



# How Ergonomics Is Contributing to Overall Equipment Effectiveness: A Case Study

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**Abstract.** A study was conducted in an automotive industry in order to analyse the impact of the ergonomic measures in the Key Performance Indicators (KPI) of the Company. The KPI selected was the Overall Equipment Effectiveness (OEE) used to estimate productivity and measured by availability, performance and quality. Due to dimension of this company an Ergonomic Workplace analysis was conducted comprising a generalist ergonomic study allowing the identification of the workstation that presented the worst ergonomic situation. After, specific ergonomic evaluation methods were applied identifying the tasks that compromised workers' health. A list of measures to improve working conditions was proposed and implemented. In about a week, there was a 5% increase in performance and 91.7% of the ergonomic aspects previously evaluated by the workers improved, highlighting the overall satisfaction. General results showed that the implementation of the ergonomic measures contributed to improve company's OEE. This research will contribute to raise awareness to the importance of the ergonomic aspects when designing and organizing workplaces in order to contribute to the economic and social objectives of the organization.

**Keywords:** Key Performance Indicators · Ergonomics · Improvements · Automotive industry

## 1 Introduction

The work environment is characterized by the existence of a set of different occupational risk factors that are responsible for the development of Work-related Musculoskeletal Disorders (WMSD) while the operator performs his activity [1].

It is admitted that there is a greater exposure to critical situations at an ergonomic level for workers who essentially perform their activities as factory workers interacting continuously with machines. At occupational level, several factors can also be identified as critical such as, static work, repetitive efforts, exposure to vibrations, posture, strength, and absence without adequate recovery, intense work rhythm, working production organization or monotony of the tasks [2].

As presented in the statistical report of health and safety at work in Europe from 1999 to 2007 [3], industry is one of the sectors in which the occurrence of musculoskeletal disorders had a greater increase. Increasingly, WMSD have been associated with 3 types of contexts: automotive industry; electrical/electronic industry and computer operators [4].

In the automotive industry, more precisely of automobile components, production is mostly characterized by numerous assembly lines that are constantly in automation processes, which makes the performance of workers much more conditioned, since they must to respond to the rhythm imposed by the machines, being seen as an extension of the machines [5]. The problem lies in the devaluation of the “man” when designing the machines and defining working methods, with most of the attention turned to the productive component only. The most frequent WMSD in these industries are in the upper limbs, particularly at the wrists and hands [4, 6]. It is then critical to evaluate and monitoring all the industrial processes.

Nowadays, quality management are one of the fundamental bases for competitiveness. As such, Key Performance Indicators (KPI) can play an important role contributing to the effectiveness of the quality management system [7]. KPI are fundamental to an organization, essentially in the industrial sector. The indicators that constitute a process monitoring system are used to collect information and data from certain processes, in order to evaluate their performance [8]. An indicator can be defined as something to provide maximum information, to know to what extent a desired result is to be achieved or the quality of the processes that lead to that result [9]. Performance indicators also allow managers of organizations to select the company processes that need the most concern and where there are more opportunities for improvement [10].

Usually, companies use Overall Equipment Effectiveness (OEE) as the indicator to control productivity. This indicator is considered to be the gold standard for measuring productivity, being based on the evaluation of three factors: availability, performance and quality. In practice, this indicator identifies the percentage of the production time in which it is actually being produced [11].

A result of 100% for OEE means that the company is exclusively producing compliant products, as quickly as possible and without a single downtime [12]. To reach this level, it is necessary to obtain a percentage of 100% in the totality of the evaluated factors, that is, 100% of quality, 100% of performance and 100% of availability [11].

It is possible to relate ergonomic factors to motivation and, consequently, relate motivation to productivity. Ergonomic improvements can contribute to the well-being of workers. Increasing their motivation and consequently the productive performance. According to Abreu (2011) [13], if company works with motivated workers, it is expected that their productivity and efficiency will grow, as improvements in essential indexes such as attendance, turnover and quality of life at work will be verified.

The automotive industry, due to their manufacture process, integrates numerous assembly lines, motivating the implementation of measures in order to improve KPI. In view of all the problems previously discussed, it has become interesting to study the relationship between ergonomic conditions and the level of performance indicators in an industrial environment.

Following the previous work [14] where the main objective was to identify problems of ergonomic nature in the workstations of the most problematic productive line, news objectives was established and presented in the present paper:

“To improve KPI in an automotive industry by implementing ergonomic improvements” and;

“To raise the level of employee’ satisfaction with the workplace’ conditions”.

To achieve the established objectives, the following research questions were asked:

“How can ergonomic improvements affect KPI in an automotive industry?” and;

“What will be the change in the employee’ satisfaction implementing ergonomic improvements in the workplace?”.

## 2 Materials and Methods

In order to fulfill the objectives of this work and answered the research questions, a case study strategy was developed in an industrial unit belonging to a Spanish multinational group, a global supplier that is dedicated to the research, development, manufacture and marketing of systems and parts for the automotive sector. The case study strategy was chosen as the research is developed within a real life context using a multiple sources for data collection to gain a rich understanding of the context [15].

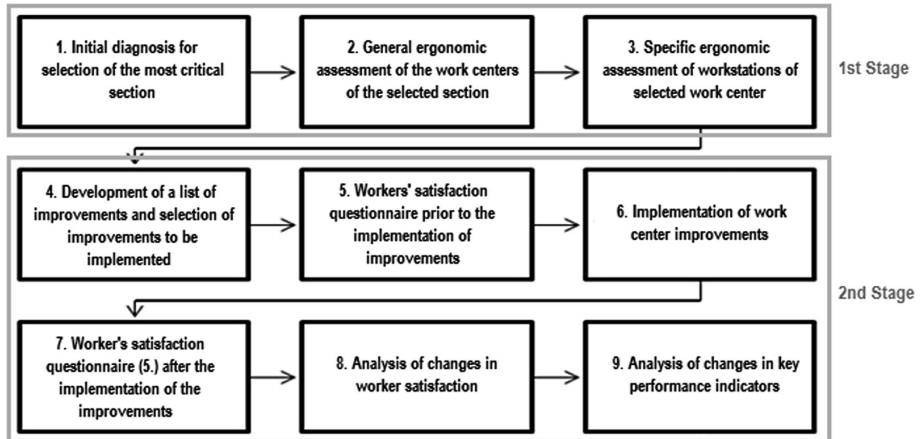
This research was characterized as a longitudinal study, which analyzed the behavior of KPI over a period of time. It followed an approach, encompassing quantitative methods. With the application of specific methods of ergonomic risk assessment, quantitative data was collected.

The industry is focused in the: development, production and commercialization worldwide of door locking cables, hood cables, fuel release cables and seat holders. The team comprises 1443 employees, of which 1183 belong to production and 260 to offices, being 65% female and 35% male. The industry works 24 h a day; 7 days a week, with three fixed shifts.

The shop-floor is divided in 4 sections: Large Series section consisting essentially of assembly lines, also having production sites and cable cutting; Injection section that mainly disposes of injection machines of plastic, where work is more customized, also having some assembly lines and cable cut’ process; Comfort Systems Section including plastic injection machines, also comprising cable cutting processes and assembly lines; and a Warehouse.

The methodology was divided in two mains stages: (1) corresponding to the general diagnosis of the working conditions and ergonomic assessment of the most critical section/work center and (2) definition and implementation of improvements and, analysis of the impact on companies KPI and workers satisfaction (Fig. 1). Details of the first stage, meaning points 1, 2 and 3 of the methodology presented in Fig. 1, can be found in scientific documents already published [14, 18]. Briefly, a diagnosis of the workers’ perceptions was initially made regarding working conditions. For this, a questionnaire was applied to evaluate their general satisfaction. Results showed the most critical productive section of the factory unit (point 1 of the methodology Fig. 1). After, the Ergonomic Workplace analysis (EWA) was used to identify the most critical work center [16] (point 2 of the methodology, Fig. 1). This method was adapted to the

context under analysis. The guidance of EN 12646-1 [17] was used to assess the illuminance item. After the selection of the more critical work center, different postures adopted by the workers were identified and registered, as well as all the materials manual handling (MMH) tasks. Methods of specific ergonomic evaluation were applied – Mital guide, Revised NIOSH Equation and RULA - in order to identify the tasks involving risk of WMDS [18]. These methods have tables with possible results that, when compared with the results obtained, reveal whether the tasks require intervention or not and the urgency of such intervention. (point 3, Fig. 1).



**Fig. 1.** Methodology plan.

Notice that stage 1 began in January 2017 and was developed in 17 months. The second stage last 5 months, ending in October 2018.

In the first step of stage 2 (point 4, Fig. 1) a document was done comprising several suggestions of changes to be made in the workplaces. The suggestions were based on literature review, previous research, International Standards and by testing several hypotheses in the specific methods that we used on the ergonomic evaluation. All the suggestions were evaluated by a multidisciplinary team, with members of the Occupational Safety and Health (OSH) and Continuous Improvement team, in order to select the most important, quick-to-implement and less costly. At this point, all the improvements to be implemented were already identified and listed. A questionnaire, consisting of 12 questions ranking from 0 (totally dissatisfied) to 10 (totally satisfied), was applied to assess workers' satisfaction in the before and after the improvements (point 5 and point 7, Fig. 1). Data was analyzed by calculating the mean for each item evaluated and comparing the averages of the ratings assigned to each item before and after the changes, analyzing their increase. Percentages of incidence of workers who reported feeling certain improvements were also generated (point 8, Fig. 1).

Notice that all the ergonomic methods that were used in point 3 (Fig. 1) were applied again in this stage highlighting the differences in terms of ergonomic risk value.

Ultimately, after working with the new methods during the 2 week trial period, OEE levels were compared before and after the implementation of line improvements (point 9, Fig. 1). The OEE was analyzed by comparing the general levels of production obtained in the two weeks of experimentation and in the previous weeks, verifying its increase or decrease and individually analyzed the specific factors considered in the OEE in the weeks before and after the implementation of improvements in the productive cell.

### 3 Results and Discussion

In this section, the results obtained related to the implementation of the improvements in the selected work center, an assembly line will be presented. The results of the first part of the research are already presented in previously prepared scientific documents [14, 18]. This involves the following steps: first the results of the ergonomic evaluation of the changed work stations, comparing the level of WMSD risk before and after the improvements. Then, the results of the employees' satisfaction with the job position during this change process will also be presented, and finally, the results regarding the impact of the improvements implemented in the organization's KPIs will be presented.

#### 3.1 Ergonomics Improvements

Among the 42 suggestions for improvement and according to previous requirements (high importance, rapid implementation and low cost associated with implementation), 6 changes were made: (#1) maximum weight to be handled in a box of raw material to supply the machine was established; (#2) a machine-operated button was centralized; (#3; #4) procedures were established to restrict the placement of boxes of raw material on the floor of two workstations and, (#5; #6) illuminance levels were changed in two workstations. As it is possible to observe in Table 1, generally the risk of WMSD reduced nevertheless this decreases was more evident in #1 and #3. In these cases, results showed that after implementation no more actions were required.

Regarding illuminance (#5; #6) the recommended average illuminance value for general machine work is 300 lx (EN 12646-1 [17]). Measures made showed 980 and 900 lx for each of the analyzed situations. Also, results from the questionnaire that was applied to assess works' satisfaction (point 5 of the methodology), workers reported headaches and visual fatigue after a few hours of work; possibly indicating excessive illuminance. After reducing the levels of illuminance to 580 lx (possible value depending on the luminaires available for installation in the industrial unit) in both workstations, the workers ensured they felt more comfortable, ceasing to feel headaches. Regarding the uniformity, both before and after the changes, it complied with the recommended values, presenting values always higher than 0.7.

#### 3.2 Improvements in Worker's Satisfaction

Through Fig. 2, is it possible to analyze the influence of the implementation on all the aspects considered. Twelve aspects were evaluated (higher the value, the higher is the

**Table 1.** List of improvements and recommendations.

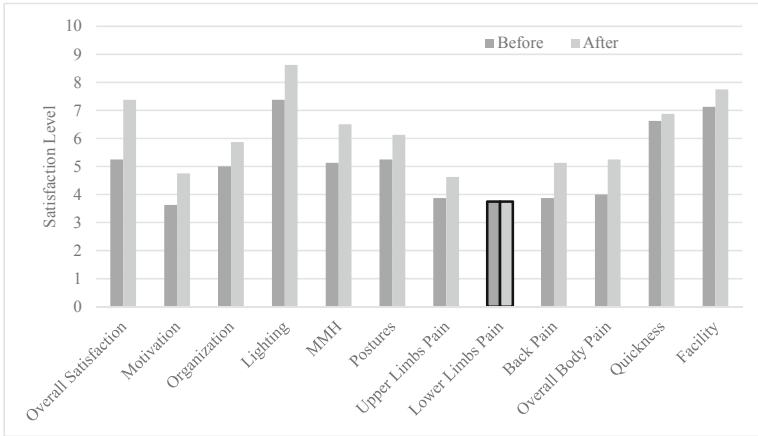
No	Evaluation method	Timing	Value	Recommendations
#1	Mital Guide	Before	1,57	There is risk. Redesign the task
		After	0,89	No intervention is required
#2	RULA	Before	4	Need for more detailed research. Changes may be necessary
		After	3	Need for more detailed research. Changes may be necessary
#3	Mital Guide	Before	1,15	There is risk. Redesign the task
		After	0,10	Acceptable risk. No intervention is required
	RULA	Before	7	Research and changes are required immediately
		After	2	Need for more detailed research. Changes may be necessary
#4	RULA	Before	7	Research and changes are required immediately
		After	6	Investigation and changes should occur briefly
	Revised NIOSH Equation	Before	1,56	There is a risk for some operators. It requires intervention with organizational and engineering measures
		After	1,52	There is a risk for some operators. It requires intervention with organizational and engineering measures

satisfaction): overall satisfaction, motivation, organization, lighting, MMH, postures, upper and lower limbs pain, back pain, overall body pain, quickness and facility. The differences can be observed based on the height of each aspect's group columns from before and after the implementation. Eleven (91.7%) of them had a positive impact on the level of employee satisfaction. Only in the perception of pain felt in the lower limbs no improvement was observed.

With regard to the incidence of the number of workers on the line who experienced improvements, it differs according to the aspect under analyzes. Regarding overall satisfaction, MMH and perceived pain in the general body, 100% of the workers felt some improvement. Motivation, lighting conditions and spinal pain are also highlighted, with 85% and 75% of workers experiencing improvement. In the remaining aspects evaluated in the questionnaire, the percentage of workers who felt improvement was lower: 62.5% reported improvements in workplaces organization and postures adopted; 37.5% experienced improvements in upper limb pain; 50% reported that tasks were being performed more easily and 25% reported that they performed tasks faster.

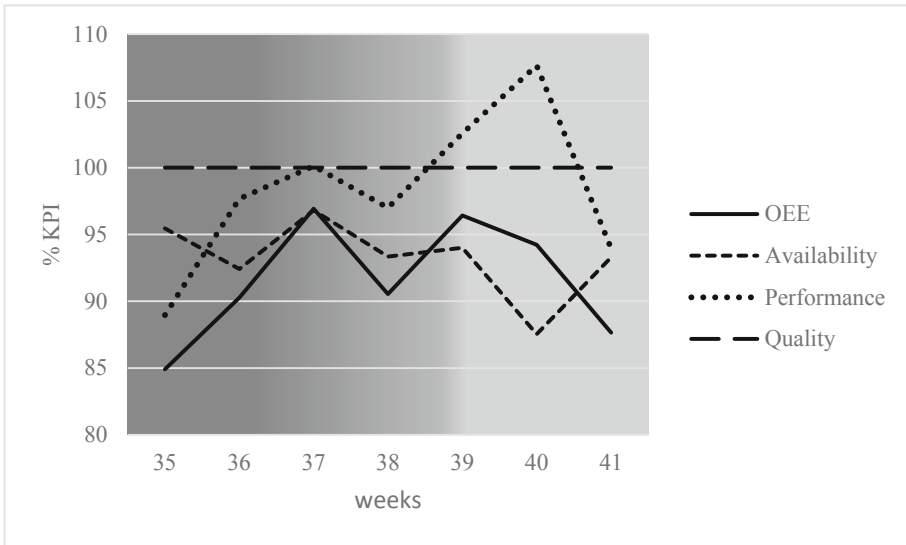
### 3.3 Overall Equipment Effectiveness Improvements

Subsequent to the implementation of the improvements, in the following two weeks (40 and 41, see light gray area in Fig. 3) there was a decrease in OEE, which goes against expectations. There are several authors who relate positively the improvement of the



**Fig. 2.** Comparison of worker satisfaction within the ergonomic aspects of the workplace before and after the implementation of improvements.

ergonomic factors with the increase of productivity ([13, 19–21]). As mentioned previously (see Introduction), OEE is based on the evaluation of three factors: availability, performance and quality. Therefore, it is essentially to analyze in detail each factor.



**Fig. 3.** Evolution of OEE before and after improvements (light gray corresponds to the time after the implementation of improvements).

As can be seen from Fig. 3, workers performance increased in the week following the implementation of the improvements (week 40), meeting the expectations and following the results founded in literature (e.g. [19–21]).

Indeed, from the three factors that are considered in the OEE indicator, performance is the one that could presents more variation as result of the changes implemented in the line. Notice that, its calculation is based on the quickness of the process without counting stops, specifically translating the quickness of the workers when performing the tasks [11].

## 4 Conclusions

This research show that ergonomic improvements can enhance the improvement of the key performance indicators (KPI) as also the satisfaction of workers with the workplace.

Regarding the impact on workers' perception of workplaces ergonomic conditions, the questionnaire applied revealed that 91.7% (11 in 12) of the aspects evaluated by workers improved compared to the prior situation to the ergonomic improvements in the line. The highlights of the improvements were the overall satisfaction of the workers with the workplace, reaching improvements of 21.3%, followed by MMH tasks, which improved by 13.8% and lighting conditions, pain in the general body and localized pains in the spine that increased employee satisfaction by 12.5%.

However, even if only minor changes were made to the line, all indications may have been that through the improvements implemented, in the first week, there was an increase in the performance of the workers in the order of 5%, reaching a level of performance that had not been verified for more than a month, which leads us to deduce that if the implemented improvements were those that would have the greatest impact on the ergonomic conditions, the more visible the results would be in terms of the increase in performance indicators.

The requirements defined by the company were a limitation, as only allowed to select 6 from 42 suggestions, namely: high performance, rapid implementation and low cost associated with the implementation. So, it is expected that the implementation of the remains suggestions the impact on the KPI could be higher.

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