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No Stress Manufacturing: work-related stress in a Lean production context

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Abstract

This study is part of a broader research, conducted by the Polytechnic of Turin in collaboration with the Department of Psychology of the University of Turin, and is aimed at investigating the relationship between working conditions and stress in a context of Lean Production. To this end, an experimental design, whose main objective is to obtain preliminary data on the relationship between stress and Lean Production, has been developed. More in depth, the experimental design is divided into two laboratory tests: the first aimed at verifying the quality the available instruments (i.e., Biopac electrodes and a modern wireless physiological monitoring system) which are used to obtain physiological data to assess the stress levels in the participants. While the second experiment has been developed to investigate the impact of two Lean practices (i.e., limited buffers and process standardization) on the stress of the operators. The implementation of the two experiments and the verification of the equipment are part of a preliminary work that anticipates the collection of physiological data to be performed at Leonardo plants. For this purpose, the study is structured in a first chapter in which Lean Production is introduced as a production philosophy that over time has revolutionized the organization of work in numerous manufacturing contexts, and in particular in the automotive industry. Subsequently, the effects of this production model on the organization of work and, in particular, on the role of operators are considered. More specifically, the main differences between the organization of work in Lean Production and traditional production systems are highlighted. In a third part of this study, through a careful analysis of the literature, the effects of Lean Production on the health and well-being of workers are presented. The Job Demand Control (Support) model is then introduced as one of the most influential models used to investigate the relationships between working conditions and the health and well-being of workers. Finally, the study proceeds with the presentation of two laboratory experiments, whose main objective is to verify the correct functioning of the equipment supplied and perform a preliminary collection of data regarding the effects of two Lean practices on the health and well-being of workers. To this end, appropriate manipulations of the experimental design have been devised, and more precisely concerning factors such as:

the degree of movement of the participants, the nature of the stress (i.e., endogenous vs exogenous), the participants' discretion over the activities to be performed (i.e., standardization) and the participants' control over the pace of work (i.e., limited buffers). The main results of this study, together with a number of limitations and suggestions for future research are finally summarized and presented in a concluding chapter.

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INTRODUCTION

Background

Following the publication of Womack et al., (1990), "The Machine that changed the world", Lean Production spread to an increasing number of organizations around the world (MacDuffie & Pil, 1996), becoming a managerial fashion (Kieser, 1997 Hamde, 2002) and finding application in several industries other than the automotive sector (Landsbergis, Cahill and Schnall, 1999; Bhamu & Sangwan, 2014). More in depth, Lean Production marked a turning point in the evolution of work organization theories, altering the conventional logic of mass production and leading to stunning results in terms of productivity and efficiency. In this regard, numerous authors have already documented multiple advantages in relation to Lean systems, including improvements on productive aspects such as "lead time, processing time, cycle time, set up time, inventory, defects and scrap, equipment effectiveness, etc. " (Bhamu & Sangwan, 2014, Applebaum & Batt, 1995). From the beginning, however, the ambiguous nature of this system for what concerns its effects on working conditions and workers' health and well-being became evident (Hasle et al., 2012), and still today it remains at the centre of a debate on the changes caused by this production system. Numerous scholars, in fact, see Lean Production as a failure with respect to its initial promises as an innovative and "humanizing production system, resulting rather in an intensification of mass production, or as it is called by some in the neo-Taylorism" (Dankbaar, 1993; Tsutsui, 1998). In this regard, some authors have tried over time to answer the question whether Lean Production must be considered intrinsically stressful, or if an appropriate implementation would be capable of improving, besides productive performances, also the health and well-being of workers. To this end, it is interesting to consider that, although most of the studies have reported a prevalence of negative effects in relation to Lean practices, such as the Just-In-Time method (Jackson & Martin, 1996), according to other authors, including Conti et al., (2006), Lean Production cannot be considered intrinsically stressful since there is no deterministic relationship between this system and the well-being of workers. More in depth, according to these authors, the stress experienced by workers strongly depends on the way in which the system is designed and implemented. Indeed, as also observed by Parker (2003), Lean Production cannot be understood as a univocal and unitary concept of production, strictly defined and composed of the same practices wherever it is implemented, but rather as a system whose success and whose effects on working conditions strongly depend on the particular context and the way in which it is implemented. Furthermore, to dispel the myth that Lean Production is intrinsically harmful to workers, are the results of some studies that have found both negative and positive effects, or even a prevalence of positive effects (Seppälä & Klemola, 2004) as a result of a Lean implementation. As Treville & Antonakis (2006) suggest, indeed, it seems possible to implement Lean Production so that, up to a certain point, the working environment is improved.

In light of this, several authors have tried to investigate those features that make a Lean implementation a "good" implementation, i.e., capable of simultaneously improving production performance and working conditions, or a "bad" implementation. In line with these scholars' results at the basis of the negative effects of Lean systems there are aspects such as an incorrect or partial implementation of the Lean principles (Koukoulaki, 2014), a lack of consideration for human aspects such as job security (Ichniowski & Shaw, 1997) and a negligence to consider the local context and other socio-cultural factors (Parker, 2003).

Furthermore, as highlighted by Conti et al., (2006), it has been observed a scarcity of studies that have explicitly investigated the impact of individual Lean practices on working conditions and workers' health and well-being. Indeed, analysing these relationships, in accordance with the results of Jackson & Mullarkey (2000), could allow to the design of a Lean system in which the positive and the negative effects balance each other, and an equilibrium is achieved.

It is therefore evident that the relationship between Lean practices and their effects on working conditions and workers' health and well-being needs further investigation and that future research should focus on the impact of the individual practices, as well as on the nature of their effects (i.e., additive, interactive). And it is precisely in this context that the present study is inserted, with the aim of further investigating the link between determined Lean practices and their impact on the work environment.

Objectives

This study is part of a broader collaboration project between the Polytechnic of Turin and the Department of Psychology of the University of Turin aimed at investigating the relationship between stress and work in a context of Lean Production. More precisely, this study constitutes a preliminary phase of research aimed at laying the foundations for a data collection to be performed at Leonardo S.p.A. (i.e., an Italian company active in the defence, aerospace, and safety sectors), in order to analyse the stress levels within this context, as well as to investigate the relationship between some Lean practices and the stress to which the workers are subject.

To this end, a design of experiment consisting of two experiments (i.e., Experiment 1, Experiment 2) was conceived in order to lay the basis for the correct progress of the project and to collect useful data for future studies on work-related stress in a Lean Production context. More in depth, as for "Experiment 1", this has the main objective of testing the effectiveness and sensitivity of two instrumentation (i.e., Biopac electrodes and a modern wireless physiological monitoring system) for the collection of physiological data (skin conductance, respiration, heartbeat, etc.) to be used for the assessment of the stress levels. Differently, the main objective of "Experiment 2" is to investigate the stress levels resulting from the experimental manipulation of “job control” through the simulation in laboratory setting of two production lines (i.e., Lean, Non-Lean) and the inclusion in the experimental design of two control-related factors (i.e., production orientation, standardization).

More comprehensively, in the course of this study, it was tried to:

- review the evolution of work organizational theories to investigate the origins of Lean Production, as well as consider the main principles and application tools underlying this system;
- analyse the work organization in Lean Production, placing particular emphasis on aspects such as control mechanisms, work specialization, standardization of procedures, leadership style, etc.

- highlight the main differences between Lean Production and traditional production systems (i.e., Fordism and Taylorism), as well as investigate the major changes in the role of operators paying particular attention to repetitive and low-complexity jobs;
- understand the concept of stress, as well as review the main theoretical models of occupational stress and introduce the Karasek's Job-Demand-Control model;
- assess the effects of Lean Production on working conditions and on workers' health and well-being through an in-depth analysis of the literature;
- determine which of the two available equipment (i.e., Biopac electrodes and a modern wireless physiological monitoring system) is most suitable in terms of compatibility and effectiveness with the objectives of the data collection to be performed at Leonardo;
- obtain preliminary data in a laboratory setting for the impact of determined Lean practices on the levels of stress perceived by assembly workers, as well as evaluate the influence of job control on the dimensions of interest.

Methodology

The development of this study is mainly based on the review of the existing literature. More precisely, the initial objectives of this analysis were to investigate the origins of Lean Production and identify the main principles and application tools underlying this model. Of particular interest for this first revision of the literature were the studies by Bhamu & Sangwan (2014), Holweg (2006) and Karlsson & Åhlström (1996), which analysed the evolution of work organizational models and presented the main elements at the basis of Lean systems.

Furthermore, the existing literature was further revised as regards: the main differences between Lean Production and traditional production systems (Forza, 1996; Genaidy & Karwowski, 2003; Niepce & Molleman, 1996; Olivella et al. , 2008), the effects of Lean Production on workers' health and well-being (Conti et al., 2006; Hasle et al., 2012; Landsbergis et al., 1999; Koukoulaki, 2014; Parker, 2003; Shouteten & Benders, 2004), the concept of stress and the main theoretical models for occupational stress (Cox &

Griffiths, 2015; Le Fevre et al., 2003) and the Karasek's Job-Demand-Control Model (De Lange et al., 2003; Doef & Maes, 1999; Kain & Jex, 2010).
In this first phase of research, most of the material has been found online, and the main source of reference has been Scopus, a database of summaries and citations made available for students by the Polytechnic of Turin. In this regard, the primary keywords used to search the existing literature were: "Lean Production", "Lean manufacturing", "Work organization in Lean Production", "Effects of Lean production", "Lean Production and workers' health" , "Lean Production and stress", "Lean Production and working conditions", "Theoretical models of occupational stress", "Job Demand Control model", "Job Demand Control (Support) model", "Noise as stressor", "Endogenous and exogenous stress ″and“ Trier social stress test ″. Furthermore, besides Scopus, other renown platforms have been used for the investigation of the literature, such as ResearchGate, PubMed e Google Scholar. At any rate, in the selection of the studies, a preference has been typically made for those publications with greater recognition in terms of citations received and validity of the results. Furthermore, bibliographies and citations were screened for the majority of the studies in order to identify further research that could be used for the purposes of the present work.
Concluded this initial phase, the efforts were dedicated to the conception of a pilot design of experiment aimed at obtaining preliminary data to be used for future studies on the relationship between stress and work in a context of Lean Production.

Structure

This document consists of three chapters, to which are added the introduction, the conclusion and the recommendation for future research.
In particular, the first chapter is dedicated to the analysis of Lean Production and the principles and application tools underlying this model. This chapter also traces the history of Lean Production from its first introduction into the Japanese automotive industry to its evolution and adoption by Western manufacturers.

In a second part of this chapter, instead, the analysis is shifted to the primary differences between Lean Production and traditional production systems (i.e., Fordism, Taylorism), paying particular attention to the role of operators in a Lean context.
Finally, in a last section of the first chapter, literature has been investigated on the impact of Lean implementations on workers' health and well-being, placing particular emphasis on those repetitive and low-complexity jobs, typical of production lines.
In the second chapter, instead, is examined the evolution of the main theoretical models of occupational stress, with an in-depth analysis of the Karasek's Job Demand Control model, one of the most influential and renown most model for studying the relationship between working conditions and workers' health and well-being.
In the third chapter, a design of experiment is introduced with the aim of further investigating the relationship between stress and work in a Lean Production context, as well as assessing the impact of certain disturbing factors (i.e., movement, stress) on the quality of the physiological parameters (e.g., heartbeat, skin conductance, respiration, etc.) to be collected in a laboratory setting.
Finally, in the conclusion are summarized the main results of this study, as well as the proposals and recommendations for future researches that seek to further investigate the impact of Lean practices on workers' health and well-being.

1. WORK-RELATED STRESS IN A LEAN CONTEXT

1.1 Lean Production

The origin of Lean Production can be traced back to the profound economic changes that marked the early twentieth century with particular reference to the transformations that took place in the Japanese industry. More in depth, the history of Lean Production begins with the foundation of Toyota, a successful company founded in the early twentieth century by Sakichi Toyoda, a young man from the countryside of Nagoya who had acquired the engineering skills from his father which were then used by Sakichi to design and build his innovative machinery to help his mother and grandmother in their weaving work. Not being able to count on any financial investment or help from other builders, the young Toyoda could only rely on his skills and work for the construction of the frames he designed. As a result, he was therefore forced to follow a trial-and-error approach, developing unknowingly one of the main pillars of the Toyota Way, i.e., the Genchi Genbutsu. In fact, according to this principle, the only way to fully understand the company's problems is to check the situation with one's own eyes, getting literally the "hands dirty". In the end, the efforts of the young Toyoda were rewarded, and he was eventually able to develop an innovative frame with an internal locking system that would be activated when production defects emerged. With this invention Toyoda also introduced for the first time one of the cardinal principles of the Lean philosophy, namely the reduction of waste. The loom, indeed, allowed the reduction of waste in relation to the defective fabric that would have been produced if the loom had continued to work in malfunctioning conditions, allowing savings in terms of resources and time. In addition, this machine also introduced one of the two pillars of the Toyota Production System (TPS), namely the Jidoka, whose translation can be "automation with a human touch" and which essentially consists in the automatic detection of problems and defects at the same time in which these occur, and with production that proceed only when the causes of these problems are resolved at their root.

In 1918 Sakichi founded the Toyota Motor Company, a spinning and weaving company based on its advanced automatic loom (Holweg, 2006). It didn't take long, however, before Sakichi realized that the automatic looms would sooner or later become obsolete, causing a rapid decline in their demand and putting the company's survival at risk. It was therefore evident to Sakichi that in order to ensure the survival and success of the companion, a change of course was therefore necessary. To implement this change was Kiichiro Toyota, the son of Sakichy, who developed his own vision of the Japanese automotive industry and was fully determined to invest in this market. In 1926 Sakichi Toyoda sold the automatic loom patent to the Platts brothers for a commercial value of around £100,000, raising the money to fund the business idea of his son Kiichiro. (Holweg, 2006). The company name was therefore changed to "Toyota" in order to simplify its pronunciation and give it an auspicious meaning in Japanese. (Holweg, 2006) It was at that time that Taiichi Ohno introduced the Just-In-Time (JIT) method, one of the main pillars of Lean Production whose functioning is similar to the way in which in some supermarkets the products on the shelves are replaced by the staff at the very moment in which they are bought by the customers, that is Just in Time. While in production context, the JIT method can be seen as a stock management system in which the necessary resources are made available at the exact moment in which every process requires it, that is "just in time" to satisfy the customer's demand (Shingo, cited in Karlsson & Åhlström, 1996), avoiding unnecessary warehouse costs and significantly improving space management.

Following its foundation, due to the outbreak of the Second World War and the economic crisis faced by Japan at the end of the conflict, the Toyota Motor Company immediately had to face adverse economic times. For Toyota, these will be years of severe financial crisis, with the demand for cars drastically dropped, leaving large quantities of unsold products in the company's warehouses (Holweg, 2006). The financial crisis faced by Toyota, and the growing protests from workers, eventually led to the resignation of Kiichiro, who was then succeeded by his first cousin Eiji Toyoda, who, like his predecessors, will profoundly influence the company's path and values. More precisely, during a visit to the USA Ford plants aimed at learning the techniques of mass production, Eiji and Taiichi Ohno, another key figure in the history of Lean Production, immediately realized that the production model operated by western companies would not be suitable for Japanese producers, and this because of the significantly lower demand for cars and the tight financial conditions caused by the war (Price, cited in Koukoulaki, 2014). From this experience, Toyota executives, and in particular Taiichi Ohno, were inspired for the development of a new and innovative production management model, which would overcome the defects of mass production and better adapt to the needs of the Japanese market (Cusumano, cited in Holweg, 2006). In fact, by analysing western production systems, Taiichi Ohno mainly found two defects. First, he argued that large batches production ultimately led to an increase in inventory, which take up space and increase production costs. Secondly, the rigidity of this system did not allow it to satisfy customer preferences in terms of product variety (Holweg, 2006). Therefore, the model proposed by Ohno consisted in the production of small batches, much smaller than the dimensions in mass production, allowing among other things the manufacturing of a greater variety of models. This in contrast to the Ford's vision for which every customer would have the car of "any color so long as it is black" Henry Ford (1863-1947).

The main goal of Ohno' system was aimed at reducing costs by eliminating waste, a concept developed from his direct experience with the automatic loom (Holweg, 2006). In addition, production in small batches would have allowed a shorter lead time, and therefore a faster return of liquidity, a resource that Toyota was in great need during the post-war period.

The TPS will mark a turning point for the Japanese automotive industry, altering the conventional logic of mass production and leading to stunning results in terms of productivity and efficiency. But although some see TPS as a totally new production concept, developed from the brilliant ideas of Taiichi Ohno, others think that a better perspective would be to see this production model as the result of a ten-year iterative learning process, which took its cue from the previous models, and that is, in some way, their worthy heir (Holweg, 2006). According to this perspective, more than anything else, at the basis of the TPS success there is exactly its “dynamic learning capacity” and the ensuing ability to evolve and improve to achieve ever higher production performance. In this regard, it is interesting to report the contribution of Fujimoto, who, in the concluding chapter of his review on the evolution of TPS, stated that:

"Toyota's production organization [.. .] adopted various elements of the Ford system selectively and in unbundled forms, and hybridized them with their ingenious system and original ideas. It also learnt from experiences with other industries (e.g., textiles). It is thus a myth that the Toyota Production System was a pure invention of genius Japanese automobile practitioners. However, we should not underestimate the entrepreneurial imagination of Toyota's production managers (e.g., Kiichiro Toyoda, Taiichi Ohno, and Eiji Toyoda), who integrated elements of the Ford system in a domestic environment quite different from that of the United States. Thus, the Toyota-style system has been neither purely original nor totally imitative. It is essentially a hybrid" (Fujimoto, 1999).

But the real turning point that made Lean Production famous internationally, attracting the interest of Western producers and academics, was the publication "The Machine that changed the world" by Womack, Jones and Roos (1990), three researchers of the Massachusetts Institute of Technology (MIT) in Boston whose main objective was to investigate and clarify the origins of the stunning competitive performance of the Japanese automotive industry (Bhamu & Sangwan, 2014), as well as presenting all together for the first time the founding principles of the TPS, which until then had been studied separately and in no particular order (Karlsson & Åhlström, 1996). More precisely, the major contribution of this publication was to conclude that the outstanding performances of the Japanese automobile industry had to be sought in the application of the TPS, an innovative production model designed to maximize the value for the final customer by systematically eliminating every form of waste, identified as any resources or activities that do not bring value to the final customer, and for which the latter is unwilling to pay.

Following the publication of Womack et al., (1990), Lean Production, so named by Krafcik (cited in Olivella et al., 2008), spread to an increasing number of organizations around the world (MacDuffie & Pil, cited in Parker, 2003), becoming a managerial fashion (Kieser and Hamde cited in Schouteten & Benders, 2004) and finding application in industries other than the automotive one, such as the garment and the service industries (Landsbergis, Cahill and Schnall, cited in Parker, 2003).

However, is interesting to observe how the spread of TPS in Western countries encountered several forms of resistance, and particularly of a political and organizational nature. More in depth, one of the greatest difficulties encountered by early Lean adopter was related to the cultural and organizational differences that existed between Japan and western countries. Indeed, as Ohno himself observed, TPS was a production concept specifically designed for the Japanese socio-cultural system, which might have not worked in other countries. When implementing Lean systems, it is therefore necessary to take into account the factors inherent to the context, since the success or failure of the system can often depend on these factors.

In this regard it is interesting to report the response of Liker and Meier (cited in Zilio, 2016) regarding the question on why the practices employed by Toyota, which were widely documented and praised for their simplicity, did so much difficulties to take root abroad. The two authors identified problems relating to the management of human resources having a key role in preventing western competitors on adopting TPS. As Robert Quinn also observed "When discussing production techniques, the importance of relationships is not sufficiently considered". Companies, therefore, tend to copy what is seen of Toyota's success without replicating its culture and infrastructure, the real pillars of TPS superior performances (Quinn, cited in Zilio, 2016).

When asked what Lean Production is, Shigeo Shingo, one of the most influential engineers in the creation of this system, replied that: "80% of the people will answer that it is a system based on kanbans, another 15% will argue that it is a productive system, and only 5% will grasp its true essence and will answer that it is a system for the elimination of waste ". More specifically, Lean Production can be defined as a production philosophy aimed at improving performances by the mean of a systematic elimination of waste (Hirano, 1990) and the implementation of a continuous improvement process through which progressively optimize production and maintain only those activities that create real value for the final customer.

While another interpretation might be that of Applebaum & Batt, which describe Lean Production as "an attempt to reduce impediments to the smooth flow of production through continuous improvement (kaizen) in productivity and quality," just-in-time "

(JIT) inventory systems (kanbari), and elimination of "wasted" time and motion " (Landsbergis et al., 1999).

In general, the definitions of Lean Production have been many and among the most varied. In an attempt to summarize them, Bhamu & Sangwan (2014) observed how, over the years, Lean Production has been defined as “a way (Storch and Lim, 1999; Howell, 1999), a process (Womack et al., 1990), a set of principles (Womack et al., 1990), a set of tools and techniques (Bicheno, 2004), an approach (NIST, 2000; Taj and Morosan, 2011), a concept (Naylor et al., 1999), a philosophy (Liker, 1996; Cox and Blackstone, 1998; Singh, 1998; Comm and Mathaisel, 2000; Liker and Wu, 2000; Alukal, 2003; Holweg, 2007; Shah and Ward, 2007; De Treville and Antonakis, 2006), a practice (Framework of the LAI, MIT, 2000; Simpson and Power, 2005), a system (Womack and Jones, 1994; Cooper, 1996; Shah and ward, 2007; Hopp and Spearman, 2004), a program (Hallgren and Olhager, 2009), a manufacturing paradigm (Rothstein, 2004; Seth and Gupta, 2005), or a model (Alves et al., 2012).”

However, Lean is not limited to the production function, but rather includes a family of practices and operational procedures that concern the entire value chain, from the very early stages of concept development to the final of production and distribution (Karlsson & Åhlström, 1996). Therefore, the realization of a Lean system requires an in-depth knowledge of the business processes, as well as a strong focus on the concept of value and its flow within the company. Only in this way is it possible to implement the methods and tools that are at the basis of a Lean system (Coimbra, 2009).

Lean Production is often illustrated with the image of a house based on two pillars: that are Just-in-time and Jidoka. Ohno himself describes the pillars of TPS as "automation" (Jidoka) and Just-In-Time (JIT), with this latter firstly conceptualized by Kiichiro, who stated that "in a sector like the automotive one, the best way to conduct operation would be to have all the parts to be assembled at the side of the production line just in time for their use' (Ohno, cited in Holweg, 2006). Indeed, while the goal of Lean Production is to create a highly reactive production system, both in terms of quantity produced and products types, it also entails lower production costs and reduced lead time compared to traditional systems (Bhamu & Sangwan, 2014; Applebaum & Batt, cited in Parker 2003). To achieve this goal, Lean Production relies on a series of tools and practices based on five fundamental principles that are at the hearth of this innovative production model.

1.1.1 The five principles of Lean Production

The five fundamental principles at the basis of the "Lean Thinking" are: Value, Value Stream, Flow, Pull, Perfection. These, according to Womack & Jones (1996), represent an applicational sequence besides a logical one.

1st Principle - Identification of value (Value): The first step in implementing Lean Production consists in the identification of value as it is perceived by the final customer. Indeed, in Lean Production, it is the final customer that defines what is valuable and what is not, with the concept of value that can be defined as the set of reasons for which a customer is willing to buy a certain product, paying a certain price that eventually depends on the value that the customer itself give to the product (Bianco, 2016). The first goal of a company willing to implement Lean Production should therefore be the identification of value in terms of quality perceived by the final customer, which in turn is achieved by the systematic reduction of all those wastes which do not contribute to the creation of such value.

2nd Principle - Identification of the value stream (Value Stream): The second principle consists in the identification of the value stream, that is the set of actions and resources necessary for the transformation of the raw materials into finished products (i.e., a good, a service or a combination of the two). To identify the value stream, as reported by Womack & Jones (1996) in their "Lean Thinking", is imperative to perform a thorough analysis of all the activities involved in the value chain, from concept development to production and distribution.

Once the analysis is concluded, each activity in the value chain can be categorized as follow:

- Activities that create value for the final customer who is willing to pay a certain price for it;

- Activities that do not create value for the final customer, but which are inevitable and/or difficult to eliminate with the current technologies (Muda type 1). Often, this type of activities become the target of company's medium and long-term plan, since their elimination on the short term is prevented by external and not manageable factors;

- Activities that do not create value for the final customer and are avoidable in all respects (Muda type 2). These activities are promptly eliminated from the system.

3rd Principle – Smooth flow (Flow**):** Once the value stream is identified and the "useless" activities eliminated, the third step consists in making the flow as regular as possible, and ideally with the product that moves along the line without interruptions. If a regular flow is achieved, it means that most of the wastes disturbing the flow have been eliminated, allowing better management of resources and improvement in costs.

4th Principle - Pull production (Pull): This principle complements the previous one and requires production to follow a "pull" orientation, i.e., pulled by the real demand and not by its estimate as occurs in "push" production, typical of traditional systems. In other words, the pull principle sees customer requests as a coordination and authorization mechanism with which organize the entire production (Bianco, 2016). The implementation of a pull orientation significantly reduces the lead times, granting a better match between the actual production and the real demand and avoiding excessive delays between the placing of the orders and the delivery of the products.

5th Principle - Search for perfection (Perfection): The fifth principle summarizes all the previous four and is, at the same time, their direct consequence. In fact, each of the principles listed above has the final aim of implementing a continuous improvement process through which achieve the ideal of perfection implied by Lean Production. But not a perfection intended as the implementation of flawless processes, but rather an iterative approach based on problem solving techniques aimed at progressively identify and correct any defects or anomalies that emerge during operations.

1.1.2 The 7 wastes of Lean Production

As previously mentioned, the first Lean principle imply the identification of value and thus the elimination of any forms of waste that are intended as any activities or resources that do not bring value for the final customer (Slack, et al., 2013), and for which the latter is unwilling to pay.

In general, in Lean Production is possible to identify seven types of waste:
Overproduction – Form of waste that consists in the overproduction of components or finished products, which are unsold or unused for a medium-long period of time, resulting in unnecessary production costs and in the use of excessive warehouse space. The phenomenon of overproduction is usually the result of a "push" production orientation, for which large quantities of product are manufactured well before their actual demand; as opposed to a "pull" orientation, in which production is pulled by the actual demand for products.
Waiting – Form of waste considered the most easily identifiable and concerning all those pauses between one process and the other that are mainly caused by an incorrect synchronization of the production phases. An example of this type of waste are the operators pauses while waiting for the pieces to be processed, or the capital that has not yet been delivered due to low demand. To this end, in Lean Production, it is essential to implement a proper balancing of the workflow, avoiding as possible downtimes.
Transportation - Transport is considered a waste since it involves an activity that does not bring value to the final customer, and for which the latter is not willing to pay. It is often the result of a poor optimization of the company layout for which an incorrect positioning of the workstations forces to move the materials inside the plant. Furthermore, another negative element associated with transportation is the risks incurred by the material during the handling, which is exposed to the danger of being damaged or lost.
Overprocessing - This type of waste occurs when production processes do not have adequate resources (equipment, machinery, operators, etc.) or procedures, which ultimately result in the implementation of activities that do not bring value to the customer. An example of this type of waste is the use of oversized machinery and equipment, capable of producing quantities well above the actual demand for products.
Inventory - Type of waste referred to over-produced material (raw materials, semi-finished products, finished products, etc.) that is stored waiting to be processed or sold to the final customer. More in general, waiting times are considered a waste by definition, since they do not add value to the final customer and represent a capital that has not yet produced profit and entails additional storage and warehouse costs (Hayes

cited in C. Karlsson, and P. Åhlström, 1996). Furthermore, the production of stocks always involves their transportation, and therefore the risk for the materials of being damaged or lost during the handling.

Motion – Are considered motion all those activities that involve a "useless" handling of resources, products, or information, for which no value is added to the final customer. They are the result of a poor company layout optimization and the improper design of workstation.

Defects - Type of waste represented by all the activities or products whose outcome does not comply with the company expectations. It often results in a scrap and/or rework o the defective pieces that generate costs for which the customer is not willing to pay. Furthermore, the presence of defects can reduce the value in the eyes of the customer and increase the company costs as regards the management of complaints and the picking and reworking of the defective products. For this reason, in Lean Production, it is preferable to stop production when necessary, to quickly identify and solve the problems at their root.

Unused employee creativity **-** Although this type of waste was not initially considered by Taiichi Ohno, over time unused creativity has been recognized in all respects as a form of waste, fully in line with Lean principles. More in depth, unused employee creativity includes all those ideas, skills, and opportunities for improvement that are not fully exploited by the management due to a lack of employee's involvement.

1.1.3 The 3M's of Lean Production

But waste, or Muda, represent only one of the three negative elements that Lean Production systematically tries to eliminate through the application of its principles. In fact, in general it is possible to identify two other elements, whose attenuation or elimination, represents a key objective for the Lean philosophy.

Together they compose the famous 3M's of Lean Production, namely Muda, Muri and Mura.

Muri – Muri is the term used to express the overload of resources (personnel, machineries, etc.). Somehow it can be considered at the opposite end of Muda, since consists in pushing machineries or people beyond their natural limits. In fact, although the overload of resources can give advantages in the short term, it can eventually lead to as many disadvantages in the medium and long term. Staff overload, for example, might involve medium and long-term disadvantages in the form of injuries (muscle strains, bruises, etc.) or occupational diseases that eventually can lead to a reduction in productivity, absences from work and a climate of general dissatisfaction. Similarly, the overloading of machineries can lead, in the medium-long run, to an acceleration in the wear of the equipment, and to premature damages which can potentially cause production interruptions and/or higher costs for the restoration or replacement of the machines. In other words, the overload of staff and resources, although it may represent a small benefit in the short term, often turns out to be a waste of time and money in the medium and long run. For this reason, in Lean is essential to organize production as balanced as possible, and if necessary, implement all those precautions that might reduce an excessive workload of resources, keeping the workflow as stable as possible and avoiding decreases in productivity.

Mura – With the term Mura are intended all those sources of fluctuations in production that might lead to irregularities in the workload of resources. The net effect of these fluctuations is to lead, in the event of high demand, to an overload of resources and personnel (Muri), while in the event of low demand, to an oversizing of the machineries which remain stationary resulting in a waste of resources (Muda). To avoid this type of waste, the ideal would be to proceed with a series of analyzes capable of levelling the fluctuations, such that the workflow remain stable over time and machineries are properly loaded. A Lean tool used to this end is the Heijunka method, which is exactly a technic to better balance resources on the line.

1.1.4 The 5S's of Lean Production

To the end of implementing properly all the tools and technics implied in Lean Production, is essential to organize workstations in a way that the onset of problems and defects is prevented (Forza, 1996). More in depth, before implementing other Lean elements and practices, such as Total Productive Maintenance (TPM), Single Minute

Exchange of Dies (SMED), and Just In Time, it is essential to organize workstations so that excessive search times for sub-assemblies, or wastes regarding the handling of materials and the manufacturing of defective pieces, are prevented.

All this can be achieved by applying the famous "5S" (i.e., Seiri, Seiton, Seiso, Seiketsu, Shitsuke) whose initials derive from the Japanese words that describe these practices. The "5S" can also be understood as an application sequence consisting of five steps whose compliance is able to increase productivity, reducing defects and improving quality (Forza, 1996).

1. Seiri (Sort): In the first phase of the 5S the operator has the task of freeing/emptying the workstation of all materials, selecting between what is useful and what is superfluous for production purposes. This will help reducing waste, keeping the workstation clean and tidy, increasing operator efficiency and reducing the occurrence of interference that could potentially lead to a reduction in products' quality.

2. Seiton (Set in order): In the second phase of the 5S the operator must arrange materials so that it is immediately available at the right time, according to the principle "everything in its place, a place for everything". An example of material arrangement is that for which each element is positioned according to its frequency of use: according to this logic, the materials used more frequently is positioned closer to the operator, while those with the least use can be placed in the most remote part of the station.

3. Seiso (Shine): The third step consists in cleaning the workstation in order to keep workspaces tidy and efficient, as well as easily detecting faults and anomalies that could potentially cause an impediment to production, thus requiring prompt repair.

4. Seiketsu (Standardize): The fourth stage consist in standardizing the rules and procedures identified in the previous three stages. This in order to empty, order and clean the workstations correctly, thus avoiding superfluous activities. A good practice is that standards must be set by the operators themselves, who will then undertake to respect and update them over time.

5. Shitsuke (Sustain): The last step of the 5S requires that standards and practices identified in the previous phases are maintained over time, in a perspective of continuous improvement. This implies the active involvement of operators, who are

required to maintain and respect the procedures that has been developed also thanks to their contribution (Forza, 1996).

1.1.5 The two pillars of Lean Production

1.1.5.1 Just in Time

Just-In-Time (JIT) is one of the two pillars of Lean Production and consists of a logistical-production method aimed at eliminating stocks generated by overproduction (together with their costs) and minimize waiting times and transports. In its basic definition, Just-In-Time can be defined as a production method for which each process is supplied with the exact quantity of pieces, at the exact time in which they are needed (Shingo cited in Karlsson & Åhlström, 1996). More in depth, JIT production involves “'producing and delivering finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated parts” (Schonberger, citato in Jackson & Martins, 1996).

Operationally, JIT consists of a production "pulled" by the actual demand for products, which is used to organize production for all workstations, so that each of them manufacture a number of pieces exactly equal to those needed to satisfy the demand. Doing so, as documented by Schonberger and Voss (cited in Jackson & Martins, 1996), it is possible to avoid situations of overproduction, and drastically reduce the stationing of material waiting to be processed, as well as guaranteeing a "quicker response to customers, higher quality and lower scrap levels. " This level of precision is only possible if processes are constantly monitored, and if the presence of defects and anomalies is minimized. The onset of any defect or anomaly, in fact, in an efficient but sensitive system such as that of Just-in-Time, can lead to an interruption of the production line, with obvious costs for the company.

In general, the Just-In-Time consists of three elements: Pull production, One-Piece-Flow and Takt Time.

Pull production - The “pull” system is a logistical method for which production is "pulled" by the actual demand for products. "Pull" systems are opposed to "push" systems, typical of traditional mass production, which are based on demand forecasts that are unlikely to reflect the actual product demand.

In other words, "pull" production consists in giving customers (external or internal to production processes) "what they want, when they want it and in the desired quantity" (Liker et al., 2014). In this way, production does not start unless orders have been placed by final customers, which in turn will be reflected in internal orders aimed at regulating production and ensuring that each workstation produces a quantity of components and pieces exactly equal to that needed to meet actual demand.

Kanban – The Kanban is a tool that allows the implementation of a pull production system. It can be described as a visual system that transmits information throughout the line and to all operators involved in production, about the materials to be supplied and the components to be produced. There are essentially two types of Kanban that can come with a container or a pallet:

Transportation (T) Kanban: whose purpose is to authorize the handling/displacement of materials from an upstream to a downstream process.

Production (P) Kanban: that are internal production orders that indicate the type and number of components required by downstream processes.

Production is therefore "pulled" by Kanbans starting from products demand, which is then reflected throughout the plant defining the exact quantities of sub-assemblies and pieces necessary to satisfy the final order. Compared to traditional systems, in which production is literally “pushed” from upstream, the Kanban system is more flexible and lighter, and also avoids redundancies in line.

One-Piece-Flow - One-Piece-Flow is an organizational method for which a continuous flow of production is created and the advancement of sub-assemblies takes place "one at a time", without interruptions between one production phase and the other, which in turn implies no intra-line-buffer between workstations. This guarantees greater production flexibility, faster switching from one product to another and a significant reduction in warehouse spaces to storage intermediate materials. However, it is evident that not always is possible to organize production in accordance with the One-Piece-

Flow method. Indeed, for instance, there might be a slower or faster process, different set-up times between workstations, or any other element that would not allow a perfect synchronization of the line. In this case it is desirable to fall back towards solutions that are as close as possible to the One-Piece-Flow method, with an optimization of batches and set-up times such that a satisfactory harmonization between production phases is created.

Takt time – **"**Takt time" is that parameter that links production to the market, or to the actual demand for products by customers. More in depth, "takt times" can be expressed as the rate of production required for each unit of final product in order to meet the actual orders. Takt time is obtained by dividing the total hours of work available in a certain time interval by the number of products to be produced in that interval. In general, "it is advisable that all cycle times are as close as possible to the Take time so that processes are then balanced to actual demand, minimizing waste of resources and reducing stock levels" (Barlotti, 2013).

One difficulty related to the implementation of a production model based on Just-In-Time is that relating to the perfect synchronization that should be achieved between workstations (Slack, et al., 2013). But although initially this characteristic of Lean Production was considered by many a weak point of this system, due to the risk of propagation of problems throughout the line, over time it has proved to be a strong point of this philosophy. More in depth, flow synchronization can make processes more efficient, forcing rapid resolution of production problems (Liker & Meier, 2007). Furthermore, this resolution is implemented by the operators themselves, in a more decentralized cultural organization compared to traditional production systems, and for which a higher operators' specialization is required.

1.1.5.2 Jidoka

Jidoka represents the second pillar of Lean Production and can be translated as "automation with a human touch". This innovative technique was first introduced by Sakichi Toyoda in 1894 when he developed an advanced locking system for the loom he produced, which was able to automatically detect the presence of defects and stop production to avoid production of defective fabric. The concept behind this technique can be summarized by the saying "Stop production so that production never stops" and is based on the idea for which it is always better to immediately find and solve production problems, even by stopping production, rather than risk repercussions on the entire production line. In fact, the immediate resolution of defects is considered less expensive than the identification and resolution at a later stage.

In Lean Production, therefore, Jidoka expresses a condition whereby both operators and machineries contribute to the detection of errors and guarantee products quality by stopping production and tracing back problems to their root.

Therefore, adequate training of Lean operators becomes of fundamental importance, so that they are not only able to promptly detect the presence of errors, but also to identify their original causes and implement solutions that solve the problems at their root so that they will not occur again in future. When Jidoka succeeds in its purpose, the most important result is to eliminate the rigid link between machine and man, allowing the latter to devote himself to other value-added activities rather than the continuous supervision of production. In this way, moreover, greater responsibility is given to operators, who can suspend production and control multiple machines at the same time.

1.6 The founding principles of the Toyota Production System

The founding principles of TPS are:

Heijunka: which is a method for leveling production, both in terms of volume and production mix, so that each workstation is well balanced and synchronized with the others. Some of the Heijunka application tools are the Kanbans, the OEE indicator and the Heijunka Box, which is a visual method that allows operators to immediately understand if production is proceeding at the expected pace or if any delays is present.

Standardization: that is the set of rules and procedures that affect all company functions (production, production support, administration, etc.), and whose definition takes place also thanks to the contribution of operators. Standardized procedures consist of an efficient sequence of operations considered to be optimal in a given time interval. The definition of standards allows for a maximization of the business processes in terms of quality and efficiency, and at the same time for a greater predictability and safety in the workplace.

Kaizen: or continuous improvement, from the union of the two Japanese words “KAI”, which means “change”, and “ZEN” which means “better”. Kaizen is at the basis of Lean philosophy and implies a continuous tension towards an ideal of perfection which, however, by its nature is never achievable. Kaizen is operationalized through a systematic search for errors and their resolution, according to a perspective in which everything can always be improved. Kaizen also entails a decentralization of responsibilities for which operators themselves are involved in continuous improvement activities; since they are the closest to production and better understand its operation and potential malfunctions.

Over time, numerous authors have documented multiple advantages related to Lean implementations, including improvements on "lead time, processing time, cycle time, set up time, inventory, defects and scrap, and overall equipment effectiveness, employee morale, communication, job satisfaction, team decision making, etc. " (Bhamu & Sangwan, 2014). As a consequence, over the years, an increasing number of industries have decided to adopt Lean Production by applying its practices to their business processes. However, not all industries have managed to achieve the desired results (Bhamu & Sangwan, 2014). According to Anand & Kodali (2010) one of the main reasons behind this failure is referred to an incorrect interpretation of Lean principles, and its application tools, by managers and workers. According to Mohanty (Bhamu & Sangwan, 2014), on the other hand, another reason why many companies have failed to obtain the desired results of continuous improvement, and whose benefits have remained localized exclusively to certain company functions, is the lack of post-implementation plans, considered fundamental for a correct Lean implementation. Furthermore, Lean Production cannot be understood as a univocal and unitary concept of production, but rather as a system whose success and whose effects on working conditions strictly depend on the particular context and the way in which it is implemented (Parker, 2003). Therefore, companies that decide to implement this system should consider that not all production contexts are the same, and that there are differences that could negatively or positively influence the success of these practices. More precisely, such companies should keep in mind that different countries have different cultures, customers, workforce, degree of development, industrialization, education, cost of living etc (Bhamu & Sangwan, 2014). According to Bhamu & Sangwan (2014) not taking these elements into account could jeopardize a correct Lean implementation, and therefore negatively impact production performance.

In addition, it should be noted that the definition of Lean Production has not yet reached a common consensus among the authors of the literature (Pettersen, cited in Koukoulaki, 2014), and that the word "lean" is often used improperly for systems and practices only remotely similar to those of Toyota, especially regarding the organization of work (Benders & van Bijsterveld cited in Olivella et al., 2008).

As for the future of Lean Production, it is interesting to report Fujimoto's opinion (cited in Biazzo & Panizzolo, 2000), who stated that "it is still not certain whether, in the next century alternative production systems will coexist or whether they will converge towards one, dominant model. Instead, many of today's auto companies in the world seem to be seeking better solutions by fusing elements of existing alternatives. Thus, in the foreseeable future, auto companies are likely to rely on ``hybrid'' production systems rather than entirely new production concepts" (Fujimoto et al., 1997). In line with this, it is interesting to note that organizations often implement hybrid systems that include both Lean and mass production elements (MacDuffie & Pil, cited in Parker, 2003).

What is certain, however, is that since its first introduction, and in particular following the publication "The machine that changed the world" (Womack et al., 1990), an increasing number of workers around the world have come into contact with a new and innovative form of work organization, which has significantly impacted their roles and their working conditions.

1.2 Work Organization in Lean Production

In this chapter an analysis is performed with the aim of highlighting the main differences between Lean Production and traditional production systems (i.e., Fordism and Taylorism). To this end, the role of operators in Lean Production has been investigated, paying particular attention to those repetitive and low-complexity jobs that are typical of production contexts, and whose treatment is more in line with the general orientation of this study.

According to Womack et al., (1990) there are two main aspects for which Lean Production differs from traditional systems. First, "it transfers the maximum number of tasks and responsibilities to those workers actually adding value to the [product]" (Womack et al., 1990), while secondly, unlike traditional systems, it systematically "implements defects detection systems that quickly trace every error back to its ultimate causes" (Womack et al., 1990). From these first elements of differentiation highlighted by Womack et al., (1990) it is therefore evident that the organization of work in Lean Production is defined starting from the concept of value, and that it also implies a strong interaction between man and machine in order to implement a system that automatically traces problems at their root.

Another contribution in the analysis of the main differences between Lean Production and traditional systems is given by MacDuffie & Pil (cited in Genaidy & Karwowski, 2003). More precisely, for these authors, traditional systems are characterized by highly specialized workers, standardized products, large batch production, and a strong hierarchical structure for work coordination. While, on the other hand, Lean Production requires multi-skilled workers, limited buffers, small batch production, and a much more decentralized system compared to traditional systems.

Before proceeding, it is also useful to observe that Lean Production is not a univocal and unitary system, strictly defined and composed of the same practices wherever it is implemented, but rather a system whose implementation strongly depends on contingent factors such as the social and economic context, the local culture, the managerial style etc. What is certain, however, is that Lean Production is a system that aims at the essential and achieve it by systematically eliminating any activities or resources that do not bring value to the final customer. Therefore, in general, compared to Fordism "it requires less inventory, less space, less material movement, less set up time, a smaller workforce, fewer computer systems and a more frugal technology" (Forza, 1996).

Furthermore, although for many authors Lean Production represents an innovative and revolutionary production system, which differs consistently from the previous ones and marks a turning point in the evolution of work organization theories, some scholars question this interpretation by claiming that Lean Production represents nothing more than a mere adaptation of previous systems to changed market conditions (Coriat; Bonazzi; Hall et al., cited in Forza, 1996). Despite this, it is evident that Lean Production shows some elements of continuity with respect to previous systems, sharing with Taylorism the objective of "total productivity", and with Fordism that of synchronicity of the production flow (Revelli, cited in Forza, 1996).

According to Niepce & Molleman (1996**),** instead, especially as regards the organization of work on the production line, the main difference between Lean Production and traditional systems consists in the minimization of buffers, which is considered in all respects an essential element for a correct implementation of the Just-In-Time method and its constitutive elements, i.e., a regular production flow and a strong interdependence between workstations. More in depth, for Niepce & Molleman (1996), the organization of work and the management of human resources in Lean Production is exactly the result of a production based on the Just-in-Time method, for which multi-specialized operators, typically organized in small multifunctional teams, are needed. Therefore, for this system to be implemented, the responsibilities of the operators are not limited to production, but extended to quality control, process improvement and problem solving (Niepce & Molleman, 1996; Taira, cited in Parker 2003).

1.2.1 Multi-specialization and Continuous improvement

In Lean Production, therefore, operators are required to perform a series of activities that are not directly related to production, among which the most common are process monitoring, inspection of parts and participation in continuous improvement (Klein; Aggarwal; cited in Forza, 1996). Furthermore, in line with the principle for which in Lean Production the use of frugal technology is preferred (i.e., technology whose ease-of-use favour the direct intervention of line personnel), also the maintenance of the equipment

should be delegated to line operators, further reducing the costs for the use of indirect personnel (Forza, 1996).
In addition, as previously mentioned, multi-specialization of resources is essential for a correct implementation of the Just-In-Time method, for which a regular flow of production is required, and any anomaly or defect has the ability to propagate along the entire line. To this end, operators must be able to perform multiple tasks along the line, replacing absent resources when necessary and constantly monitoring the processes in search for any issues or defect that might jeopardize the entire production. In this regard, it is interesting to note that this work organization would not be possible in traditional systems, in which the operators are specialized in a limited number of tasks and the presence of intra line buffers allows for the accumulation of stocks avoiding that the disruption of a workstation forces the entire line to stop.
Therefore, in Lean Production it is necessary that operators can work on multiple stations along the production line, changing their role when the need arises. As pointed out by Niepce & Molleman (1996), job rotation represents exactly one of the most common features in Lean Production, allowing for that flexibility and reactivity that are crucial to respond promptly and efficiently to any unpredictable events that might jeopardize production. Furthermore, In Lean Production operators are not only asked to rotate within their own team, but also between one team and another, and sometimes even between different departments (Niepce & Molleman, 1996). This according to a perspective for which a wider range of skills allows operators to develop a broader view of the entire production line, facilitating learning and participation in continuous improvement. However, although the ideal would be that each operator is able to perform all the production tasks, a workforce that possesses all the skills necessary for production is generally impossible to achieve, and this due to both training cost limits and worker preferences (Slomp & Molleman, cited in Olivella et al., 2008).
Furthermore, it is interesting to observe that Lean systems are famous for their ability to evolve and learn. As a matter of fact, operators do not acquire their skills exclusively during the initial training, but also through the participation in continuous improvement activities, in which they not only they use their creativity to search for optimal solutions, but also increase their knowledge of the processes. According to Spear and Bowen (cited

in Olivella et al., 2008), the degree to which Lean systems learn and acquire new knowledge, both at the individual and the company level, is proportional to their ability to constantly question, through the rigorous application of the scientific method, the adequacy of the processes. And this in line to a perspective that emphasizes a continuous tension towards an ideal of perfection (Kaizen), which although by nature can never be achieved, in Lean Production must be constantly sought in order to evolve and improve. Therefore, as observed, unlike Taylorism and Fordism, which place a particular emphasis on the strict control of workers, for instance through an extensive fragmentation of work, in Lean Production operators are encouraged to participate in continuous improvement activities (Jørgensen et al., cited in Olivella et al., 2008) through which exert a certain influence over their work (Strauss, cited in Olivella et al., 2008). The first recognized form of involvement in Lean Production were the so-called quality circles (Shingo and Dillon, cited in Olivella et al., 2008); that are meetings attended in which both workers and managers are invited to highlight problems, flaws or anomalies and offer suggestions for their resolution. The members of the quality circles can come from the same production team or from different teams; in some cases even from different functional areas of the company (Monden, cited in Olivella et al., 2008).

These groups are generally known as "Kaizen groups", while the other term "Kaizen Workshop" refers to those meetings specifically organized to address a precise problem with the use of a specific group of professionals (Liker, cited in Olivella et al., 2008).

These activities stand in direct contrast to those generally used in traditional systems, in which participation takes place in a more anonymous manner, and often inviting operators to put their suggestions in written form in boxes specially designed for this purpose. Such is instead the importance of this aspect in Lean Production, that often the efficiency of Lean systems is evaluated on the number of recommendations per employee per year. Although, in addition to this measure, it is always recommended to also investigate the number of times that these suggestions are actually implemented, and this to assess the quality of the solutions offered by the workers (Karlsson & Åhlström, 1996).

Furthermore, it is evident a certain link between quality circles and the need for a multi-functional workforce. As highlighted by Karlsson & Åhlström (1996), in fact, the implementation of quality circles is the direct consequence of having a multi-specialized workforce capable of having a broader view of the production processes. At the same time, it is also clear that the success of continuous improvement largely depends on the seriousness with which management approaches these activities. It is in fact of fundamental importance that workers suggestions are taken seriously by the management, who must always give clear and complete feedbacks so that these tasks are not performed superficially. To this end, it is always good practice that operators are informed both when their suggestions are implemented in favour of a more efficient redesign, as well as in the event in which their solutions are rejected. In this case it is also necessary to explain the reasons behind rejection (Forza, 1996).

1.2.2 Standardization

One of the most evident results of continuous improvement activities is the definition of new and more efficient Standard Operating Procedures (SOPs), which specify both the sequence of activities that each worker must perform, and the way in which each of these activities must be performed (Monden, cited in Olivella et al., 2008). Indeed, unlike traditional production systems, in which the definition of standards is performed by a small number of experts and the adoption is imposed hierarchically, in Lean Production the operators themselves are involved in the definition of the standards, according to the idea for which their proximity to production, and their subsequent knowledge of the processes, make them the best candidates to offer solutions for their optimization (Bonazzi; Revelli, cited in Forza, 1996).

It is also evident that without standardization there would be no basis for the qualitative analysis of the processes, the stabilization of the flow and the rotation of jobs. Indeed, if each operator performed production tasks according to its own methods, then the basis for job rotation would be lacking, cause each rotation would impact the workflow; an undesirable condition in Lean production, where each station is exactly balanced with the others and the flow must be as regular and synchronized as possible (Olivella et al., 2008).

Furthermore, a more detailed documentation of the procedures, apart from being useful to guarantee a lower variability and reduce the frequency of errors, also allows for greater flexibility of production (Flynn, B.B., cited in Forza, 1996), since each operator has at its disposal a well-documented and updated source to inspect procedures and thanks to which less time is required to change role along the production line.
However, although Lean Production seems to improve Fordism and Taylorism from a human perspective, guaranteeing a lower hierarchical imposition and enriching operators' skills, on the other hand, the active participation of workers in continuous improvement activities ultimately leads to the definition of increasingly standardized procedures, according to what Bonazzi (cited in Forza, 1996) calls "an endless spiral of continuous improvement". For this reason, as also observed by Olivella et al., (2008), operators could be discouraged from participating in such activities if their ultimate result is to make their work even more standardized, further limiting their control. Furthermore, as observed by many authors, despite the initial promises of greater involvement, in Lean Production the participation of employees in decision-making tends to be very limited and restricted to a small part of the total working hours (Berggren; M. Parker & Slaughter, cited in Parker, 2003).

1.2.3 Teamwork and training

Another typical feature of Lean Production, considered by Womack et al., (cited in Olivella et al., 2008) an essential element of this production system, is the organization of work in multifunctional teams in which each member is able to perform a significantly greater number of tasks than their counterparts in traditional systems (Åhlström, 1998). To this end, in Lean systems, operators are assigned to a multifunctional team, and each multifunctional team is assigned to a specific number of tasks (Van Amelsvoort & Benders, cited in Olivella et al., 2008). Furthermore, each team is also given a certain discretion in the internal distribution of tasks (Rahimifard, cited in Olivella et al., 2008), such to foster a greater sense of control, satisfaction and job security (Batt, cited in Olivella et al., 2008). Additionally, each worker is also encouraged to relate with the members of other teams, in a logic that differs from traditional production systems for its tendency to favour a perception of the working boundaries at the level of the entire factory and not of the individual production unit (Niepce & Molleman, 1996). Moreover, one of the most direct consequences of such work organization is the ability to significantly reduce the vulnerability of the system, since any absent resources can be easily replaced and their lack does not necessarily imply the interruption of the production unit.

Furthermore, the use of multifunctional units is an element of fundamental importance for a correct implementation of the Just in Time method, for which the production of each working station strictly depends on what happens downstream from it, and production cannot start until a signal is sent by the following stations. In fact, this implies a greater degree of communication between the members of each group, who are required to work in a group rather than an individual perspective (Heard, JA, cited in Forza, 1996). For the same reason, in Lean plants it is preferable to evaluate the production performance in terms of the group results, rather than those of the individuals (Groebner, D.F., cited in Forza, 1996).

In Lean Production, therefore, the horizontal coordination of work prevails over the vertical (van der Meer & Gudim, cited in Olivella et al., 2008) and operators are required to work in a logic of mutual support and control, rather than an individual one. In the more elaborate versions of multifunctional systems this often results in the total lack of a hierarchical structure within the unit, with the tasks of supervision and guidance that are assigned to each member of the team, or alternatively, to one member at a time, who take the formal role of supervisor and guidance. A direct result of this, is the fewer number of hierarchical levels, as well of univocal classification of roles, that characterize Lean Production compared to traditional systems (Karlsson & Åhlström, 1996).

However, although many scholars have praised the use of multifunctional teams for its effects on working conditions, for some authors this organization of work is just a pretext to "facilitate the process of work intensification" (Turnbull, cited in Parker, 2003) and to exploit peer pressure in order to discourage delays, absenteeism and errors (Wilkins, cited in Forza 1996). According to these authors, a team-based organization of work encourages a climate of hostility and blame, and this since the results of individuals are closely linked to those of the entire team. Indeed, the mistake of individuals affects the performance of the entire group, in the same way in which the delay or the absence of a team member would result in a work intensification for the remaining members.

Furthermore, a work organization based on multifunctional teams, and therefore on operators able to perform a higher number of tasks than in traditional systems, requires an initial training for workers far more elaborate than in previous systems, as well as a continuous updating through ongoing training. Indeed, if in traditional systems employees are trained to perform a very limited number of tasks, mainly related to production, in Lean systems the preparation courses include elements of "statistical process control, quality tools, computers, performing set-ups, carrying out maintenance, etc" (Karlsson & Åhlström, 1996).

Finally, since the success of a team-based work organization largely depends on the relations between members, besides the more technical aspects, it is of fundamental importance that workers develop a set of interpersonal skills that ultimately allows for a better communication between team members. As Bidanda et al., (2005) observed, in fact, "communication" represents the most valuable aspect for a cell-based work organization.

An excellent example of team-based work organization is that of autonomous production cells, the adoption of which has been particularly active in Japan in the last ten years (Olivella et al., 2008). The main peculiarity of these cells is that they operate fully autonomously without the intervention of external actors (Yin et al., cited in Olivella et al., 2008). In this regard, it is interesting to report the similarity made by Suzaki (1993), who compared these cells to a group of mini businesses operating within the company, and in which each team leader act as the CEO of the cell.

As for the training of operators, as previously noted, this is of fundamental importance to develop a multi-specialized workforce capable of working in multifunctional groups (Olivella et al., 2008). Despite this, it is important to consider that staff training is also subject to limits in terms of time and costs (Allwood and Lee, cited in Olivella et al., 2008). In some cases, for instance, excessively long and expensive training may not be compensated by the value that the developed skills could bring to the company in terms of profit. To this end, it is always advisable to perform a cost-benefit analysis in order to investigate the profitability of the training. Normally, however, it is possible to say that trainings aimed at multi-skilling adapts well to the needs of a production line, since typically the jobs that this includes are repetitive and entail low-complexity tasks. In this case, in fact, the time and costs necessary to acquire a certain skill would be sustainable and would benefit the possibility of job rotating within the team. For this reason, in Lean Production, it is advisable to perform multiple training courses with the aim of making operators acquire a growing number of skills and therefore allow for a more efficient job rotation. In this regard it is interesting to observe that in Toyota there are only two types of workers for the entire production line: the "assembly line worker" and the "craft technician", with the first able to perform any task in any part of the line (Vaghefi et al., Olivella et al., 2008).

To conclude, it is evident, as also highlighted by Ramarapu et al., (cited in Olivella et al., 2008), that learning and training are critical elements for Lean systems, thanks to which it is possible to transmit professional, interpersonal, and technical competences in a perspective for which workers become multipurpose actors, able both to perform the assigned tasks and to learn new ones (Duguay et al., cited in Olivella et al., 2008).

1.2.4 Control mechanisms and leadership style

Another substantial difference between traditional production systems and Lean Production is that related to control mechanisms. If in Taylorism and Fordism, in fact, the control mechanisms are mainly exercised on a hierarchical scale and are of a disciplinary nature, such that workers often perceive this control as a limit to their freedom and seek subterfuge to escape and adapt the work to their needs, in Lean Production the work organization itself acts as a control mechanism for the operators. More precisely, in Lean Production the production pace is ideally the same across the entire line and each workstation is highly balanced with the others. In a system as such, therefore, any error or slowdown related to a certain workstation would be immediately evident, since it would be reflected on the entire production line. In this sense, in Lean Production, any variability concerning the work of the operators is immediately visible and the system itself acts as a control mechanism, reducing the need for external intervention by the management (Niepce & Molleman, 1996).

Consequently, another difference between Lean and traditional systems is that relating to the leadership style and the role played by the managerial group (Olivella et al., 2008). In Lean Production, in fact, the delegation of greater responsibilities in the hands of the operators entails less control over them by the managerial group (Wilkinson, B., cited in Forza, 1996), whose members are now required to act more in the role of facilitators, coordinators and trainers, rather than mere supervisors (Groebner, DF, cited in Forza, 1996); thus fostering a climate that encourages worker participation and learning (Forza, 1996).

Despite this, the role of managers in Lean systems is generally more demanding than the equivalent of traditional systems, and this for the particular emphasis that this philosophy places on teamwork and on the need for managers to participate in continuous improvement activities and quality circles. To make the role of managers in Lean Production even more challenging is the importance that this system places on the free circulation of information, identified as capable of increasing learning, both at the individual and the company level. In this sense, the managerial group also takes the role of crucial centre for sorting and managing the information flows, with operators that are encouraged to communicate with their superiors to report errors, opportunities etc. In Lean Production, therefore, it is essential to have a good point of contact between the management and the executive groups, so that the flow of information between the two is present and efficient. One way to achieve this level of interaction is by having engineers and managers circulating more frequently along the production line, relating to workers in order to obtain valuable information regarding the progress of production. This would not only allow a faster analysis of the processes and a quicker detection of any problems concerning production, but it would also improve the perception of the operators with respect to their work, as well as guaranteeing a reduction of the barriers between the managerial and worker group (Forza, 1996).

1.2.5 Commitment and remuneration systems

Another fundamental characteristic of Lean systems is that relating to the motivation of workers and their commitment to corporate values. It has been proven, in fact, that for new forms of work organization, such as Lean Production (Shapiro, cited in Bhamu & Sangwan, 2014), the commitment of workers to corporate values is of crucial importance (Cutcher-Gershenfeld et al., cited in Bhamu & Sangwan, 2014), without which the operation of such systems could be compromised.

In this regard, it is interesting to report the observations of Besser (cited in Olivella et al., 2008) who carefully analysed the mechanisms used by Toyota to obtain the commitment of the workforce to corporate values. According to this author, in fact, a method used by Toyota to align individual goals and organizational goals is by assessing production performance at the level of the entire team, thus linking the results of individuals to those of the other members and taking advantage of the resulting peer pressure. While other means noticed by Besser (1995, 1996) in order to obtain workers commitment are the implicit guarantee of permanent employment (thus increasing job security), and the reduction of barriers between the management and workers groups. For McLachlin (cited in Bhamu & Sangwan, 2014), on the other hand, another useful mechanism for obtaining employees engagement is the use of managers as a model of commitment for the other workers, which in turn will be inspired to align their interests with those of the company.

However, in Lean Production, as also reported by Biazzo & Panizzolo, (2000), obtaining high workers commitment could result arduous, and this because of the negative effects that this system often entails on working conditions. As a matter of fact, over the years, a good part of the literature has reported many cases of Lean implementations that have led to a worsening in working conditions, with direct consequences on the workers' health and well-being. For this reason, workers may find it difficult to align their interests with that of the company and work efficiently and productively.

In this regard, as also observed by Karlsson & Åhlström (1996), in order to motivate the workforce and obtain satisfactory level of commitment a fundamental role is played by the remuneration system. More in depth, according to these authors, in Lean Production the remuneration system can increase workers engagement and should be composed of a fixed part, linked to the actual competences and responsibilities of each operator, and a variable part (in the form of bonus) linked to production performances; this according to a logic whereby the fixed compensation rewards dimensions such as learning, multi-specialization and teamwork, while the variable part enhance involvement and commitment (Olivella et al., 2008). Furthermore, for several authors, always to increase workers engagement, the remuneration system should be also based on team rather than individual performance (David, cited in Olivella et al., 2008), and this according to a well-defined scheme that links salaries to predetermined indicators of quality, cost and delivery (Sodenkamp, cited in Karlsson & Ahlstrom, 1996). The same Womack and Jones (cited in Olivella et al., 2008) stressed the importance for Lean systems to implement a remuneration scheme that is somehow related to performance, while Panizzolo (cited in Olivella et al., 2008) has effectively observed that this type of systems are very common in Lean systems.

Finally, another element that according to Bessant & Francis (cited in Olivella et al., 2008), should not be missing in Lean implementations is that relating to reward systems, considered as having the ability of further increasing the level of motivation and involvement of workers. More precisely, such systems should be composed of rewards for the performance at the level of the entire group, as well as at the individual level. Although for the latter, according to Kerrin and Oliver (cited in Olivella et al., 2008), limits should be set, since the performance of the individual could go in direct contrast to that of the group. Finally, reward systems should be also designed to be as transparent as possible, as well as being based on modest monetary incentives. In fact, as Suzaki (cited in Olivella et al., 2008) observed, it must be clear to workers that improvement should be a normal part of the job and not something to put in practice exclusively in view of bonuses and rewards.

The main differences between Lean Production and traditional production systems (i.e., Fordism and Taylorism) have been investigated and presented. The main discrepancies were observed in dimensions such as worker involvement, specialization, standardization, teamwork, control mechanisms, managerial style, remuneration systems and employees' compensation. It should be noted, however, that Lean implementations have not always included all these elements but have rather created hybrid systems composed partly of Lean practices and partly of elements relating to other production systems. For many authors, this could explain the failure of Lean implementations to fulfil the initial promises of improved health and well-being of workers, and why in many cases such implementations have been followed by a worsening in the working conditions. In this regard, in the next chapter an analysis of the literature will be performed in order to investigate the effects of Lean implementations on working conditions and workers' health and well-being, placing particular attention on the impact of each Lean practice on these dimensions.

1.3 The effects of lean production on workers' health and well-being

Since its first introduction, Lean Production has immediately received international attention by manufacturers and academics whose main interest concerned two fields of research; the first aimed at evaluating the effective capabilities of this system in improving production performance, while the second intended to investigate the effects of Lean Production on workers' health and well-being. Despite the years, however, the literature has not yet managed to reach a common consensus and the debate regarding the effects of Lean Production is still the subject of heated discussions. There is no doubt, indeed, that Lean Production represents an ambiguous concept, capable of dividing the literature from the very first moment of its appearance on the international scene (Hasle et al., 2012).

Unsurprisingly, the first series of publications on the effects of Lean Production was conducted by a group of Japanese authors, who before their Western counterparts had the opportunity to closely analyse this production model, investigating the changes that this entailed on the organization of work. One of the very first publications on Lean Production was carried out by a group of four Toyota engineers (Sugimori et al., cited in Shouteten & Benders, 2004), who sided in favour of this production system, praising its "" humanization "and its intrinsic ability to eliminate, together with the waste, the so-called useless jobs so that employees could mainly perform activities that bring value to the final customers" (Shouteten & Benders, 2004). In 1986, however, Satoshi Kamata, a journalist who worked undercover in a Toyota factory to investigate the real conditions of workers under Lean Production, arrived at diametrically opposite results to those obtained by Sugimori et al., (cited in Shouteten & Benders, 2004). The image that Kamata draws of what at the time was called Toyota Production System (TPS) is rather negative and reports a worsening of working conditions such as "long working hours, constant pressure to improve, hard physical working conditions, lack of ergonomic measures, unsure employment for the extensive temporary staff and the tight company control of worker dormitories, to name but some aspects" (cited in Shouteten & Benders, 2004). Of particular interest is to observe how the contrasting positions proposed by Sugimori et al., (1977) and Kamata S. (1986) are the same that have divided the debate on the effects of Lean Production in the years to come, separating the advocates of this system on the one hand and the opponents on the other (Shouteten & Benders, 2004).

To further ignite the debate on the effects of Lean Production was the publication "The Machine that changed the World" (Womack et al., 1990), whose main objective was to compare production systems in the automobile industry at a global scale, and whose results made Lean Production famous internationally. Womack et al., (1990), in fact, concluded that the performances of Japanese car manufacturers were significantly better than those of their Western competitors, but also that the basis of such superior performances could be copied.

Despite this, its adoption in the West met with certain resistance, and particularly in the UK, where at that time was present a strong Marxist current. This model was in fact accused of "intensifying the surveillance of workers, increasing their responsibilities, exploiting peer pressure (Sewell and Wilkinson, 1992), increasing the workload due to continuos improvement and kaizen practices (Conti and Warner, 1992: Malloch, 1997)" (Shouteten & Benders, 2004). In America, instead, the tones were much more enthusiastic, and the adoption of Lean Production met with less resistance compared to Europe.

Over time, therefore, both in the direct form of Japanese investments, and in the indirect one of to the adoption by Western producers of Japanese-like systems, workers from all over the world, and especially those employed in the automobile industry, were confronted with a completely new organization of work. This allowed Western academics to study Lean Production more closely, investigating more in depth the effects of this production philosophy on the health and well-being of workers (Shouteten & Benders, 2004). From the beginning, however, the ambiguous nature of this system for

what concerns its effects on working conditions and workers' health and well-being became evident (Hasle et al., 2012).
As highlighted by Koukoulaki, (2014) the same Womack et al., (1990), in their key publication on Lean Production, highlighted how one of the key aspects inherent to this model, that is the systematic elimination of waste, could have led to a condition of redundancy of workers, who for this reason could have shown a lack of motivation in taking part in continuous improvement activities, precisely because of their ability to jeopardize their working position.
Despite this, over time, many authors supported Lean Production seeing in this model not only a system capable of enhancing production performances, but also a philosophy capable of improving working conditions, by optimizing dimensions such as workers' autonomy, participation, breadth of roles, cognitive demand, etc. (Koukoulaki, 2014). Otherwise, the image given by the opponents of Lean Production is much more negative and identifies in this model a "failure in its initial promises to present itself to the world as an innovative and "humanizing" production system, resulting rather in an intensification of mass production, or as it is called by some in the neo-Taylorism" (Dankbaar; Tsutsui; cited in Parker, 2003).
First of all, however, before proceeding with the exposition of some of the most important studies' results on the effects of Lean Production, it is useful to observe how in the discussion of this chapter particular attention is given to manual, highly repetitive and low complexity jobs; whose discussion is more in line with the objectives of this thesis, as well as being those that are most impacted by the introduction of Lean Production practices (Young, cited in Shouteten & Benders, 2004).
Lean practices such as the removal of intra-line buffers, Just-In-Time and the reduction of idle times all seem to have negative effects on working conditions, and consequently on the workers' health and well-being. More specifically, as also observed by Hasle et al., (2012), this kind of practices seem to increase work pace and load and to reduce operators' autonomy, to the point that the positive effects of other Lean practices, such as the participation in quality circles and teamwork, do not seem capable to compensate for these negative effects.

As for the organization of work in the production line, this is typically composed of repetitive and low complexity jobs, and the ideal is that the products move along the line without interruptions, passing from a station to the other without the use of intra line buffers. Cycle times are relatively short and a "pull" production orientation is adopted so that each workstation needs a signal from the next to start production. The reason why intra-line buffers are considered a possible source of waste, and systematically eliminated, is related to their ability to hide production defects. Precisely, if for any reason production anomalies were to occur and intra-line buffers were present, the defective pieces would be stacked in the output buffers, delaying the detection of the error, and producing pieces that are considered waste in all respects; both in case they are thrown away and that in which they need to be reworked. This leads to an efficient but very fragile production system, to the point that a small source of variability, or the occurrence of any error, could compromise production throughout the production line. Also for this reason, under Lean Production the operations are highly standardized and operators are involved in continuous improvement activities, whose purpose is essentially to lead to even more efficient Standard Operating Procedures (SOPs).
Before proceeding, it is of particular interest to observe how, in general, studies on the effects of Lean Production pass first through the analysis of the working conditions, and in particular through the investigation of some dimensions inherent to the working environment such as the control of operators over their activities, the workload to which they are subject, the social support of colleagues and superiors etc. (Hasle et al., 2012). In fact, thanks to the wide availability in the literature of models that link these dimensions, it is possible to predict the changes that a variation of one of these could cause on the output variables. An example is the renowned Job Demand Control model by Karasek (1979), which relates working dimensions such as job demand and control to workers' stress levels.
In the following paragraphs, to analyse the effects of Lean Production, some of the most important research on this object of study will be reported. Indeed, as noted previously, following the publication "The Machine that changed the World" by Womack et al., (1990), many authors decided to investigate the relationship between Lean Production, working conditions and workers' health and well-being. Among these, one of the very

first studies was the one conducted by Klein (1991), who concluded that Lean practices led in most cases to a worsening of the working environment. More in depth, Klein (1991) observed that the elimination of intra line buffers had mainly led to a reduction of operators’ control over the pace of work. In fact, if in presence of intra-line buffers the operators had the possibility to speed up or slow down their work, exactly thanks to the presence of a buffer in which to place the finished pieces, in the absence of intra-line buffer the production rate of each workstation it is punctuated by that of the entire line. Furthermore, in line with other studies, Klein (1991) noticed that the continuous tension towards perfection, typical of Lean Production, progressively leads to a greater standardization of the SOPs, further reducing workers' control over their activities.

Another study of particular interest is that carried out by Jackson and Mullarkey (cited in Hasle et al., 2012), in which the authors compared a Lean with a non-Lean production line within the same plant. The interesting contribution of this study was to paint a rather ambiguous image of Lean Production. In fact, if on the one hand this study confirms some of the negative results reported previously, on the other it also highlights positive effects on dimensions such as employees' breadth of role, skills’ discretion and cognitive demand (Hasle et al., 2012). It is also interesting to observe that for Jackson & Mullarkey (2000) the negative and positive effects cancel each other out, leading to a situation of apparent equilibrium. This study will be part of a large series of others that will report both positive and negative effects, further fuelling the debate on the effects of Lean Production.

Another study worth reporting is that of Shouteten & Benders (2004), in which the authors investigated the effects of a Lean implementation in a bicycle factory in the Netherlands. Besides being one of the very first studies to analyse the effects of a Lean implementation outside the automotive industry, of particular interest is the authors' decision to use an external framework for the analysis, i.e., the Karasek’s (1979) Job Demand Control (JDC) model. Also in this case, the results paint a rather negative image of Lean Production reporting very low operators’ autonomy, highly standardized procedures and very small control over the pace of work. Despite this, a particular result of this study that from a certain perspective may appear paradoxical, is that for which the use of highly standardized SOPs, together with a great focus on the elimination of waste, can lead to a situation for which the occurrence of production problems is so low that the operators' control over their activities, although scarce, is sufficient to meet their work demand.

A study instead that seems to move in an opposite direction to those just reported is the one conducted by Seppälä & Klemola (2004), in which the authors analyzed the effects of four Lean implementations in four different metal production plants. Differently from most of the studies, in fact, Seppälä & Klemola (2004) concluded that Lean Production has mainly positive effects on the working conditions, and therefore on the workers' health and well-being. In particular, the authors reported improvements in working dimensions such as work's content, operators'participation, control and learning (Hasle et al., 2012).

Finally, in one of the most comprehensive studies on the effects of Lean Production, Conti et al., (2006) compiled 21 hypotheses, finding confirmation for 11 of them. Faced with the question whether "Lean is Mean?" the authors reply that in line with their results Lean Production it is not considerable intrinsically detrimental for the working environment, but rather the results of each implementation will depend strongly on other variables, such as the management's choices over the implementation process and the system' structure. In fact, if on the one hand the results obtained by Conti et al., (2006) seem to confirm a negative image of Lean Production, some practices such as workers' participation in continuous improvement and the extensive use of teamwork, appear to have a positive impact on the working environment, with consequently positive improvements on workers' health and well-being. In addition to those just mentioned, a good number of other studies have tried to investigate the relationship between Lean Production and the dimensions of interest, reaching similar conclusions to those obtained in the studies just reported.

Therefore, given the ambiguity of these results, and the need of clarifying the relationship of interest, the results of the two largest reviews on the effects of Lean Production are here reported. The first major review on the effects of Lean Production was made by Landsbergis et al., (1999) who analysed 38 studies, of which the only ones considered methodologically valid by the literature are those relating to the automotive industry (13 out of 38), since in all other cases the term "lean" was not explicitly mentioned, or only some practices, and not the whole system, were adopted. The picture that Landsbergis et al., (1999) paint of Lean Production in the automotive industry is predominantly negative, with operators' control that remain significantly low, and job demand that is significantly greater compared to traditional systems.

Of the same opinion is the other major review conducted by Hasle et al., (2012), for which a total number of 11 were investigated. The main contribution of this review, besides confirming the results of Landsbergis et al., (1999) for the automotive industry, was to extend these results to other industries that employ manual and low complexity jobs. However, although the studies considered seemed to prevalently describe a negative impact of lean Production, the authors also reported of cases with both positive and negative effects, while in others only positive effects were reported. In fact, as Treville & Antonakis (cited in Hasle et al., 2012) suggest, it seems possible to implement Lean Production so that, up to a certain point, the working environment is improved.

The discussion regarding the possible sources of ambiguity and the elements apparently capable of determining a successful implementation is left at the end of the chapter. In the next paragraph, instead, we will take a closer look at the effects of some Lean practices such as workers' participation in continuous improvement, process standardization, JIT production orientation etc. all identified by the literature as capable of influencing the output variable of interest (working condition, workers' health and well-being).

1.3.1 Working Conditions

A Lean practice, considered as one of the most positive aspects implied by this system, is that relating to the participation of workers in continuous improvement activities, in which operators have the possibility to offer their suggestions proposing solutions that could potentially optimize the production processes. More precisely, these activities are considered by Lean Production 'advocated as an element capable of increasing operators' participation, involvement and cognitive demand, as well as allowing them to carry out activities not directly related to production. Forza (1996), in one of the most renowned studies on the effects of Lean Production on the organization of work, confirmed this perspective, reporting that generally, the consultations of operators regarding workplace changes are considerably greater in Lean Production than in traditional systems. For some authors, however, the positive effects linked to workers' involvement in Lean Production context are not capable of compensating the negative effects caused by other Lean practices. Of this opinion are Conti & Warner (cited in Koukoulaki, 2014) for whom workers' participation in quality circles occupies a very small part compared to the total number of working hours; to the point that "the employees spend 4 hours per month in a very non-Taylorist manner to make their work for the rest of the month even more Taylor-like" (Conti & Warner, cited in Shouteten & Benders, 2004).

Interesting in this regard is the contribution of Jones et al., (cited in Koukoulaki, 2014), who observed that in Lean Production the implementation of activities involving workers' participation, are not meant to enhance workers' empowerment, but rather to maintain its illusion. According to the authors, in fact, activities involving workers' participation in Lean Production are generally manipulated by the management so that consensus is reached only when the solutions proposed by the operators are in line with the values of the managers, precisely maintaining an illusion of participation. Of the same opinion are Fucini & Fucini (cited in Koukoulaki, 2014), who report that the only solutions generally accepted by the management are those that provide for a reduction in costs, an increase in productivity or a shortening of cycle times. Finally, in line with the previous results there are also those of Niepce & Molleman (cited in Koukoulaki, 2014), which confirm how the involvement of employees in Lean Production is present but restricted to certain areas of decision-making such as products quality and work procedures. Furthermore, participation in continuous improvement activities involves a greater use by operators of problem-solving skills, which can be judged either positively (greater control and participation) or negatively (greater cognitive demand) (Landsbergis et al., cited in Shouteten & Benders, 2004). In conclusion, it is also important to consider what the result of these practices is. If on the one hand these activities seem to entail grater control for operators, giving workers the opportunity to use their creativity and experience (Conti et al., 2006), on the other, as also observed by Conti & Warner (cited in Shouteten & Benders, 2004), these practices lead to an always greater standardization and monotony of the operating procedures, in a process that Buchanan (cited in Conti et al., 2006) describes as "the ruthless pursuit of continuous improvement".

And it is precisely the high standardization of the processes that is considered by the opponents of Lean Production another negative element capable of further reducing the control of operators; already considered scarce due to the changes entailed by the implementation of a JIT production orientation. Indeed, as Niepce & Molleman (cited in Koukoulaki, 2014) observed, in Lean Production it is difficult for workers to reach a sufficient degree of autonomy, since the use of highly standardized operating procedures drastically reduce operators' control over their tasks. Furthermore, in line with the results of Sorge and Benders, (cited in Shouteten & Benders, 2004), the monotony of operations does not only depend on the way in which work is organized but also on external variables linked to production, such as the batch sizes and the variety of products manufactured. More precisely, the monotony of the activities will be greater the lower the variety of products manufactured and the greater the size of the batches.

Paradoxically, some authors have also observed positive effects in relation to the standardization of processes. More precisely, Shouteten & Benders (2004) noted that in some cases the control granted to employees proved to be sufficient. But this not thanks to the participation of the employees in continuous improvement activities, as one might think, but rather due to the high standardization of the processes, and the subsequent reduction in production problems that this entails, to the point for which the control in the hands of the operators is enough to face their demand.

Another common feature in Lean Production is the use of relatively autonomous multifunctional teams, in which operators are asked to carry out a range of tasks that is generally greater to that performed in traditional production systems. For Forza (1996) and Conti et al., (2006), the use of multifunctional teams leads to mixed results. Indeed, if on the one hand, it is believed that the use of multifunctional teams leads to greater social support, and therefore to lower stress levels (Karasek, 1979), as well as to an increase in the operators' breadth, knowledge and work experience (Conti et al., 2006), on the other hand, teamwork is accused of leading to an increase in job demand. More precisely, as observed by Conti et al., (2006), one of the potentially negative effects of multifunctional teams is that for which operators might find themselves in the condition of having to perform, besides their tasks, also those of their colleagues that are unable to maintain the pace of production. Furthermore, it is evident how the use of teamwork could potentially lead to greater interpersonal conflicts, as well as to a greater peer pressure. In this regard, it is interesting to report the results of Delbridge & Turnbull (cited in Conti et al., 2006), which suggest that in Lean Production, precisely because of teamwork and the immediate traceability of defects, are present the basis for encouraging the development of a "blame culture". Indeed, as also Huber & Brown (cited in Conti et al., 2006) observe, since the presence of defects is immediately detectable and readily shared by group members, operators may feel increasingly pressured for their work, further increasing their stress levels.

Furthermore, over time the literature has also identified other Lean practices apparently capable of influencing the quality of working life. Among these, there is certainly the Lean common practice of interrupting the production line whenever defects or anomalies are detected. If, indeed, in traditional production systems the interruption of the line is rather rare and avoidable thanks to the use of intra-line-buffers, in Lean Production the strong interdependence between workstations could cause a rapid propagation of errors throughout the line, and then requires the production to be stopped whenever problems are detected. However, the net effect of these interruptions seems to lead to a deterioration in the quality of working life, as for instance reported by Womack et al, (cited in Conti et al., 2006) who, studying the early stages of the TPS implementation, observed that the frequent interruptions of the line often resulted in a workers' discouragement and increased psychological demand.

A positive aspect regarding Lean practices and their effects on working conditions is that relating to the significantly lower occurrence of errors or production anomalies. Indeed, the systematic elimination of variability sources, the standardization of processes and the use of fool-proof design are all practices capable of significantly reducing the occurrence of errors, and consequently improving the working quality of operators, as well as generating in them a sense of pride and job security (Koenigsaeker, cited in Conti et al., 2006). Moreover, as observed by Womack et al., (cited in Conti et al., 2006), the demoralization associated with the assembly of incompatible parts due to manufacturing defects is again largely eliminated by the use of "fool proof design".

1.3.2 Workers' health and well-being

Another object of particular interest for scholars has been that relating to the effects of Lean Production on the physiological health of workers. According to T. Koukoulaki (2014), however, not always a correct monitoring of this relationship in Lean contexts is possible, and this because of a work organization based on teams. In Lean Production, indeed, appear to be frequent the phenomenon for which the operators tend to underreport physiological problems, fearing the consequences that this could have in the relationship with their colleagues, who would be forced to perform the job of the absent members. Of the same opinion are Berggren and Adler (cited in Koukoulaki, 2014) who suggest that, in Lean Production, there is a common tendency to develop a work culture that encourages working in "painful conditions".

Despite this, over time literature has managed to obtain remarkable results regarding the relationship between Lean Production and the workers' physiological health. A result of particular interest is that obtained by Landsbergis et al., (1999), who found in their first major review on the effects of Lean Production a moderate association between this system and musculoskeletal disorders (MSD), which can be defined as any injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs[1]. disorders/index.html In line with these results are Brenner et al., (cited in Shouteten & Benders, 2004) who suggest that the increase in musculoskeletal disorders, occurred exactly during the diffused adoption of Lean Production, is precisely to be attributed to this system and to the worsening in working conditions, in terms of autonomy and work pace, that this entailed. To further confirm these results there are also those of Adler et al., (cited in Koukoulaki, 2014) who observed that, in the Lean plants under analysis, the implementation of Lean practices was associated with a 12% increase in absences related to health and safety problems.

[1] Centre for Disease Control and Prevention:
https://www.cdc.gov/workplacehealthpromotion/health-strategies/musculoskeletal-

Over time, some authors have also tried to investigate in depth what could have been the underlying causes of these physiological problems, trying to directly relate Lean practices to operators' physiological health. As reported in a detailed study by Koukoulaki (2014) the occurrence of musculoskeletal disorders in relation to Lean Production has been traced over time to aspects such as the increase in the total number of working hours (Robertson et al. cited in Koukoulaki, 2014), the participation of workers in quality circles, and the implementation of the JIT method (Brenner et al., cited in Koukoulaki, 2014); the latter accused of reducing cycle times and intensifying work pace.

Finally, although the image given by the literature on the effects of Lean Production on physiological health seem to be predominantly negative, precisely because of some practices capable to worsen the working conditions, over time some Lean elements have been identified by some authors as capable of positively influencing workers health. More in depth, it has been observed that the systematic reduction of waste addressed by Lean Production bring to a significant reduction in the operators' movements within the plant and in general of all those movements considered by this philosophy as "useless" for their inability to enhance final customers perceived value. The consequence of this is that in Lean Production a number of mechanical risk factors accused to cause musculoskeletal disorders, such as the assumption of uncomfortable postures and manual handlings, are drastically reduced.

Another relationship that over time has been able to attract the interest of scholars has been that between Lean Production and stress; defined "as a mental or bodily tension whose causes can be traced back to external factors (such as psychological, environmental or social factors) or internal (such as a disease)"[2] While another definition can be that given by Cranwell-Ward (1998) for which stress is viewed as "the physiological and psychological reaction which occurs when individuals meet a threat or a challenge and the individuals' perception, whether consciously or subconsciously, is that it is beyond their immediate capacity". Furthermore, according to Kvarnström (1997), stress is not only capable of negatively impacting the health of individuals by

[2] Medicine Net.
<https://www.medicinenet.com/stress/definition .htm>

compromising their ability to cope with work and social situations, but it is also able to negatively affect company performance due to an increase in absenteeism, medical costs, and workers' turnover.

As noted above, the general trend for Lean Production involves a worsening of working conditions with a consequent negative impact on the operators' health and well-being. More precisely, scholars have tried over time to answer the question whether Lean Production must be considered intrinsically stressful, or if an appropriate implementation would be capable of improving, besides productive performances, also the well-being of workers in terms of stress. Although most studies have reported a prevalence of negative effects in relation to Lean practices such as the Just-In-Time method (Jackson & Martin, 1996), according to other authors, including Conti et al., (2006), Lean Production cannot be considered intrinsically stressful since there is no deterministic relationship between the system and the well-being of workers. More in depth, according to these authors, the stress experienced by workers strongly depends on the way in which the system is designed and implemented. These results are also confirmed by Mullarkey et al., (cited in Koukoulaki, 2014) whose study reports of cases in which some Lean practices have been implemented without negatively impacting the working conditions. Another example of good implementation is that given by Conti et al., (2006) with reference to a Toyota plant in which an updated version of Lean Production has been implemented. The main difference between this implementation and the original version of Lean Production concerned a series of human practices identified as capable of improving workers' conditions, without however worsening production performance. The changes were such that, as reported by Conti et al., (2006), in 2001 the JD Power Initial Quality Study rated this factory the best auto plant in the world.

It is therefore clear that the relationship between Lean Production and its effects on workers' conditions, health and well-being has not yet been clarified, and still remains at the centre of the debate on the changes caused by this production system. Despite this, most of the studies on the effects of Lean Production paint a rather negative picture, with Lean practices accused of worsening workers' conditions. However, some authors have also reported cases of Lean implementations that have led to predominantly positive effects, dispelling the myth that Lean Production is intrinsically harmful to workers.

What is clear, instead, is that in the vast majority of cases, Lean Production has failed with respect to its initial promises, through which it was presented to the world as a "humanizing" system capable of revolutionizing production both in terms of performance and quality of working life. It is no coincidence that Klein (cited in Conti et al., 2006) warns management against indulging in over-promises of greater autonomy when Lean Production is implemented, since this could lead to conflicts between management and workers, as reported by Bruno and Jordan (cited in Conti et al., 2006) regarding an episode that took place at a Mitsubishi plant.

In addition, some authors have tried over time to investigate the reasons behind this failure, which in some cases led to implementations very far from the ideal and positive image that was painted by Womack et al., (1990) in their key publication "The machine that changed the world". As noted by Koukoulaki (2014), some attribute the failure of many Lean implementations to the only partial adoption, by many companies, of the principles that this system implies. Indeed, several companies over time, in implementing Lean Production, have neglected important dimensions such as job security, that is considered by Pfeffer (cited in T. Koukoulaki, 2014) an essential element for high-performance work systems such as Lean Production. This has led, for instance, to leave behind important elements of the Japanese Lean such as the permanent employment of the workforce (Ichniowski; Shaw, cited in Koukoulaki, 2014).

Furthermore, it must be taken into account that change itself can be considered a source of stress and uncertainty (Bordia et al.; Kiefer and Womack cited in Hasle et al., 2012), and that therefore the operators, at least in the early days of Lean introduction, may find themselves disoriented and possibly discouraged. This is particularly true in the case of Lean Production since, as some authors describe it, can be defined as a philosophy that includes continuous changes (Paez et al., cited in Hasle et al., 2012)

To conclude, it may be useful to make some reflections on the characteristics that make a Lean implementation a "good" implementation, that means capable of improving production performance and working conditions at the same time. In this regard, it is important to observe how each Lean practice causes effects on the working environment, which will possibly add up or interact with the effects of the other practices. A good implementation could, for example, might consider building a system in which the positive effects and negative ones balance each other out to reach a condition of equilibrium. As observed by Westgaard & Winkel (cited in Koukoulaki, 2014) the Lean practices considered most capable of acting as buffers, i.e., able to alleviate somehow the negative effects of other practices, are "group autonomy, social support at work and worker participation in improvement programs".

2 THE JOB DEMAND CONTROL (SUPPORT) MODEL

2.1 The context

The concept of "stress" in its modern meaning is relatively recent and was first proposed by Selye, an Austrian scientist who became over time the father of stress research (Le Fevre et al., 2003). Before Selye, the term stress was primarily used in materials science referring to the tension a body is subjected to when a force is exerted on it. One of Selye's major contributions was precisely that of extending this term to human experiences in order to define the state of tension to which a person is subjected when exposed to external stimuli of various kinds.

More specifically, the word "stress" was first introduced by Selye in an article published in "Nature" (1936) in reference to a condition called "general adaptation syndrome"; i.e., a physiological reaction aimed at restoring the internal balance when an individual is exposed to stressful factors. In the article Selye also proposed the term “stressors” to define the stressful stimuli, and term "strain" in relation to the effects - positive or negative - that these stressors can cause in the individual (Selye, citato in Le Fevre et al., 2003)[3]. As for the stress, Selye describes it as "a state of nonspecific tension of living matter, which manifests itself through tangible morphological changes in various

[3] De Carlo, N. A., Falco, A., Bartolucci, G. B. & Marcuzzo, G. Manuale Esplicativo: Stress & Benessere nel lavoro (p.4). <https://www.unipd.it/sites/unipd.it/files/2019/Manuale%20esplicativo%20stress%20lavoro-correlato.pdf>

organs, and particularly in the endocrine glands" and later as a "nonspecific response of the organism to every request made on it by the external environment "(Selye 1936)[4].

Over time, numerous other definitions of stress have been developed in addition to the one proposed by Selye. Among these, one is that adopted by the European Agreement on work-related stress of 2004, according to which: "Stress is a condition, accompanied by physical, psychological, psychological or social suffering or dysfunction, which arises from the individual feeling of not being able to respond to requests or not to live up to expectations " (European Framework Agreement on work-related stress, 8 October 2004).

Another contribution of Selye was to make a distinction between positive stress, or "eustress", and negative stress, or "distress" (Selye, cited in Le Fevre et al., 2003), as for Selye (1974) stress does not assume exclusively a negative connotation but is rather an integral and inevitable element of life. In fact, considering stress as a functional adaptation response of the organism aimed at maintaining psychophysiological balance, the term "eustress" is used to indicate the tension to which an individual is subjected when this does not exceed his tolerance level. More precisely, "eustress" can be considered as a constructive tension for which the individual is effectively able to deal with the external stimuli, developing an adequate level of motivation, learning and change.

Otherwise, the term "distress" is used when the tension goes beyond the tolerability level of the individual, arousing in the subject strong feelings of inadequacy and loss of control. Long-term distress can result in a psycho-physiological deterioration of the organism, until a condition of exhaustion is reached by the individual[5].

And it is precisely distress, i.e., the negative dimension of stress, that is considered the cause of the growing concerns on the issue of work-related stress at the European and global level; concerns that are further ignited by the current social and economic situation, which is characterized by a growing instability and indeterminacy, as well as

[4] Grossi, L. Rapporto Fiom-Cgil sullo stress lavoro-correlato. <https://www.fiom-cgil.it/net/attachments/article/2564/15_10_23-grossi.pdf>

[5] De Carlo, N. A., Falco, A., Bartolucci, G. B. & Marcuzzo, G. Manuale Esplicativo: Stress & Benessere nel lavoro (p. 6). <https://www.unipd.it/sites/unipd.it/files/2019/Manuale%20esplicativo%20stress%20lavoro-correlato.pdf>

by a significant intensification of work. The development of new technologies, as well as the implementation of modern forms of work organization seem to have led to significant changes in working conditions, causing growing levels of stress among workers and "representing a real threat to the quality of life of employees" (Danna & Griffin; Dyck, cited in Le Fevre, 2003). For the past 20 years, work-related stress has been a major concern for employers and national governments worldwide, with the former that over time have become increasingly responsible for its resulting negative effects, both in terms of prevention and legal accountability (Midgley; Rees, cited in Le Fevre et al., 2003). It is in this particular context that the complex and articulated Italian reform in the field of health and safety in the workplace, launched with the Legislative Decree no. 81 of 9 April 2008, has established the obligation for employers to assess the risks of work-related stress by providing a series of indications concerning the preventive and protective measures to be adopted, in addition to the procedures for their implementation (D.lgs. 9 aprile 2008, n. 81. Gazzetta Ufficiale n. 101 del 30 aprile 2008).
Moreover, as observed by the European Framework Agreement of 2004, "addressing the issue of work-related stress can lead to greater efficiency and an improvement in the health and safety of workers, with consequent economic and social benefits for companies, workers and society as a whole " (European Agreement, 8 October 2004, Stress in the workplace, art. 1). While another contribution of the European Agreement was to highlight the problem of work-related stress by making it relevant "at the national, European and international level, taking the connotation of an object of concern for both employers and workers, since no workplace and no worker can be considered immune from stress. " (European Agreement, 8 October 2004, Stress in the workplace, art.1)
Before proceeding, however, it is good to define what is meant by work-related stress. One definition of this concept is that given by the National Institute for Insurance against Industrial Injuries (INAIL), which defines it as "a state of tension linked to the work activity that occurs when the demands of the work environment exceed the capacity of the worker to face them or control them "[6]. While another definition is that of the

[6] Alavie. Stress da lavoro correlato: definizione, sanzioni e impatto sulle PMI. <https://www.alavie.it/stress-da-lavoro-correlato/>

National Institute for Occupational Safety and Health (NIOSH) that defined it as "the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker"[7].

What is certain is that work-related stress represents one of the main challenges that the European Union is facing in the field of health and safety, both for the health of workers and for the costs that this risk entails on the financial statements of individual companies and national governments. In 2002, the European Agency for Safety and Health at Work, following the activation of an Observatory on psychosocial risks, analysed the phenomenon of work-related stress within the European Union, reporting worrying data with respect to the situation. According to the data reported by this agency, around 20 billion euros are spent yearly in Europe for problems related to stress, while 50-60% of the working days lost annually have causes attributable to stress. While another research performed by the European Foundation in 2007 has also observed an increase in psychosocial risks and identified work-related stress as one of the most common causes of illness, reported by over 40 million workers across the EU[8].

2.2 Theoretical models of occupational stress

Over time, numerous theoretical models have tried to define and explain the phenomenon of work-related stress by looking at it from different perspectives. The most famous categorization of theoretical models is that operated by Cox (1978) who divided the approaches underlying the models into three macro-categories: the technical, physiological and psychological approach[9] (Cox & Griffiths, 2015).

As for the technical approach, this places particular emphasis on the external stimuli, conceiving stress as a characteristic of the work environment and not of the individual (Cox & Griffiths, 2015). In this regard, it is interesting to report Symonds' statement for

7 Center for Disease Control and Prevention. STRESS...At Work. https://www.cdc.gov/niosh/docs/99-101/default.html

8 Informazione per la Sicurezza (InSic). Stress lavoro-correlato. https://www.insic.it/sicurezza-sul-lavoro/malattie-professionali/stress-lavoro-correlato/

9 Andrea Castello. Modelli Teorici di Riferimento dello Stress sul Lavoro. <https://www.psicologiadellavoro.org/modelli-teorici-di-riferimento-dello-stress-sul-lavoro/>

which "stress is what happens to individuals, and not what happens in them", to indicate once again the interpretation of stress considered by this approach, which refers to the series of external causes and not to the symptoms of the individual (Bianchi, 2015). The physiological approach, on the other hand, places particular emphasis on the physiological reaction caused by the external stimuli, perceived by the individual as adverse or dangerous, and therefore capable of threatening his psychophysiological balance (Cox & Griffiths, 2015). More precisely, the physiological approach focuses on changes in the biological system that occur as a result of the exposure to stressors.

In accordance with the model proposed by Selye, this approach identifies three main phases of the biological response: alarm, resistance, and exhaustion. As for the "alarm" reaction, this implies a first mobilization of internal energies aimed at stabilizing the imbalance caused by the stress factors. The "resistance" phase instead concerns the physiological reactions aimed at maintaining a state of balance and control of the stimulus. While the third phase, named "exhaustion", defined the situation in which the stimulus exceeds the tolerability level, and it is not possible to maintain an adequate degree of adaptation[10].

Over time these two approaches have been the subject of numerous criticisms, in particular because of their inability to explain empirical data, their limited and dated conceptualization of the dimensions of interest, their excessive emphasis on the medical aspect and their lack of consideration for individual differences, considered by other authors as capable to influence the relationship between stimuli and perceived stress (Cox & Griffiths, 2015). More precisely, the need to consider individual differences in terms of psychological structure and in terms of cognitive and perceptual mechanisms has led to the birth of the psychological approach, which considers stress as the result of the dynamic interaction between the individual and the environment[11] (Cox & Griffiths, 2015). With regard to this approach, considered to date the most accredited of the three, it is possible to identify two variants that have dominated the contemporary theory of

[10] Grossi, L. Rapporto Fiom-Cgil sullo stress lavoro-correlato. <https://www.fiom-cgil.it/net/attachments/article/2564/15_10_23-grossi.pdf>

[11] Grossi, L. Rapporto Fiom-Cgil sullo stress lavoro-correlato. <https://www.fiom-cgil.it/net/attachments/article/2564/15_10_23-grossi.pdf>

stress: the "interactional", which focuses on the interaction between the individual and the working environment, and the "transactional" one, which focuses on the psychological mechanisms (e.g. emotional reactions, cognitive processes, etc.) that nourish and strengthen this interaction (Cooper & Dewe, cited in Bianchi, 2015; Cox & Griffiths, 2015). The main difference between the interactional and the transactional approach concerns the perspective with which the relationship between the environment and the individual is observed and the way in which the variables of interest are considered. For the interactional approach, in fact, the stimuli and the responses are linked by a one-way and univocal causal relationship, in which the stimuli constitute the independent variables and the psychophysiological responses the dependent ones. Differently, in the transactional approach, the relationship between the two sets of variables is not unique and unidirectional but based on a complex system of relationships in which also other variables can play a fundamental role in defining the dimensions of interest (e.g., individual style of coping, etc.). From these two sub-approaches, numerous theoretical models have been developed in order to investigate the phenomenon of work-related stress, its causes and the effects at the individual and corporate level (Cooper, cited in Bianchi, 2015).

2.2.1 Transactional models

As for transactional models, these analyse occupational stress considering the interaction between the person and the work environment, placing particular emphasis on the emotional reactions and the psychological mechanisms that regulate this interaction. One of the most renowned transactional models is certainly the Effort-Reward Imbalance, developed by Johannes Siegrist (1996), which considers stress as a consequence of an imbalance between the commitment of the individual during its working activities and the rewards (tangible and intangible) obtained from this commitment: stress derives from a condition in which workers make high efforts but receive in turn limited rewards (Siegrist et al., cited in Bianchi, 2015). A contribution of the Siegrist model is therefore to consider the influence of individual motivation in the perception of environmental demands and consequently of perceived stress. In other words, according to the Effort-Reward Imbalance, the greater the individual motivation, the lower the perceived stress, and viceversa[12].

Another transactional model is that of Cooper, which places particular emphasis on the nature and type of work-related stress and consider the effects of stressors both at the individual and organizational level (Cooper & Marshall, cited in Bianchi, 2015). Indeed, numerous elements related to the work context have been identified by this model as capable of provoking negative consequences in terms of stress. More precisely, this model identifies five macro-categories of stressors such as: the working environment (e.g. noise, lighting, temperature etc.), the organizational roles (e.g. ambiguity about objectives and expectations, role conflicts, responsibilities, etc.), social relationships (e.g. leadership style, social density, group pressure etc.), career prospects (e.g. promotions, relegations, job insecurity, etc.) and the organizational structure (sense of belonging, discretion, emotional involvement, etc.).

Finally, a last noteworthy transactional model is that of Cox and Mackay (1981), in which stress is defined as a fundamentally individual phenomenon resulting from the interaction between the individual and the contingent situation; stress is then defined as part of a complex and dynamic process in which the perceived demand plays a fundamental role, i.e., the way of each person to perceive the environmental demands. For Cox and Mackay (1981), stress arises from the imbalance between the demand perceived by the individual and his perception of being able to cope with it. As for other models also in this one individual characteristic play a crucial role, and in particular for Cox (1978) the "stressogenic imbalance is always mediated by individual perceptions"[13].

2.2.2. Interactional models

As for interactional models, these consider the structure of the interaction between the individual and the surrounding environment (Cox & Griffiths, 2015). One of the most renowned models within the interactional variant is certainly the one developed by

[12] Andrea Castello. Modelli Teorici di Riferimento dello Stress sul Lavoro. <https://www.psicologiadellavoro.org/modelli-teorici-di-riferimento-dello-stress-sul-lavoro/>

[13] Grossi, L. Rapporto Fiom-Cgil sullo stress lavoro-correlato. <https://www.fiom-cgil.it/net/attachments/article/2564/15_10_23-grossi.pdf>

French et al. (1982), or the Person-environment fit model, which takes its cue from Lewin's studies on personality dynamics to explain the stress process (Bianchi, 2015).

In this model, work-related stress is interpreted by considering the interaction and adaptation process of the individual to the work environment; stress is defined as the reaction of the individual in response to an imbalance between the demands of the environment and the capacity of the individual to cope with it (Le Fevre et al., 2003). A contribution of this model is to also consider the condition for which the demands of the environment (i.e., stressors) is excessively low and unable to meet the individual needs in terms of participation, involvement, gain, use of skills etc.[14]. In this case it is possible that stress levels increase due to boredom and the inability of the environment to meet the individual's needs (Maslow, Le Fevre et al., 2003).

While two other well-known interactional models are the Job Demand Control (JDC) model by Karasek (1979) and its extension, the Job Demand-Control-Support (JDCS) model by Johnson & Hall (1988), which, as observed by Van der Doef and Maes (1999), have been among the most influential models in the study of work-related stress, dominating research in the recent decades.

2.3 The Job Demand Control (Support) model

As said, one of the most influential models used for studying the relationship between working conditions and workers' health and well-being is certainly the Job Demand Control (JDC) model, first proposed by Robert A. Karasek, Jr in 1979. At the basis of this model there is the idea for which each job can be defined according to two fundamental dimensions, namely “job demand” and “control” (Karasek, 1979), and that it is then possible to establish a relationship between these two dimensions and worker’s health

[14] Grossi, L. Rapporto Fiom-Cgil sullo stress lavoro-correlato. <https://www.fiom-cgil.it/net/attachments/article/2564/15_10_23-grossi.pdf>

in terms of perceived stress. For what concern job demand, this is defined by Karasek as the workload to which each worker is subjected, whatever his occupation, and is expressed in terms of pressure on time and role conflicts. While as regards the dimension of Control, also called by Karasek "decision latitude", this is generally conceptualized as the ability of workers to have a certain control over their activities. Control is then also divided into two other components: "skill discretion" (measured as the breadth of skills that can be used by the worker) and "decision authority" (identified as the formal authority to make decisions).

The assumptions underlying the model are basically two. The "strain-hypothesis", for which the most stressful occupations are those with a combination of high demand and low control. And the "buffer hypothesis", whereby greater control over one's work would be able to moderate the negative effects deriving from a high demand for work.

According to Karasek (1979), the main reason why high-demand and low-control jobs are able to produce higher levels of strain is linked to the inability of the workers to carry out their activities following their own methods and times. According to the author, this situation involves a higher devotion of cognitive resources aimed at performing the task, the overall result of which is a greater physiological activation and a greater

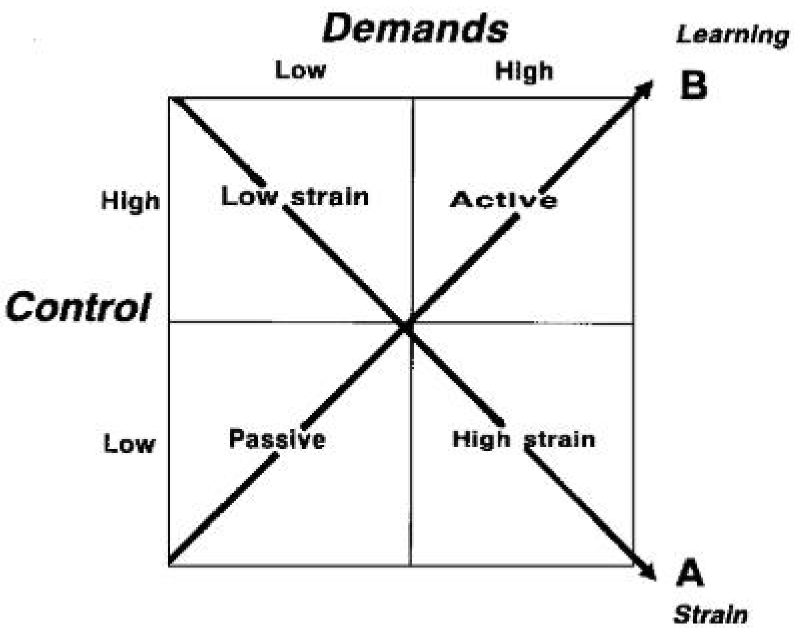

Fig 2. 1 The Job-Demand-Control model (adapted from Karasek, 1979)
Source: *Doef, M. Van der & Maes, S. (1999). The Job Demand-Control (-Support) Model and psychological well-being: a review of 20 years of empirical research.*

cardiovascular and nervous tension (Karasek, 1979). More precisely, when workers are unable to complete their assigned work, and tension is not properly released, their bodies begin to lack resources and their heartbeat is sustained for a significant period of time, of which result is the onset of physiological symptoms and diseases (Karasek, 1979).

Referring to the graph in fig 2.1, proposed for the first time by Karasek in his introductory study of the model, in addition to the diagonal that identifies the various levels of strain, there is another that identifies what Karasek calls the learning levels. More precisely, according to the Karasek model, a high control over one's work is not only able to moderate the negative effects deriving from a high demand for work but is also capable of increasing the levels of learning, motivation and workers' development. According to this interpretation of the model, occupations with a high level of learning are therefore those characterized by a high job demand and high control, and are defined by Karasek as "active jobs". Typical examples of this kind of jobs are those of the senior manager and the doctor, both typically characterized by a high job demand accompanied by high control. In this regard, some research has shown that occupations corresponding to this type of work are "highly satisfactory in the health sector (de Jonge, Van Breukelen, Landeweerd, & Nijhuis, 1999; de Jonge, Dollard, Dormann, Le Blanc, & Houtman , 2000; Landsbergis, Schnall, Deitz, Friedman, & Pickering, 1992), correspond to a lower mortality rate (Tsutsumi, Kayaba, Hirokawa, & Shizukiyo, 2006), lead to a more varied learning of skills in young employees (de Witte , Verhofstady, & Omey, 2007), and produce together higher levels of self-efficacy, mastery, job involvement and commitment " (Demerouti et al.; Landsbergis et al., Cited in Kain & Jex, 2010). Conversely, diametrically opposite results have been obtained from similar research to those just mentioned. According to these studies, in fact, a high job demand is always disadvantageous for learning, even when combined with high control. And this because an excessive workload would always prevent the worker from concentrating on acquiring new skills (Demerouti et al.; Taris & Feij, cited in Kain & Jex, 2010). While another evidence that emerged in this series of studies is that workers employed in an "active job" tend, thanks to the high control over their activities, to take their work at home and be more negligent regarding household care (Butler et al., cited in Kain & Jex, 2010). One of the main reasons why the research seems to give such conflicting results regarding “active jobs” seems to be linked to the variability with which Karasek himself (1979) referred for the first time to the effects relating to this type of work. In fact, trying to explain what the outcomes of active jobs were, Karasek referred to a series of concepts such as "learning, increased motivation, effective learning, feelings of mastery, etc." (Taris et al., cited in Kain & Jex, 2010), thus leaving ample margins for interpretation to subsequent authors who worked on the model. According to the JDC model, low learning jobs are those characterized by low demand and low control.

As for the diagonal strain, i.e., the one that identifies the various levels of stress, it is possible to see from the graph how the jobs characterized by a high strain are those with high demand and low control, while those characterized by low levels of strain are those characterized by low demand and high control. The typical example of a high strain job is that of the assembly line worker, who is generally subjected to a high job demand and low control over his activities.

2.3.1 Extension to the JDC model

Since the model was first introduced by Karasek (1979), numerous other variables have been proposed as influencing the relationship between demand, control, and strain. In his first publication of the model, Karasek himself mentioned the existence of other potentially significant variables but remained very vague about it (Kain & Jex, 2010). Some of these variables are age, educational level, salary level, social context etc. (Karasek, 1979). Over time, many studies have observed how the exclusion of these variables from the model could be at the basis of the inconsistency of the results obtained from the literature (Frese & Zapf; Kasl; Kristensen; Parkes; Van Der Deof & Maes cited in Kain & Jex, 2010). In response to these criticisms, some of the most recent research has decided to include some of these additional variables in the study of the model and to quantitatively evaluate their impact on the relationship between demand and control.

2.3.1.1 Social Support

Of all the variables proposed over time, certainly the most famous and studied is that relating to social support, first introduced in 1988 by Johnson and Hall. Specifically, this extension of the model arose from the need of its authors to take into account the negative effects resulting from social isolation and the lack of support from colleagues and superiors (Johnson & Hall, cited in De Lange et al., 2003). The model is called Job-Demand-Control-Support (JDC(S)) and the assumptions are similar to those of the JDC model, except for the fact that in this case the first assumption, that for the JDC(S) model takes name "iso-strain hypothesis", states that the jobs with the greatest level of strain are those characterized by a condition of high demand, low control and low social support. While the second hypothesis, which, as in the previous model is called the "buffer hypothesis", states that social support, and not control as in the case of the JDC model, is able to moderate the effects of a working condition with high demand and low control.

2.3.1.2 Other extensions

Among the other variables proposed over time as capable of influencing the relationship between demand and control, we find, for example, proactive personality, coping mode, locus of control and self-efficacy.

Proactive **-** With regard to proactive personality, it has been observed by some authors that people with a high level of proactivity, i.e., those who faced with a problem show initiative and actively seek in the surrounding environment the resources and means to solve it, tend to benefit more from greater control over their work. In other words, the moderating effects of control are more pronounced for those people who have a highly proactive personality. At the basis of this result there is the ability of this type of people to effectively use any control granted to them, while for the same reason people with low levels of proactivity tend to benefit less or not at all from greater control (Parker & Sprigg, cited in Kain & Jex, 2010).

Coping **-** Another variable studied in the literature and considered capable of influencing the relationship between demand and control is "coping", or the way in which each person deals with the onset of a problem. In particular, it has been observed by some studies that people with a high level of active coping, i.e. those who faced with a problem tend to analyse the situation and make concrete decisions to solve it, benefit more from a higher control over their work (Ippolito et al.; Rijk et al., cited in Kain & Jex, 2010), and this because they are more able to use the control accorded to meet demand.

Self-efficacy - A further variable that has been found to influence the relationship between demand and control is the so-called self-efficacy, that is the belief that everyone has regarding the use of personal motivation, cognitive resources, and actions to deal with a given situation. The main reason why self-efficacy is able to influence the relationship between demand and control is related to its ability to change the perception of individuals about their power in changing the surrounding environment. People with high levels of self-efficacy will have the belief that they can change the surrounding environment thanks to their actions and will therefore benefit to a greater extent from an increase in control over their activities. Conversely, people with low levels of self-efficacy will benefit less from the greater control accorded to them (Litt; Salanova et al.; Schaubroeck & Merritt, cited in Kain & Jex, 2010).

Locus of Control - A final variable considered by the literature for its ability to influence the relationship between demand and control is the locus of control, or the personal belief for which what happen in the environment depends on personal actions and not on something external (Rotter, cited in Kain & Jex, 2010). It has been proven by the literature that people with a low locus of control tend to benefit less from greater control over their work, and this because of their perception that the result of their work does not depend on their efforts, but on variables external to them (Daniels & Guppy; Meier et al., cited in Kain & Jex, 2010).

As seen, since the first introduction of the JDC model a certain number of variables have been proposed by the literature as being able to influence the relationship between demand and control. Among these, the most famous and studied is certainly that relating to social support. So much that in the most recent studies some authors refer to the Karasek's model with the name of JDC(S) model. In addition to social support, numerous other variables have been proposed for their ability to influence the relationship between demand and control. Among these, proactive personality, active coping, self-efficacy, and internal locus of control are some of the most renown.

Regarding the latter variables, it is useful to note, however, that each of them has the ability to change the perception of individuals towards control, both in terms of desirability and in terms of the effective capacity of its exploitation. That said, it is evident that the moderating effects of control on the relationship between demand and strain are not the same for everyone and depend on specific third variables for each individual and for each work environment. To obtain more satisfactory results these variables should be integrated into the model and studied in subsequent research.

2.3.2 Research on the JDC(S) model

Over time, both the JDC model and the JDC(S) model have been examined by the literature, which has systematically tried to validate or reject the hypotheses proposed by each of the two models. In general, the results obtained from the literature are mixed, with the strain and the iso-strain hypotheses of the two models that have received overall greater support than the buffer hypotheses of each model. The way in which the various dimensions of the two models have been conceptualized and interpreted by the various authors may have played a fundamental role in determining this situation. Precisely, a good part of the studies suggests that the moderating effects of control on stress largely depend on the type of control considered, and on how much this dimension is actually related to the question taken into consideration. In other words, they state that the buffer hypothesis is valid only in the event that the control taken into consideration is actually capable of having concrete and direct effects on the Job Demand considered.

	JDC model		JDCS model		Total number of studies
Outcome	Strain	Buffer	Iso-strain	Buffer	
General psychological well-being	28/41	15/31	9/19	2/5	43
Job-related well-being					
Job satisfaction	18/30	10/23	8/14	2/6	31
Burnout	3/4	0/4	1/1	0/2	4
Job-related psychological well-being	7/8	1/2	1/2	1/1	8

Fig 2. 2 Ratio of supportive studies to the total number of studies on each hypothesis of the JDC(S) model per outcome category.

Source: *Doef, M. Van der & Maes, S. (1999). The Job Demand-Control (-Support) Model and psychological well-being: a review of 20 years of empirical research.*

Over time, other variables have certainly played a decisive role in the discrepancy of the results obtained in the literature. Some of these variables are the scarcity of longitudinal studies, (which better than cross-sectionals are able to investigate the relationship between the variables), the insufficient methodological rigor of some studies and the use of subjective data (which are more easily subject to bias).

Moreover, the literature has also dealt with the study of the type of relationship between the dimensions of interest, and in particular it has tried to understand whether the effects of the two dimensions are additive or interactive (De Lange et al., 2003). In his first publication of the model, Karasek stated that "the exact form of the interaction term is not the main issue, since the 'primary' interaction claimed in the model is that two separate sets of outcomes (strain and activity level) are jointly predicted by two different combinations of demands and control" (Karasek, cited in De Lange et al., 2003). The definition of the type of relationship existing between the two dimensions of the model is very important, particularly for the practical implications linked to the two models. In fact, if it is assumed that the effects linked to demand and control are additive, then increasing control would have a limited effect on the reduction of stress in the worker. If on the other hand, the relationship between the two components is interactive, and control is actually able to moderate the effects of a high demand, then it would make sense to maintain a high demand and operate on the control in order to reduce the levels of stress to which workers are subjected.

Over time, several authors have tried to review the empirical studies on the JDC and JDC(S) models, and this in order to have a clearer and more comprehensive view of the results obtained from the various research and therefore validate or reject the hypothesis of each model. A first major review on the JDC and JDC (S) models was conducted by Doef & Maes (1999) to validate or reject their hypotheses. For this review, the authors identified 63 studies, whose main and explicit objective was to study the relationship between working conditions and the psychophysiological health and well-being of workers. To become part of the review, each of the studies had to expressly refer to at least one of the two models and had to consider at least the two main dimensions of demand and control. As can be seen from the summary table in fig 2.2, the strain, the iso-strain and buffer hypotheses of the JDC model are those that have received the most support. It should be noted, however, that each of the hypotheses was supported by only about half of the studies, while another half rejected their assumptions. This indicates that further studies would need to be conducted on these hypotheses in order to assess the origin of this discrepancy in the results. Furthermore, it is useful to observe how the buffer hypothesis of the JDC model, according to which the control is able to moderate the negative effects of a high job demand, found support in a part of the studies only for a sub-population of the whole sample. More in depth, such moderating effects were found to be greater for those categories of individuals with high self-awareness (Kivimaki & Lindtrom, cited in Doef & Maes, 1999), with an internal locus of control (Daniels & Guppy, cited in Doef & Maes, 1999) and to a lesser extent for people with an external locus of control (Parkes, cited in Doef & Maes, 1999). This indicates that the moderating effects of control on worker stress could depend on the personal characteristics of each individual, and that this could be the basis of the conflicting results reported in the literature. Furthermore, in general it is possible to observe another link between the studies that have offered support to the buffer hypothesis and those that have rejected the assumptions. More precisely, it has been possible to observe how the smaller the conceptual distance between the demand and the control, the greater the probability that the study offers support to the buffer hypothesis of the JDC. For instance, if we consider a study that conceptualizes the demand for work in terms of pressure on time and the control in terms of control over time, then, according to the reasoning just exposed, it is very likely that this study will offer support to the buffer hypothesis of the JDC model (Kushnir & Melamed; Kivimaki & Lindstrom; Wall et al, cited in Doef & Maes, 1999). On the other hand, a study that considers a very general and distant conceptualization of control and demand is very likely to offer no support for the buffer hypothesis since more control would have little if no impact on the demand faced by the worker (Kivimaki & Lindstrom; Kasl; cited in Doef & Maes, 1999).

In 2003 another important review on empirical studies related to the JDC(S) model was conducted by De Lange et al., (2003) in order to reject or validate the hypotheses underlying the model and to analyse more in depth the relational nature between the two effects, that is to understand if there is some kind of interaction between them or if both can be considered independent and therefore additive. In this review, the authors considered exclusively methodologically rigorous, longitudinal, full crossed lagged data with multiple time points studies, that included both objective and subjective data, as well as a large number of output variables such as self-reported stress, cardiovascular disease and other factors related to individuals' lifestyle. In total, the authors were able to identify only 19 studies that met the selection criteria considered, and of these only 8 offered support to the buffer hypothesis. On the other hand, of the 19 studies identified by the authors, 12 offered support to the additive hypothesis of the demand on stress, while 9 out of 12 confirmed the main effects of control. These results therefore seem to confirm the hypothesis for which the effects of the two dimensions are independent and additive, rather than interactive in nature (De Lange et al., 2003).

As mentioned earlier, one of the major criticisms levelled at the model is that more specific measures of demand, control and strain are needed. According to many researchers, this variability and arbitrariness in the measurement of the dimensions of interest, not only would not allow the comparison between studies, but would also be the basis of the conflicting results obtained from the literature. In his introductory publication of the model, Karasek himself had left ample room for interpretations as regards the dimensions considered. With job demand being conceptualized exclusively in terms of workload and role conflicts, and control in terms of skill discretion and decision authority. While as regards the output variables, the author's only note was that it would be preferable to use both subjective and objective measures (Karasek, 1979).

In order to address this issue, more recent research has used different measures for the dimensions of job demand, control and strain. Specifically, measures such as cognitive demand, sensory demand, emotional demand, risk-related demand, etc. were used for job demand. While regarding control, measures such as decision-making authority and skill discretion were used. And finally, in relation to outcomes, measures such as mastery, health complaints and job satisfaction were used to measure this dimension. In these studies, in which different measures were used for the various dimensions, it was noted that only the quantitative and emotional demand better predicted outcomes such as work stress, subjective health complaints and job satisfaction, while mastery better predicted the cognitive, sensory and emotional demand (Kain & Jex, 2010). As for the buffering effect, the only variable that reported an interactive effect with all types of demand, influencing the output variables, was skill discretion (Mikkelsen et al., Cited in Kain & Jex, 2010).

Another important discussion regarding the applications of the model concerns the use of objective and subjective data. Some studies have in fact observed how the use of questionnaires to obtain data concerning the work characteristics and the output variables of the model could in some way be affected by bias, linked for example to the specific personality traits of each individual (Schnall et al., cited in De Lange et al., 2003). While, another major criticisms to the model, which for many scholars is the basis of the inconsistent results of the literature, is the poor relationship between the variables of control considered and the real demand to which the worker is subjected. Specifically, it has been observed that the conceptualization of control must somehow be linked to the nature of the demand faced by the worker, and that more precisely it must be able to have a direct impact on it (Cohen & Wills, cited in Kain & Jex , 2010). The first researches on this matter seem to confirm this hypothesis, and in particular they seem to indicate how a control strictly linked to the tasks (control over times, methods, scheduling, etc.) is more able to moderate the negative effects of a high demand on workers' health, than peripheral control (e.g. control on corporate decisions) (Sargent & Terry, cited in Kein & Jex, 2010). In general, it can be said that studies in which specific dimensions of control and demand are used, whose measures are in some way linked to each other, and in which objective measurements for the output variables are used (e.g. cardiovascular measures, cortisol levels, physical symptoms etc.) give more support to the buffer hypothesis of the Karasek model (Fox et al.; Ganster; Johnson & Hall; Karasek; Kristensen; Landsbergis; Schnall et al., cited in Kein & Jex, 2010).

Another important criticism, moved this time not to the model, but to the studies that have attempted to investigate it over time, is the scarcity of longitudinal studies (De Lange et al., 2003). This type of study, in fact, would be more capable than cross-sectionals, to evaluate the causal relationships between the variables of interest, as well as determining the presence or absence of reciprocal or reversed relationships. Furthermore, if variables external to the model were included in these longitudinal studies (e.g., years of experience, job changes, salary level etc.) it would be possible to determine the effects of these variables on the outcome variables of the model. Another reason why the use of longitudinal studies should be taken into consideration is that it would allow to evaluate the effect of the variables over time. More precisely, if a complete panel design was used, it would be possible to evaluate the necessary time for the causal variables to have an influence on the effect variables (De Lange et al., 2003). Unfortunately, to these days most of the studies are lacking in providing information about the temporal evolution of the variables of interest (Taris & Kompier, cited in De Lange et al., 2003). However, most longitudinal studies on the model have reported similar results, and in particular they observed main effects of demand and control, but no interactive effects between these two variables (Bourbonnais et al.; Carayon; Daniels & Guppy; Johnson et al.; Kivimaki et al., cited in Jax & Kein, 2010).

One of the aspects that should also be taken into consideration in future research concerns the use of objective data. And this because the data obtained through self-reports could be subject to bias, such as those relating to the particular personality traits of each individual or to the way in which each person could be influenced by their own state of health and well-being in the evaluation of the work characteristics inherent to their occupation. More specifically, some authors consider it necessary to use objective data both as regards demand and control, for example by collaborating with the managerial structure of the company to determine the levels of workload and skill discretion, and for what it concerns the output variables, for example through the use of physiological measurements of workers.

A final consideration that should be made in further research of a longitudinal nature is that concerning the correct duration of time lag, i.e., the time elapsing between one measurement of the variables and another. So far only a very small part of the studies has focused on this particular feature, without however reaching significant conclusions. An interesting field of study for the forthcoming research could therefore be that concerning the temporal evolution of the variables, as well as the relationships existing between them and the trend that each parameter follows over time. In this regard, a suggestion for future research of a longitudinal nature is to use time lag of different amplitudes, in order to better evaluate the temporal relationship between the causal variables and the effect variables (De Lange et al., 2003).

3 DESIGN OF EXPERIMENT

3.1 Objectives

Following the analysis on theoretical models of occupational stress and the on the effects of Lean Production on workers' health and well-being, a design of experiment has been devised as part of a wider collaboration project between the Polytechnic of Turin and the Psychology Department of the University of Turin.

More precisely, this design of experiment constitutes a preliminary research phase aimed at laying the foundations for a data collection to be performed at Leonardo S.p.A. (i.e., an Italian company active in the defence, aerospace, and safety sectors[15]), in order to analyse the stress levels within this context, as well as to investigate the relationship between some Lean practices and the stress to which the workers are subject.

As for the first experiment, which will be referred to as "Experiment 1", this has the main objective of testing the effectiveness and sensitivity of two instrumentation (i.e., Biopac electrodes and a modern wireless physiological monitoring system) for the collection of physiological data (skin conductance, respiration, heartbeat, etc.) to be used for the assessment of the stress levels. To this end, two factors (i.e., movement, stress) have been included in the experimental design in order to evaluate their impact on the quality of the data well as to investigate the levels of physiological activation caused by two different forms of stress (i.e., endogenous, exogenous). The final goal of Experiment 1 is therefore to determine which of the two available equipment is most suitable in terms of compatibility and effectiveness with the objectives of the data collection to be performed at Leonardo.

Otherwise, the main objective of the second experiment, which will be referred to as "Experiment 2", is to investigate the stress levels resulting from the experimental manipulation of job control through the simulation in laboratory setting of two

[15] Leonardo S.p.A. <https://it.wikipedia.org/wiki/Leonardo_(azienda)>

production lines (i.e., Lean, Non-Lean) and the inclusion of two control-related factors (i.e., production orientation, standardization).

3.2 Experiment 1

As previously mentioned, the objective of Experiment 1 is to test the available instrumentation and assess which of the equipment already available is most compatible with the data collection to performed at Leonardo.

To this end, in Experiment 1 two factors have been included in order to evaluate their impact on the quality of the data collected, as well as to investigate the levels of physiological activation caused by two different forms of stress (i.e., endogenous, exogenous).

As regards the "stress" factor, this has been declined in four different conditions according to the type of stress considered, i.e., endogenous, exogenous, mixed, and stress-free conditions. While as regards the "movement" factor, this has been declined in two conditions, i.e. "low movement" and "high movement", with the main difference between the two represented by the distinct task that test participants are required to perform in the two cases. As previously noted, the choice of the two factors has been motivated by the need to evaluate the effectiveness and reliability of the available equipment, as well as to assess the impact of potential disturbing factors on the quality of the data collected. Indeed, considering the data collection to be performed at Leonardo, this experiment represents a preliminary phase aimed at understanding how some sources of disturbance (e.g., operators' movement, exogenous stress, endogenous stress, punctual stress, etc.) could potentially represent a threat for the quality of the data to be collected.

Experiment 1 implies then the comparison between a "traditional" and a modern wireless physiological monitoring system aimed at investigating the limits and possibilities associated with the two instruments. Furthermore, considering the compatibility of the two instruments in terms of wearability, it has been decided to proceed with the joint detection of the physiological parameters, thanks to which it is also possible a greater comparability of the data and a significant reduction of the time required to perform the two tests.

As for the "traditional" equipment, this is composed of Biopac electrodes connected by cables for the analysis of the electrothermal activity. While as regards the second solution, this is constituted of a wireless wearable medical device through which it is possible to perform an analysis of the physiological parameters staying at a certain distance from the test participant. More precisely, for this latter solution, contacts have been established with GEA solutions, an Italian company that provides management software and advanced medical instruments for clinics and research. In particular, GEA[16] would provide a wireless monitoring system for real-time data acquisition composed of an elastic multisensory band inside which the electrodes for the electrocardiogram and the breath transducer are incorporated. The lightness, the easy wearability, and the complete absence of cables contribute all together at making this instrument highly compatible with the objectives of the data collection at Leonardo, allowing for a greater mobility of the subjects compared to traditional detection systems.

As for the task of Experiment 1, this involves the assembly of an airplane model using LEGO bricks as shown in fig 3.3. The use of simulation games based on the construction LEGO models has been observed to be a recurring element in laboratory setting experiments aimed at simulating Lean Production assembly lines. An example is the study by Rybkowski et al. (2008), in which the authors proposed a version of the Airplane Game based on the use of LEGO bricks, as opposed to the paper airplanes presented in other studies (Billington, 2004). Although the objectives of this simulation

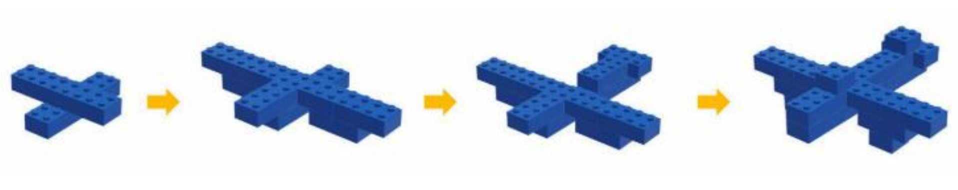

Fig 3.3 Assembly sequence for Experiment 1

[16] GEA soluzioni. <https://www.geasoluzioni.it/prodotti-gea-soluzioni/117-monitoraggio-fisiologico-indossabile.feed?type=rs>

were different from those of the present study and essentially consisted in the calibration of a computer model, the compatibility of the task with Experiment 1 purposes, as well as its adoption in numerous other laboratory experiments aimed at simulating Lean practices, favoured the choice of this task. Furthermore, according to Badurdeen et al., (cited in Fabiano et al., 2017**)** the problem-based learning method (PBL), i.e., "a student-centered and active learning method based on interdisciplinary integration" (Lima et al., Cited in Fabiano et al., 2017), is the ideal for teaching Lean manufacturing, since one of the distinctive features of this production model is exactly the particular emphasis that it places on problem solving and learning. Moreover, LEGO bricks are considered a useful tool in the application of the PBL method, since they generate high levels of involvement and interaction (Roos et al., Cited in Fabiano et al., 2017) as well as promoting reflective thinking (Castro-Alonso et al., Cited in Fabiano et al., 2017). Furthermore, the choice of the Airplane Game as a task for Experiment 1 is well suited for the goal of replicating a production line in a laboratory setting, since the sequence of actions required to complete the task faithfully represents the operations that could take place in a productive context.
In the following, an accurate analysis of Experiment 1 factors will be performed, in order to demonstrate the ground for the choice of each factor.

3.2.1. Factors

As noted previously, the main objective of Experiment 1 is to test the available instrumentation in order to make a choice as to which equipment is most suitable for the data collection at Leonardo. To this end, two factors were chosen for their impact on the quality of the data collected, as well as on the level and type of physiological activation that they entail. More precisely, the "stress" factor and the "movement" factor were chosen for their compatibility with the objectives of Experiment 1: the first because it allows for the trend and quality evaluation of the data collected in response to a physiological activation in the event that this is triggers by stressors of a different nature (i.e., endogenous vs exogenous), and the second because it includes in the experimental design a condition of "disturbance" linked to the movement of the participant, which is a condition present in any work context, and in particular in production lines.

As regards the "stress" factor, this has been declined in four different conditions according to the type of stress considered. More in depth, a distinction has been made between "exogenous" and "endogenous" stress: with the former referring to stressors attributable to events external to the individual, while the latter relating to stressors attributable to events internal to the subject, and mainly of a psychological nature. More in depth, the objective of Experiment 1 in relation to the "stress" factor is to analyse the trend of physiological parameters as a result of stressful events of a different nature, and this in order to have a reference framework to be used for the data collection to be performed at Leonardo. The decision to include the "stress" factor in the experimental design is based on the awareness that in work environments, and in particular in a production context, are present different types of stressors, each of which is capable of causing a specific physiological activation. Indeed, it has been demonstrated that stressors of different nature (i.e., exogenous, endogenous) are able to activate different physiological systems, and therefore determine a substantially different trend in physiological parameters. The hypothesis in this regard, is that the analysis of these trends will allow for laying the foundations for the investigation of the data to be collected at Leonardo, and more precisely to make a distinction between the stress caused for example by a high-pitched sound (such as that of an alarm or a beating hammer) and an endogenous stress, resulting for instance from the difficulty of performing a certain activity or from a quarrel with a work colleague.

For the choice of the stressors, once again reference was made to the literature thanks to which it was possible to identify a series of stressors for each type of stress considered. In particular, after a careful analysis of the literature, "noise" was chosen as the exogenous stressor, and this due to its ability to generate a physiological response that is sufficiently important to be detected by the available instrumentation. In fact, many studies have reported that noise affects both physical and mental well-being. As observed by Valluri (2010): "it is believed that noise acts as a generic element of stress and as such can activate different physiological systems, causing changes such as increased blood pressure and heart rhythm, and vasoconstriction".

To get an idea of the value of noise as a stressful element, it was observed that in Italy 40% of the total cases of occupational diseases are attributable to exposure to high noise (National institute for insurance against industrial injuries (INAIL)). Regarding the noise issue, in Italy in 2003 the Directive 2003/10 / EC of the European Parliament and of the Council was adopted on the minimum safety and health requirements relating to the exposure of workers to the risks deriving from physical agents (e.g., noise). The directive, in addition to defining a new daily exposure limit value of 87 dB (A), states that, given the availability of modern technologies and risk control measures, "the risks deriving from exposure to noise can be eliminated at the source or reduced to a minimum " (European Agency for Safety and Health at Work (2004), The impact of noise in the workplace). In other words, the national legislation put in place to protect workers from the risk of noise requires all employers to perform a noise risk assessment within their workplace and, in the event of exceeding the established thresholds, take all the necessary measures to reduce these risks at source (Valluri, 2010). Among the many publications that have dealt with the relationship between noise and physiological responses in terms of stress, of particular interest is the study by Reynald (2006), which more than the others inspired the choice of noise as exogenous stressor. More precisely, in a first part of the study, the author describes the physiological response of the human body as a consequence of listening to a noise, with the latter being defined as an unexpected and unwanted sound (although the same author reports that this is a subjective classification). More specifically, in the study by Reynald (2006) it is described the path of the nerve impulse deriving from listening to a noise, which is directed on one side to the cerebral cortex for a conscious interpretation of the signal, while on the other to subcortical regions of the brain (i.e., the hypothalamus) which in turn redirect the input to the autonomic nervous system, the endocrine system and the limbic system (Spreng et al., cited in Münzel et al., 2014). According to Babisch (cited in Münzel et al., 2014) this physiological response linked to acute noise exposure can cause an increase in blood pressure, heart rate and cardiac output, probably mediated by the release of hormones of stress such as catecholamines. Noise is therefore capable of stimulating an automatic response in the organism that activates physiological systems of adaptation and defense, which ultimately prepare the subject to “flight or fight”. In addition, the authors also made a distinction between “acute noise”, which is of greater interest for the experimental design in question, and “chronic noise”: with the former that can be defined as a high intensity sound that occurs in a sufficiently short time interval, and the latter with reference to noises that are repeated over time and that in the long term are capable of developing in the individual a condition of "annoyance", which is defined as a sensation of disturbance of the activities in progress or as an interference with the quality of the environment. Furthermore, the exposure to acute noise is able to generate certain autonomous responses, namely the orientiring, the startle and the fight response: with the first that involves a body (i.e., eyes, head, etc.) and mental addressing towards the source of the noise. The second that implies an involuntary contraction of the muscles around the eyes, the abdomen and the legs that is aimed at protecting the most vulnerable parts of the individual. And the latter, the fight response, that consist in a reaction that involves the muscles of legs and arms in order to prepare the individual for the real escape or fight. Reynald also reported that these reactions are more pronounced and intense the louder and more unexpected is the noise. Interesting about the link between noise and stress is the study by Münzel et al., (2014) in which the authors, reporting the results of previous studies, affirm that noise can be considered in all respects a stress factor since it causes physiological responses quite similar to those of other stressors (Babisch et al., cited in Münzel et al., 2014). For the noise to be used in Experiment 1, the choice has been driven by the need to recreate in the laboratory setting a condition that was as close as possible to that that could be encountered during a work shift in the production line. More precisely, for the present study it was decided to use the sound of an alarm as a noise stressor.

Furthermore, as previously mentioned, in addition to the exogenous stressor, an endogenous one was included, with the latter that can be defined as any form of stress whose triggering factors are internal to the person experiencing the state of stress. The reason behind this choice is linked to the need of studying the physiological responses of both types of stress, and this in order to have a better reference framework for the actual data collection to be held at Leonardo. More in depth, it has been demonstrated that these two types of stressors activate different physiological systems causing a trend of physiological parameters that is substantially different in terms of intensity, duration, and persistence. Understanding these parameters would allow the distinction, when collecting data, between the physiological responses caused by an exogenous stressor from those generated by an endogenous stressor. To this end, as for the endogenous stressor, it was decided to combine the effects of two factors extensively recognized in the literature for their ability to generate stressful responses, i.e., a mathematical task and a productive constraint. More precisely, participant will be required to assemble the largest number of airplanes in a predetermined time interval, respecting all the production constraint imposed, i.e., a punishment if they fail to produce a certain threshold number of airplanes in the time interval, and a premium in the opposite case. At the same time, every 30 seconds each participant will be asked to provide the result of a simple mathematical operation, with a penalty in case of error.

The use of mathematical tasks as a stressor is a recurring element in experimental studies that require to reproduce a stressful condition in a laboratory setting. An example is the Trier Social Stress Test (TSST), one of the most renowned tests for experimentally re-creating a state of stress caused both by endogenous stressors (i.e., social pressure, cognitive load) and by exogenous stressors (i.e., hand in cold water), thus stimulating a complete physiological response in terms of stress-related systems activation (Allen et al., 2013). Furthermore, also the use of time limits and rewards/punishments is well documented in the literature and identified as a valuable tool for exerting a certain degree of pressure on test participants.

As for the structure of the test, it was decided to decline the different stress conditions as follows: first a separate implementation to evaluate the contribution of each stressor. Secondly, a joint implementation to investigate the possible presence of interactive effects between the two variables. And finally a control condition, named “No-stress”, to highlight the impact of the movement factor in the absence of other factors influencing the data. In total, therefore, the “stress” factor has been declined into four conditions:

- No Stress
- Endogenous Stress
- Exogenous Stress
- Stress Mix

As regards the “movement” factor, as previously mentioned, the main objective of Experiment 1 is to evaluate the quality of the data in different conditions of mobility (i.e., low movement, high movement), and this in order to determine which of the available equipment is better suited for the parameters collection to be performed at Leonardo. Indeed, the inclusion of the movement factor is mainly linked to the need of incorporating in the experimental design disturbing elements that can be found in any production context, and the presence of which could jeopardize the quality of the data collected. In this regard, it was chosen to decline the movement factor into two conditions, namely "low movement" and "high movement", whose substantial difference is linked to the type of task performed by the test participants. More precisely, in the "high movement" condition the assembly of the airplanes takes place physically, using real LEGO bricks to build the model, while in the "low movement" condition the task is performed virtually through the use of Mecabricks[17],an online software for the construction of 3D LEGO models similar in all respects to the real ones. In fact, this software allows the perfect replicability of the assembly sequence to be performed for the physical task, with the only difference that it could take longer than the latter and the activity could be more complex. In this regard, further analysis on the virtual task are required, and are left to future studies. In particular, future studies should understand whether the two tasks (i.e., physical, virtual) are actually comparable in terms of time and complexity, or whether they present elements of differentiation that could compromise the validity of the data and stagger the results of the experiment. Finally, during the "high movement" condition, participants will be also required to get up and sit down with a predetermined frequency, and this in order to induce a punctual disturbance on the quality of the data to be collected. The inclusion of this element, in fact, would allow to reproduce rather faithfully in the laboratory setting the movements of an operator engaged in a production context, further increasing the ecological validity of the experiment.

3.2.2 The implementation

[17] Mecabricks. <https://www.mecabricks.com/it/>

As regards the implementation, eight different conditions have been devised from the combination of the different declinations of the factors (fig. 3.4). Participants will be given the test one at a time, and the total number of participants required to take the test is 10-15 participants.

The eight experimental conditions resulting from the combination of the factors are:

CONDITION 1 - (No Stress + High Movement): The task is manual. The subject builds airplanes by physically assembling real LEGO bricks, getting up and down every 30 seconds in order to recreate a punctual disturbance. There are no production constraints in terms of airplanes to be built in the time interval;

- CONDITION 2 - (Endogenous Stress + High Movement): The task is manual. The subject builds airplanes by physically assembling real LEGO bricks, getting up and down every 30 seconds in order to recreate a punctual disturbance. The subject is asked to make the largest number of airplanes in the time interval, considering a penalty if he fails to reach a predetermined threshold. Furthermore, every 30 seconds the participant is required to solve a simple mathematical operation, implying also in this case a penalty in the event of wrong answer;

- CONDITION 3 (Exogenous Stress + High Movement): The task is manual. The subject builds airplanes by physically assembling real LEGO bricks, getting up and down every 30 seconds in order to recreate a punctual disturbance. There are no production constraints in terms of airplanes to be built in the time interval. Finally, a background noise is played for the entire duration of the task;

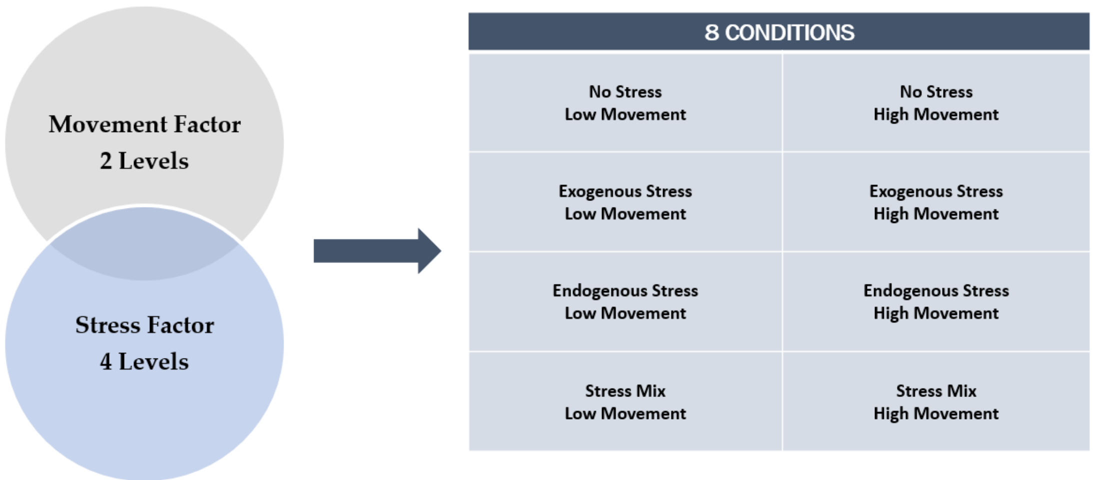

Figure 3.4 Experimental conditions Exp. 1

- CONDITION 4 (Stress Mix + High Movement): The task is manual. The subject builds airplanes by physically assembling real LEGO bricks, getting up and down every 30 seconds in order to recreate a punctual disturbance. The subject is asked to make the largest number of airplanes in the time interval, considering a penalty if he fails to reach a predetermined threshold. Furthermore, every 30 seconds the participant is required to solve a simple mathematical operation, implying also in this case a penalty in the event of wrong answer. Finally, a background noise is played for the entire duration of the task;

- CONDITION 5 (No Stress + Low Movement): The task is virtual. Subject builds airplanes "digitally" by assembling LEGO bricks through an online game. There are no production constraints in terms of airplanes to be built in the time interval;

- CONDITION 6 (Endogenous Stress + Low Movement): The task is virtual. The subject builds the airplanes "digitally" by assembling LEGO bricks through an online game. The subject is asked to make the largest number of airplanes in the time interval, considering a penalty if he fails to reach a predetermined threshold. Furthermore, every 30 seconds the participant is required to solve a simple mathematical operation, implying also in this case a penalty in the event of wrong answer;

- CONDITION 7 (Exogenous Stress + Low Movement): The task is virtual. Subject builds airplanes "digitally" by assembling LEGO bricks through an online game. There are no production constraints in terms of airplanes to be built in the time interval. A background noise is played for the entire duration of the task;

- CONDITION 8 (Stress Mix + Low Movement): The task is virtual. The subject builds the airplanes "digitally" by assembling LEGO bricks through an online game. The subject is asked to make the largest number of airplanes in the time interval, considering a penalty if he fails to reach a predetermined threshold. Furthermore, every 30 seconds the participant is required to solve a simple mathematical operation, implying also in this case a penalty in the event of wrong answer. A background noise is played for the duration of the task.

As regards the implementation, it has been decided to randomize the conditions in order to prevent specific sequences from affecting the validity of the data. In particular, the randomization will be operated in such a way that the total possible sequences will be equally and randomly distributed to the subjects participating in the test. Finally, during the data analysis it will be also necessary to perform a check in order to highlight any trends in relation to a specific sequence, which if not taken into account could compromise the study and the validity of the data.

As for the “movement” factor, it has been chosen to keep the two conditions separate for the purpose of implementing the experiment. At the basis of this choice there is the significantly different nature of the two conditions, both in terms of tasks and physiological activation, as well as the desire to avoid an excessively long and complex test that might lead to conditions of fatigue or boredom in the participants.

In light of this, a within subject implementation better suits with the terms of the project, in particular as regards the possibility of comparing the results and avoiding as much as possible trends that do not depend on experimental manipulations. Furthermore, again to avoid as much as possible the influence of external variables, it is preferable to implement the two conditions on different days but at the same time. If implementation on different days is not possible due to participants availability issues, it is also considered an implementation to be realized on the same day. In this latter case, the break between one condition and another should be of at least 30 minutes, and this in order to allow a re-stabilization of the physiological parameters at baseline levels. At any rate, a randomization of the movement conditions is considered so that one half of the participants will begin with "the low movement" condition and the rest with the "high movement" condition. Moreover, if the within subject design results not feasible, the possibility of operating in a between subject mode is also provided. In this case one half of the participants would perform the “high movement” condition, and the remaining the “low movement” one.

An initial baseline period of 5 minutes has been set up for each movement condition. In this regard, it has been observed from the literature that during the baseline period it is good practice to avoid that participants are left free to think, and this because it could provoke an emotional response that would distort the data. In particular, it has been noted that the best way to conduct the baseline phase is to ask the participants simple and neutral questions, preventing them from thinking about personal facts or anything that could cause emotional responses (Linden et al., 1997). Finally, a 10-minute break between one condition and another was considered. This to allow for the physiological parameters, influenced by the experimental conditions, to return to baseline levels. From an analysis of the literature, in fact, 10 minutes seem to be enough for the parameters to return to baseline levels, especially with regard to breathing and heart rate (Kudielka et al., 2004; Nilsen et al. , 2007).

3.3 Experiment 2

The goal of the second experiment is to evaluate the stress levels originating from the simulation of two production lines containing elements typical of traditional production systems and Lean Production. More precisely, the Experiment 2 has been developed with the intention of investigating the impact of certain production factors (i.e. production orientation, standardization) on the stress of the test participants in terms of physiological activation (eg heartbeat, respiration, skin conductance, etc.).
As regards the manipulation of the factors, this is aimed at simulating different control conditions on the activities to be performed. In fact, according to the Job Demand Control (JDC) model of Karasek (1979), a variation of control over the activities to be performed is able to provoke a more or less pronounced stress response. Specifically, for the JDC model, high levels of stress will result from a combination of high job demand and low control, while as demand decreases and control increases, stress levels will tend to decrease in turn. As regards both dimensions, additive effects on stress have been amply demonstrated in the literature, while the presence of interactive effects is still under discussion.
As for the control dimension, its manipulation in this experiment will be operated through the alteration of both factors considered (i.e. production orientation, standardization). Precisely, in accordance with the Karasek model and the literature on the effects of Lean Production, a reduction in the size of the buffers should result in a reduction in control over the pace of work. Similarly, again in accordance with the JDC and the analysis of the literature, greater standardization of procedures should lead to a reduction in control over the methods by the operator.

As regards the effects of these alterations on stress levels, the discussion is left in the paragraph on the starting hypotheses; this due to the ambiguity of the literature on the effects of reduced control in Lean contexts, as well as the conflicting results obtained through a series of questionnaires proposed in this study to line workers.

Regarding the task considered for Experiment 2, this is similar to the one proposed for Experiment 1 and consists in the construction of a series of models using LEGO bricks. However, differently from the previous experiment, in which only one LEGO model was used, in Experiment 2 a model will be used for each condition resulting from the combination of the factors, and this to avoid learning effects that could offset the data collected. Furthermore, unlike the previous experiment, in Experiment 2 the construction will be carried out only physically using real lego bricks, and therefore the use of online software will not be envisaged.

As for the factors of Experiment 2, these will be "production orientation" and "standardization"; thanks to which it will be possible to introduce specific elements of Lean and traditional systems and analyze how each of them affects stress levels. As regards the "production orientation" factor, the structure of the experiment is such as to reproduce in a laboratory setting both a "pull" type production line, i.e., pulled by the actual production demand, and a "push" type, i.e. based on demand forecasts.

As regards the “standardization” factor, it has been decided to decline this factor in the two conditions “good standardization” and “bad standardization”; with the first that refers to an optimal standardization of the procedures to perform the task, while the second that expresses a non-optimal standardization of the processes which can rather result in a waste, in terms of time and effort, for the operator. Furthermore, the results of this experiment could allow to take further steps in the discussion on the effects of Lean Production, which sees on the one hand the opponents of this model, for which Lean Production is always harmful regardless of a good or bad implementation, and on the other the supporters of this model, who affirm that a good implementation would be able to eliminate the negative effects while maintaining high production performance (Conti et. al., 2006).

Finally, as regards the simulation of the production lines, a total number of 3 sequential operators will be used; this although the data collection will be performed only for one of them. The reason behind this choice is related to the will of simulating production lines that are as similar as possible to those found in real production contexts. Furthermore, the presence of two operators, one downstream and one upstream of the central subject, allows the evaluation of the effects on the stress of the "starving" and "blocking" phenomena, identifying in the first the condition for which the operator cannot start the production due to lack of pieces in the input buffer, and in the second the impossibility of proceeding with production due to the downstream buffer which is full and therefore cannot be further filled.

3.3.1 Factors

As previously mentioned, the choice of the factors has been conditioned by the need of simulating two different production lines typical respectively of traditional and Lean systems.

To this end, "production orientation" and "standardization" were chosen as factors for the Experiment 2, the manipulation of which allows to include in the experimental design elements characteristic of traditional and Lean systems.

More precisely, as regards the "production orientation" factor, this has been declined in the "pull" and "push" conditions, typical of traditional and Lean systems, respectively.

The main difference between the two orientations is that in "push" production the real demand for products is not known and production is pushed from the bottom, while in the "pull" type production the demand for products is known and production is internally organized based on that information.

More precisely, in "pull" production the pace is determined by the actual demand for products, which has a cascading impact on each workstation within the line, determining the daily production goals for each of them. Generally, in "pull" type production information are transmitted between working stations using the Kanban method: a method that makes use of tags that contain information to produce, purchase or move components and materials between one workstation and another[18].

[18] Kanban. <https://www.kanban.it/it/>

As regards the two conditions considered (i.e., push, pull) it has been decided to implement variations in the size of the buffers in order to simulate each of them. In particular, as regards the "push" condition, it has been decided to use buffers of infinite size, this further indicating how production in this specific regime does not depend on the real demand for products but on its forecast; and therefore the production is pushed from the bottom, independently from the other working stations. In particular, in this production regime the operators have ideally infinite buffers, from which they can take the pieces necessary for production and stack those already produced.

As regards the two conditions (i.e., push, pull), it has been decided, in order to implement them in the laboratory setting, to modify the size of the buffers downstream and upstream of the central operator. For what concern the "push" condition, typical of traditional systems, it is well known that this organizes production independently of the real demand for products, and is rather based on its forecast. More precisely, when a "push" type production is implemented, each operator has at his disposal a downstream and upstream buffer, of ideally infinite size, from which to take the pieces to be processed and deposit the finished ones. In other words, in "push" productions each workstation operates independently of the others and the downstream buffer does not need to be free to start production. In this way operators have greater discretion on the production rate, given that the presence of downstream and upstream buffers allow them to accelerate or decelerate production independently of the other stations.

On the other hand, in Lean Production, in order to reduce any source of variability and systematically eliminate the presence of waste (buffers are considered elements capable of hiding the presence of defects), the size of the buffers is significantly smaller than traditional systems, and ideally equal to one. Indeed, in Lean Production the ideal would be that each operator works only one piece at a time, transferring the finished piece to the next station only when the incoming buffer of the latter is free.

This significantly reduces operators' discretion regarding production, since ideally the production rate is the same for the entire line and is determined by the total demand for products. Furthermore, the presence of limited buffers allows the evaluation of two particular phenomena, namely "starving" and "blocking". With the first referring to an interruption in the activities of a workstation caused by the lack of pieces to be processes in the input buffer. While the secondo to an interruption caused by downstream buffer, which is full and no longer refillable.

As regards the experimental design, in the "push" condition the size of the buffers must be such as to consider the total number of pieces that the participant would be able to build in the time interval if he produced the pieces with the predetermined timing for carrying out the task. In other words, the operator will have at his disposal a number of components in the input buffer that correspond to the pieces he will have to produce in the time interval. Differently, as regards the "pull" condition, in order to simulate an ideal Lean system, the size of the inbound and outbound buffers will be equal to one, with production that cannot start until the downstream buffer is emptied.

As regards to the standardization factor, this has been declined in the two conditions "good standardization" and "bad standardization", to indicate respectively the case in which the standardization of the processes is the optimal one and the one in which the standardization is not the optimal one. More precisely, the condition of "good standardization" has been designed to simulate Lean systems, since this put particular emphasis in the elimination of any source of variability that could jeopardize production, including the operators variability in performing the task. Indeed, it is well documented by the literature how generally in Lean Production contexts the standardization of procedures is significantly higher than traditional systems, and this also due to the implementation of continuous improvement activities, the ultimate result of which is to lead to even more standardized Standard Operating Procedures (SOPs).

Furthermore, in order to simulate a Lean production line as faithful as possible, in addition to an optimal standardization of the procedures, further typical elements of this system have been included in the experimental design, the adoption of which is considered capable of increasing the levels of efficiency and productivity. These elements are:

- A perfect synchronization of the actors upstream and downstream of the central operator, in order to create a production flow that is as regular as possible and avoid the aforementioned "starving" and "blocking" phenomena. (e.g., if the cycle time of the central actor is 30 seconds, then the lateral subjects will have to refuel and collect the pieces with a cadence exactly equal to 30 seconds).

- A delivery of incoming pieces exactly equal to that required for the assembly of each model, and this in order to simulate the implementation of a Poka Yoke practice,i.e. Lean method aimed at reducing the sources of variability and error.
- A supply of incoming LEGO pieces optimally ordered in terms of color and size, symbolizing the implementation of the Lean 5S practice, detailed in the first chapter.

As for the "bad standardization" condition, in this the assembly procedure is standardized but not the optimal one. The objective in this case is to evaluate the effects on stress of a bad standardization, which in turn involves a waste of energy and time for the operator. Furthermore, in the "bad standardization" condition, the additional Lean elements just mentioned above will not be implemented, further negatively impacting production and stress levels of the central subject.

The layout considered for the Experiment 2 is that shown in fig 3.5 with only the central subject to whom the physiological data will be collected.

Furthermore, during the analysis of the literature, additional elements were found capable of characterizing and distinguishing the two production lines considered. Among these two are the layout arrangement and the presence/absence of set up times, but for reasons related to the complexity of the experimental design it has been decided to exclude these elements from the present experiment. Nevertheless, the possibility of including these elements and studying their effects on stress is left to future studies.

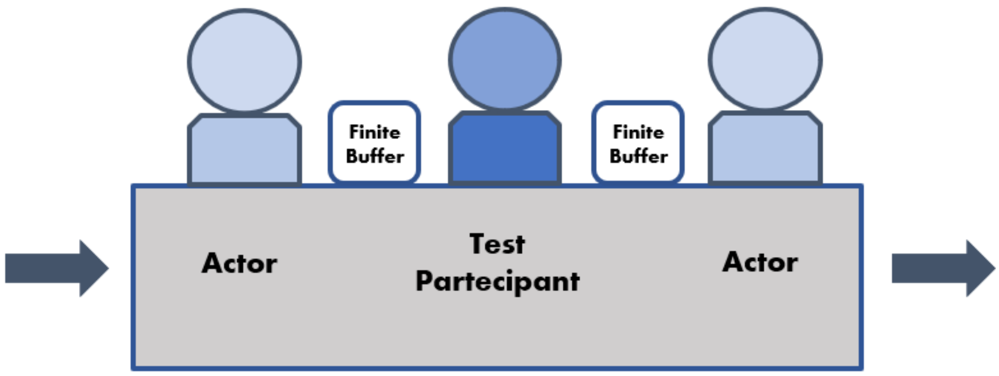

Figure 3.5 Experimental Layout for Exp 2

3.3.3. The implementation

As in Experiment 1 it has been decided to carry out a joint implementation of the factors, the combination of which determines a total of four experimental conditions reported in fig. 3.6.

The characteristics of each experimental condition are here outlined:

CONDITION 1 (Bad Standardization + Buffer n = 1): Buffer with size n = 1. The subject has in its input buffer a number of pieces to only build one model at a time. The subject can only transfer one finished model at a time to the next station and cannot start producing until the next station has emptied the incoming buffer. The assembly process is standardized but not optimal and the production context is chaotic (asynchrony of the actors, LEGO pieces not ordered by size and color and supplied in a greater number than necessary);

- CONDITION 2 (Bad Standardization + Buffer n = x): Buffer with size n = x. The subject has a sufficient number of pieces to build n = x finished objects at a time. The subject can only transfer n = x finished objects at a time to the next station and cannot start producing until the next station has emptied the incoming buffer. The assembly process is standardized but not optimal and the production context is chaotic (asynchrony of the actors, LEGO pieces not ordered by size and color and supplied in a greater number than necessary);

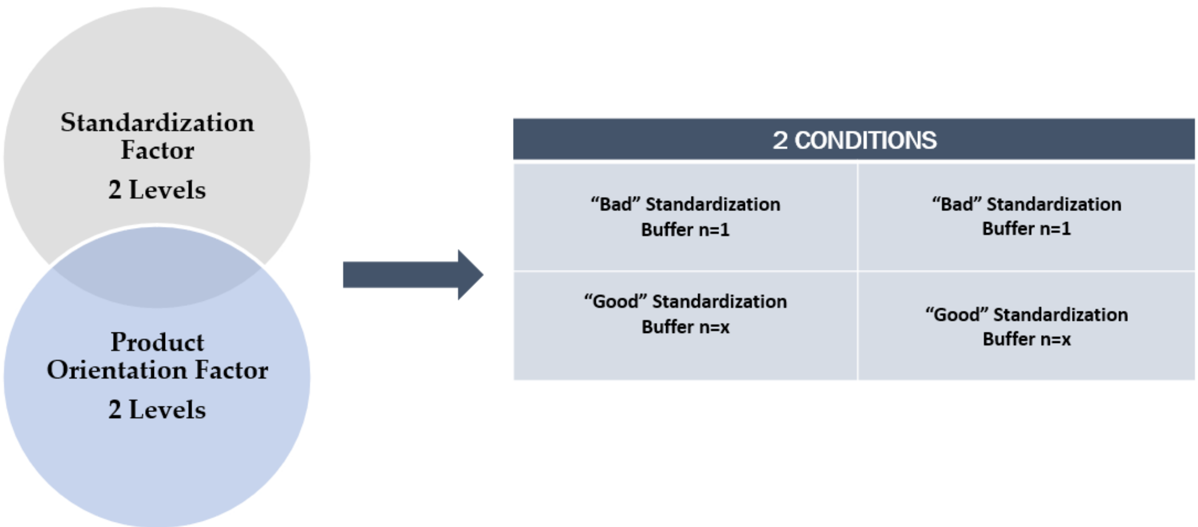

Figure 3.6 Experimental Conditions Exp.2

- CONDITION 3 (Good Standardization + Buffer n = 1): Buffer with size n = 1. The subject can only transfer one finished model at a time to the next station and cannot start producing until the next station has emptied the incoming buffer. The assembly process is standardized and optimal and the production context is ordered (synchrony of the actors, LEGO pieces ordered by size and color and supplied in the exact number for production);
- CONDITION 4 (Good Standardization + Buffer n = x): Buffer with size n = x. The subject has a sufficient number of pieces to build n = x finished objects at a time. The subject can only transfer n = x finished objects at a time to the next station and cannot start producing until the next station has emptied the incoming buffer. The assembly process is standardized and optimal and the production context is ordered (synchrony of the actors, LEGO pieces ordered by size and color and supplied in the exact number for production).

Also in this case, after careful evaluation, a within subject implementation has been chosen, with each subject called to face all four conditions. A randomization of conditions has been also envisaged, so that the total number of possible sequences is equally redistributed over the total number of participants; with randomization that eliminate the potential side effects related to a specific sequence or the interactive effects between one sequence and another.

Furthermore, in this experiment a randomization of the objects to be assembled in each of the four conditions is also considered, and this in order to avoid any learning effects that could possibly offset the data by distorting the relationship between the factors of interest and the stress levels. In particular, the objects to be used for this experiment must be such as to be comparable in terms of effort and assembly times; this in order to avoid that a greater job demand increases physiological activation levels, obscuring the contribution of the factors "productive orientation" and "standardization".

Finally, as regards the total duration of the experiment, the time of each condition will be equal to 5 minutes to which has to be added a baseline period of 5 minutes and pauses between one condition and another of 10 minutes; for a total duration of 55 minutes for the entire Experiment 2.

The choice of a 10-minute break between one condition and another is the result of a careful study of the literature, and in particular of those researches that have implemented similar experimental conditions and which reported the trend of the physiological activation in terms of heartbeat, respiration, skin conductance, etc. Thanks to these publications it has been possible to evaluate how long it took on average for each physiological parameter to return to baseline levels.

DISCUSSION

From the analysis of the literature, a certain ambiguity emerged as regards the effects of Lean Production on working conditions and workers' health and well-being (Hasle et al., 2012). But despite the evidence of the rather negative image of Lean Production drawn by numerous studies, researches have also emerged in which working conditions have improved following a Lean implementation, to the point that in some applications a prevalence of positive effects has been observed. (Seppälä & Klemola, 2004). One of the major contributions of these studies was precisely to dispel the myth, long supported by the opponents of Lean Production, for which this system is intrinsically stressful and unable to combine superior performance with an improvement in workers' health and well-being. As suggested by several authors, indeed, as Treville & Antonakis (2006), it is possible to implement Lean systems so that, up to a certain point, the working environment is improved. More precisely, it has been observed how the stress experienced by workers strongly depends on the way in which the system is designed and implemented (Conti et al., 2006). In this regard, it is useful to note that Lean Production cannot be understood as a univocal and unitary concept of production, strictly defined and composed of the same practices wherever it is implemented, but rather as a system whose success and whose effects on working conditions strongly depend on the particular context and the way in which it is implemented. In line with these results, several authors have therefore tried to study the main differentiation elements underlying a correct implementation, trying to distinguish the effects of each Lean practices on the health and well-being of workers. Nevertheless, as highlighted also by Conti et al., (2006), it has been noted a scarcity of these studies in the literature, to indicate that a greater commitment is necessary to investigate this aspect of Lean Production, the understanding of which would allow to devise systems that are effectively capable of improving operators' quality of working life, as well as satisfying the promises of improved business performance.

And it is precisely in this context that the present study constitutes a preliminary phase of research aimed at further investigating the link between determined Lean practices and their impact on the work environment, as well as their effects on workers' well-being. More in depth, in order to participate at the heated debate on the effects of Lean Production, which has long divided the literature between opponents and supporters of this production model, the present study is insert as part of a broader collaboration project between the Polytechnic of Turin and the Department of Psychology of the University of Turin aimed at laying the foundations for a data collection to be performed at Leonardo S.p.A. (i.e., an Italian company active in the defence, aerospace, and safety sectors), in order to analyse the stress levels within this context, as well as to investigate the relationship between some Lean practices and the stress to which the workers are subject.

As regards the methodology, the development of this study is mainly based on the review of the existing literature. In particular, a first phase of research has been dedicated to the analysis of Lean Production and the main principles and application tools underlying this model. Subsequently, the analysis is shifted to the primary differences between Lean Production and traditional production systems (i.e., Fordism, Taylorism), paying particular attention to the role of operators in a Lean context. Furthermore, literature has been also investigated on the impact of Lean Production on workers' health and well-being, placing particular emphasis on those manual, repetitive and low-complexity jobs, typical of production lines. The main contribution of this analysis, as previously mentioned, has been to dispel the myth for which Lean Production is intrinsically harmful and confirm, on the other hand, that the success and effects of this system strongly depend on the particular context and the way in which it is implemented (Parker, 2003).

Then, an analysis has been performed on the evolution of the main theoretical models of occupational stress, with an in-depth analysis of the Karasek's Job Demand Control model, one of the most influential and renown most model for studying the relationship between working conditions and workers' health and well-being. The major contribution of this investigation has been to study in more detail the relationship between specific work dimensions and stress levels. In particular, the JDC model offers a valid starting point for understanding the influence of certain work aspects variation on stress levels, as well as offering a reference framework for the interpretation of the data and the formulation of the starting hypotheses.

Once the literature analysis phase has been concluded, and the necessary information has been obtained, a design of experiment (i.e., Experiment 1, Experiment 2) has been developed with the aim of further investigating the relationship between stress and work in a Lean Production context, as well as assessing the impact of certain disturbing factors (i.e., movement, stress) on the quality of the physiological parameters (e.g., heartbeat, skin conductance, respiration, etc.) to be collected in a laboratory setting. As regards the two experiments, these have the main objectives of testing the effectiveness and sensitivity of two instrumentation (i.e., Biopac electrodes and a modern wireless physiological monitoring system) for the collection of physiological data (skin conductance, respiration, heartbeat, etc.) to be used for the assessment of the stress levels, as well as investigating the stress levels resulting from the experimental manipulation of job control in a laboratory setting.

Finally, the analysis of the literature, and the valuable information obtained along the development of the design of experiment, made it possible to define guidelines and recommendations to be used as a starting point for the future collection of data to performed at Leonardo, as well as for future research aimed at implementing the two experiments.

CONCLSUSION

To conclude from the analysis of the literature it has been possible to reach several conclusions. First of all, the ambiguous nature of Lean Production became evident as regards its effects on workers' health and well-being. Indeed, although most of the studies have drawn a rather negative picture of Lean Production, researches have also emerged in which both positive and negative effects have been detected as a consequence of a Lean implementation. More in depth, a number of studies in which a prevalence of positive effects has been observed have dispelled the myth for which Lean Production is intrinsically harmful and unable to combine increased performance with an improvement in working conditions.

Furthermore, it has been noticed that Lean Production cannot be understood as a univocal and unitary concept of production, strictly defined and composed of the same practices wherever it is implemented, but rather as a system whose success and whose

effects on working conditions strongly depend on the particular context and the way in which it is implemented.
These results therefore not only have dispelled the myth for which Lean Production is intrinsically harmful but have also highlighted the need for further investigation on the individual impact of Lean practices on the work environment. Furthermore, to make this need even more urgent is the scarcity in the literature of studies that have explicitly concentrated their analyses on these relationships.
And it is precisely in this context that the present study is insert as part of a broader collaboration project between the Polytechnic of Turin and the Department of Psychology of the University of Turin, aimed at investigating the relationship between stress and work in a context of Lean Production.
More precisely, in a preliminary phase of research aimed at laying the foundations for a data collection to be performed at Leonardo S.p.A., a design of experiment (i.e., Experiment 1, Experiment 2) has been conceived in order to lay the basis for the correct progress of the project and to collect useful data for future studies on work-related stress.
The analysis of the literature, and the valuable information obtained along the development of the design of experiment, made it possible to define guidelines and recommendations to be used as a starting point for the future collection of data to be performed at Leonardo, as well as for future research aimed at implementing the two experiments.

LIMITS AND RECOMMENDATIONS FOR FUTURE RESEARCH

As noted above, this study constitutes a preliminary research phase within a broader collaboration project between the Polytechnic of Turin and the Department of Psychology of the University of Turin aimed at investigating the relationship between stress and work in a context of Lean Production. As a result, this work leaves to future studies the treatment of a series of limits deriving exactly from its exploratory nature. In this regard, it is recommended to consider these elements as a starting point for the future implementation of the design of experiment and for the data collection to be performed at Leonardo. In this regard, the main limitations of this study, as well as some recommendations and suggestions for future research, are here presented.

More precisely, as regards Experiment 1, further investigations of the virtual task are postponed to future studies, and this in order to allow for a comparison, in terms of timing and complexity, with the physical task, i.e., the realization of a predetermined model through the use of LEGO bricks. More in depth, for the correct implementation of the experiment, it is necessary that the two tasks are exactly comparable in terms of cognitive and physiological load, and this in order to avoid that a greater or lesser load associated with one of the two tasks may result in a increased physiological activation, staggering the data and compromising the validity of the experiment.

Furthermore, as regards Experiment 2, also in this case it is of fundamental importance that the tasks considered for each experimental condition are exactly comparable in terms of duration and effort. In particular, the choice of three tasks to be added to that of the airplane model is left to future studies, highlighting once again the need to perform pilot tests to confirm their comparability.

Furthermore, as regards to both experiments, another recommendation for future studies is to include in the experimental design questionnaires for the evaluation of determined psychological traits of test participants. Indeed, it has been demonstrated that some individual characteristics of a psychological nature (e.g., proactive personality, active coping, self-efficacy, and internal locus of control) are able to influence the effects on stress levels of a lesser or greater control on one's activities (Kain & Jax, 2010). In particular, it has been observed that such traits have the ability to change the perception of individuals towards control, both in terms of desirability and in terms of the effective capacity of its exploitation. Introducing these elements in the experimental design, therefore, would not only allow for the evaluation of their influence on the relationship between stress and working dimensions, but would also give the possibility to interpret the data from a different and more comprehensive perspective.

Finally, as regards both experiments, a further analysis on the validity of a 10-minute rest time between one experimental condition and another is left to future studies. This value was in fact defined by virtue of some studies, obtained through an analysis of the literature, and in which physiological activations were determined using stress factors similar to those considered in this study experiments. Despite this, it is advisable to verify the validity of this data by performing a pilot test of the two experiments and evaluating the actual timing necessary for the physiological parameters to return to baseline levels.

As for the actual data collection to be carried out at Leonardo, here too it is necessary to make recommendations for future studies.

In particular, the use of a longitudinal design is highly recommended. This type of study, in fact, would be more capable than cross-sectionals, to evaluate the causal relationships between the variables of interest, as well as to determine the presence or absence of reciprocal and reversed relationships. Furthermore, if variables external to the model were included in these longitudinal studies (e.g., years of experience, job changes, salary level etc.) it would be possible to determine the effects of these on the outcome variables, further increasing the validity of the study.

In this regard, it is also recommended to include a series of confounding variables that could affect the relationship between the causal and the effect variables, compromising the validity of the data and preventing a proper investigation of the stress levels associated with working conditions.

Furthermore, it is preferable, for the evaluation of the variables of interest, to use objective rather than subjective data. In fact, the evaluation of job characteristics and stress levels through the use of subjective data could be subject to bias of a personal nature. This does not represent a problem as regard the levels of stress, since their measurement takes place through the detection of physiological parameters, but it could be an issue with regard the working characteristics, since the psychological state of each operator could influence his perception of the working environment.

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