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DMAICR in an ergonomic risks analysis

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Abstract. The DMAICR problem-solving methodology is used throughout this paper to show you how to implement ergonomics recommendations. The DMAICR method consists of the following five six steps by which you can solve ergonomic design problems: The steps of the proposed method, adapting DMAICR, are the following: In the steep D, there is the definition of the project or the situation to be assessed and its guiding objectives, known as demand. In the step M, it relates to the work, tasks and organizational protocols and also includes the need of measuring. In the step A, all concepts are about the analysis itself. The step I is the moment of improving or incrementing. In the step C, control, prevention from prospective troublesome situation and implementation of management are the activities controlling the situation. R is Report. Some relevant technical and conceptual aspects for the comparison of these methodologies are illustrated in this paper. The steps of DMAICR were taken by a multifunctional team (multi-professional and multi-disciplinary) termed as focus group, composed by selected members of the company and supported by experts in ergonomics.

Keywords:

1. Introduction

Integrating ergonomics with Lean Six Sigma initiatives may mean a systematic and efficient application driven to result. The method proposed on this work does not tolerate the exclusive experts opinions and intuition. The decisions are made through a participative view and the projects are led based on data analysis. The key is the quality of information about the ergonomic risks and the justifications of improvement proposals. The use of DMAIC (Define, Measure, Analyze, Improve, Control), proposed on the Six Sigma methodology (ANTONY & BANUELAS, 2002), is the strategy that guides the method, termed ELSS – Ergonomic Lean Six Sigma (SANTOS, 2010). The analysis aims at the reduction of losses, elimination of unnecessary movements and other concepts proposed by Lean philosophy (WOMACK & JONES, 1996). Table 1 shows these interconnections of ergonomics, Lean and Six Sigma in relation to the solution of problems that is proposed by ELSS.

2. Using the Microsoft Word template

The steps of the proposed method, adapting DMAICR flow, are the following:

- D - there is the definition of the project or the situation to be assessed and its guiding objectives, known as demand.
- M - that for Six Sigma stands for Measure, in ELSS means Model, once it relates to the work, tasks and organizational protocols and also includes the need of measuring.
- A - all concepts are about the analysis itself.
- I - is the moment of improving or incrementing.
- C - control, prevention from prospective troublesome situation and implementation of management are the activities controlling the situation.
- Report, or share out with others

The method consists of a set of tools, techniques, principles and rules, organized in a clear, logical and systematic way so that they can be used to reach the objectives. The standardization of the use of assessment methods towards reaching a certain objective can provide all with a common language, an under-

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standing and, consequently, a higher commitment with the objectives and goals of the organization (ADAMS et al., 2003).

A case study research method (DUL & HAK, 2007) was also applied on this work targeted at a chemicals company, specifically at a job post named “packing area”. This job post was initially selected for being one of the main posts of the process line and for having a long history of complaints related to musculoskeletal pains. The goal was to evaluate ELSS application in a job post that markedly showed problems related to ergonomics.

The steps of ELSS DMAICR were taken by a multifunctional team (multi-professional and multi-disciplinary) termed as focus group, composed by selected members of the company and supported by experts in ergonomics.

3. Results

Table 1 resumes the main objectives and results of each DMAIC step.

3.1. Application of step D – Define

To start up the process, a “Project of Ergonomic Risks Analysis” was created. Pertinent records were inspected so that these elements could be understood in details. Thus, the first step was the analysis of the most common complaints received at medical clinic (records of accidents and complaints) that prevailed in the segment. Records from years 2007 and 2008 were studied. Data before these years were inexistent due to the lack of an appropriate management system. The investigation showed that a large majority of medical clinic complaints received were delivered by the operators of the packing area, i.e., 36% of the complaints of the medical clinic. This data revision was led by a member of the focus group and supported by the occupational nursing assistant of the company.

The most frequent complaints from the packing area were related to musculoskeletal disorders in the shoulders and in the spine, confirming the previously mentioned data.

The complaints can be seen as indicators of imminent medical leaves. Medical leaves were then investigated (less and more than 15-day-leaves) within years 2007 and 2008.

Six workers had medical leaves (some more than once) mainly provoked by musculoskeletal pains. The average value of medicine consumption at the medical clinic of the company was R$ 7.52 per assistance. Based on such information, a simulation of the number of medical assistances (visits to doctor) in financial terms.

Also considering the cost of a man-hour in that department (R$42.89 according to the production planning department), the days of absenteeism would represent the financial numbers.

Besides these data it was found that, in 2007, there was a lawsuit for compensation requested by an employee whose final agreement has resulted in an expense of R$ 30,000.00 without considering the costs of the defense process which were not included.

Functional disability of the movements of the shoulder after a surgical procedure acquired due to the handling of sacks was claimed. There is another legal action in progress with R$ 250,000.00 of liabilities requested in the legal action. These legal data were categorized by a member of the focus group with the support of the attorney coordinator of the legal department of the company. These financial data and simulated studies can give a dimension of the losses that can be generated related to the object of this study.

3.2. Application of step M – Modeling

After the data presentation on step D a new event was scheduled so that the ergonomist could present explanations about process modeling strategies to the focus group. With that, all could appreciate the variants of ergonomics basing them on the details of the packing activity. As after training activity, the members of the focus group got together and presented what could be grouped and defined as homogeneous (HGEE –Homogeneous Group of Ergonomic Exposure) to the execution of process modeling connected with the packaging.

Packing area is presented with six job posts (six packaging makers) who work in three shifts. The shifts are developed on the scale of 6x1 (Monday to Saturday, Sundays off).

There is no function job rotation; the shifts take place in fixed schedules. Then, to meet the needs of packing area, 21 workers are necessary but the area has 38 employees named Production Operators once other tasks are also part of the process. The input and output processes of the packing were defined. The HGEE was also defined and the object of the evaluation was the Packing Machine Operator. In this machine the process takes the following steps: pack the product, check the weight of the bag; seal the bag; send it to belts for palletizing. In order to better illustrate these elements, the focus group led a simple study of cronoanalysis in the process flow. The timings were systematized through a sample of 10 workers, where the arithmetic averages of the execution times of each task element were observed since a simple approach for cronoanalysis has been defined. Through a review, gathering findings of the study with the appreciation of the members of the focus group, an Occupational Health and Safety agent and an Ergonomist, the following considerations were done:

- The plastic bag is instable. The operator acts several times in order to prevent some waste of product. In three of the observations made it was necessary to add some more product after the inspection to reach the right weight because the way the plastic bag was handled (instability) caused some loss of product that fell out of the bag. A bucket was placed next to the scale to face this problem that can represent a waste of time in the process, waste of product and unnecessary movements of the workers;
- In 60% of the observation it was necessary to hammer the output funnel of the packing line with a rubber hammer so that the product could be easily pushed out of the machine since the filling speed is compromised by the situation mentioned above named as “impasto” or building up by the process operators. This problem is a result of the high relative humidity of the air in the place (72%) once the job is performed next to the cooking area that produces vapors going around the packaging area. These situations cause waste of time once they do not allow a continuous and uniform product flow besides demanding unnecessary movement from the workers;
- There is no appropriate place to store the hammer and the plastic bag. The space designated to the plastic bags store can only prevent them from being damaged or torn.

The bags are stored in a place that is beyond the reach of the operator so that they have to bend the body to get them. This results in unnecessary movements of the worker. If the relative humidity of the air could be improved it would also reduce the use of the hammer;

- Equipment layout is also inappropriate demanding the operator to turn around his body carrying a load and to move unnecessarily. This item is also considered a waste of time and biomechanical overload due to the execution of unnecessary movements (effort to hold the bags) what may victimize the worker with muscle fatigue and strain injuries;
- The sealing machine is wrongly placed in relation to the height of the scale (it is placed higher) what may overload the body and the vertebral column of the operator since he needs to lift the bags to compensate the depression what may also victimize the workers with muscle fatigue and strain injuries.

Given these findings, ergonomic mapping was carried out by assessing of variants. The group went to the field for this activity, filming, interviewing and confronting the initial findings with the experience of the workers. The problems were discussed at a formal meeting attended by everyone involved (focus group, ergonomist) and jot down into the form with the initial description of each of the found problems.

This assessment demonstrates the understanding of the focus group about the problems involved in the manual packaging.

3.3. Application of step A – Analyze

Based on the previous mapping and on the modeling of the activities it is possible to look deeper and systematically into the response to the problems found in this step.

Items related to the kinesiology of upper limbs (displacement, catching and positioning) and cognitive demands (adjustments and inspections) were added. These items allow the elements of the process to be more precisely analyzed in terms of unnecessary movements and possible losses in the process. The sample has represented the same made by the focus group since all of them were recorded in a video.

The findings were critically reviewed on its root cause leading to the following conclusions:

- The waiting time represents 48.2% of the cycle time. It is assumed that eliminating the “building up” the flow could be higher and the waiting time reduced.
- Transportation represents the biggest time waste in the cycle. 19.2% of the time is wasted due to the transportation of loads between locations. It is assumed that the improvement of the layout of the machines could minimize or even eliminate this waste.

This item is also considered the one that demands body torsions, load handling and unevenness of the heights (scale-sealing) which cause overloads to the upper and lower limbs and spine;

- Preparation and adjustment consume 12.5% of the cycle. The longest time occurs when the packing is adjusted in the scale so that it can be placed vertically. Due to the plastic bag the operator spends 4 seconds on average (out of the total 7) trying to place the package in a vertical position.

Reviewing the identification of aspects and hazards it is possible to conclude the following:

- Relative humidity can contribute to the increase of waiting time and unnecessary movements of hammering which can also damage the equipment.
- The displacement of materials is the highest risk of the process. Besides wasting time it can be responsible for human costs (medical leaves and complaints on vertebral column and shoulders) and administrative costs (lawsuits).
- The quality of some process input items such as the position of the packaging material and the package itself can contribute with the improvement of timing in the production cycles and also with the organization of the work.
- Possibilities of introducing shift rotation or programmed pauses in this job post should be considered where there is a strong risk of physiological overload due to the long lasting standing position that the activity demands.

Other initiatives were taken in order to improve performance:

- Financial simulation so that the unnecessary waste of time could be calculated – It was performed by one of the members of the focus group and the production supervisor. This simulation was based on the product price and took into consideration the waste of time only during the displacement process. The loss can reach 19.2% of the cycle time. Considering the value of the bag that is R$ 9.02 (sale price) losses can reach R$1.73 per bag, representing R$ 889.22 per equipment in one shift. Multiplying equipment (6) and (3) losses can reach R$16,005.96 per day or R$ 400,149.00 on a monthly basis (25 working days in average) what could possibly justify the implementation of the improvement action.
- Analysis of the observance of requirements of current legislation – The verification of conformities and occupational liabilities was led by the Ergonomist, Occupational Physician and Safety Engineer. Eleven requirements of NR17 (MTE, 1990) are liable to penalties in the current condition of the workplace, ranging between R$ 33,000.00 and R$ 363,000.00 depending on the criteria adopted for notification.

The time (19.2%) mentioned was based in a loss simulation per year in a hypothetical situation in which the company produced the amount showed considering current production and values. Some values should be added to that from simulation like the in-progress lawsuit of R$250,000.00 liability (amount requested in the action) and the liabilities regarding to possible inspections based on the NR17 that can reach a minimum of R$ 33,000.00 and a maximum of R$ 363,000.00.

ELSS allows a deeper verification of the causes of problems discussed with all members of the focus group on the performance of the Root Cause Analysis – RCA- (Ishikawa diagram) and analysis of the "The Five Whys" on the general findings in a Kaizen event named Labor Collective Analysis attended by all operators from the manual packing area and championed by both the ergonomist and the leader of the focus group.

They did not focus on the consequences of the events but they discussed the basic causes of the processes. Looking for sharing their opinions in a broaden perspective and without any embarrassment the operators received a sheet of paper with a guiding question created by the ergonomist that they would answer and give back without identifying themselves. The question was: "What would I improve in my job post if I had enough money?"

The result of the answers showed that automation of the filling machine was the first choice, justified by the fact that the process was old and there are machines that can do it automatically needing only feeding and monitoring actions. The second choice was modification of the layout putting machines closer from each other.

The results of the evaluation were grouped in an form based on FMEA (Failure Mode and Effect Analysis) that was adapted to the ELSS (Ergonomic Risks Analysis).

Thus, the following steps were taken:

- The variants were classified in conformity with the field research form and were described through a systematic observation by the focus group and the Ergonomist. The application then followed standardized criteria (specific form) that could be used as a basis for future application during the implementation of OHSAS 18001 (ASBURY & ASHWELL, 2006);
- Various documents mentioned in the observed items were verified throughout the form. Images and tools were also mentioned and attached to the reports.
- The existing means of control of each situation were mentioned and evaluated in terms of efficiency through the scales created for the organization (control).

The creation of Risk Indicators (Severity x Probability x Control) was brainstormed and reviewed in specific events (Kaizen). Then, a specific code was created for each item. When the indicator shows duplicity (two items in Severity and Probability fields), the higher value prevails.

Table 1
ELSS Expected Objectives and Results with DMAIC

		Objective	Main Expected Results
DMAIC Steps	D	Define clear objectives of the Study	Definition of main action group; Definition of the scope of the actions; Definition of the objectives of the analysis.
	M	Understand the work	Selection of the objects of evaluation (definition of homogeneous groups of exposure in ergonomics), Understand the analyzed process (modeling of the process, tasks analysis); Preliminary Ergonomic Mapping, identification risks and wastes of the process.
	A	Systematically analyze	Systematic study of each problem; Identification of root cause; Confrontation of problems with the operators; Prioritization of risks.
	I	Develop attitudes that can bring improvement of the identified conditions	Propose improvement actions; Select the best option; Simulation; Organization and analysis in a standard form.
	C	Establish criteria that assures the improvements	Establish a plan that assures the implementation of the improvements; Development of assessment and results review.

Based on these findings (spread sheet presented in the appendix) and on performed reviews it can be stated that:

- The main risks are related to the act of transiting around the equipment with the loads. This situation can cause biomechanical overload on the upper limbs and spine leading to waste of time in the process. The layout should be reorganized so that the equipment could be placed closer what would eliminate body rotation and displacement of loads.

- The high relative humidity of the air generated in the cooking area slows the flow of the product. Ways of insulating this area should be studied.

- The activity is performed non-stop by the operator. A fatigue prevention program with specific and compensatory pauses focusing on the muscle group that is most required by the activities should be studied.

- The package of the product should be replaced by a less flexible one.

Thus, the proposals for elimination, mitigation and/or risk control were discussed in a Kaizen event.

3.4. Application of step I – Increment

After the root causes were identified, possible solutions for the problems could be defined in the Kaizen event that took one working day (8 hours) and counted on the participation of everyone involved.

The activities in the event were:

- Proposals of actions for all the findings in FMEA were voted and selected;

- Revision of the proposed procedures (FMEA reapplication);

- The Ergonomist was requested the simulation of the projects comparing before after status through the utilization of CATIA® software;

- The proposed actions and the reapplication of FMEA were organized.

The simulation was performed through the data analysis modeled in CATIA® Software V5 R18 and presented in a meeting where it was studied by the focus group. Through the application of RULA - Rapid Upper Limb Analysis – (MCATAMNEY and CORLETT, 1993); NIOSH (NIOSH, 1994) and CARRY (SNOOK and CIRIELLO, 1991) methods of the module Ergonomic Analysis of CATIA® V5, it was possible to note that the risk of overload on the upper limbs and spine would be reduced with the implementation of the proposed improvements.

The reduction of the cycle time was also simulated. Two seconds, as a result of the flow improvement (relative air humidity improvement with the insulation of the areas) and one second, as a result of the replacement of the package could be optimized through the implementation of the suggested actions. Another important gain comes as a result of the elimination of the transit and body rotation that consequently eliminates the biomechanical overloads on shoulders and spine. As a general result, the cycle time reaches 44 seconds.

Considering that 514 bags were produced in an 8 hours shift, if the suggested improvements were implemented, 654 bags would be produced within the same total time. With one bag at the price of R$9.02 (sale price), R$5,899.08 could be produced er equipment, R$ 106,183.40 per six equipment unities in three shifts resulting in R$2,684,586.00 for 25 working days against R$2,086,326.00 produced under the current circumstances. A R$ 598,260.00 profit would be generated monthly.

Surely the amount saved in one month overcomes the amount necessary for the investment on the improvement of this job post and justifies the suggested proposal.

The full analysis was once again checked by the focus group and then presented to the board of the company by the Ergonomist and the Occupational Physician. Then, the action plan for the implementation of the suggested improvements was requested.

3.5. Application of step C - Control

An action plan was then created. The high leadership of the company assured the implementation and the extension of ELSS project all over the company through the standardization of the system and definition of an operational system. Due to the success of the method four more four-hour-events were conducted and the procedure of ergonomic management was installed.

3.6. Application of step R - Report

The case study was shared out with others sites.

4. Conclusions

The presented model assumes that the appropriate articulation of Lean and Six Sigma methods of analysis allows the application of the participative Ergonomics in order to project safe, healthy, comfortable and efficient environments when integrated to Ergonomics practices, improving not only the ergonomic aspects but also increasing the efficiency of the line enhancing the working conditions what may bring improvements to production performance.

This study aimed at showing the application of ELSS method and identifying its benefits in a real case through the implementation of a specific project of improvement which used DMAICR steps and Kaizen events in order to find ways of improving working conditions on the target of the evaluation. It presents the case study in details of each phase having the literature and the research conducted at the company as a reference. The benefits of the use of this methodology on the analysis and troubleshooting were presented.

DMAICR cycle was used at ELSS as a standard approach for the improvement projects and in the combination of Lean Six Sigma philosophies it preserved the same approach for trouble-shooting and organization of problems. The proposal of using Kaizen event at ELSS was validated. During step I – Increment – Kaizen event sped up the proposals of improvement initiatives and, consequently, the gains of ELSS project.

It is possible to note that Lean, Six Sigma and Ergonomics can be integrated aiming at trouble shooting. The proposal was validated inside the scope of the studies since DMAIC allowed the use of Lean tools for the mapping of the process, brainstorms, Kaizen, The 5 Why s and Six Sigma tools as FMEA, Ishikawa Diagram, process mapping, cause and effect analysis.

The gains of the improvement process go beyond the results of risk assessment representing financial gains. This proposal was validated. Besides the financial gains presented in this study, problems were solved in an organized way.

Another relevant aspect to be considered is that the internal resources of the company were not split in three work fronts (Lean, Six Sigma and Ergonomics); instead, a hybrid model which is in conformity with current world class management methodologies was presented.

The existence of a generation process of a step-by-step implementation plan, and the plan itself aligned with the reality of the organization may bring important gains and positive feedback to the efforts for changes in the ergonomic management.

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