QFD methodology in cascade helps refine decisions in case of ergonomic intervention and highlights the most advantageous solutions. We mention that we do not propose to solve a concrete case of ergonomic intervention, but we provide an example of how to use the QFD tool in an ergonomic intervention, applicable to any work activity.

Keywords
Ergonomics, Ergonomic intervention, House of Quality, QFD, Continuous Improvement

JEL Classification
L15, J28, I25, M12

Introduction

Ergonomics studies and also understands work enviroment and aims to propose ways to improve working conditions. Ergonomics is the science that promotes stress and fatigue reduction, increase comfort, quality of working life and compatibility of human beings with the environment. Ergonomics is a discipline in constant evolution due to development of scientific knowledge about humans (Căruţaşu et al., 2017). The goal of ergonomics is to transform work in order to improve it. The aim is to find out what is not working well in order to improve it, but at the same time it must maintain what works well and keep this state in the future. Generally, the Quality Function Deployment method (QFD) is used to identify critical attributes and to create a specific link between thes attributes and the design parameters. In other words, QFD makes visible and measurable link between the discovery requirements and the solutions founded (Valter & Duca, 2015; Valter et al., 2015). Matrices are used to organize information to help the management team to Visualize better and

answer three primary questions: What attributes are critical? What parameters or solutions are important in meeting those attributes? What should the parameter or found solution targets be for the new analyse? The authors believe that by applying the QFD methodology in ergonomic intervention, this process will become clearer and more concise, providing precise results.

1. Literature review-definitions and theories

1.1 Ergonomic intervention concept

Ergonomic intervention has been designed to help better understanding and transformation of work situations. To do so, ergonomist must understand very well the person during his activity, understand the person's work, and also the consequences of performing work.
Ergonomic intervention makes continuous improvement necessary to achieve success and market competitiveness (Androniceanu, 2017a). Ergonomic intervention starts from knowing the individual's activity. Thus, who analyzes the activity of the individual must have general knowledge of how "it works" as a "person" (from the point of view of rationality, biological rhythm, etc.) and to analyze him in relation to his tasks at work and with labor situation in which the individual works. (Vallone et al., 2015). Ergonomic intervention models have evolved over time; the approach to key concepts of ergonomics as the variability of work situations has developed in the 2000s (Coutarel et al., 2015, Naddeo et al., 2013). In order to develop an effective action plan, when starting an ergonomic intervention, the ergonomist studies the expression of the existing work situation in the company and proposes new targets in solving the working situations through a new interpretation of the difficulties encountered (Daniellou, 1996; Naddeo et al., 2017; Enache et al., 2014). Based on changes in social demand as well as the increasing complexity of intervention practices, authors as (Garrigou et al., 2001; Daniellou, 2003; Hubault & Bourgeois, 2004; Beguin, 2007; Guérin et al., 2007; Coutarel & Petit, 2009; Androniceanu, 2017b) insist on defining steps and ways that are required in situations of ergonomic intervention.

1.2 Stages in the ergonomic intervention process

During ergonomic interventions there may be tensioned, contradictory situations, even conflicts between participants. Therefore, it is necessary to create constructive conditions of absolutely necessary social dialogue, centered on work and activity, as well as organizing the collective action of the participants. Also, the ergonomics and the ergonomic profession have been marked by the approach of the ergonomic intervention developed in the paper (Guérin et al., 2007; Di Pardo et al., 2008; Androniceanu & Ohanyan, 2016), in which the authors show the importance of participation in the different phases of the intervention (demand analysis, pre-diagnosis, diagnosis, recommendations, etc.). In the paper St-Vincent et al., 2014, the authors present the basics of ergonomic intervention, composed of the ergonomic representation of work situations and also the representation of the ergonomic intervention process. Also, the authors approach the presentation of the step-by-step ergonomic intervention process, emphasizing the iterative aspect of this multi-looped process. These stages are presented in fig. no. 1.

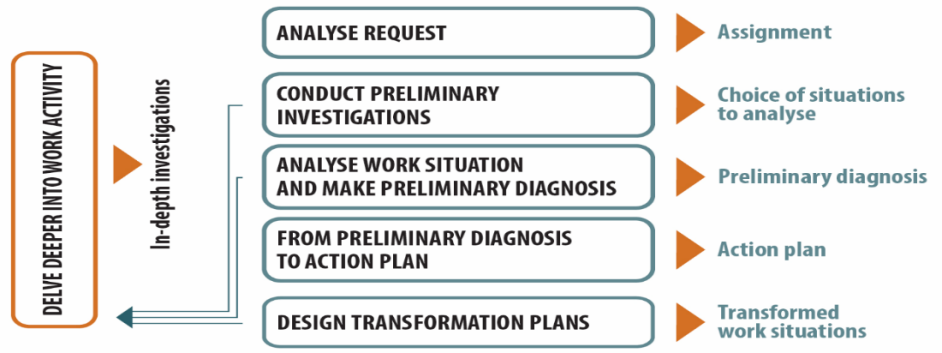


Fig. no. 1 Steps and deliverrables in ergonomic intervention process

Source: Adapted from St-Vincent, M., Vézina, N., Bellemare, M., Denis, D., Ledoux, É., and Imbeau, D., 2014. Ergonomic Intervention, ISBN: 978-2-89631-725-7- IRSST

Often, ergonomics is not considered as a tool for continuous improvement (Nunes, 2015). This attitude results from the fact that ergonomics is considered only for experts and is not passed on to all workers within the organization.

1.3 The House of Quality

The "House of Quality" is the basic design tool of the management approach known as Quality Function Deployment (QFD) (Larson et al., 2009; Hauser, 2015; Tapke et al., 2003).

House of Quality is a grid that provides the means for inter-functional planning and communication.

House of Quality is an approach that captures the "customer's voice", its needs and expectations, in order to prioritize requirements, and which takes into account market needs, identifying where quality efforts are needed. On the roof of the house are identified the correlations between the different functions or solution found.

By interpreting the obtained matrix, we identify the correlations that solve the problems.

Industrial applications were generally limited to a single QFD matrix. The QFD goal should generate a second House of Quality, based on the elements of the first house, to further clarify the requirements of the clients. The process may continue in a third and a fourth house, taking the "hows" of a house in the "whats" position of the next house. An example is shown in fig. no. 2.

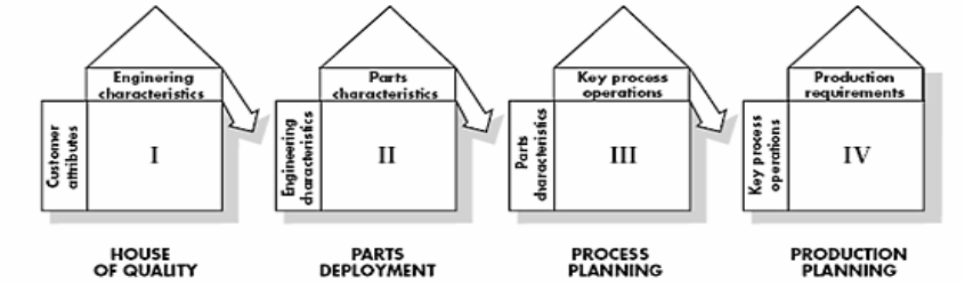


Fig. no. 2 Cascade of QFD – evaluation matrices

Source: Hauser, J. R. and Clausing, D.P., 1988. "The House of Quality", Harvard Business Review, May/June

2. Research methodology

In our paper, starting from the stages presented by (St-Vincent et al., 2014), we propose a schematic solution performed using the QFD quality tool, cascade variant, which facilitates the passage of ergonomic intervention stages. This solution is valid for any situation that needs to be analyzed and the authors believe that using the QFD methodology in cascade helps refine decisions and highlights the most advantageous solutions.

Ergonomic intervention stages are adjusted according to the actual situation encountered. The exemplification of the proposed method was done for the activity of manual handling of the masses because this work is found in almost all sectors of activity and in most jobs with a high frequency in construction, commerce, agriculture, logging, harboring, etc. The proposed method can be applied for any job, taking into account the specificity of the analyzed site.

The work situation chosen for the example is simplified in order to make an easy-to-understand presentation, following that in the application of this method to take into account the situation in its full complexity. The proposed method facilitates solving the problem by highlighting the compatibility of the ideas that emerged from the brainstorming meetings between the management and the workers. We mention that we do not propose to solve a concrete case of ergonomic intervention but we propose to give an example on showing how to use the QFD tool in an ergonomic intervention for any work activity.

The QFD chart in cascade allows finding the best solutions to solve ergonomic problems because it is always selected for a new House of Quality the most important HOWS-solutions found named "B", which are treated as requirements in the next House of Quality as element named "A" (see this in the figures that follow in this work). In fig. no. 3 is schematically presented the method discussed below. The authors propose four Houses of Quality designed to solve an ergonomic intervention taken as a case study to illustrate the successful use of QFD in ergonomics schematic presentation of the study proposed by the authors.

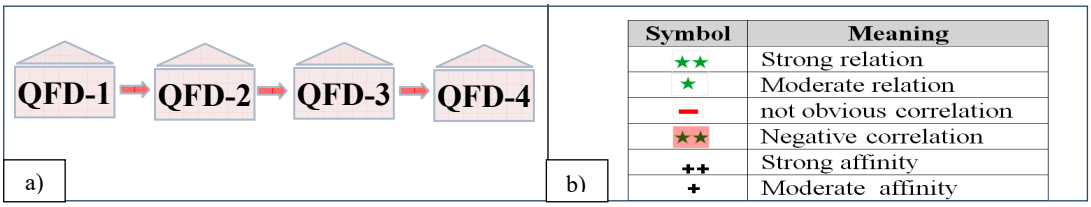
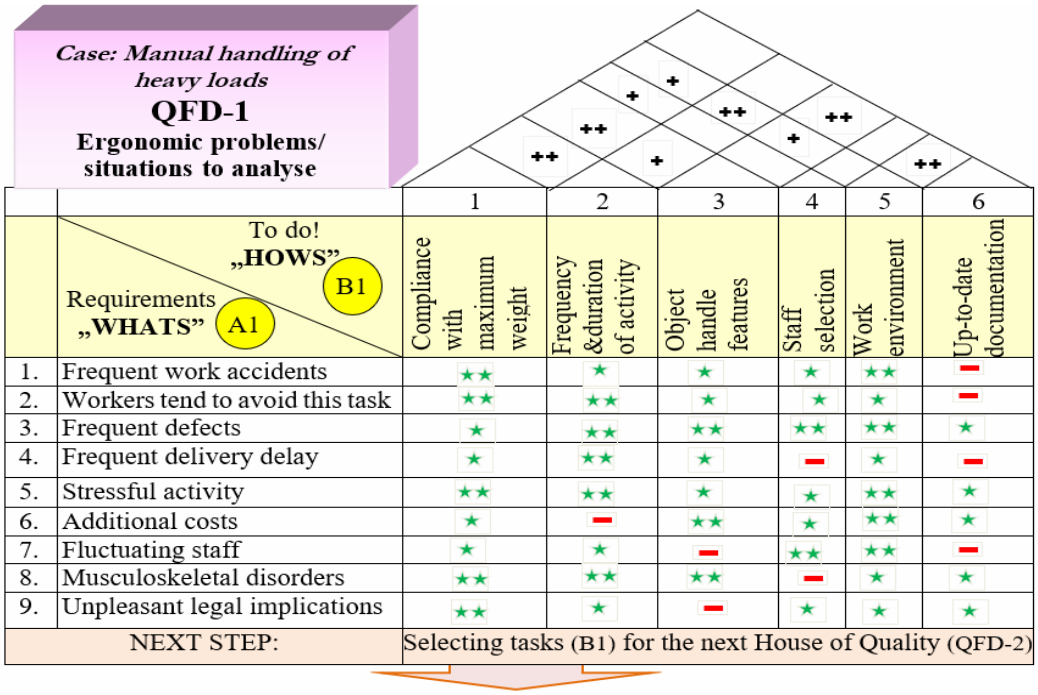


Fig. no. 3 a) Using four QFD in cascade b) The symbolism used in the case study proposed by the authors

Source: Authors

2.1 Case study – Ergonomic intervention in manual handling of loads

Further, the authors present a case study to exemplify the application of the QFD methodology in ergonomic intervention when handling masses. We propose to build the first House of Quality (as seen in fig. no. 4) corresponding to the first two stages of an ergonomic intervention presented by St-Vincent et al., 2014 (see fig. no. 1). This will lead to a better understanding of the problems of ergonomic intervention, of the characteristics of the work place, and to a better understanding of the context, by helping the ergonomist to lay the foundations for the intervention. Also, in the preliminary investigations we can retrieve data on accidents at work, occupational diseases, absenteeism, turnover, leaving the company and their causes, etc. Taking as an example the manual handling of masses, a number of specific requirements have been chosen (see requirements 1-9 of fig. no. 4).



Case: Manual handling of heavy loads

QFD-1

Ergonomic problems/ situations to analyse

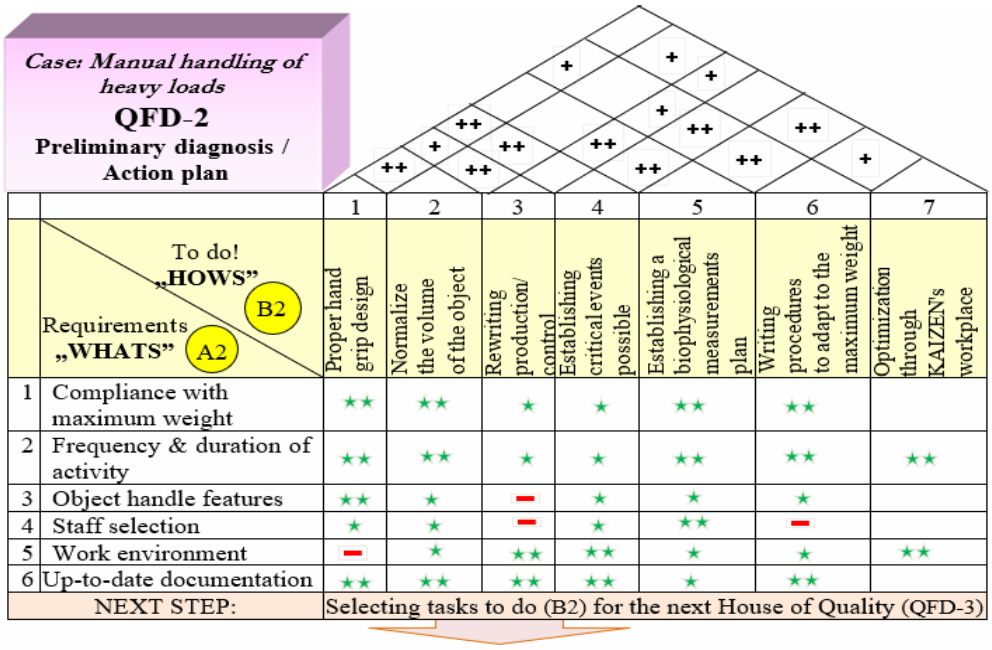
		1	2	3	4	5	6
	To do! „HOWS" (B1) / Requirements „WHATS" (A1)	Compliance with maximum weight	Frequency &duration of activity	Object handle features	Staff selection	Work environment	Up-to-date documentation
1.	Frequent work accidents	★★	★	★	★	★★	−
2.	Workers tend to avoid this task	★★	★★	★	★	★	−
3.	Frequent defects	★	★★	★★	★★	★★	★
4.	Frequent delivery delay	★	★★	★	−	★	−
5.	Stressful activity	★★	★★	★	★	★★	★
6.	Additional costs	★	−	★★	★	★★	★
7.	Fluctuating staff	★	★	−	★★	★★	−
8.	Musculoskeletal disorders	★★	★★	★★	−	★	★
9.	Unpleasant legal implications	★★	★	−	★	★	★
NEXT STEP:		Selecting tasks (B1) for the next House of Quality (QFD-2)					

Fig. no. 4 QFD no. 1 – Ergonomic problems and situations to analyse

Source: Authors

Interpretation: Classifying and analyzing those presented in QFD-1 allows the choice of working situations that need to be analyzed and thus prepare the preliminary diagnosis stage.

We continue with the construction of a new House of Quality (fig. no. 5) in which we consider the B elements of QFD-1 as elements A in QFD-2.



Case: Manual handling of heavy loads

QFD-2

Preliminary diagnosis / Action plan

		1	2	3	4	5	6	7
	To do! „HOWS" (B2) / Requirements „WHATS" (A2)	Proper hand grip design	Normalize the volume of the object	Rewriting production/ control	Establishing critical events possible	Establishing a biophysiological measurements plan	Writing procedures to adapt to the maximum weight	Optimization through KAIZEN's workplace
1	Compliance with maximum weight	★★	★★	★	★	★★	★★	
2	Frequency & duration of activity	★★	★★	★	★	★★	★★	★★
3	Object handle features	★★	★	−	★	★	★	
4	Staff selection	★	★	−	★	★★	−	
5	Work environment	−	★	★★	★★	★	★	★★
6	Up-to-date documentation	★★	★★	★★	★★	★	★★	
NEXT STEP:		Selecting tasks to do (B2) for the next House of Quality (QFD-3)						

Fig. no. 5 QFD no. 2 – Preliminary diagnosis and action plan

Source: Authors

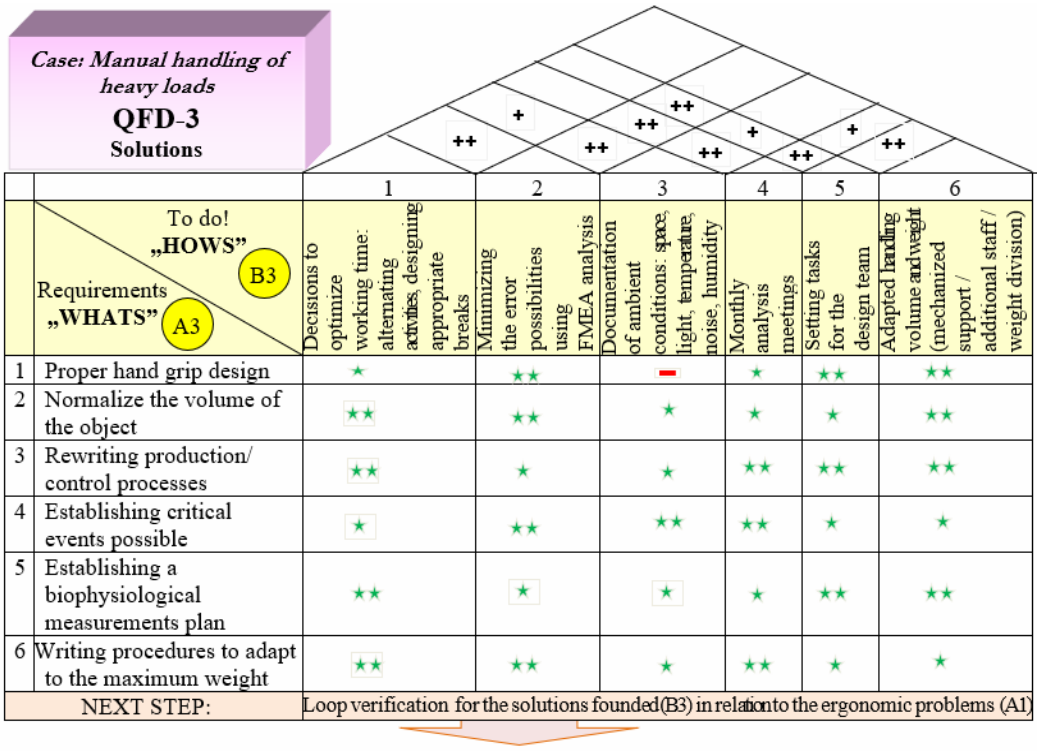


Fig. no. 6 QFD no. 3 – Action plan and solutions
Source: Authors

We propose to build the second House of Quality corresponding to the stages no. 3 and 4 of an ergonomic intervention presented by St-Vincent et al., 2014 (see fig. no. 1).
The next stage was to build a new quality house (QFD-3, see the fig. no. 6) where the team that made the ergonomic intervention offers concrete solutions and draws precise tasks for those interested.
This House of Quality proposes the concrete solution of the ergonomic problems found at QFD-1 and it is noticeable that it has the same valences as stage 5 of the schematic presented by St-Vincent et al., 2014.
We propose to build the last House of Quality (QFD-4) as an additional verification in the loop to highlight the solutions that have the greatest positive impact (see the fig. no. 7 and the legend of the signs in fig. no. 3) on the ergonomic problems encountered.

3. Results

The authors have noticed that this verification in the loop brings to light another kind of connection between the solutions found at QFD-3 (items B3) and the problems to be solved (items A1 from QFD-1). Fig. no. 7 shows a new symbol (two stars on a red background) which highlights the strong link between the solutions found and the ergonomic solutions to be solved, but with negative impact for the company which can generate additional costs for the company or lead to delays in product delivery.

Case: Manual handling of heavy loads - **QFD-4**
Loop verification

	COMPATIBILITIES	1	2	3	4	5	6	7	8	9
	Problems SOLVED (A1) / SOLUTIONS founded (B3)	Frequent work accidents	Workers tend to avoid this task	Frequent defects	Frequent delivery delay	Stressful activity	Additional costs	Fluctuating staff	Musculoskeletal disorders	Unpleasant legal implications
1	Decisions to optimize working time: alternating activities, designing appropriate breaks	★★	★★	★	★★	★★	★★	★★	★★	★
2	Minimizing the error possibilities using FMEA analysis	★★	★	★★	★	★	★	★	★★	★★
3	Documentation of ambient conditions: space, light, temperature, noise, humidity- *rules to be respected*	★	★★	★★	★	★★	★★	★★	★	★★
4	Monthly analysis meetings	★★	★	★★	★★	★★	★★	★★	★	★★
5	Setting tasks for the design team	★	★	★	★	★	★★	★	★	★
6	Adapted handling volume and weight (mechanized support/additional staff / weight division)	★★	★★	★	★★	★★	★★	★★	★★	★
CONCLUSIONS :		Refine decisions and highlights the most advantageous solutions (B3) which solves the client's requirements or needs (A1)								

Fig. no. 7 QFD no. 4 – Loop verification
Source: Authors

This QFD-4 offers a sharp perspective to the team in that it clearly shows the issues that need to be further focused and we propose this additional stage in the analysis of the ergonomic intervention.
Therefore, the management team together with the ergonomists must do research and find solutions for this strong negative correlation, which I signaled in fig. no. 7.

Conclusions
The paper proposes an efficient method and a better visibility in solving an ergonomic intervention starting from the stages presented by (St Vincent et al., 2014).
The authors believe that using the QFD methodology in cascade helps refine decisions in case of ergonomic intervention and highlights the most advantageous solutions.
It is to be noticed that the last phase of QFD-4 that author proposed in solving an ergonomic intervention closes the loop exactly as it is recommended in the Quality Management, checking if the solutions proposed fall exactly on the client's wishes.
Because of the strong negative correlations highlighted by the method proposed by the authors, the management team has to make decisions that preserve what was good before the ergonomic intervention.
The use of QFD in dealing with ergonomic problems also highlights the compatibility of the solutions found; this compatibility is seen in the "roof" of the House of Quality.
It is worth noting that in our case study there are no incompatibilities between the solutions found in the cascade (B1, B2 or B3).
Stablishes clearly what the work team is focusing on, in order to make visible improvements in the workplace.

The authors used the QFD in the simplified version, but in order to solve any ergonomic intervention, the management team can use the House of Quality in full version, given by the specialized literature.

References

Androniceanu, A., 2017a. The three-dimensional approach of Total Quality Management, an essential strategic option for business excellence. *Amfiteatru Economic*, 19(44), pp.61-78

Androniceanu, A., 2017b. Hospital management based on the relationship between doctors and patients. *Administratie si Management Public*, iss. 29, pp.41-53.

Androniceanu, A. and Ohanyan, G., 2016. Comparative approach on education and healthcare in Romania and Bulgaria as beneficiaries of the IMF financial assistance, *Administratie si Management Public,* iss. 26, pp.25-48.

Beguin, P., 2007. Prendre en compte l'activité de travail pour concevoir. *Activités,* 4 (2), pp.107-114.

Caruţaşu, N.L., Adîr, V., Pascu, N.E., Căruţaşu G. and Arion A.F., 2017. Signage and ergonomics in packaging systems. *Annals of DAAAM & Proceedings*, 28, pp.173-179.

Coutarel, F., Caroly, S., Vézina, N. and Daniellou, F., 2015. Marge de manoeuvre situationnelle et pouvoir d'agir : des concepts à l'intervention ergonomique. *Le Travail Humain*, 78 (1), pp. 9-29.

Coutarel, F. and Petit, J., 2009. Le réseau social dans l'intervention ergonomique : enjeux pour la conception organisationnelle. *Revue Management & Avenir*, 27, pp.135-151.

Daniellou, F., 1996. Questions épistémologiques soulevées par l'ergonomie de conception. In: F. Daniellou, ed. 1996. *L'ergonomie en quête de ses principes débats épistémologiques*. Toulouse, France: Octarès, p. 242

Enache, I.C., Simion, I., Chiscop, F. and Chiscop, M.A., 2014. Injection process improvement using Six Sigma. *Universitatea Politehnica din Bucureşti, Buletinul Ştiinţific, Seria D, Inginerie Mecanică*, 76(1), pp. 161-170.

Garrigou, A., Thibault, J.F., Jackson, M. and Mascia, F., 2001. Contributions et démarche de l'ergonomie dans les processus de conception. *Pistes*, 3-2, pp.1-17

Guérin, F., Laville, A., Daniellou, F., Duraffourg, J. and Kerguelen, A., 2007. *Comprendre le travail pour le transformer. La pratique de l'ergonomie*. France: ANACT.

Hubault, F. and Bourgeois, F., 2004. Disputes sur l'ergonomie de la tâche et de l'activité, ou la finalité de l'ergonomie en question. *Activités*, 1(1), pp.34-53.

Larson, W.J., Kirkpatrick, D., Sellers, J., Thomas, L. and Verma, D., eds., 2009. *Applied Space Systems Engineering. Space Technology. United States of America.* s.l: McGraw-Hill.

Naddeo, A., Cappetti, N., Califano, R. and Vallone, M., 2013. Manual Assembly Workstation Redesign Based on a New Quantitative Method for Postural Comfort Evaluation. *Applied Mechanics and Materials*, 459, pp.368-379.

Vallone, M., Naddeo, A., Cappetti, N. and Califano, R., 2015. Comfort Driven Redesign Methods: An Application to Mattresses Production Systems. *Open Mechanical Engineering Journal,* 9(1), pp.492-507.

Valter, N. and Duca. M., 2015. About efficiency of modular designed devices. *Journal of Industrial Design and Engineering Graphics*, 10(1), fascicle 4, pp.17-20.

Valter, N., Duca, M. and Enache, C., 2015. Robust design for control devices with imaginary prism adjustable supports. *Journal of Industrial Design and Engineering Graphics*, 10(Special Issue), fascicle 4, pp.79-84.