Ergonomic intervention combined with an occupational and organizational psychology and sociology perspectives in production systems

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Abstract. The paper describes a propose interdisciplinary approach for improving working conditions in production systems. The proposed approach has been customized and apply in the case of a lean production system in order to demonstrate its efficiency and effectiveness. The research approach and its associated methodology consists of three stages: (1) a qualitative research using the Grounded Theory, which provide a theoretical model on the the employees behavior within the analyzed lean production system; (2) a quantitative research, survey based on a designed questionnaire, for the investigation of the motivation – satisfaction relation; (3) a quantitative research for the ergonomic risk assessment associated with repetitive upper limb movements (that are dominant in the case of the assembly line that has been studied) using the OCRA method for the improvement of the workers stress. The research results contribute to the knowledge development and to the the diminishing of the occupational hazards and generating workplace wellbeing.

1 Introduction

In the last years, ergonomics approach has extended its interdisciplinarity including knowledge management approaches, occupational health and safety, risk management and organizational psychology and sociology perspectives [1]. Furthermore, the research results and interventions have a greater impact on improving working conditions in the industrial systems and better adapt human operators to their working environment, by reducing risks f all categories [2, 3, 4, 5, 6]. Moreover, participatory ergonomics requires more attention to be payed to organizational psychology and sociology in human behavior characterization. This approach is always supported effective improvement measures development and implementation by human resources specialists in industrial companies [7, 8, 9, 10]. Furthermore, the transformation of ergonomics way of action (extension of its interdisciplinarity and integrating it in organizational psychology and sociology approaches) has supported the continuous improvement processes in lean manufacturing

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systems. Thus, ergonomics has been proved as a valuable field of knowledge and action for the multidisciplinary improvements [1, 2, 3, 6]. This is the research context of the presented study, too.

The paper will describe a propose interdisciplinary approach for improving working conditions in production systems. The proposed approach has been customized and apply in the case of a lean production system (a company from the automotive industry) in order to demonstrate its efficiency and effectiveness. The ergonomic analysis and intervention generally aim to identify ways to improve system's operations and organization management, simultaneously with the improving of the workers' occupational health (by reducing ergonomic risks, occupational stress and increasing work satisfaction) and their safety (by eliminating wastes due to work accidents or incidents). The research approach consists of: (1) a qualitative research using the Grounded Theory, which provide a series of interdependencies on the dimensions associated with the behavior of employees and managers within the analyzed lean production system; (2) a quantitative research based on a designed questionnaire, applied to human operators of the production system for the investigation of the motivation – satisfaction relation; (3) a quantitative research for the ergonomic risk assessment associated with repetitive upper limb movements (that are dominant in the case of the assembly line that has been studied) using the OCRA method for the improvement of the workers stress. The practical "exploitation" of the proposed framework has contributed to the development of the measures to improve human operator activity by increasing motivation and satisfaction at the workplace, simultaneously with the diminishing of the ergonomic risks and work stress. The conclusions of the research underline the usefulness of an interdisciplinary research on solving complex human operators or human resources problems.

2 Research on employees' satisfaction

In the following there will be presented details on the adopted methodology aspects for the analysis of employees' satisfaction in a mature lean manufacturing system, using the Grounded Theory (GT) method complemented by a survey based on a designed questionnaire.

2.1 Qualitative research using Grounded Theory method

The research aim was to understand the socio-professional behavior of the human operators that are involved in the context of a mature lean manufacturing system, by characterizing employees' level of motivation and satisfaction (behavioral dimensions in support of their continuous adaptation to the continuous changes imposed by the lean management of the company).

GT is based on a progressive identification of the semantic categories generated by the direct analysis of speeches, discourses (obtained through interviews, focus group, consultation of written documents belonging to the investigated population, extensive audio-visual texts or any other technique of obtaining discursive data) and their aggregation into a theory, also similar to a theoretical model. Specialty literature defines GT as an inductive approach that starts with general observations and, during the analytical process, it creates conceptual categories that explain the investigated theme [1, 11]. Data interpretation within this research was achieved through successive induction method specific to GT. The methodology involves a systematic generating process of concepts and theories based on collected data (structured interview method was applied). It insists on the role of the theory to manage the research data to provide ways of conceptualizing the

descriptions and explanations. We took into consideration that the supervision practice of employees in lean manufacturing systems is continue and thus our research has an explorative generative character. The methodological approach that has been adopted in the research consist of three phases: (1) data collection and open encoding - The working model adopted for data analysis included their structuring into four categories, namely:

- a) The form in which they occur (*in situ* or *in vivo*) according to open coding (Induction 1) accompanied by some memo type statements;
- b) Identify keywords by open coding (Induction 1);
- c) Associate or group codes (primary) resulting from open coding (Induction 1);
- d) Definition of general categories related to axial coding (Induction 2).

(2) axial coding (the second step of the induction approach) was intended to clarify the theoretical conceptual or semantic categories that characterize the behavior of the employees and to identify the links between them. Thus, the first partial explanatory models were developed that were then aggregated into a global analysis model; (3) selective coding (third step of the induction process) has the role of determining the central category and the relation between the categories/sub-categories. These are redefined as a result of interdependencies or outlined relationships. Often this process is accompanied by changes in the name of semantic categories, the unification of similar categories, or the abandonment of some that can be considered insignificant to the purpose of the study, or which are different from a semantic point of view.

Application of the GT follows specific coding steps (open, axial and selective) to identify semantic categories and their interdependencies; this first research step provides information from the organizational psychology and sociology perspectives to understand the professional behavior of employees (workers and managers) in terms of their motivation and satisfaction. The critical observation resulting from the application of the GT approach is that: "The work motivation of an individual is determined by a series of factors: intrinsic (individual) and extrinsic (organizational): (a) among the individual factors are needs, attitudes, interests, value system and perception of tasks, all expressed both as employees and managers; (b) the organizational factors include salary, specification of tasks (detail degree), work group characteristics, communication and control systems.

The main semantic categories identified inductively as a result of the data centralization that have been generated by a semi-structured interviews and a focus group, and which were considered in the model, Figure 1, have provided clues to define the content and structure of the second phase of the survey on operator satisfaction and motivation.

Noteworthy is that research has identified three semantic axes (Figure 1): (1) human resource management, (2) the work relations characteristics, and (3) employees' characteristics, to which 2 to 4 semantic categories have been added. However, there is a semantic category that has proven to be very strong, often invoked in the respondents' speech and proven by relations with all the other categories, namely "Working processes in organization". The relationships between the identification categories (Figure 1) proved to be strong and reciprocal (bi-directional), which were highlighted by a detailed analysis using the MindManager software. In Figure 2 is presented the general model or the theoretical one as a result of the analysis of each semantic category that was identified after the open and axial coding operations (associated with two consecutive logical induction processes) and their relations with other related categories, as determined using the data provided by employees and managers and that were processed and analyzed. Conceptually, the theoretical model demonstrates how to induce motivated or demotivated employee behavior in order to achieve the expected performance and their satisfaction. The result of the selective coding step and the induced successive deduction cycles led to the elaboration of the conceptual theoretical model of the research as presented in Figure 2. The developed model characterizes the investigated social phenomenon with a high degree of generality.

Fig. 1 Semantic axes and concepts identified at the end of the axial coding phase (research results)

Fig. 2 The employees' socio-professional behavior characterization (theoretical model)

2.2 Qualitative experimental research - survey based on questionnaire

In the second stage of the research there have been used the results of the GT approach application (the semantic characteristics identified and the relations between them), in order to deepen the research of employees satisfaction in the lean manufacturing system, in the form of a questionnaire survey. The designed questionnaire aims to bring to the fore the motivational factors that influence the employees' behavior. The research tool design was based on the theoretical model presented in Figure 2 that support the construct and associated items establishment.

Proportional layered sampling was adapted to determine the sample size of the research; finally, the size of the sample being 256 (sampling base of 1198 people employed in the department where the research was conducted). For the purpose of these article there will be presented only the research results for the constructs “satisfaction” and “motivation”, being of great interest for the socio-professional behavior. The research hypothesis that has been tested was: “There is a direct and statistically significant link between motivations and satisfaction with the workplace” and the results of the statistical data process are shown in Table 1.

Table 1. Survey results for testing the research hypothesis (relation motivation – satisfaction).

Independent variable	Dependent variable	Correlation coef. (R)	Determination coef. (R ²)	Regression function coef. (β)	Level of signification (p)
Intrinsic motivation	Satisfaction with the workplace	0.451	0.204	0.549	0.000
Extrinsic motivation				- 0.183	0.056

From the data in Table 1 we can see that the only statistically significant link is between intrinsic motivations and job satisfaction ($p = 0.000$). Regarding the nature of the relationship between these two variables, this is positive ($\beta = 0.549$). Thus, increasing the level of intrinsic motivation will increase the level of satisfaction with the workplace. Based on the analysis we conclude that the relation between extrinsic motivations and job satisfaction is statistically insignificant because the significance level ($p = 0.056$) exceeds the threshold of 0.05. In addition, the estimated regression function predicts with average accuracy (correlation coefficient $R = 0.451$) the level of satisfaction with the workplace. Furthermore, 20.40% of the variance of the dependent variable (overall job satisfaction) is generated by the variance of the independent variable (both intrinsic and extrinsic nature). The research general conclusion is that the hypothesis is partially confirmed because only one of the two types of motivation has a significant effect on overall job satisfaction.

3 Workplaces ergonomic risks assessment

The third research step has been focused on the ergonomic risk assessment because the deep analysis of the extrinsic motivation factors has underlined problems with the work organization and some occupational health and safety (OHS) issues that could be improved. In the case of the lean manufacturing system, for each assembly sequence there has been analyzed the ergonomic risk using the OCRA (Occupational Repetitive Action method according to Risk Assessment Scale, ISO 11228-3/2007 [12]) method to meet the OHS standard requirements associated with the repetitive movements of the upper limbs (adequate for the working processes). Specifically, OCRA method is frequently used in the assessment of musculoskeletal risks and in determining the ergonomic risk of repetitive movements of upper limbs when handling materials manually (with reduced mass but high frequency of use). OCRA defines an ergonomic risk level for human operators performing manual-mechanical processes, comparing the actual number of actions and maneuvers performed with a required number of technical actions that human operator can perform safely (scale limit values evaluation of the OCRA risk index). Table 2 presents the parameter’s values for the ergonomic risk assessment using OCRA method. As can be seen, the values of technical actions $n_{TC,t}$ refer to the most required arm for each worker (right hand MD for all workers).

Table 2 OCRA parameters for the ergonomic risk assessment [1, 12].

OCRA		The task <i>t</i>					
Parameters	Symbol	1	2	3	4	5	6
Number of technical actions for product 1 and task <i>t</i>	$n_{TC,pt}$	14	8	5	4	3	12
Number of technical actions for product 2 and task <i>t</i>	$n_{TC,pt}$	15	8	5	5	3	12
Number of technical actions for product 3 and task <i>t</i>	$n_{TC,pt}$	14	8	5	4	3	12
Number of technical actions for product 4 and task <i>t</i>	$n_{TC,pt}$	15	10	5	5	3	12
Frequency constant of technical actions per min. for products 1 ... 4	k_f	30	30	30	30	30	30
The force multiplier for products 1 ... 4 and task <i>t</i>	$F_{M,t}$	0.65	0.35	1.00	0.85	1.00	0.20
The product multiplier 1 ... 4 and task <i>t</i>	$P_{M,t}$	0.60	0.60	1.00	0.60	1.00	0.60
The repeater multiplier for products 1 ... 4 and task <i>t</i>	$R_{eM, pt}$	1.00	0.70	1.00	0.70	1.00	0.70
Additional multiplier for products 1 ... 4 and task <i>t</i>	$A_{M,t}$	1.00	0.90	1.00	0.95	1.00	0.80
Multiplier of the recovery period	R_{CM}	0.60	0.60	0.60	0.60	0.60	0.60
Multiplier for the task <i>t</i> duration	t_M	1.00	1.00	1.00	1.00	1.00	1.00

The work shift is 8 hours and the breaks are: 20 minutes lunch break and two 10 minutes breaks distributed during the working day (before and after the lunch break). Given the distribution of work capacity recovery, $R_{CM} = 0.60$ per worker, which corresponds to an activity within 4 hours without an adequate recovery period. Job rotations (on different tasks) are not allowed during the working day, so each human operator performing the same single task over the entire 8 hours period. Therefore, repetitive manual tasks take a long time during the exchange and, therefore, $t_M = 1$ for the case of each human operator.

Table 3 The synthesis of the ergonomic risk indexes determinate with OCRA method [1].

Human operator (right hand determination)	1	2	3	4	5	6
Ergonomic risk index – initial calculation results	3.4	1.3	0.7	1.5	0.6	3.7
Ergonomic risk index –calculation results after the re-organization of the assembly line	2.1	2.1	0.7	0.0	0.4	0.0

Research results in Table 3 were determine by assessing the risk associated with the repetitive movements of upper limbs, according to the methodology presented in [12]. Further, the limit value of the OCRA index for manual activities considered acceptable in terms of ergonomic requirements is 2.2 (according to [12]). The lower OCRA index (≤ 2.2) values show that human operator activities have an acceptable (optimal) ergonomic risk. If the OCRA index have higher values (≥ 3.5), the case corresponds to a high-risk repetitive task [12]. As can be seen from Table 3, the result of OCRA ergonomic risk index for the employee at workplace 6 shows that repetitive movements exhibit a high risk in the upper limbs (OCRA index = 3.7). In this case, “job improvement, medical supervision and training are recommended” [12]. Furthermore, the assembly line re-organization proposals were: complete automatization of the processes in the case of the workplaces 4 and 6 (see the new OCRA index in Table 3); improvements of the work processes by introducing new devices for diminishing the ergonomic stress in the case of the workplaces 1, 2 and 5. Thus, a new optimized scheme or assembly line organization solution has been proposed. Limited investments for automation were accepted by the company because total assembly process

automation requires high investment costs (not only for the machine-tools and equipment, but also in providing internal logistics systems and reconfiguration, re-organizing the production system as a whole). In the case study, there have not been neglected that automation is particularly effective when working conditions are dangerous for workers, and when performing the workload involves a high labor cost (labor) of specialized human operators (as the situation for the workplace 6 was).

4 Conclusions

The research approach has proved that ergonomic intervention combined with OHS and organizational psychology and sociology methods can be efficient in the characterization of human operators' occupational behavior and create workplace wellbeing in production systems. First, research has characterized the socio-professional behavior of operators from the manufacturing assembly line, using the Grounded Theory approach and a quantitative research consists of a survey based on a questionnaire. The interdisciplinary analysis of the intermediate results (engineers, economists, sociopsychologists and ergonomic specialists from the company and the university) and the *in situ* observations on the studied production system has created the framework for an efficient ergonomic intervention (OCRA method for repetitive movements of the upper limbs). The research approach can be applied to other manufacturing systems where manual, mechanical and automation processes co-exist; the proposed methodology (methods, tools) are considered mature because they were tested and validated in the case of a complex process for a company operating in the real economy.

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