A Lean approach for improving workers' ergonomics: a case study

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Abstract: The measure of a company's ultimate success is not only measured through financial aspects but also through its stance on social and environmental sustainability. When discussing sustainability, this refers to the issues of managing the safety and ergonomics of workers. Companies know that the performance of their workers is key to the success of their business. Still, on the other hand, many companies often find it difficult to identify and resolve problems related to safety and ergonomics, especially in manufacturing contexts where operators are often subject to musculoskeletal stress. Many companies have turned to the Lean management approach to address safety issues in manufacturing. However, in some companies, there is a lack of approach to identifying potential ergonomic risks. This study seeks to understand how the lean approach, through the framework of A3, is able to identify and solve ergonomic problems of operators in manufacturing environments. This study analyses a case study of an Italian company. To solve ergonomic problems, acting on the OCRA value, the company relied on the use of the A3 framework. The study shows that the company, through the use of A3, was able to improve the ergonomic conditions of its operators, decreasing the OCRA value. The use of A3 brought the company many advantages; it was able to identify problems to be attacked, select the most effective countermeasures and monitor the success. This paper can be of help to managers who find it difficult to solve safety problems for their operators. The lean approach is very flexible and can be adapted not only in other manufacturing contexts but also in many other sectors. The research limit is referred to the use of a single case study and the lack of a long-term analysis of the context.

Keywords: lean management, OCRA, A3, ergonomics, safety management

I. INTRODUCTION

In recent decades, economic growth and increased human wellbeing worldwide have come at the cost of rapidly increasing use of natural and social resources, these factors have driven companies to increasingly sustainable management solutions (Lindahl, 2013). To be more precise when talking about sustainability in business one can refer to the triple bottom line view (Govindan, 2012). The triple bottom line view measures the ultimate success of a company not only by its financial aspect, but also by its ethical and environmental performance (Andriolo, 2015). The achievement of sustainable performance by the company has now become a priority, in fact companies try to make the most of the approach to sustainability proposed by the triple bottom line in order to have a competitive advantage (Gimenez, 2012). On the other hand, the continuous pressure that companies are under in terms of increasing performance in terms of productivity and flexibility of response towards the customer, can lead to affect some aspects of social sustainability, especially in the manufacturing sector. (Francas, 2011). On the one hand, companies know that "human-centricity" will play a key role in the factories of the future to achieve flexibility, agility and competitiveness (Germani, 2020). For this reason, society has become aware that there is a strong urgency to address issues on social sustainability; at the same time, organizations are increasingly struggling for corporate sustainability to gain a competitive advantage. (Souza, 2018). For years now, progress has been made in improving working practices. Indeed, there is an increasing focus on respecting fundamental principles and rights at work. Organisations are continuously implementing Safety Management Systems. Organizations have duties towards society, they must generate value but at the same time not burden the social and health security system; therefore, they must ensure Safety Management systems by incorporating an effective management response with dynamic strategies in their decision-making processes (Souza, 2018). Therefore, it is very interesting to go and investigate the area of social sustainability and have more knowledge regarding its practical implications in companies. (Mossa, 2015)

The objective of this paper is to increase understanding of how companies address issues related to the social sustainability of their workers, particularly on ergonomics issues in the context of manufacturing companies. Through an initial part of literature review necessary to identify the research question of the paper, a single case study of an Italian manufacturing company in the oil and gas sector was analyzed. Finally through the analysis of the case study, conclusions were extrapolated to answer the research question.

II. LITERATURE REVIEW

Given the growing interest of society and companies in social sustainability issues, there is a need to understand the factors that make up this context. A review of the literature should therefore be used to identify the most interesting issues to be analysed for a growing understanding of social sustainability issues. When it comes to issues of social sustainability, especially with reference to manufacturing contexts, there is a great deal of consideration of issues relating to the management of workers' safety and ergonomics (Gallo, 2013).

Specifically, ergonomics is a scientific discipline concerned with understanding the interactions between humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance (Antenucci, 2019). One of the fields of application of this discipline is the prevention of occupational risks in the workplace, preventing the presentation of musculoskeletal disorders and thus establishing the conditions to increase productivity in organisations. One of the most effective ways of expressing the ergonomic situation to which an operator is subjected is through the calculation of the OCRA (OCcupational Repetitive Actions) (Baykasoglu, 2017). The OCRA is a numerical value that quantitatively and immediately expresses the risk in ergonomic terms of an operator carrying out a given activity.

Because of its versatility and detail, the OCRA is considered the primary method of detailed ergonomic risk assessment. It can also be used in the case of activities consisting of more than one repetitive task. Its application requires determination of the basic elements for calculating the risk index (frequency of actions, applied force, postural aspects, extent of recovery periods, complementary factors, etc.) as well as careful observation of the various phases of the work activity, which are useful in the stage of determining the values to be assigned to the various parameters. It must be preceded by a careful analysis of the distribution of work times. When properly applied, the method is extremely accurate. It allows a prediction of the incidence of biomechanical overload pathologies and allows a redesign targeted activity according to ergonomic criteria (Colombini, 2013).

It is essential for companies to monitor this data in order to limit possible injuries as much as possible. Musculoskeletal disorders, together with work-related stress, are the most common pathologies in the industrial sector (Occhipinti, 1998). In Europe, more than 60% of work-related illnesses are due to musculoskeletal disorders (Rosie, 2018).

From the studies carried out, the most critical part of the body in terms of biomechanical overload of operators are the upper limbs. In detail, the hand, wrist, elbow and shoulder are the most affected parts (Cecchini, 2010). The OCRA is the most comprehensive and effective method to assess the biomechanical overload of operators' upper limbs. This method is based on clinical data that can determine the risk levels and probability of having a musculoskeletal disorder related to the work of the upper limbs. For this reason it is considered in the standard UNI ISO 11228-3: 2007, "Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency". (ISO 11228-3, 2007)

In order to deal with occupational safety issues in manufacturing environments, one can rely on an approach that has been bringing countless benefits to companies implementing it for decades. The lean management approach focuses on reducing waste - anything that does not add value to the product. The system developed by Toyota, the Toyota Production Systems (TPS), has revolutionised the approach of waste elimination/reduction and has been recognised for years as a winning approach by companies worldwide (Womack, 2007). To identify, eliminate and prevent inefficiencies in production processes and beyond, the Lean approach exploits different tools, such as 5S workplace organisation, total production maintenance, Just-In-Time, standard work, pull production, or value stream mapping (Shah, 2002). LM is widely applied in industry, giving companies that exploit it a competitive advantage by reducing production costs while improving working conditions (Colim, 2021).

The growing interest in the conditions of social sustainability, combined with the well-established lean approach, has given companies the opportunity to solve ergonomic problems with a new vision. This has led some companies to focus on the process of continuous improvement of ergonomic performance through the use of Lean Manufacturing. However, it is necessary to have an intervention methodology focused on the correct application of both concepts under the premise of obtaining results without neglecting the human factor (Colim, 2021). In fact, on the part of some companies to date there is a lack of approach to identify potential ergonomic risks. Moreover, it is difficult for companies to assess the impact of improvement interventions on social sustainability and ergonomics of the operators. (Golabchi, 2018).

There are examples in the literature of positive integration between lean methodology and social sustainability issues. In fact, there are studies that show how the lean methodology applied in manufacturing to assembly lines, is able to improve the ergonomic conditions of operators; keeping production parameters such as takt time, cycle time and work in progress unchanged (Botti, 2017). Nonetheless, the identification and resolution of problems related to ergonomics and operator safety is a topic that has yet to be studied in depth. Lean methodology over the years has developed a framework capable, through sequential steps, of identifying and solving specific problems in even very complex environments. (Rossini, 2019). The framework is known as the "A3 model." A widely used framework in the lean approach is the A3 framework. The A3 methodology was developed based on Toyota's problem-solving approach (Rother, 1999). The A3 model has been widely used to conduct continuous improvement projects and at the same time to introduce Lean thinking in companies. This tool through 8 successive steps that make up the cycle of Plan, Do, Check, Act allows to analyse a situation in detail to identify problems and then countermeasures to address these problems (Rossini, 2019).

It is therefore interesting to study how lean, through the framework of A3, is able to identify, analyse and solve possible ergonomic problems; and how this approach to problem solving is useful for companies to evaluate and impact the implementation of social sustainability practices. This paper through the analysis of a case study of an Italian company tries to analyse, if and how exploiting the lean management approach, in particular using the A3 framework, improves the ergonomic performance of operators.

III. Methodology

Try to answer the research question, a case study of a leading Italian manufacturing company in the oil and gas sector was examined. The company follows the lean manufacturing methodology and aims to continuously improve many aspects of operations to solve different types of problems. In particular, in order to mitigate risks and ensure the continuity of production in its plants, in recent years, the board of directors has been pushing towards the safety of operators in the production line. In particular, the company intends to improve OCRA in the lines. Under Italian law there is no specific level to be reached, but companies must make all necessary efforts to reduce the risks of accidents.

In the case study analysed, risk estimation is performed by a simple assessment of jobs composed of a single repetitive task. The risk classification is done with a risk zone approach, where each of these zones is associated with a numerical range of OCRA (Caputo, 2019)

TABLE 1
RISKS RELATED TO OCRA VALUES

OCRA checklist score	**Level of risk**
<5	No risk (excellent)
5.1-7.5	No risk
7.6-11	Very low risk
11.1-14	Low risk
14.1-22.5	Medium risk

The method also considers and assesses four main collective risk factors based on their respective duration:

- Lack of proper recovery periods;
- Repetitiveness (frequency or actions);
- Force values;
- Awkward postures and movements;

The synthetic index of exposure derives from the ratio between the daily number of actions actually performed with the upper limbs in repetitive tasks and the corresponding number of recommended actions (Lasota, 2015).

The methodology used for this paper is that of a real case study analysis. In the next section we will show how through the Plan, Do, Check, Act (PDCA) steps of the lean framework A3, the improvement of the OCRA was made possible. In particular, the case study shows the company's desire to improve the safety and ergonomic conditions of its workers on an assembly line by acting directly on the OCRA value.

A. Case study analysis

The company decided to dedicate a task force of two consultants to continuously improve the working conditions of its operators, initially focusing on a single assembly line. The company developed the analysis following the PDCA steps (Fig. 1).

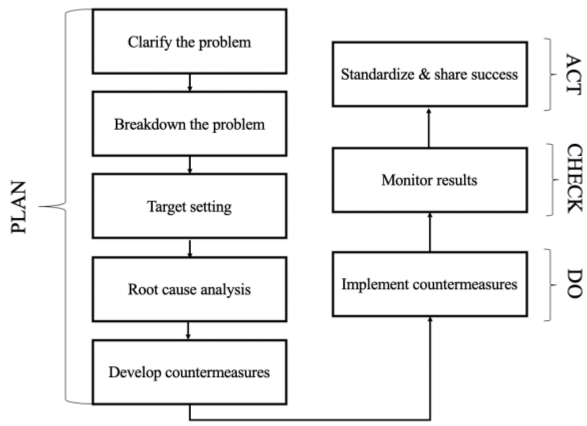

Fig. 1.A3 framework: 8 steps model

The first step started by trying to define the problem back ground and the AS-IS situation. By mapping the material flow and the layout of the line, we had a deep understanding of the line and which stations make it up (station 10, station 20 and station 30&40). The manual assembly line has undergone Lean Thinking before. During these improvements, the process was designed to be sequenced and divided into 4 different machines with 3 total operators, resulting in 3 stations. The first operator is assigned to machine #10, the second to machine #20, and both produce a WIP needed to get half of the final product. Between these two stations is a FIFO line, with a capacity of 25 WIP, which allows pulling instead of pushing. In addition, the last station with another operator includes machines #30 and #40 and, here, 2 Final Products are produced. Between the second and last position, another FIFO is introduced, which picks up the completed parts from machine #20. In terms of material flow, the line implements a supermarket for each component needed (Fig.2).

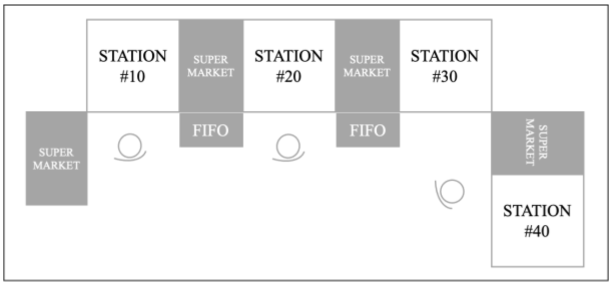

Fig. 2. Representation of the line

Then, with the help of Lean tools such as the Standard Work Module or Yamazumi, it was possible to collect data to calculate the initial OCRA values through operator observations and procedure measurements.

The OCRA value at line level is not that critical. It was clear to the company that the problem should be defined not at line level but at the level of each individual station. In fact, it was found that station 10 has an OCRA for left and right hands, both at medium risk. For station 20, the analysis shows a drastic imbalance between the right and left hands. The OCRA value for station 30&40 indicates a relatively safe situation for the operators, although the right hand is slightly problematic (Table 2).

TABLE 2
AS-IS OCRA SITUATION

OCRA (critical value > 11)	**Station #10**	**Station #20**	**Station #30&#40**
Left	13,98	5,85	5,9
Right	12,37	11,7	8,6

Once the problem to be attacked has been identified, i.e. the OCRA values of each individual station, according to the A3 framework, the company set targets according to the problem. The targets are divided into must-have and nice-to-have and concern the OCRA value and the OCRA balance between left and right hand (Table 3).

TABLE 3
TARGET SETTING

	OCRA Station #10	**OCRA Station #20 /#30&#40**	**Balance between Left and Right**
Must have	<11	<10	+-2
Nice to have	<9	<8	+-2

With specific, measurable, achievable, relevant and time-limited targets, the company moved on to studying the root causes of the problems. The company started by analysing the variables at a macro level for each station, arriving at the formulation of the fishbone diagram. Given the large number, it was decided to prioritise the root causes based on their impact on OCRA and balance. As for the development of countermeasures, the concept of the kaizen 7 wastes was exploited (Ali, 2016). Accordingly, the company aggregated solutions based on the priority root causes for each station. Subsequently, it is prioritized the ideas through a multi-criteria decision tool, the criteria considered were OCRA, Balance, Cost and Time.

In accordance with the criteria considered, a countermeasure was selected and implemented for each station involved. At station #10, the aim was to reduce the time of the technical action of the operators by making changes to the sequence of the procedure, implementing automation, and changing the layout of the components on the station. Station #20 was focused on greasing activities and changing the cardboard conformation. While in station 30&40 the priority was given to the heaviness of the jig holder, so it was replaced with lighter materials such as aluminium or plastic.

After the implementation of countermeasures, OCRA values improved for all stations managing to reach for all stations a value less than 11, which is considered the upper critical value. In particular at station 10 a value of 9.01 was reached for the right hand and 11.4 for the left hand. While for station 2 both hands the OCRA value of 6 was calculated. Finally for station 30&40 for both hands the OCRA value decreased by one point compared to the AS-IS situation. As can be seen by relating Table 3 and Table 4, the final values, both OCRA and the balance of hands, reached the must-have values. The only exceptions are the left hand of station 10 and the balance of station 10 and 30&40, which are slightly above the must-have values. The final results, expressed by the values commented on above, were highly appreciated by the company.

TABLE 4
COUNTERMEASURES AND THEIR IMPACTS ON TARGETS

Countermeasures	**Sequence and Layout Chang - *Station #10***	**Brush Elimination and Cardboard Change - *Station #20***	**Jig Support Lightnening - *Station #30&#40***
ΔOCRA (left and right hand)	-2,5/-3,4	-5,7/+0,2	-1/-1
Balance	2,4	0	2,7

Moving on to implementation, the programming was defined by dividing the milestones into smaller actions and assigning each of them an owner, a status, a start date and an end date. After the implementation phase, there was a phase of monitoring, consolidation and standardisation of the procedures and improvements introduced.

IV. Findings

In order to answer the research question of this paper, it is interesting to highlight the advantages of using the lean approach to solve ergonomics problems. The A3 framework of the lean approach has been of fundamental importance for the successful implementation of ergonomics improvements. Although the concept of lean manufacturing is much more frequently applied to issues concerning the economic sustainability of production processes, such as optimising production and reducing waste, it can also be successfully applied for social sustainability purposes as this case study shows. The structure of A3, which has been established for years, is a guarantee of success. As shown in the case study it is able to provide a methodology, making consultants who use it follow a logical path of self-assessment steps. In this way, the risk of a misjudgement of a possible intervention is reduced. Taking the case study into consideration, it highlights that without a clear definition of the problem to be attacked, in this case OCRA value, the counter measures implemented would not have been as effective and targeted. In addition, thanks to the preliminary analysis of the AS-IS situation and the breakdown of the problem, i.e. the OCRA value of the line, the company became aware of the fact that the problem to be attacked was not one of macro operations, considering the line as a single entity. In fact, the OCRA value of the entire line was not alarming, but by breaking down the problem into individual stations the inefficiencies came to light, so it was necessary to analyse the operations on the various stations that made up the line. Target setting is also of fundamental importance for the consultants' work. They are able to give a clear vision for the implementation of countermeasures; effective countermeasures are those that create a direct impact on the target value that the company has set. Without quantitative metrics one does not know whether improvement actions have had a real effect. This is especially useful in this case study where we are working on improving the working conditions of operators, where often the perception of an operator about their working conditions may be different from another even if they perform the same activity. Having a quantitative measure mitigates the subjective perception of individuals which on the contrary could lead to misalignment with the real context. Other advantages of using A3 was the ability to take advantage of lean tools that facilitated both the process of analysis and data collection, and the process of decision making and problem solving. The Standard Work Module and Yamazumi made it possible to synthesise and schematise the large amount of data collected from the observations. The fishbone diagram tool made it possible to schematise the causes that plagued OCRA's performance and to manage them according to clear priorities. Another aspect of fundamental importance in the A3 approach is that of those responsible for the relevant counter measures. This is an aspect that is very often underestimated during continuous improvement projects. By managing change and consolidating results through regular monitoring, the company can maximise the value of the time and money it spends on improvement projects. Without monitoring and sharing the results, the risk is firstly that the results obtained are lost in a short time and secondly that the knowledge created by these improvements is not used in other similar scenarios.

V. Conclusions

By taking advantage of the A3 framework, the company was able to improve the ergonomic performance of the assembly line under investigation. Thanks to the identification of targeted countermeasures for each station, it was possible to improve the OCRA values. In fact, the "must have" values for each station were reached in a short time, while the company is confident that through continuous training of the operators it will also reach "nice to have" targets. Therefore, one can answer the first research question by saying that the lean approach led to the improvement of ergonomic performance in the case study analysed.

As explained in the results section, the A3 approach has brought countless advantages to the company in solving the ergonomic problem of the assembly line. Therefore, to answer the second question, it can be said that the lean approach has been able to give a structured methodology to the company. The company, through the A3 framenwork, was able to identify specific problems and their causes within a turbulent and chaotic context, where cause and effect relationships were not clear. Using the PDCA steps, combined with lean tools, the company broke down the AS-IS situation to reveal ergonomic and safety inefficiencies, set quantitative targets to ensure that the implemented countermeasures were successful, identified priorities for action to implement improvements and finally monitored and standardised the results. Through the standardisation and sharing of success, steps included in the A3 framework, there is the possibility to scale up and implement the same approach to solving problems related to operator safety and ergonomics on other assembly lines in the company. In addition to the ability to scale these improvements within the case study company, this paper can also be of value to managers in other companies who are struggling with operator safety issues. The lean approach is very flexible and can be adapted not only in other manufacturing contexts but also in the service sector. In terms of its contribution to the literature, this paper enriches the knowledge of safety management using lean methodologies; it is an approach that for solving problems related to waste reduction but has also proved to be very effective in social sustainability contexts.

The research was influenced by a number of constraints that may have limited it. The main limitations derive from the methodology used. In fact, this work and its results are based on a single case study, and in addition the company under analysis implemented this approach only in a limited portion of its production facility. The results of single case studies are not statistically generalisable, so further studies are needed (Welsh, 2001). A possible solution for future research could be to adopt a multiple case study approach, collecting data from both the same sector as this case study and from other sectors. This would provide a larger and more heterogeneous sample, which could disprove that the lean approach can be a winning solution for the continuous improvement of social sustainability related to the working conditions of workers.

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