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Licenciatura em Ciências de Engenharia Civil

Beyond Lean and the Working Environment

Dissertação para obtenção do Grau de Mestre em Engenharia e Gestão Industrial

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FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

setembro de 2017

Beyond Lean and the Woking Environment

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ACKNOWLEDGMENTS

I would like to extend my deepest thanks to Professor Helena Victorovna Navas and Professor Antonio Sartal Rodríguez for their guidance, dedication, sympathy and professionalism.

I thank my mother for the untiring support and dedication she has given me throughout my life. I would like to thank also for the education that was given me and the investment made to make my journey possible.

ABSTRACT

Lean Production System (LPS) has become very popular among manufacturing industries, services and large commercial areas over the years due to its production increase abilities. However, LPS practices can have both negative and positive impacts in worker's psychosocial factors like motivation, satisfaction and commitment and physical and psychological health factor like musculoskeletal disorders (MSD) and stress.

Since LPS is a very broad term, there is no simple relation between LPS implementation and its consequences over work environment and workers. Therefore, it is necessary to study the different factors that can affect the work environment in each case. A wide variety of LPS practices can have negative and positive impacts on workers. Furthermore, the effects of lean may also depend on the sector and country in which it is implemented. There are no studies in the literature that cover all these effects and analyse them together with the involved environment. In this study, articles were collected in scientific publications in the last 26 years and analysed.

Results show that Just-in-Time (JIT) practices are strongly related with negative effects in MSDs and stress caused by intensification of work and increase of control over workers. However, JIT practices such as manufacturing cells can increase job enrichment trough multi-skilling.

Respect for people practices can act as buffers to lean practices. Job rotation reduces human effort and work pace trough the increase of recovery time. Workgroups create job support acting as buffers to psychosocial factors. Results show a majority of negative effects in the automotive sector and in countries such as Canada, USA and UK. Scandinavian countries have implemented hybrid forms of Lean which are related to an increase in effects such as motivation and job satisfaction. However, the overall analysis is that the effects of lean on workers depend more on the way companies manage and implement it rather than the countries cultural factors.

This study can be useful for managers and leaders who seek to transform traditional enterprises into exemplars of lean success, showing the need to balance lean and good working conditions.

Key-words: Lean, MSD, Stress, Commitment, Motivation, Satisfaction

RESUMO

O *Lean Production System* (LPS) tornou-se muito popular entre as indústrias de produção, os serviços e as grandes áreas comerciais ao longo dos anos, devido às suas potencialidades de aumento de produção. No entanto, as práticas de LPS podem ter impactos negativos e positivos nos fatores psicossociais dos trabalhadores, nomeadamente na motivação, satisfação e empenho, e nos fatores de saúde física e psicológica, nomeadamente nas lesões músculo-esqueléticas e no stress.

Como o LPS é um termo muito abrangente, não existe uma relação simples entre a sua implementação e as consequências no ambiente de trabalho e trabalhadores. Portanto, é necessário estudar os diferentes fatores que podem afetar cada caso. Uma grande variedade de práticas do LPS pode ter impactos negativos e positivos sobre os trabalhadores. Além disso, os efeitos do LPS também podem depender do setor e país em que é implementado. Não existem estudos na literatura que cubram todos estes efeitos e os analisem em conjunto com o meio envolvente. Neste estudo, os artigos analisados foram recolhidos em publicações científicas dos últimos 26 anos.

Os resultados mostram que as práticas Just-in-Time (JIT) estão fortemente relacionadas com efeitos negativos nas lesões músculo-esqueléticas e no stress causado pela intensificação do trabalho e aumento do controlo sobre os trabalhadores. No entanto, as práticas do JIT, como as células de produção em U, podem aumentar o enriquecimento do trabalho através da multivalência.

O respeito pelas pessoas pode aliviar os efeitos negativos das práticas do Lean. A rotatividade do trabalho reduz o esforço humano e o ritmo através do aumento do tempo de recuperação. O trabalho em equipa cria suporte, contribuindo para aliviar efeitos psicossociais como motivação e satisfação. A maioria das referências a efeitos negativos foi encontrado no setor automóvel e em países como o Canadá, EUA e Reino Unido. Os países escandinavos implementaram formas híbridas do Lean que estão relacionadas com um aumento de efeitos positivos, como motivação e satisfação no trabalho. No entanto, a análise geral é que os efeitos do Lean sobre os trabalhadores dependem mais do modo como as empresas o gerem e implementam, do que dos fatores culturais dos países.

Este estudo poderá ser útil para gestores e líderes que procuram transformar as empresas tradicionais em exemplos de sucesso do Lean, mostrando que é necessário equilibrar o Lean e as boas condições de trabalho.

Palavras-chave: Lean, lesões músculo-esqueléticas, stress, empenho, motivação, satisfação

Contents

Figure Index

Table Index

Acronyms

IMVP - International Motor Vehicle Program

JIT - Just-In-Time

MSC - Motivation, Satisfaction and Commitment

MSD - Musculoskeletal Disorders

QC - Quality Circles

QCC - Quality Control Circles

RfP - Respect for People

TPM - Total Preventive Maintenance

TPS - Toyota Production System

TQM - Total Quality Management

UK - United Kingdom

USA - United States of America

VSM - Value Stream Mapping

1 Introduction

With this chapter, it is intended to introduce the work's development. Firstly, is presented the theme context and the objectives to be achieved. The following is the methodology presentation and lastly, is presented the dissertation structure overview.

1.1 Background and study objectives

Lean Production is nowadays the main waste free concept applied in manufacturing industries and it is now spreading to many sectors beyond manufacturing worldwide. Lean Production was born in Japan, more specifically in the Toyota company in the 1970's and was founded on a belief that the key to improving profit was to reduce cost (Ohno, 1988). However, its practices like "Just-in-Time" and "zero defects" can be very stressful for workers and have negative impacts like demotivation and physical and psychological health problems.

There are many studies of lean production found in literature, first in the automotive industry in the 1990s (Adler et al., 1997; Babson, 1993; Berggren et al., 1991; Lewchuck & Robertson, 1996). In more recent years, authors focused their studies on lean effects in other manufacturing sectors and services sector (Conti et al., 2006; Jackson & Mullarkey, 2000; Sprigg & Jackson, 2006). Most authors reported that in the automotive industry, lean is mainly bad for workers due to specific lean practices which were correlated with stress and musculoskeletal disorders. They also reported that in other sectors than automotive, this negative effect of lean can be also found where lean is not fully implemented. Existing studies in the literature show contradictory opinions regarding the effects of Lean on workers.

Since Lean is a very broad term, there is no unidirectional relation between lean implementation and its consequences in the work environment and the worker, that is why it is important to study the different factors that affect each case.

The objective of this dissertation is to understand which factors and characteristics of lean production lead to positive, negative or mixed effects in musculoskeletal disorders (MSD), stress and motivation, satisfaction and commitment (MSC). To achieve this objective, a systematic review of literature was carried out, reviewing papers published in the past 26 years studying this matter. In this dissertation, it is done a comparison between the three pillars of lean and their main practices, these pillars are Just-in-time, *Jidoka*, based on zero defects concept and a commonly ignored but very important pillar, the Respect for people. Factors like the country where lean is implemented, the sector, the company

technological intensity, and the type of journal where papers were published are also control variables in this study to find a multi-directional relation between lean production and its effects on workers. Finally, an interaction model of effects of lean production on job characteristics and their relation to MSD, stress and MSC is proposed.

1.2 Outline

The structure of this dissertation is divided in 7 different chapters, from the "Introduction" to the "Conclusions".

1. Introduction
2. Lean Philosophy
3. Physical and psychological health effects description
4. Study Methodology
5. Effects of Lean production on workers and hypotheses presentation
6. Interaction models between lean practices and effects on workers
7. Bibliographic analysis results and discussion
8. Proposed Interaction model between lean practices and the effects on workers
9. Conclusions

In this first chapter, an introduction is done to the addressed subject, as well as the motivation of the work and its objectives. A brief description of each chapter of the dissertation is also presented.

In chapter 2 the theoretical concepts of Lean Philosophy are covered. The philosophy is described and the fundamental principles reviewed. The main practices intrinsic to Lean are specified with focus on the three pillars of Lean which are Just-in-Time, *Jidoka* and Respect for People.

In chapter 3, the theoretical concepts of physical and psychological health effects are covered. It describes physical health effects, namely musculoskeletal disorders. Also, psychological health effects like stress, motivation, satisfaction and commitment, are described in this chapter.

Chapter 4 addresses the study methodology, bibliographic research and screening.

Chapter 5 addresses the effects of Lean on workers well-being, based in both theoretical and empirical aspects found in literature and presents the hypotheses to be studied.

In chapter 6, interaction models between lean practices and effects on workers found in literature are presented and described.

In chapter 7, bibliographic results are analysed and discussed trough diagrams showing the effects of lean on workers, positive negative or mixed. In the sub-chapters, different combinations of control variables like the sector where lean is implemented and the country are analysed to better understand these effects.

In chapter 8, an interaction model between lean and the effects on workers is proposed, based on the results found in chapter 7.

Finally, in chapter 9 a succinct summary of the work developed through the present dissertation is made, a breakdown of the conclusions that were obtained is presented and future research is proposed.

2 Lean Philosophy

The term Lean Production was used by Krafcik in 1988 to nominate the production organisation system used in some Japanese automotive plants installed in the U.S. during the 1980's (Holweg, 2007). This system, called Toyota Production System (TPS) was developed in Toyota automotive plants after the World War II by the Vice-President of Toyota Motor Company, Mr. Taiichi Ohno and became known since the first oil crisis in 1973. Despite the crisis, Toyota results were extraordinary, generating curiosity in other plants. Their ability in designing and building cars in less time, with less people and lower inventories was remarkable (Arezes et al., 2014).

About TPS concept, it's stands point was in recognizing of Japan's distinguishing features (Sugimori et al., 1977). The most distinctive feature of Japan is the lack of natural resources, which makes it necessary to import vast amounts of materials including food. Japan is placed under a disadvantageous condition in terms of cost of raw material when compared to the European and American countries. To overcome this handicap, it is essential to put forth the best efforts to produce better quality goods having higher added value and at an even lower production cost than in the other countries. This was the first thing that Toyota recognized.

The second distinctive feature is that Japanese concept of work, such as consciousness and attitude, differed from that held by the European and American workers. The Japanese traits includes: group consciousness, sense of equality, desire to improve, and diligence born from a long history of a homogeneous race; high degree of ability resulting from higher education brought by desire to improve; and centring their daily living around work. Such Japanese traits have also been reflected in the enterprises. Customs such as lifetime employment system, labor unions by companies, little discrimination between shop workers and white-collar staff, and chances available to workers for promotion to managerial positions, have the problem of foreign workers. Therefore from the standpoint of labor environment, Japan is much better than the European and American countries. To make full use of the Japanese advantages, it is important that the industries have their workers display their capabilities to the utmost. This was the second thing that Toyota recognized (Sugimori et al., 1977).

5 Principles of Lean Thinking

According to Futata (2005), the TPS main goal is to eliminate any activity or resource that does not add value to the final product, ending with waste this way. Lean production's paradigm evolved in to a thinking paradigm, Lean Thinking, which focuses in improving productivity, efficiency and quality of the products or services using the least quantity of resources as possible. According to Womack & Jones (1996), there are 5 principles of Lean Thinking:

Value- Specification of the value of a particular product that the costumer really needs;

Value stream- Identification and analysis of the value flow for each product;

Continuous flow- Establishing a continuous value flow, characterized by the ability to produce just the necessary for the moment;

Pull- Let the costumer "pull" the product, trough the implementation of Pull system allowing to produce only when the costumer order is made, producing just the necessary when necessary;

Perfection- Seeks perfection and innovation trough continuous improvement.

A Lean organization understands what constitutes value to the customer, being that, from this definition, it focusses in the key processes to increase it. The final objective will be the creation of a perfect process of value creation to the costumer, seeking its continuous improvement (Womack et al., 1990).

7 Major Kinds of Waste

Continuous improvement focuses on the elimination of 7 major types of waste (Shingo & Dillon, 1989; Suzaki, 1987; Art of Lean Inc., 2017):

Defects: Correction / Scrap- Producing defective products or products requiring repairs adds the cost of extra manpower, materials, facilities and conveyance measures. Some examples are: the waste of extra handling; the waste of additional labor; the risk of further defects caused by additional handling; and the risk giving to customers an inferior product. The impacts of scraped items are, for example: financial loss related to the part; the waste associated with holding extra parts in inventory; the labor wasted producing the defective part; and the waste of handling, moving and discard the scrap item.

Over-production- There are two types of overproduction, producing too much and producing too early. Examples of waste caused by overproduction are: necessity for extra material and parts; increase in containers such as pallets and skids; increase in conveyance vehicles; the growth of stock and increase in labor.hours for stock control and increase in storage and warehouse space. The principal factors that causes overproduction are: a sense of security against machine breakdown, defects and absenteeism.

Waiting-idle time- Time is a limited resource. Any waiting due to breakdowns, changeovers, delays, poor layout or work sequence needs to be eliminated. Reducing cycle time by eliminating waiting within the work sequence can have a profound effect in productivity.

Processing - redundant or inefficient steps in the process. Employees must learn to identify over processing waste, and perform the appropriate amount of processing on parts without spending more time or effort than is necessary.

Inventory- parts waiting in process or in finished goods storage. The smooth, continuous flow of work through each process ensures that excess amounts of inventory are minimized. If work-in-process develops because of unequal capabilities within the process, efforts need to be made to balance the flow of work through the system. Inventories often require additional handling which requires additional labour and equipment.

Motion- Wasted motion occupies time and energy. Much of the wasted motion is often overlooked because it has become such a part of the process. Work processes should be designed so that items are positioned close to each other. Unnecessary amounts of turning, lifting and reaching are eliminated. The same improvements that eliminate wasted motion often have ergonomic benefits as well.

Conveyance - Inefficient layouts and facility design results in conveying parts, materials and people more than is necessary. Material should progress from one cell or position to the next as quickly as possible without stopping at any intermediate storage place. Shipping areas should be close to the end of the process. Work teams and support units should be located close together.

TPS Fundamental Pillars

The underlying idea behind TPS is to maintain a continuous flow of in-line products that is readily available for the open demand. To do so, this system is supported by two TPS fundamental pillars, represented by Just-in-Time (JIT) and *Jidoka* as shown in Figure 2.1. The foundations of these pillars are the standardization of work, *Heijunka* which mean production smoothing and the continuous

improvement philosophy more known as *Kaizen* (Ohno, 1988; Liker 2004), see Fig.2.1, as adapted from Liker (2004) for the TPS house.

Although these two pillars appear in most of the literature regarding Lean Manufacturing, there is little literature referring the heart of the TPS house, being that the Respect for People (Emiliani, 2008). Toyota is convinced that the company goals can be reached in the best way through participation of all employees. A major part of the production system is the underlying concept of respect for all employee (Art of Lean Inc., 2017). Also, TPS identifies the four main areas where the production team members can participate in achieving company goals (Art of Lean Inc., 2017):

- **Standards** - setting and maintaining work standards;
- **Problem solving** - solving daily performance problems;
- **Improvement** - participating in the continuous improvement process;
- **Teamwork** - organizing teamwork efficiently.

Figure 2.1-Toyota Production System House (Adapted from Liker, 2004)

2.1 Main Lean practices and tools

This sub-chapter describes the most common Lean practices and tools found in each of the Toyota Production System House pillars as shown in Figure 2.1.

2.1.1 Just-In-Time

When first developed in Japan in the 1970s, the idea of the Just-in-Time (JIT) advocated: producing and/or delivering only the necessary parts, within the necessary time in the necessary quantity using the minimum necessary resources. This is called a Pull System. A typical vending machine is a good example of a pull system in action. The customer 'pulls' the items needed, in the quantity needed, at the time needed. The supplier replaces (fills up) only those items 'pulled' by the customer (Art of Lean Inc., 2017). The old system became known, by contrast, as just-in-case or Push System. Inventory was held for every possible eventuality, just in case it came about.

JIT eliminated buffer stocks for each stage in the production process, resulting in remarkable savings. This production philosophy also increased workforce involvement in controlling their own inventory needs and allowed a variety of products to be produced on the same assembly line simultaneously. Before JIT, assembly lines had been able to produce only one type of product at a time, in a way that, to produce another type of product the production line was required to stop and the retooling was expensive.

JIT characteristics: There are three characteristics that define the nature of JIT systems: increased workflow integration, pooled interdependency, and process simplification, (Jackson & Martin,1996):

Workflow integration: A key defining characteristic of JIT is the removal of barriers between stages in the production process so that work flows directly from one stage to the next without the buffering of in-progress inventory. This feature of technological systems has been described as workflow integration (Jackson & Martin,1996).

Team interdependence: The removal of the protection afforded by in-progress buffering paces a much greater emphasis on keeping the production process going; and, as consequence, workers are expected to do whatever is needed to solve problems that arise. This generates a high level of collaboration between work group members or team interdependence (Jackson & Martin,1996).

Process simplification: The third key feature of JIT is the simplification of work procedures and production schedules to remove blockages to the free flow of production (Jackson & Martin,1996).

U-shaped production line

The U-shaped production line is described as the special type of cellular manufacturing used in JIT production systems. The U-line arranges machines around a U-shaped line in the order in which production operations are performed. Operators work inside the U-line. One operator supervises both the entrance and the exit of the line. Machine-work is separated from operator-work so that machines work independently as much as possible. Standard operation charts specify exactly how all work is done. U-lines may be simple or complex. U-lines are rebalanced periodically when production requirements change. The U-line satisfies the flow manufacturing principle. This requires operators to be multi-skilled to operate several different machines or processes. It also requires operators to work standing up and walking. When setup times are negligible, U-lines are operated as mixed-model lines where each station can produce any product in any cycle. When setup times are larger, multiple U-lines are formed and dedicated to different products. The average U-line has 10 machines and 3 operators (Miltenburg, 2001). Figure 2.2 illustrates a U-shaped production line layout.

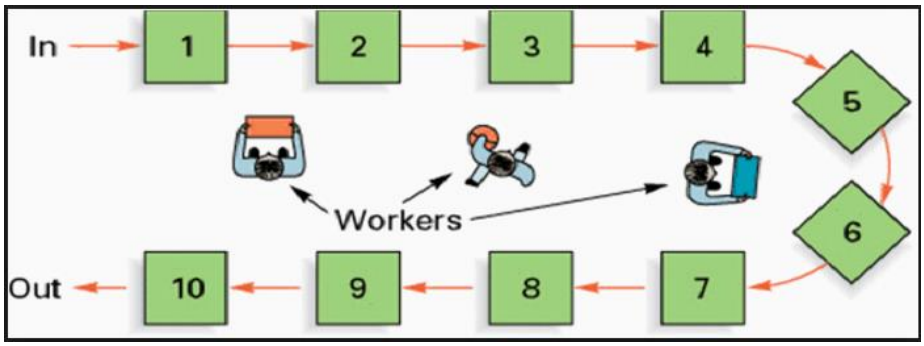

Figure 2.2- U-shaped production line layout (Miltenburg, 2001)

Kanban

One of the most used tools in the JIT system is the *Kanban*, which means card in Japanese. This card is sent to reorder a standard quantity of parts when they have been used up in the manufacturing process. Before JIT, batches of X + Y parts were ordered at a time, and the *Kanban* would be sent for a replacement order when only Y parts were left. With JIT, only Y parts were ordered, and the *Kanban* was sent off as soon as the new order arrived, this way eliminating the need to hold X parts in permanent storage (Cheng & Podolsky, 1996).

Takt Time

Another indispensable tool in a JIT system is the Takt Time. It aims at eliminating over-production, the greatest of the seven wastes. "*Takt*" is the German word for rate and it is the principle that all activity within a business is synchronized by a pulse, set by the customer demand. Takt time is calculated dividing the production time available by the customer demand. For example, if the demand is 100 products per day and the time available for production is 450 minutes per day, the calculated takt time would be 4,5 minutes. Cycle Time is the time required for the execution of a part, or the time elapsed between the repetition from start to end of operation. This two metrics should always be compared to have a smooth production flow and the right quantity of products in inventory.

Value Stream Mapping (VSM)

One of the essential tools for achieving the goals outlined by Lean Production is the Value Stream Mapping (VSM) and its main objective is to diagnose the value flow in an organization. Through this diagnosis, it is possible to verify the existence of waste, being later adopted measures for its disposal. The study is carried out on a product, from the form of raw material up to the finished product, identifying the relationship between the material flow and the information flow over the entire production (Rother & Shook, 2009). Ohno (1988), defends the importance of the quantitative data represented in the VSM, since it will be from the values collected that decisions will be taken to improve the value flow.

2.1.2 Jidoka

Jidoka is a Japanese term used in the TPS that can be defined as "automation with a human touch". The term *Jidoka* first appeared with the invention of the automatic loom by Sakichi Toyoda, the Founder of the Toyota Group. This loom had some devices incorporated that allowed the machine to stop when a defect was detected. Also, later Sakichi invented the world's first automatic loom, with non-stop shuttle-change motion, which could detect defects and correct them without stopping operation. This built-in device applied in machines for making judgments are referred by Toyota as "*jido*". This production system meant that a single operator could be put in charge of numerous looms, resulting in a huge improvement in productivity (Toyota Company., 2017).

Jidoka frees people being tied to machines and monitoring them and puts people to use in a more value-added fashion. This ability to separate man from machine reflects Toyota's respect for the employee and is an important enabler for Standardized Work to flourish (Art of Lean Inc., 2017).

Total Quality Management

Some of *Jidoka*'s tools are part of Total Quality Management (TQM). TQM is "The management of quality at every stage of operations, from planning and design trough self-inspection, to continual process monitoring for improvement opportunities" (Radnor, 2000). Also, other authors referred that "TQM is a corporate culture characterized by increased customer satisfaction trough continuous improvement, in which all employees in the companies participate actively" (Boaden, 1997). One of the most popular concepts used in quality control is zero defects. "Zero Defects is a management tool aimed at the reduction of defects through prevention. It is directed at motivating people to prevent mistakes by developing a constant, conscious desire to do their job right the first time" (Halpin et al., 1966). Activities such as improvement, statistical control, supply control and quality engineering are ingredients of TQM.

Building in Quality, means that each team member of a work chain, must be aware that the downstream process is a costumer and must never pass on a defective product. If something abnormal happens, the operation must be stopped.

***Andon* Boards**

An important tool for "visual control" or "problem visualization" is the *Andon* boards. These boards consist in displaying boards that show when an equipment stops due to a problem, allowing operators to identify problems in the production line with only a glance.

Poka-Yoke

Another way to improve quality in the production process is trough utilization of defect-proof tools, called *Poka-yoke*. This tool when installed in a machine or workstation prevents mistakes, in other words, even if you want to do wrong, *poka-yoke* does not allow it.

Standardized Work

The best way to produce in time, without waste is producing always in the same mode. This means, in a standardized mode, because consistency in methods is critical to limiting variation in the process.

Many documents exist to guide operators, define processes, document standard methods, and train team members. Two common documents posted in the production area are the Standardized Work Chart and Quality Check Sheets.

The Standardized Work Chart is a document, centred around repetitive human movement, that combines the elements of a job into an effective work sequence, without waste. It also serves as a visual control tool for leaders and managers to easily determine if there is a problem in the work area.

Quality check sheets define the quality checks that must be performed by team members in the work area. It provides instruction on which characteristics are to be checked, the required specifications to be met, what inspection method is used, where data is recorded, the frequency of the quality check, and what the inspector must do if there is a problem (Art of Lean Inc., 2017).

5 Whys Technique

Productivity can be increased trough measures that prevent the occurrence of anomalous situations. Once an anomaly is detected, it is necessary to go deep into the root cause to solve it at once and avoid recurrence. With *Jidoka*, an equipment stops whenever an anomaly is detected. In this occasion, it is necessary to analyse carefully the reason the equipment stopped, acting swiftly in eradicating the anomaly and avoiding its occurrence again.

A powerful tool that aims at finding the root cause of a problem is the 5 whys technique. It consists at asking 5 times why a problem occurred. Figure 2.3 shows an example of a 5 whys technique.

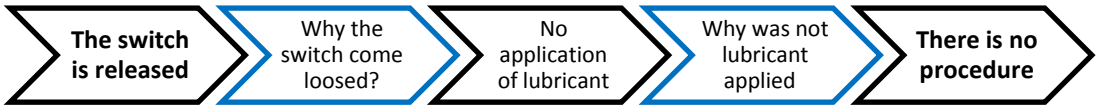

Figure 2.3- Example of 5 whys technique

Therefore, questioning the answers with successive whys, the root cause of a problem can be found, corrected and procedures can be standardized. Workers must be conditioned to question every situation. Not only the occurrences of anomalies, but also the situations in which successes are obtained, questioning “why did it work?”.

Total Preventive Maintenance

Another practice is the Total Preventive Maintenance (TPM), which consists in a highly organised program of periodic machine maintenance and pre-emptive replacement of components such as bearings to minimise the frequency and duration of machine break-downs. Routine minor maintenance during work hours is done by workers. This practice avoids major maintenance problems with associated production losses and costs.

Kaizen

Taiichi Ohno, the founder of TPS, once said "If a problem is left unsolved and the supervisor in uninformed, neither *kaizen* nor cost reduction can be applied. When there is trouble, stopping the machine means also identifying the problem. Once the problem is clear, *kaizen* becomes possible" (Ohno, 1988).

Kaizen is a concept that focuses on continuous improvement of all levels of company and involves all. Everyone is encouraged to come up with small improvement suggestions on a regular basis. This is not a once a month or once a year activity. It is continuous (Liker, 2004). Japanese managers have generally decided that at least 50 % of their time should be spent at activities which are related to improving and developing" (Imai, 1986). In a visit at the Toyota assembly plant in the Unites States of America, it was found that the employees handed over 80 thousand improvement proposals within one year. Total of 99 percent of them were implemented in the plant (Liker, 2004). It is necessary to recognize the need for improvement to improve. Problem recognition is necessary. If no problem is recognized, there is no recognition of the need for improvement. "Complacency is the arch-enemy of *Kaizen*. Therefore, *Kaizen* emphasizes problem awareness and provides clues for identifying problems" (Imai, 1986).

Quality Control Circles

Quality Control Circles (QCC) (Boaden, 1997), consists in small groups of workers that discuss quality control issues or improvement methods for production. The circle is seen as a continuous way to improve the quality of work. The objectives of Quality Control Circles are multifaced, acting in change in attitude, self-development, development of team spirit and improvement in organizational culture (Welekar, 2013). Once a QCC is formed, it must pass through the following distinct phases of development: Problem to be identified, analysed and solved; Solutions to be implemented in due time; Monitoring to be carried out; Higher management to encourage QCs to innovate Problem solving methods. The most commonly techniques used to analyse and solve work related problems are brain

storming, pareto diagrams, Ishikawa diagram, cause & effect analysis, data collection and data analysis (Welekar, 2013).

5S

Another powerful tool is 5S, a five-step housekeeping discipline that includes methods for creating and maintaining an organized, clean, high performance workplace (Art of Lean Inc., 2017). The philosophy of the 5S has its roots in Japan. The name 5S is the acronym of five Japanese words of the following meanings: *Seiri* (Sort); *Seiton* (Set in order); *Seiso* (Shine), *Seiketsu* (Standardize), *Shitsuke* (Sustain). The benefits of a good workplace include the prevention of defects, prevention of accidents and the elimination of time wasted for searching tools, documentation and other ingredients of manufacture (Wazed & Ahmed 2009). Its result is the effective organization of the workplace, elimination of losses connected with failures and breakdowns in machines, improvement of the quality and safety of work.

2.1.3 Respect for People

Lean is not just tools, it is also respect for people. Lean community leaders have recently made two huge changes in how they present Lean. The first change is Lean as a management system rather than "Lean manufacturing". Second, they are finally taking note of the long-established "Respect for People" principle (Emiliani, 2008). Toyota's top-level representation of the "Respect for People" principle consists of two parts: "Respect" and "Teamwork", and is as follows (Liker, 2004):

"**Respect**: We respect others, make every effort to understand each other, take responsibility and do our best to build mutual trust.

Teamwork: We stimulate personal and professional growth, share the opportunities of development and maximize individual and team performance."

The "Respect for People" principle encompasses all key stakeholders: employees, suppliers, customers, investors and communities (Liker, 2004). This principle is a multilateral expression of the need for balanced, mutually respectful relationships, cooperation and co-prosperity with all these stakeholders. This is why this principle is anything but trivial to understand (Emiliani, 2008).

At Toyota, the heart of the system is the employees as individuals and as members of their work teams. Toyota is convinced that the company goals can be reached in the best way through participation of all employees. A major part of the production system is the underlying concept of respect for all employee.

Participation can be exercised primarily in areas where the employee or the work team has sufficient knowledge, or in other words, is competent. TPS identifies four areas where team members can participate in achieving company goals (Art of Lean Inc, 2017):

- Setting and maintaining work standards (standards);
- solving daily performance problems (problem solving);
- participating in the continuous improvement process (improvement);
- organizing teamwork efficiently (teamwork).

Continuous improvement recognizes the creativity and problem-solving ability of all participants. Leadership must make every attempt to utilize the knowledge, experience and creativity of all employees. This shows respect for the individuals' dignity and worth. Creating an environment of mutual respect, trust, and cooperation is critical for making improvements and maintaining morale.

In the Toyota culture, it is impossible to achieve quality, cost and productivity improvements without consideration for safety and morale. Issues that affect individuals are critically important and must be addressed continuously.

Improving workplace safety is an ongoing topic for continuous improvement. Statistics show a high incidence of accidents occur when an individual is doing something out of the ordinary, the area is unorganized, or when tasks are difficult to perform. Reducing workplace hazards shows respect for people. Every effort should be made to make the workplace as safe as possible. Safety should never be sacrificed in the name of productivity. For this reason, Toyota places a lot of emphasis on standardized work and 5S housekeeping. If proper standards are in place, and adhered to, then the probability for a safe work environment is greatly enhanced (Art of Lean Inc, 2017).

Respect for workers can be conceptualized as the glue that holds the other lean tools and practices together and according to De Treville (2006), the objectives of respect for employees are to reduce alienation through expressing respect, recognition and appreciation and making the job more interesting, thereby reducing variability, as well as to make maximum use of worker knowledge, thereby increasing resource utilization and reducing the need to hold buffer inventories.

Respect for workers begins, at least ideally, with a competitive wage and giving workers, the training and equipment required to allow them to perform well (Womack et al., 1990). Practice of grouping workers into teams according to their production line or cell encourages respect for workers (Florida & Kenney, 1993). Some authors referred that "a team shall be understood as a group of people that has between 8 and 15 members, is responsible for producing a well-defined output within a recognizable

territory, where members rotate from job to job with some regularity, under a flexible allocation of tasks" (Mueller, 1994). Normally, this teams work in a U-shaped cell layout with all machines necessary to produce a product or a family of products (Hyer, 2001). U-shaped layout is preferred because it contributes to less monotony in terms of work (Miltenburg, 2001; Zhenyuan, 2011). Working on this cell arrangement, the team members can adopt different and flexible work patterns or cell operating modes. According to Cialdini and Goldstein, work teams has been observed in lean to be a source of both support and stress. Support, in that team members help each other, and stress, in that team norms can induce (Cialdini & Goldstein, 2004).

Respect for workers can be demonstrated by simple practices such as empathizing the relationship between the worker and the company (Adler et al., 1997), communication between management and workers (Monden, 1983), and even gestures such as giving workers business cards (Adler et al., 1997).

3 Musculoskeletal disorders, stress and psychosocial health effects description

In this chapter, the aimed studied effects of Lean on workers are described. Musculoskeletal disorders are described in chapter 3.1, stress is described in chapter 3.2 and psychosocial effects including job satisfaction, commitment and motivation, are described in chapter 3.3.

3.1 Musculoskeletal disorders

Work-related musculoskeletal disorders (MSDs) cover a broad range of health problems associated with repetitive and strenuous work. These health problems range from discomfort, minor aches and pains, to more serious medical conditions which can lead to permanent disability. Every year millions of European workers are affected by MSDs. The most well-known MSDs are low back pain and work-related upper limb disorders. The first is mainly associated with manual handling while the main risk factors for the latter are associated with task repetition and awkward work postures. Nowadays lower limb work-related MSDs are also been recognized as disorders that may be associated with occupational activity (Nunes, 2017). The term work-related MSDs refers to health problems affecting the muscles, tendons, ligaments, cartilage, the vascular system, nerves or other soft tissues and joints of the musculoskeletal system. They are caused or aggravated primarily by work itself and they can affect the upper limb extremities, the neck and shoulders, the lower back area, and the lower limbs (Nunes, 2017).

Although automation systems have been introduced and reduction of intensive work has been achieved with the help of ergonomic interventions in the last decades, there is an increasing trend towards more musculoskeletal disorders (Koukoulaki, 2014). According to data from the Sixth European Working Conditions Survey, conducted in 35 countries, about 75-80 million workers, almost half of European workers, suffer from work-related MSDs. 44.7% of the workers reported backache and 44.4% muscular pains in shoulders, neck and/or upper/lower limbs (Nunes, 2017).

Other factors contributing to the relevance of the subject are the economic consequences resulting from the work-related MSDs's high prevalence and the suffering they cause, often leading to permanent, partial or total disability of the worker. The economic consequences are twofold: for employers, MSDs reduce company efficiency due to loss of productivity; and they increase societal costs, namely worker compensation, medical and administrative costs. In some EU Member States 40% of the costs of workers' compensation are caused by MSDs, reaching up to 1.6% of the gross domestic product of the

country itself. In general, the cost to the EU each year in lost productivity and sickness absences is estimated at 2% of the gross domestic product (Nunes, 2017).

Findings suggest that the impact on the prevalence of MSDs is not related to the industry sector but to the actual content of the job. When controlling for the actual content of the job, no significant differences emerge among industries (Nunes, 2017).

The strong correlation between the incidence of MSDs and working conditions is well known, particularly considering the physical risk factors associated with jobs (e.g., awkward postures, high repetition, force exertion, static work, cold or vibration. Work intensification, stress and other psychosocial factors also seem to be factors that increasingly contribute to the onset of those disorders (Nunes, 2017).

The causes of work-related MSDs are multifactorial and there are numerous work-related risk factors for the various types of MSDs. Several risk factors including physical and mechanical factors, organisational and psychosocial factors, and individual and personal factors may contribute to the genesis of MSDs (Nunes, 2017).

Work-related MSDs refer to injuries developed over time that are caused by a combination of risk factors that act simultaneously on a joint or body region, in a synergistic effect. Until now the biological pathogenesis associated with the development of the majority of the work-related MSDs is unknown. Several models have been proposed to explain the biological mechanisms. Usually three sets of factors are considered (Nunes, 2017):

- Physical factors (e.g., sustained or awkward postures, repetition of the same movements, forceful exertions, hand-arm vibration, all-body vibration, mechanical compression, and cold);
- Psychosocial factors (e.g., work pace, autonomy, monotony, work/rest cycle, task demands, social support from colleagues and management and job uncertainty);
- Individual factors (e.g., age, gender, professional activities, sport activities, domestic activities, recreational activities, alcohol/tobacco consumption and, previous work-related MSDs).

3.2 Stress

Many people are motivated by the challenges encountered within their work environment. However, when pressure due to work demands, and other so-called ‘stressors’, becomes excessive and prolonged in relation to the perceived ability to cope this can lead to the experience of stress. The concept of stress is often confused with challenge; sometimes leading people to refer to ‘good’ and ‘bad’ stress. However, these concepts are not the same. Experiencing challenges in our work can energise us psychologically and physically, and encourage us to learn new skills. Feeling challenged by one’s work is an important

ingredient in developing and sustaining a psychologically healthy work environment. However, excessive and prolonged pressure and demands that exceed the worker's perceived resources, capabilities and skills to cope should not be understood as a 'healthy pressure' or 'good stress', but rather as the defining components of work-related stress (Hassard & Cox, 2017).

Poole & Warner (1998) describes the prevailing view: "It (stress) is widely viewed today as the physiological and psychological reaction which occurs when individuals meet a threat or challenge and the individuals' perception, whether consciously or subconsciously, is that it is beyond their immediate capacity". Repeated exposure to this condition can result in strains that cause physical reactions (such as insomnia), emotional reactions (such as depression), and mental reactions (such as forgetfulness).

Contemporary theories of stress have been used to inform the definition of work-related stress. There is a growing consensus around the definition of stress as a negative psychological state with cognitive and emotional components, and its effect on the health of both the individual and the organisation. That is, stress is defined by a dynamic interaction between the individual and their environment, and is often inferred by the existence of a problematic person-environment fit and the emotional reactions which underpin those interactions. Central to this approach is the role that environmental factors, particularly the role of psychosocial and organisational factors, play in work stress (Hassard & Cox, 2017). Examples of psychosocial risks are low job control, job demands, time pressure, social relations with superiors and colleagues and job insecurity, which are all related to work-related stress, violence and bullying (Leka et al., 2003).

The 4th European Working Condition Survey found that 22% of workers from 25 Member States and two Acceding Countries of the EU reported experiencing stress in the workplace. The reported prevalence of stress is markedly different between the new Member states and the old EU-15. Results from the 4th European Working Conditions Survey showed that 20% of workers from the EU-15 and 30% of the 10 new Member states believed their health was at risk due to stress at work (Hassard & Cox, 2017).

The European Commission reported in 2002 that the cost of work-related stress in the EU15 was approximately €20, 000 million annually. Studies estimate that 50-60% of all lost working days have some links with work-related stress. At a national level, stress has been found to have significant and real costs to employers and to society-at-large. In Germany, the cost of psychological disorders was estimated to be €3,000 million in 2001. In the Netherlands in 1998, mental disorders were the main cause of incapacity (32%) and the cost of psychological illness was estimated to be €2.26 million a year (Hassard & Cox, 2017).

In the UK, an estimated 70 million working days are lost annually through poor mental health and 10 million of these are the result of anxiety, depression and stress. In 2005/06 stress, depression and anxiety was estimated to cost Great Britain in excess of £530 million. Undoubtedly, the causes and effects of work stress reflect the changing nature and demands of work and the work environment (Hassard & Cox, 2017).

However, researchers have reported the effects of buffers in high demand environments. Dalgard et al. (2009) tested the Karasek's (1979) demand-control model of occupational stress and reported a strong 'buffering effect' for the interaction between demands and control. There was almost no increase in psychological distress when high job demands were combined with high control. Figure 3.2 illustrates Karasek's job demands-control model.

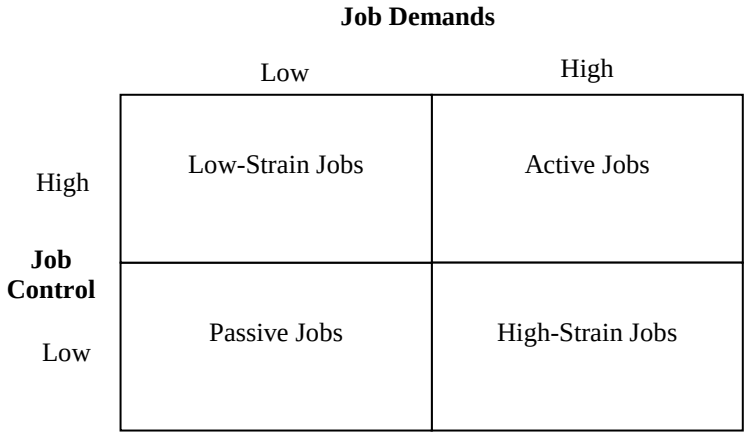

Figure 3.2-Job demands-control model (Karasek, 1979)

3.3 Psychosocial health

Job Satisfaction is related to task characteristics like monotony, type of work, control over job, and work methods. Repetitive tasks and monotony of work may be a cause of dissatisfaction for workers. Workers who don't have the necessary skills to effectively perform certain tasks can also cause job dissatisfaction (Kauppinen et al. 1983).

Commitment is the attitude of the worker towards an organization which predicts the degree of involvement of the worker in their organization (Harrison et.al, 1998). Commitment also includes considerable effort of the workers on behalf of an organization, belief in organizational goals and values, and desire to maintain membership in the organization (Chen et.al, 2004). A committed worker plays a significant role in the success of an organization. Commitment is found to have positive biases with motivation, job performance and job satisfaction. Workers that are committed to the organization tend to perform at higher levels and are less likely to leave their jobs (Gamble et.al, 2008).

Motivation can be defined as "predisposition to behave in a purposeful manner to achieve specific, unmet needs and the will to achieve, and the inner force that drives individuals to accomplish personal organizational goals" (Williams, 2012). The more motivated an employee is, the more likely they are to have organizational commitment and identify themselves with the organization. This will meet some of the unmet needs, and connect them with the organization. If willing, the manager can give the employee incentives to meet their own goals and the goals set by the organization (Burton, 2012).

Richard Ryan and Edward Deci, from the University of Rochester, agree that motivated means that the person is moved to do a particular act. The authors describe motivation as, the "orientation of motivation concerns the underlying attitudes and goals that give rise to action" (Ryan & Deci, 2000).

4 Study methodology

In this study, a systematic literature review was done with the purpose of identifying the effects, positive or negative, of lean practices on people at work. It was looked for effects on MSD and ergonomic risk factors, stress and MSC. To do so, over 50 papers and dissertations published between 1991 and 2016 were reviewed, which was helpful to study the changes in the focus of investigations over this period. There are a few literature reviews aiming this subject (Koukoulaki, 2014; Brännmark & Håkansson, 2012; Arezes et al., 2014) with a wide variety of conclusions, but since Lean is a very broad term, there are no simple relations between its implementation and consequences in work environment. This study tries to go beyond the studies already done by including several control variables aiming to better understand which ones have more impact on workers' effects.

4.1 Research design

The research was made using the databases Business Source Premier and Web of Knowledge. In the research, there were two group terms (dependent variable and independents variables). The first one to identify Lean (here we use only two search items: Lean and JIT) and the second to identify the independent variables associated with well-being (stress, job satisfaction, psychosocial, health, disease, well-being or wellbeing, working conditions, injuries).

The inclusion criteria for the search were:

- Papers published in English from 1992-2017 (June);
- Studies published in peer-reviewed scientific journals;
- Studies carried out in manufacturing sectors and services.

The exclusion criteria were:

- Papers investigating only lean implementation and company productivity or similar performance effects were excluded.

Approximately 250 papers were identified in the initial search. At the first level, the papers were screened by their title and abstract and 194 were excluded. At the second level 56 papers were screened by reading full text. Some of the 56 papers referred another 7 papers which allowed collecting information from a total of 63 papers, final sample.

Lean practices and tools were identified and subcategorized according to the 3 pillars of TPS House, which are JIT, *Jidoka*, and Respect for people.

Nowadays Lean is a practice worldwide, so the countries and cultures where it is applied may affect work environment. The origin of Lean Production in the automotive sector and its application over the years in other sectors like industrial manufacture and services is a factor that may also be critic to work environment, since Lean's development in automotive sector may not be adequate to other sectors. 91% of the papers analysed referred the country where Lean was applied and 77% referred the sector which the studied company belonged.

Company age and dimension were also chosen factors to analyse, unfortunately only 19% of the papers analysed contained this information in relation to company age and 25% in relation to company dimension, therefore excluding this factors from the study, despite the believe that these factors have a crucial impact in workers well-being.

The journal publication type was also a study factor because authors believe that, for example an ergonomics journal will focus on the negative effects of Lean, while an industrial, economics or technological journal will focus in the positive effects of Lean. Therefore, the analysed papers were grouped in Organizational Health journal's type, including Ergonomics, Psychology, Human Factors and Labour Relations and in Industrial journal's type, including Economy, Industrial, Production, Operations, Science and Technology. Only 73% of the papers analysed belonged to the 2 groups of journals previously described.

Table 4.1 shows the percentage of 63 papers that refers the analysed factors in the study.

Table 4.1- Percentage of papers refering the analyzed factors

Factors analysed	% collected
Lean Practice/tool	100%
Country	91%
Sector	77%
journal type	73%
Company age	19%
Company dimension	25%

Due to the low percentage of information collected in the last two factors on the table, company age and dimension, these were not used in the study.

Figure 4.1 shows the systematic literature review flowchart including some of the most important factors analysed.

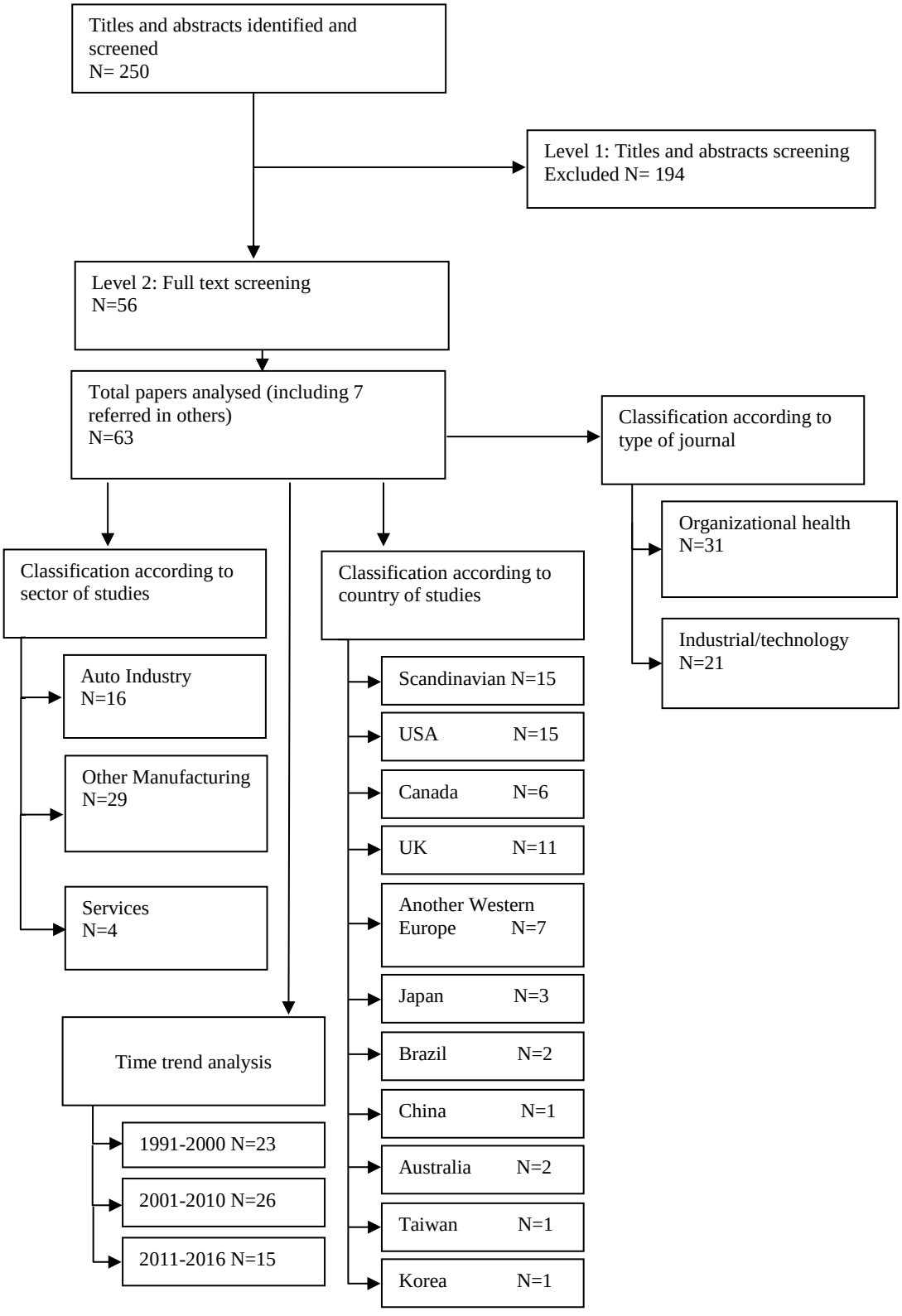

Figure 4.1-Literature review flowchart

5 Effects of lean production on workers and hypotheses presentation

In this chapter, the formulation of the study hypotheses is achieved through empirical and theoretical data found in the literature. Seven hypotheses are proposed, based on the different factors of Lean which affect the workers, and posteriorly evaluated with study results in chapter 7.

Lean pillar's practices hypotheses

The principles of lean production are controversial from the point of view of human well-being (Antoni, 1996; Dankbaar, 1997; Delbridge, Lowe & Oliver, 2000; Jackson & Mullarkey, 2000; Kochan & Lansbury, 1997; Wall, 1996).

JIT pillar characteristics like Just-In-Time production, takt time and U-shaped production line have a common objective of maximising efficiency within the cycle time, causing work intensification and increased demands. JIT practices operates with balanced, synchronised material flow which aid in achieving this flow with minimum use of 'wasteful' contingencies of material, people and machinery. This improves performance but increases the intensity of work – the proportion of work time actually spent performing production tasks. Increased intensity increases job demands and the potential for job stress (Conti et al, 2006).

The Karasek model, presented in chapter 3.1, predicts that practices with high levels of physical and psychological job demands will be associated with high job stress levels. Practices that reduce these demands will accordingly be associated with lower stress levels.

The 'Bristol Stress and Health at Work' studies showed strong associations between perceived stress and several working conditions, including "having to work fast" (Smith, 2001). The stress of 'working fast' is understandable. The energy to perform a task is proportional to the work rate, determined by the required work pace and intensity (Conti & Gill, 1998). Physical job demands are greater at higher energy levels.

Researchers have raised the question of whether JIT practices are deterministically stressful and that the benefits gained are at the expense of workers (Bruno & Jordan, 2002; Brenner et al., 2004; Lewchuk et al., 2001). This leads to hypothesis one as follows:

H1: Application of JIT practices alone increase stress on workers.

Job Satisfaction is related to task characteristics like monotony, type of work, control over job, and work methods as referred in chapter 3.2. *Jidoka* pillar practices like TQM, *poka-yoke* and standardization expose workers to several psychological risk factors such as low job control and effort-reward imbalance. Dierickx (2016), referred that when these practices were applied, there was a decrease in workers motivation.

Lindskog (2016) conducted a longitudinal quantitative study involving employees and managers in the healthcare service in Sweden and reported that standardized work was not considered sustainable due to the lack of job resources which ultimately reduced job satisfaction. This leads to hypothesis two as follows:

H2: *Jidoka* practices are negatively related to MSC effects on workers.

Respect for people pillar practices such as work teams, job support and multi-skilling. can act as buffers to the psychological effects like stress, motivation and satisfaction. Job rotation and multi-tasking act as a buffer in MSDs because it allows workers to perform different tasks which reduces repetitive work and static postures. The concept of Lean Teams implemented in many lean environments improves the working conditions for operators and stimulates satisfaction in the work (Koukoulaki, 2014). This leads to hypotheses three as follows:

H3: Respect for people practices are positively related to MSD decrease, stress reduction and MSC increase.

Company sector hypotheses

Nowadays there are several studies related to the effects of lean production in different industry sectors. Lean production was firstly implemented in the automotive sector, however due to its production increase capability it started to spread to other sectors such as other manufacturing than automotive and services sector. Some authors (Koukoulaki, 2014), did a research in this field with a total of 36 studies reviewing the adverse health effects of lean production systems and found that in the automotive industry 90% of the studies report negative outcome whereas in manufacturing mixed effects outnumber the negative ones. Koukoulaki also reported that in services there is a relatively equal distribution of all types of outcomes. This leads to hypothesis four as follows:

H4: **Services sector shows better effects to MSD, stress and MSC than manufacturing sector.**

Country's culture hypotheses

Lean Production was introduced in many countries in the beginning of the 1990's. In Sweden, Lean production started to become unfashionable towards the last years of the 1990's decade. Companies in Sweden tried to copy the Japanese concepts, which created difficulties due to cultural differences (Seppälä & Klemola, 2004).

Some authors referred that, a common view is that Western workers will never really embrace manufacturing practices such as those involved in Lean since the Japanese work culture of commitment to the company, hard work, and group solidary are major determinants of the success of Lean in Japan. Others, refer that Japanese workers show greater commitment to their organization than workers in the West by, for example, acceptance of authority and company goals, low labour turnover, long working hours, short leave periods and high work discipline (Ouchi, 1981; Yoshida, 1989, Franke et al., 1991). This leads to hypothesis five as follows:

H5: The greater the well-being concern of the country, the greater the perception of negative effects of lean practices on workers.

Type of journal hypotheses

Nowadays, only few empirical studies of Lean Production or TPS effects on workers can be found in the scientific literature. In most cases, these point to positive effects following the introduction of Lean Production, and they have been published in engineering, logistics or economic journals. Only single empirical studies have been published from ergonomics or human science journals (Li, 2007).

Researchers sympathetic to the International Motor Vehicle Program (IMVP) are strategically placed to study management and its concerns with the impact of organisational change on productivity and competitiveness, have for the most part, ignored the impact on employees (Lewchuk et al., 2001).

Engineering and economics journals are interested in addressing the benefits that lean production brings to companies in terms of productivity and profit, ignoring the human side and the effects that this type of production may have on workers, while the ergonomics and psychology type of journals have an interest in addressing the lean effect on workers. Do industrial and economics type of journals attempt to "praise" the effect of lean on workers to defend their real interest like productivity and profit? Is there

a relationship between engineering type journals and lean positive effects on workers whereas ergonomics and psychology type of journals have a negative relation? This study is of great importance since there is none in the existing literature. This leads to hypothesis six as follows:

H6: There are positive biases related to lean practices effects on workers in industrial journals in comparison with organizational health journals.

Time trend hypotheses

Nowadays literature presents extensive studies regarding the different effects of lean production in workers focusing the MSD effects, stress and MSC. But this concerning about the different effects of lean production on workers as being evolving trough time. (Koukoulaki, 2014) studied a trend in lean production and its effects on workers trough time in his study. His analysis identifies three-time periods. The first period is after the implementation wave of lean production in automotive sector in the USA and Canada (1991-1997) in which the focus of this studies was in physical and psychological health effects like MSDs and stress. Most of the studies show negative effects. The second period (1998-2000) presents studies investigating other manufacturing sectors than the automotive mostly in Europe. The research focus started to change from MSD to psychological factors and stress. Studies' findings show mixed effects with both positive and negative effects of different lean practices. In the last period from 2000 to present the studies were done in various sectors including the service sector that also started gradually implementing lean practices. Results show controversial both negative and mixes effects. This leads to hypothesis seven as follows:

H7: The concern of the lean effect on workers in relation to MSD, stress and MSC has been increasing over time.

6 Interaction models between lean practices and effects on workers

This chapter presents and describes interaction models created by different authors in their studies between lean practices and the effects on workers. The models show similarities and differences. Each one of them focus on different aspects of Lean.

6.1 Jackson & Martin Model

Jackson & Martin (1996), in their study about just-in-time introduction in a batch processing environment, addressed two aims: to assess the impact of JIT on operator job content and to relate the introduction of JIT to changes in psychological outcomes. The design is strong in two respects: first, measurements were taken on two periods, before and after work design changes; and second, operators on an adjacent line not involved in the introduction of JIT were used as a comparison group.

A conceptual framework was developed based on early studies on the relationship between job characteristics and affective and behavioural outcomes. Also, technological and structural characteristics that influence choices about how jobs are design were studied as well and incorporated in the framework. Figure 6.1 shows the conceptual framework developed by Jackson & Martin (1996), for links between JIT characteristics, job content and psychological outcomes.

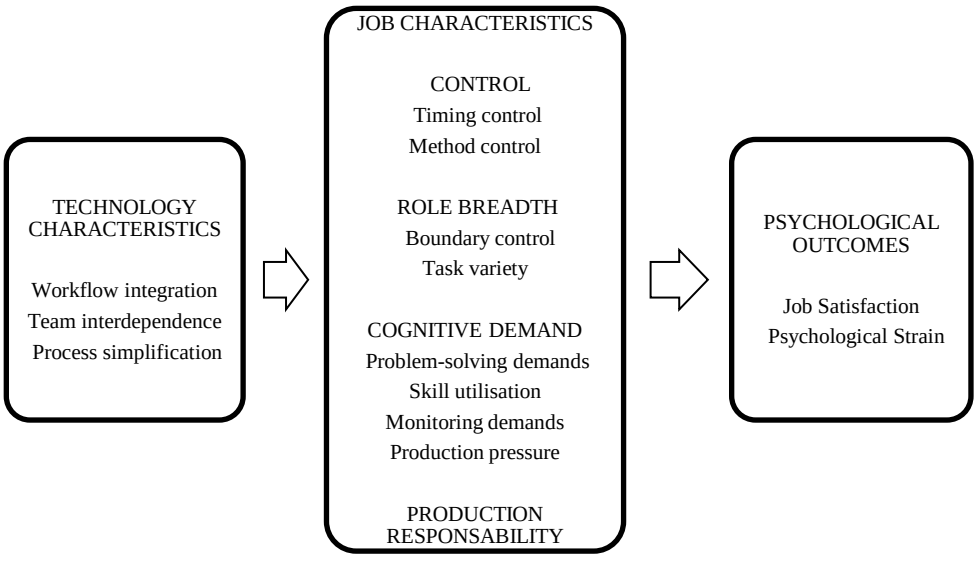

Figure 6.1-Jackson & Martin model (1996)

Each of the key components of the framework are now described:

JIT characteristics: There are three characteristics that define the nature of JIT systems: increased workflow integration, pooled interdependency, and process simplification which are described in chapter 2.1.1.

Job characteristics: The second element of the theoretical framework defines four dimensions of operator jobs that may be affected by JIT.

Operator control: The increased workflow integration associated with the removal of buffers between successive stages would be expected to redue the scope for operators to influence the timing of their work tasks. Measures of two aspects of control are utilized: control over work timing and control over work methods.

Role breadth: Role breadth encompasses two elements: the variety of tasks performed in a job, and boundary activities that support the primary operating tasks. The introduction of JIT, with its greatly enhcanced team interdependence, would be expected to lead to increases in both boundary control and task variety.

Cognitive demands: The second category of variable that is considered is that of cognitive demand in the light of suggestions that integrated manufacturing emphasizes mental rather than physical activiy. In examinng the impact of JIT on this aspect of job characteristics, two elements are considered: problem-solving demand and monitoring demand.

Job characteristics and psychological outcomes: Introduction of JIT leads to a reduction in timing control and increases production pressure, and also reduces job satisfaction. In relation to job content, the study concluded that the introduction of JIT did not changed workers' job content in fundamental ways. Jackson & Martin (1996), study suggests that there are psyhological costs resulting from JIT that need to be taken into account in making design decisions, specially where there is no associated change in role breadth or problem-solving demands that may enlarge and enrich workers' jobs.

6.2 Parker Model

Parker (2003), in his study, proposed a model, shown in Figure 6.2, about the effects of lean production of work characteristics in employee outcomes. He proposed that work characteristics mediate the link between lean production practices and employee outcomes. In other words, the effects of lean production on outcomes depends, at least in part, on its effects on employees' work characteristics. He also, hypothesised a relationship between cultural and organizational contingencies and work characteristics, but did not tested it in his study.

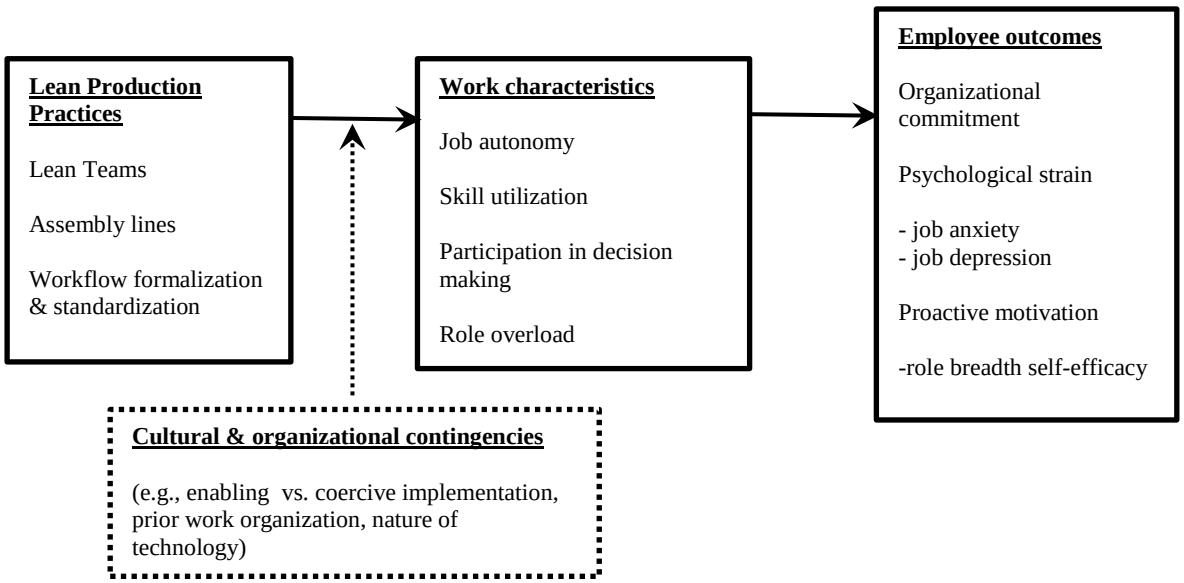

Figure 6.2-Parker model (2003)

To test the other relationships in the model, Parker investigated in a three-year study period a UK-based company that manufactures and assembles large vehicles. This company had introduced new initiatives to improve product quality like continuous improvement groups, and increased training. Due to the increasing demand for company products, production increased and three lean production practices were introduced: lean teams, assembly lines and workflow formalization and standardization.

The results of the study suggested negative effects on employee outcomes after the implementation of three lean production practices: lean teams, assembly lines and work standardization. Employees in all lean production groups were negatively affected, but those in assembly lines feared the worst, with reduced organizational commitment and role breadth self-efficacy and increased depression. Mediational analyses showed that the negative effects of lean production were at least partly attributable to declines in work characteristics like job autonomy, skill utilization and participation in decision making.

6.3 Womack Model

Womack et al. (2009), focused his study in Lean effects on physical health. His study aimed to further examine the relationship between job design and MSD risk by investigating differences in job characteristics that lend themselves to productivity and ergonomic risk differences at an exemplar lean manufacturing plant. This study was done in two companies comparing a lean manufacturing plant and a traditional manufacturing plant. In the study, authors presented a conceptual framework showed. in Figure 6.3 which shows the hypothesized links between lean manufacturing, work characteristics, injuries, and plant performance metrics.

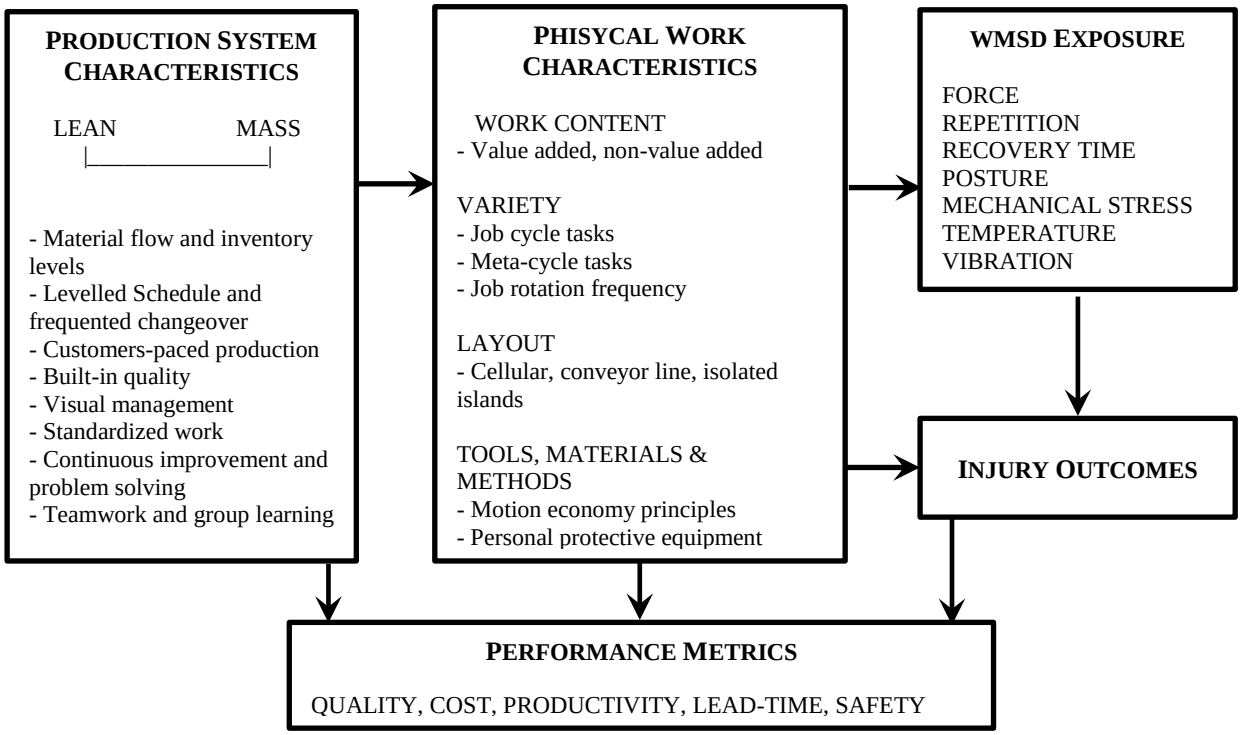

Figure 6.3- Womack model (2009)

The exogenous "production system characteristics" construct depicts the "journey" toward becoming leaner by simplifying material flow, reducing inventory, levelling the production schedule, increasing the frequency of changeovers and producing based on customers demand (Liker, 1997). These practices have effects on how work is performed, which consequently affects MSD risk factors and injuries.

Results showed greater productivity in the lean plant, with less waiting and walking, and greater repetition exposure. Repetition was higer in the lean plant comparing to the tradicional plant. However, the lean plant had significantly lower peak hand force ratings. The findings suggested that lean manufacturing does not necessarily increase workers' risk for MSD injuries.

7 Bibliographic analysis results and discussion

In this chapter, the data was analysed based on the information collected in the papers described in chapter 4. The table presented in appendix B, presents a short example from the entire table that contains the papers reviewed as well as all the relevant information for the study, like the lean practices and their outcomes in MSD, stress and MSC, the country and sector where Lean was applied, the type of journal where the studies were published and the correspondent publication year.

A survey was done over the papers referring positive "+", negative "- ", neutral "0" and mixed "+/- "effects in workers, in the literature review, as shown in Figure 7.1.

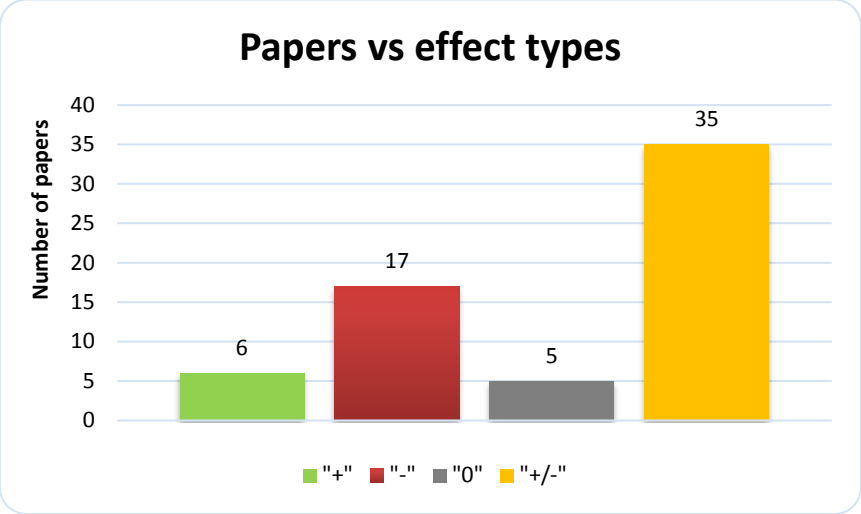

Figure 7.1-Number of papers according to effects' type in literature review

Looking at Figure 7.1, it is clearly visible that the number of papers referring the negative effects of lean in workers are predominant in relation to positive. On the other hand, there are also 5 papers referring neutral effects of lean on workers and 35 papers referring both positive and negative effects of lean in workers. As expected, there are a big number of mixed effects. To better understand this numbers, it was required to compare the study's factors since this analysis is short limited in a way that the MSD, stress and MSC where not studied separated.

To understand the relations between these factors, in this study was established some comparison criteria based on various two-dimensional analysis which it is believed to have a stronger correlation. These comparisons are:

- Lean practices Vs MSD/Stress/MSC;

- Sector Vs MSD/Stress/MSC;
- Journal type Vs MSD/Stress/MSC;
- MSD/Stress/MSC Vs Time trend;

7.1 Lean practices Vs MSD/Stress/MSC

Lean practices based on JIT, *Jidoka* and Respect for People were analysed, separately and combined with the effects on workers. In the literature relating specifically to JIT, evidences for effects of JIT on psychological and MSD outcomes is fragmented and contradictory.

Some authors referred that JIT's increasing work intensity are positively related to stress and MSDs increase. Other authors referred that *Jidoka* practices based in "zero defects" philosophy kills motivation and create a great tension within an organization and among employees. Also, some authors referred that Respect for people practices like work teams, training and empowerment and multi skilling have more positive effects on workers and when combined with other practices like JIT and *Jidoka* can attenuate the negative effects of these.

7.1.1 *JIT* Vs MSD/Stress/MSC

Figure 7.2 shows the number of effect's references, 24 in total, found in 14 papers, where only JIT practices were implemented.

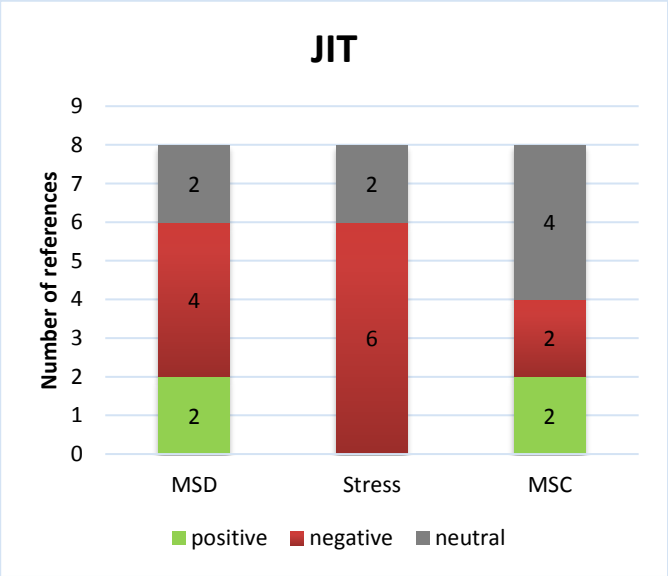

Figure 7.2-Effects' references accorging to JIT practices in literature review

As expected, most of negative effects of JIT practices were on stress, some authors (Babson,1993) pointed out that the possible outcome to this increase of stress was the perceived work demands increase. It should be mentioned that no author referred that stress has positive effects when JIT is applied alone. Some authors (Brown & O'Rourke, 2007), studied a shoe factory in China, referred that practices like JIT reduces inventories and cycle time prevents workers from managing their own work pace. Also, the worry of not reaching set goals, the unrealistic goal setting, too much work and unfair supervisors were critical factors to the increased stress.

This result suggests that hypothesis one can be accepted. The application of JIT practices alone increase stress on workers.

Regarding MSD, authors have different opinions since the results are very balanced between positive, negative and neutral. Some authors (Arezes et al., 2014) cited that the reduction of work cycle to small values, often less than 60 seconds, are linked with TPS and is considered one important risk factor for work-related injuries and may have a negative impact on worker's well-being.

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Other authors (Brännmark & Håkansson, 2012) also referred that when JIT is implemented, there is a tendency for risk of MSD, especially if the implementation is not accompanied by an ergonomic intervention program, focused on addressing issues such as reducing repetitiveness of work. Lewchuk & Robertson (1996), made a survey with 1670 questionnaires to workers in 16 suppliers to car manufacturing companies in Canada and study's results suggested that work life under Lean Production has not improved. Compared with workers in traditional plants, those at Lean companies reported their work load was heavier and faster. They reported workloads were increasing and becoming faster. They reported it was difficult to change things they did not like about their job and that it was becoming more difficult to get time off. While the survey results suggested that "working in traditional plants is far from paradise", they also suggest that working in Lean plants is worse.

On the other hand, Hunter (2002) referred that the proper adoption of cell manufacturing may result in positive health effects, including the reduction of chronic and traumatic work injuries. This author, for example, referred that one typical goal of the cell designer is to promote job enlargement, and not job simplification. Accordingly, job enlargement will result in better ergonomics, for example, by including additional time to do the additional work it will allow the human body to "heal micro injuries", which, according to the author, are related to chronic MSD. However, this research was based on a computer simulation and other engineering analysis tools, which does not reflect the true reality of a practical research.

Jackson & Mullarkey (2000), referred in their study comparing a normal production line with a cell manufacturing in a garment manufacturing company, that work-related effort unchanged when JIT practices were applied.

Regarding MSC there are also different opinions in the literature about this matter. (Hunter,2002; Scott et al., 1992) referred that JIT practices like cycle time and manufacturing cells increased qualification of the workforce, job enrichment and multi-skills which are all related to motivation increase for workers as their JIT involvement increases. Other authors (Jackson & Martin ,1996; Babson ,1993) have opposite opinions when they refer that JIT practices have negative impacts in MSC due to the increase of repetitive work and work control decrease.

7.1.2 *Jidoka* Vs MSD/Stress/MSC

The same analysis was done in Figure 7.3, where only *Jidoka* practices where implemented with a total of 12 effects' references, found in 4 papers.

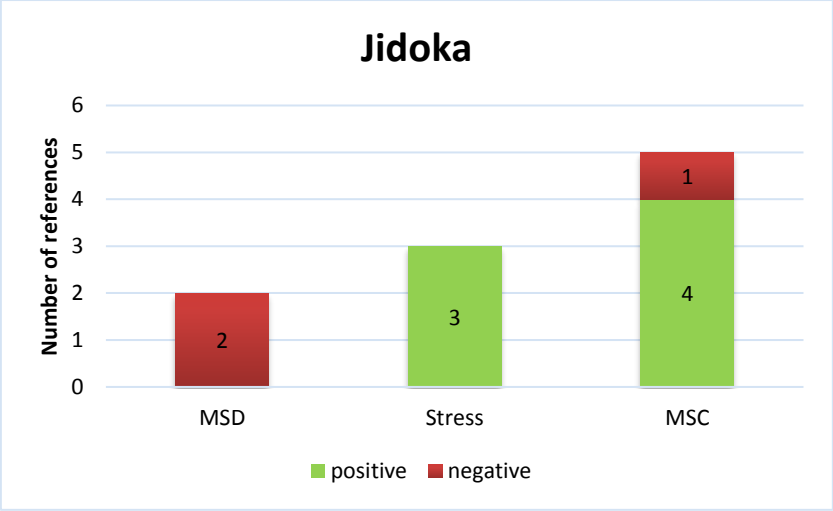

Figure 7.3-Effects' references accorging to *Jidoka* practices in literature review

Despite this analysis contains 12 references to effects found in literature, these references were only found in 4 papers. Dierickx (2016), did a multi-case study, comprising five Japanese and five Belgian companies and referred that there was not much attention to workers well-being when applying work standardization.

Contrary to what expected regarding stress, the same author pointed that 5S reduced stress and increased mental health. Also, Benders et al., (2016), did a survey measuring job demands and job resources including 52 nurses in a hospital in Holland and reported that with the introduction of continuous

improvement techniques, burnout risk decreased slightly. Thiele et al., (2016), referred that in Denmark's Postal Service *kaizen* served as a mechanism that increased the level of awareness and capacity to manage psychosocial issues, which, in turn, predicted increased mental health.

Regarding MSC, Thiele et al., (2016) also predicted increased job satisfaction trough *Kaizen* boards. Dierickx (2016), also referred that when *Jidoka*'s practices like *poka-yoke*, checklists, root cause analysis and standard work were applied, there was an increase in commitment to improvement, skill development, intrinsic motivation and, also, contributed to multi-skilled and flexible employees. On the other hand, when only standardization of work was implemented there was a decrease in workers motivation.

7.1.3 JIT and *Jidoka* Vs MSD/Stress/MSC

About JIT and *Jidoka* combination, there was found a total of 15 effects' references in 6 papers. Figure 7.4 shows the analysis results.

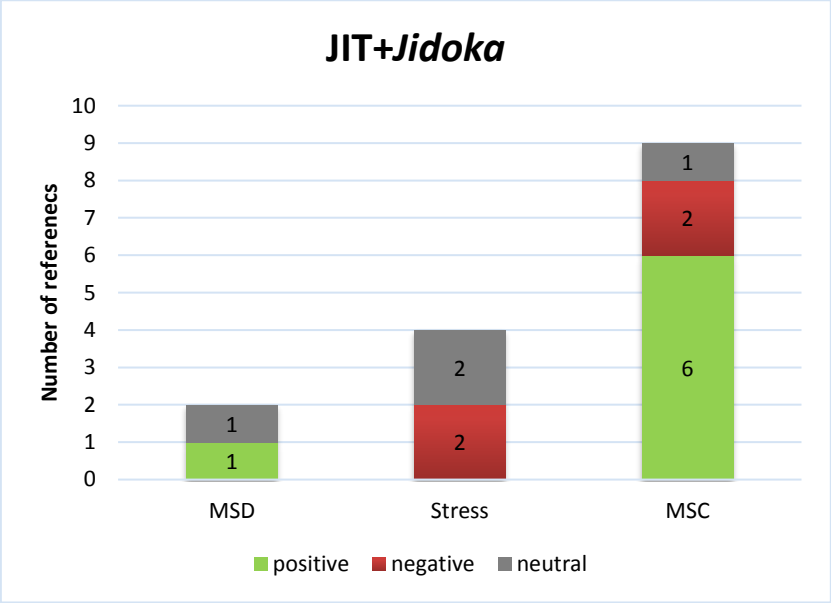

Figure 7.4-Effects' references accorging to JIT+ *Jidoka* practices in literature review

The main analysis in this diagram is that stress have no positive effects in literature when JIT and *Jidoka* practices are applied together, on the other hand, MSC results show most of positive effects. Schouteten & Benders (2004) surveyed 63 workers in a bike assembly company in Holland applying JIT practices and *Jidoka* practices such as standardization, TQM and *Kaizen* and the findings suggested that there were few problems with MSDs.

In relation to stress outcomes, Brenner et al., (2004) in is theoretical study focusing the relationship between cumulative trauma disorders and workplace transformation reported that JIT when combined with TQM and quality circles, there is a positive correlation between these practices and cumulative trauma disorders. Godard (2001) surveyed 508 Canadian workers and the results showed that JIT combined with TQM and re-engineering caused more stressful work.

Nielsen (1996) in his study, interviewed 150 persons from all levels of 6 manufacturing companies in Denmark and said that integration of sporadic implementation of JIT and quality control in the normal job design was perceived as creating better job satisfaction but physical workload unchanged. Dierickx (2016), pointed that when JIT and *Jidoka* practices are combined, there are skill development, most employees can manage multiple machines, commitment to improvement, skill development, intrinsic motivation, multi-skilled and flexible employees, all these positive factors to MSC. It is important to refer that 4 of the 6 positive effects in MSC are described by Dierickx in the previously referred paper. Klein (1991), referred that JIT and standardisation practices offer limited autonomy to workers and Godard (2001), said that JIT combined with TQM and re-engineering have negative effects in Job satisfaction and commitment.

Summing up the overall analysis of *Jidoka* practices applied alone and combined with JIT practices, results show most of positive effect's references in MSC, thereby denying hypotheses two which says "*Jidoka* practices are negatively related to MSC effects on workers".

7.1.4 JIT, *Jidoka* and RfP Vs MSD/Stress/MSC

Figure 7.5 shows the combination of all Lean practices including JIT, *Jidoka* and Respect for People effects with a total of 39 effects references found in 16 papers.

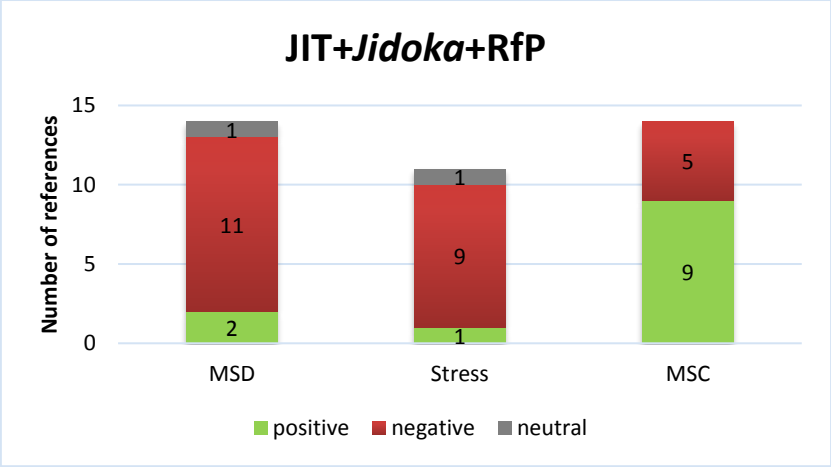

Figure 7.5-Effects' references accorging to JIT+*Jidoka*+RfP practices in literature review

This combination of all three pillar's practices appears to be the most common in literature as well as JIT implementation alone, as already analysed in Figure 7.2. Comparing both, MSD effects show no improvement even with respect for people practices. In the other hand, MSC has improved.

Sim et al. (2011), pointed the importance of nurturing, training and empowering which may have contributed to the successful implementation of lean manufacturing. Brännmark & Håkansson (2012), also pointed that employee involvement in problem solving increased job satisfaction. Other authors (Eklund & Berglund, 2007) pointed out the positive effects when applied *Kanban*, paced line production, 5S, continuous improvement and process orientation there was a lower workload, due to slower and more even work pace and an increase in job satisfaction, through employee involvement in continuous improvement and problem solving. Seppälä & Klemola (2004), in his study in manufacturing companies in Finland pointed out that teamwork increased job enlargement and job enrichment trough multi-skills requirements. Adler et al. (1997), did a longitudinal case study, investigating the ergonomic situation during launches of new car models in 1993 and 1995. He referred that there was a health and safety improvement as injuries after an ergonomic intervention program implementation.

Most important are the choices companies do in lean implementation. For example, a company could choose to apply one lean practice to its extreme, like removal of waste activities, having a direct effect on work intensification and at the same time minimising other practices that could act as buffers to stress, like group support in teams. This dangerous combination could only bring the negative effects of lean production.

Summing up, results show that application of JIT practices alone increase stress on workers, validating hypothesis one. *Jidoka* practices results show most of positive effects on MSC either if *Jidoka* is applied alone or combined with JIT practices. These results deny hypothesis two which says that *Jidoka* practices are negatively related to MSC effects on workers. Regarding the respect for people practices when combined with JIT and *Jidoka*, results show a slightly improvement in MSC, stress and MSD.

These results support hypotheses three which says that respect for people practices are positively related to MSD decrease, stress reduction and MSC increase.

7.2 Sector Vs MSD/Stress/MSC

In this analysis, the number of papers for each sector (automotive, other manufacturing, services) were very different from each other as table 6.1 shows. Most of papers analysed on this sub-chapter were on the manufacturing sector with a total of 29, almost the double than the automotive sector with a total of

16. Papers analysing the services sector were only 4, this may be justified because this sector only started to be studied more in recent years.

Table 7.1-Number of papers reviewed by sector

Sectors analysed	N articles
Automotive	16
Other manufacturing	29
Services	4

To make a valid analysis, since the number of papers reviewed by sector are very different from each other, the results are shown in percentage of number of references of effects by sector.

Figure 7.6 show the analysis results regarding the percentage of number of authors references to the all three effects combined (MSD, stress and MSC) effects of lean in the three different sectors.

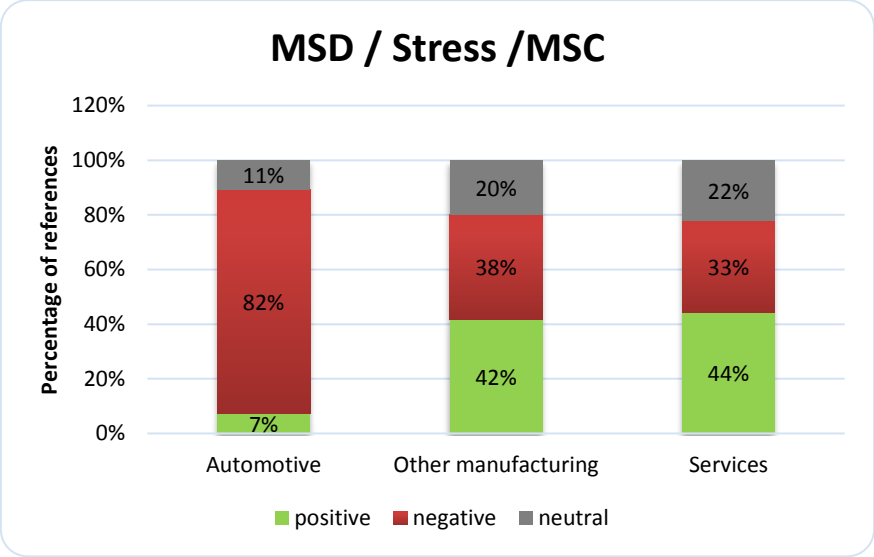

Figure 7.6-Overall effects' references on workers in literature review according to Sector

These results show what was predicted in hypotheses 4. Services sector shows better effects to workers well-being than manufacturing sector. Despite this agreement with hypotheses 4, results show that the difference between other manufacturing and services sector is not that great. Also, the number of papers analysing services sector is only 4. This lack of data does not allow the hypotheses four validation. It is also important to mention that the automotive sector, presents much of negative effects, showing 82% negative effects and only 7% positive effects.

To make a deeper investigation, the same analysis was done but instead of combining all the three types of effects (MSD, stress and MSC), these were analysed alone.

Figure 7.7 shows the analysis results regarding the percentage of number of authors references to the effects of lean in the three different sectors to workers MSD.

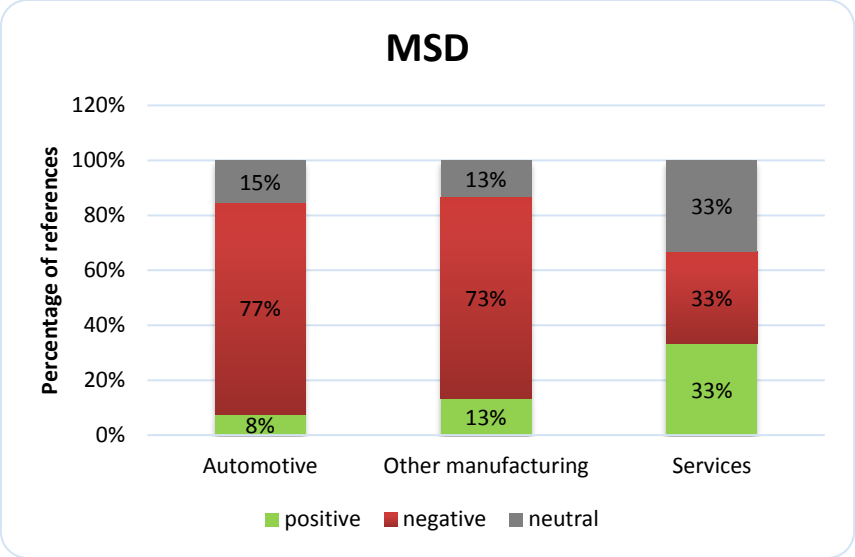

Figure 7.7-Effects' references on MSD in literature review according to Sector

Figure7.8 shows the analysis results regarding the percentage of number of authors references to the effects of lean in the three different sectors to workers stress.

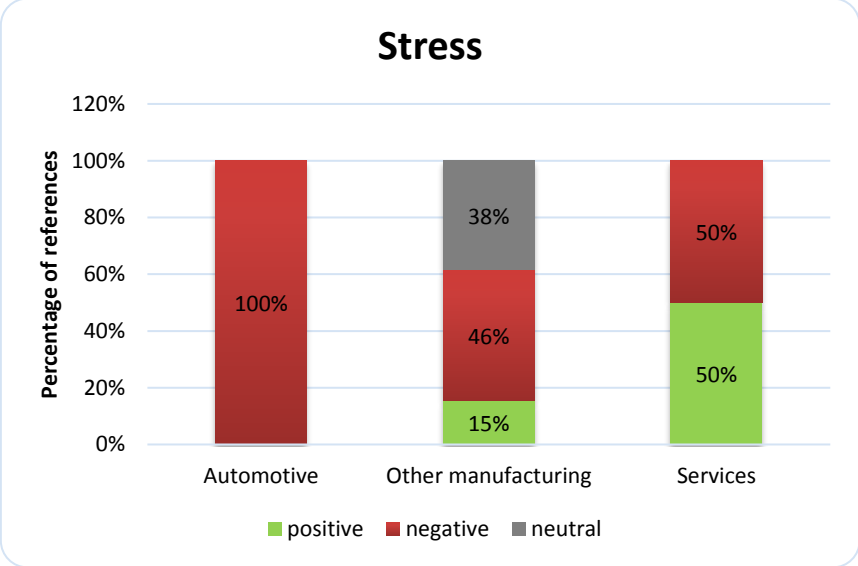

Figure 7.8-Effects' references on Stress in literature review according to Sector

Figure7.9 shows the analysis results regarding the percentage of number of authors references to the effects of lean in the three different sectors to workers MSC.

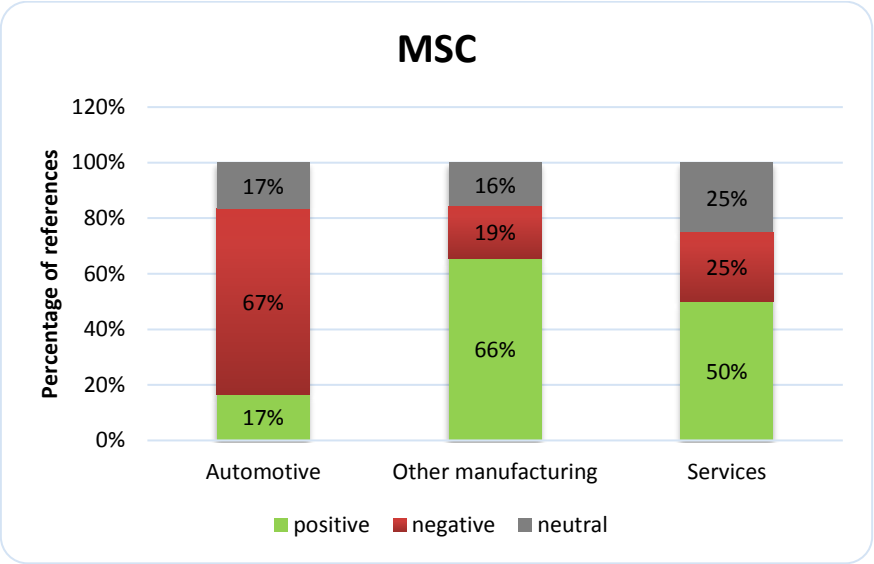

Figure 7.9-Effects' references on MSC in literature review according to Sector

Looking at Figures 7.7, 7.8 and 7.9 and analysing the automotive sector, the results show that much of negative effects come from stress which presents 100% negative effects. It is important to mention that no positive effects were found in literature review regarding stress effects in automotive sector. Berggren (1993) characterises lean production in automotive industry as 'mean production'. According to Berggren the experience of Japanese lean production transplants to the USA has been problematic. Specifically, the 'mean' characteristics of lean production were relentless performance demands, unlimited working hours and a rigorous factory regime. Also, Niepcel & Molleman (1998) have criticised the type of lean production developed in the car industry. They have pointed out that some key features of lean production, such as continuous flow of production and lack of buffers result in time pressure and stress.

Analysing other manufacturing, the major difference between this sector and the automotive is in an increase in MSC effects on other manufacturing companies. Regarding the services sector, all the three types of effects studied are equibalanced between positive, negative and neutral. An explanation for these results might be that the first studies regarding effects of lean on workers started in the automotive and the authors focused in MSD and stress effects. Only later authors, changed the focus of their studies to another kind of effects like psychosocial effects, including MSC, and studied other sectors like other manufacturing and services. This analysis is done in chapter 7.5 analysing the studies' trends trough time.

The studies in automotive sector are mostly from the USA and focus on musculoskeletal disorders and stress, which are related to faster work pace, increased upper limb disorders and perceived stress. Studies in other manufacturing sectors are mostly from Europe and the research focus shifted from mechanical exposure and health effects such as musculoskeletal disorders to psychological factors and stress. These studies found mixed effects. The reason behind this shifting between negative effects in automotive sector to mixed effects in other manufacturing sectors might be that lean practices characteristics that caused musculoskeletal disorders were not so extreme (work pace, long working hours, etc.) in the manufacturing sectors compared with the automotive sector. Other reason might be that in manufacturing companies lean production was not implemented in its full form like in the automotive companies and some of lean practices characteristics that lead to negative effects were not implemented (Koukoulaki, 2014).

Regarding the lean effects in services sectors, studies results show controversial both negative and mixed effects. The nature of this effects depend on factors like the way lean practices are implemented, including management decisions on which lean practices to implement and how.

In conclusion, automotive sector is the most affected, showing most of negative effects, followed by other manufacturing with an improvement in positive effects and finally services sector shows the best results with much of positive effects. Much of negative effects in automotive sector comes from stress and MSD effects and most of positive effects on other manufacturing and services sectors comes from MSC effects. Despite this, hypotheses four cannot be accepted due to the shortage of data regarding services sector. H4: While manufacturing sector is negatively related to effects on workers, service sector shows a better relationship.

7.3 Country Vs MSD/Stress/MSC

In this sub-chapter, an analysis was made of the effects' references of Lean on workers in different countries to understand if there is any relationship between the effects of lean and the culture of the country. Table 7.2 shows the number of papers analysed in each country. Other Western Europe countries includes Belgium, Holland, Germany, France, Ireland, Italy and Spain. These countries were combined in the analysis because they all have a similar work culture. Some countries were excluded from the analysis due to the short number of papers studying the effects of lean on workers in these countries to reduce the noise. Despite the number of papers analysing Japan, it was included in the analysis as a reference since Japan is the country where Lean was born.

Table 7.2-Numbers of papers reviewed according to country and included/excluded in analysis

Countries included	N papers	Countries excluded	N papers
Scandinavian	15	Brazil	2
USA	15	China	1
Canada	6	Australia	2
UK	11	Taiwan	1
Other Western Europe	7	Korea	1
Japan	3		

To make a valid analysis, since the number of papers reviewed by country are very different from each other, the results are shown in percentage of number of references of effects by country. Figure 7.10 shows an analysis of the three types of lean effects on workers that is intended to study to have a more general idea of the effects of lean per country.

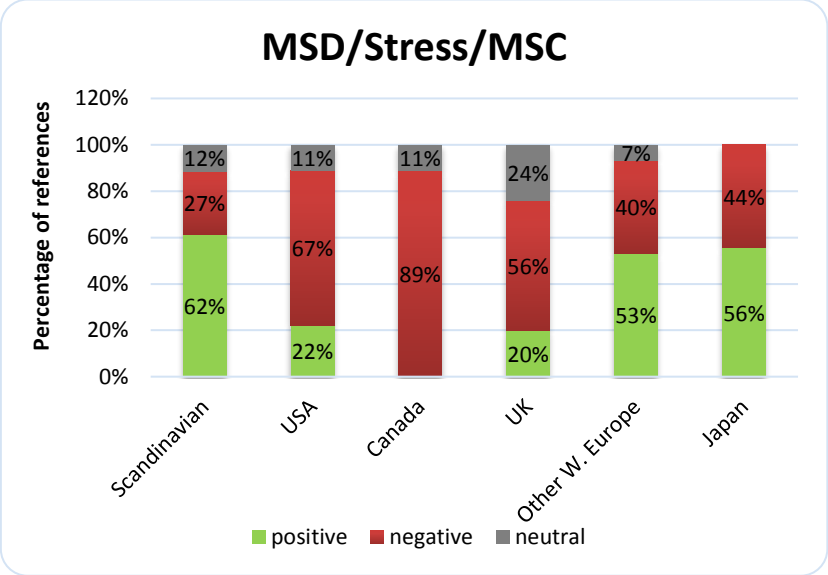

Figure 7.10-Combined effects in literature review according to Country

Results show that Canada, UK and USA present much of negative effects. Other countries like Scandinavian ones, other Western Europe and Japan show a more even results with a ratio of generally 50% positive and 50% negative effects.

To understand which type of effects are predominant in each country Figures 7.11, 7.12 and 7.13 show the results related to effects on MSD, stress and MSC respectively and separated.

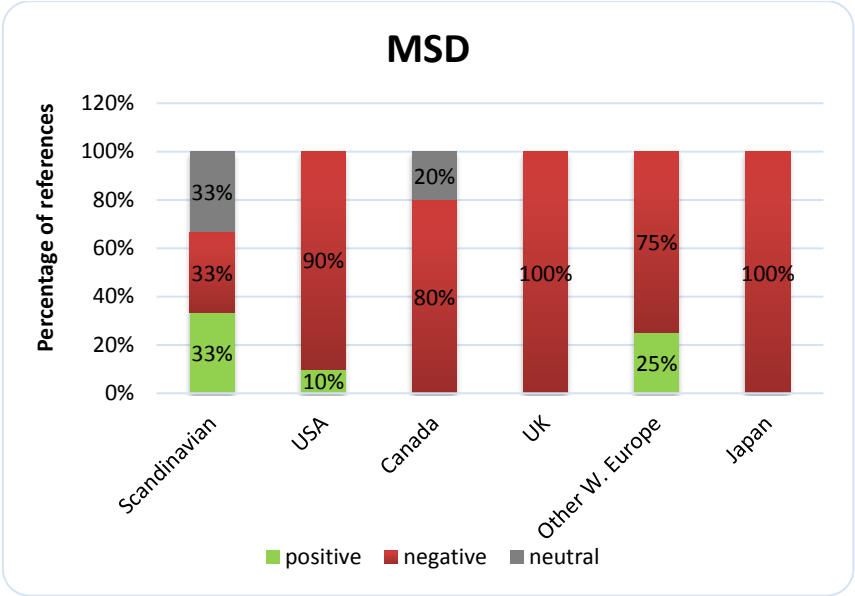

Figure 7.11-Effects on MSD in literature review according to Country

Analysing Figure 7.11, it is visible the negative impact of lean on MSD effects. The only countries showing a slightly improvement are Scandinavian and other western European countries.

The stress effects of lean in workers according to country are shown in Figure 7.12.

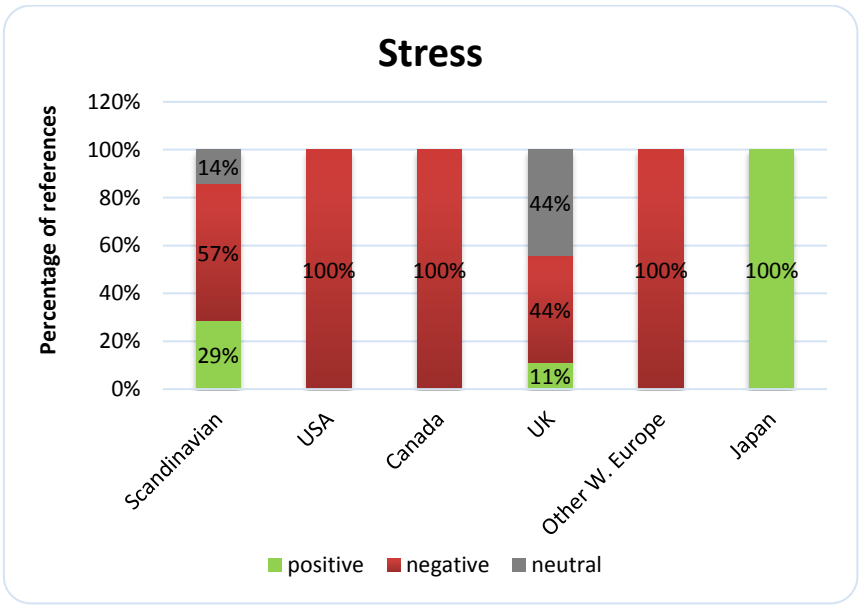

Figure 7.12-Effects' references on Stress in literature review according to Country

Regarding effects on stress and analysing Figure 7.12, USA, Canada and Western Europe countries, they all show 100% negative effects. UK presents 44% in both negative and neutral effects and only 11% positive effects. Scandinavian countries show an improvement in relation to UK with 29% positive,

however it shows more negative effects (57%) and less neutral effects (14%). Finally, Japan shows a surprisingly 100% positive effects. However, in the 3 papers analysing Japan, there was only one reference to effects on stress saying that 5S reduces stress (Dierickx, 2016), that is why Japan shows 100% positive effects.

The MSC effects' references of lean in workers according to country are shown in Figure 7.13.

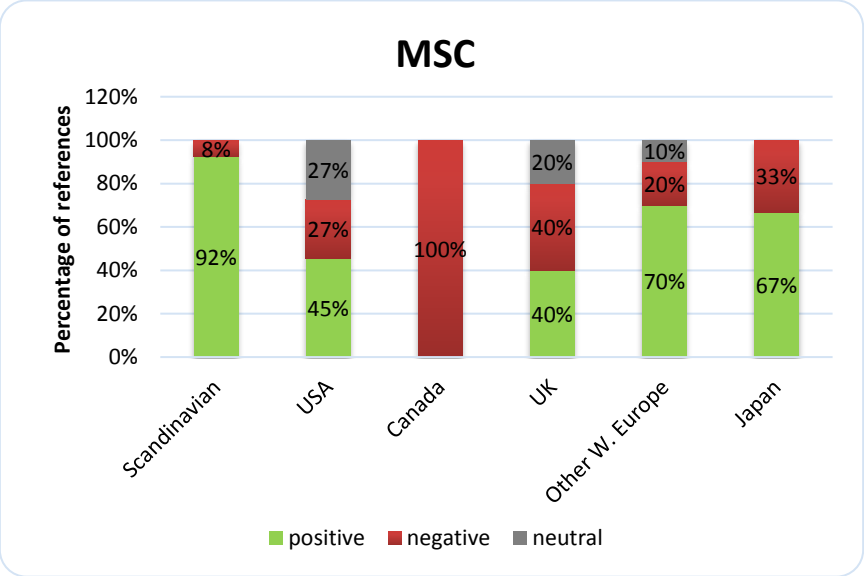

Figure 7.13-Effects on MSC in literature review according to Country

In relation to MSC effects of Lean, Scandinavian countries show the best results with 92% positive effects, followed by other Western Europe countries, with 70%, Japan with 67%, USA with 45% and UK with only 40%. Canada shows the worst results with 100% negative effects.

Summarizing the results, the countries analysed show predominance of negative effects in MSD with a slight improvement in Scandinavian and other western Europe countries. In relation to effects on stress, countries studied show also predominance of negative effects, however Scandinavian countries show an improvement when compared to others. Japan shows 100% positive effects, but these results are misleading since there was only one effect related to stress in found in the literature. Finally, the effects on MSC are equibalanced in relation to positive and negative effects, in exception to Scandinavian with 92% positive effects and Canada with 100% negative effects.

It can be concluded that the Scandinavian countries have more positive effects in the application of lean while in Canada the effects are mostly negative.

These effects studied in the Canada can be explained by the fact that 67% of the studies carried out are related to the automotive sector and between the years 1990-2001. The Figure 7.20 shows this sector trend trough time periods. Koukoulaki (2014), referred in his study that the first period (1991-1997) of studies regarding the effects of lean on workers was after the implementation wave of lean production in automotive industries in USA and Canada. Also at the time, the studies' focus was on MSD and stress, reporting negative effects related to faster work pace, increased upper limb disorders and perceived stress.

Lewchuk et al. (2001), compared the quality of working life in the automotive industry between Canada and UK and found that lean production is not associated with increased empowerment or greater employee control over work. On the contrary, workers reported quite different experiences of work effort, health and safety and relations with management, suggestive of differences that vary more between companies than across countries. An explanation for this is that there is an expectation that pressures of globalisation will erode national differences in production and labour relation systems (Oliver, 1991).

Scandinavian countries result show an improvement in positive effects in relation to others. This may be due to a mixture of concepts inspired by Lean and Sociotechnical systems. Scandinavian manufacturing companies had not launched radical changes toward the Japanese mode of lean production. Instead, they had adopted principles of lean production that complemented their earlier technological and organizational developments. Womack et al. (1990) compared the Volvo Uddevalla plant (a famous example of the application of sociotechnical systems thinking) and lean production. They claimed that work in a lean-production system is challenging and fulfilling because the workers are solving problems all the time and are trying to improve the work methods to make the process fluent. However, at the same time they stated that because lean production has no buffers, the running of the system requires that every worker try very hard all the time (Seppälä & Klemola, 2004).

Further, a common view is that Western workers will never really embrace manufacturing practices such as those involved in Lean since the Japanese work culture of commitment to the company, hard work, and group solidary are major determinants of the success of Lean in Japan.

Finally, hypotheses 5 which says, "The greater the well-being concern of the country, the greater the perception of negative effects of lean practices on workers" is denied. While the negative effects on overall countries are related to the Japanese Lean transplants, the positive effects on Scandinavian countries are related to the fact that these countries adopted principles of lean production that complemented their earlier technological and organizational developments. However, these results are more related to the worker's well-being concern of the company rather than the country.

7.4 Journal type Vs MSD/Stress/MSC

This analysis aimed at understanding if the type of journal publication has any relation with effects presented by authors. A separation was made in two groups, organizational health and Industrial. Organizational health, includes ergonomics, psychology, labour relations, human factors and industrial, includes economics, technological and Lean. Figures 7.14 and 7.15 show the results of this analysis.

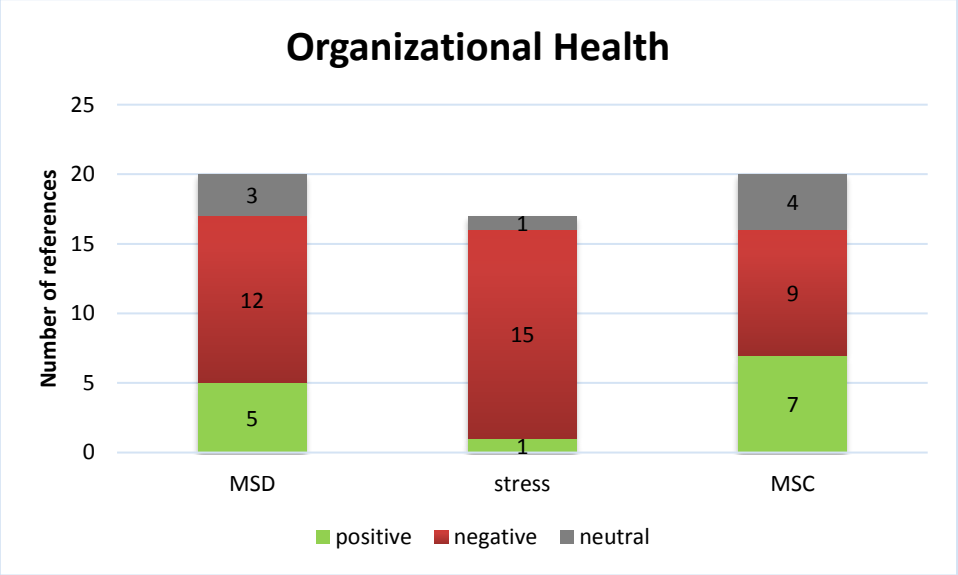

Figure 7.14-Effects in literature review according to Organizational Health journal type

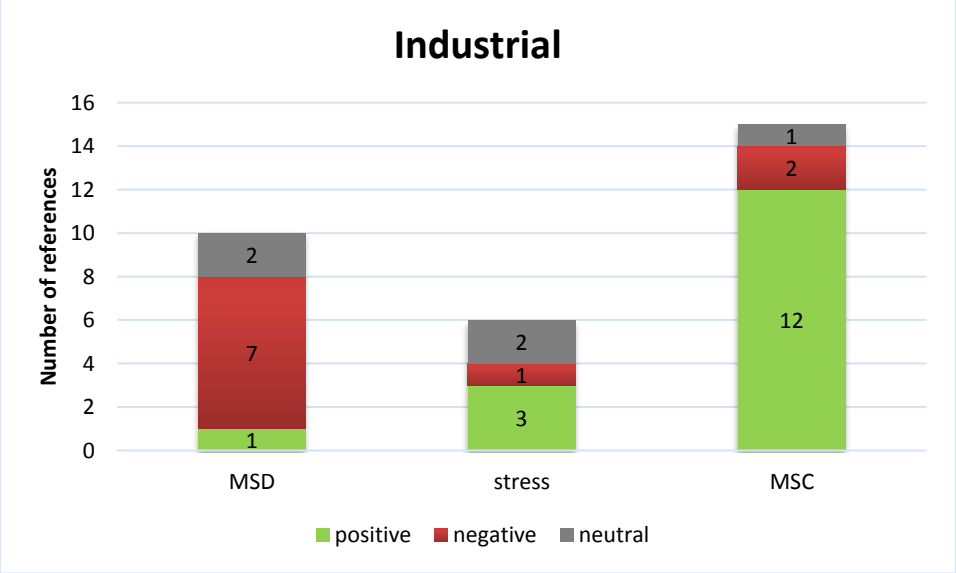

Figure 7.15-Effects in literature review according to Industrial journal type

Analysing the two diagrams, it can be observed that the Industrial Journal type shows more positive effects in MSC than the organizational health type Journal. These results may be explained by the fact that in an organizational health journal the authors focus more on the negative effects of lean on the worker well-being. While the industrial journals, can create an illusion that lean production can lead to many benefits for workers, including empowerment and job control, but the reality can be very different. Jones et al. (2013), referred that in a lean company, workers involvement was only asked for to establish a set of company values and consensus was reached when the values reflected the views of the managers. The authors concluded that this illusion process in common in lean companies, where there is a consensus decision-making process but it is manipulated by the management to favour cost and production solutions.

Therefore, hypotheses six can be accepted. H6: There are positive biases related to lean practices effects on workers in industrial journals in comparison with organizational health journals.

7.5 Time trend Vs MSD/Stress/MSC

This analysis aimed at understanding the evolution over time of the effects of Lean practices in workers. (Koukoulaki, 2014) developed a trend analysis of lean effects in literature as shown in Figure 7.16.

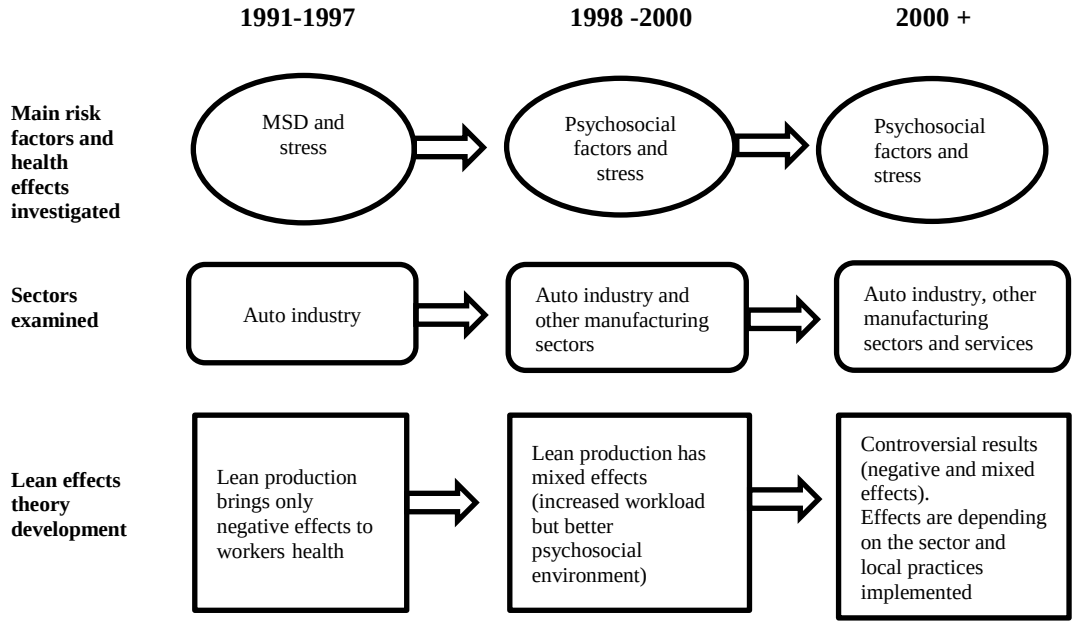

Figure 7.16-Trend analysis on lean effects literature (Koukoulaki, 2014)

Koukoulaki referred that, in his analysis, between 1991 and 1997 there were only negative effects in literature and they were all related to MSD's and stress. Between 1998 and 2000, there were mixed

effects in Lean production related to stress and psychological factors. Lastly in the new millennium, it started to appear controversial results, depending in different factors.

In this study, we developed our own analysis to understand if there are any differences between ours and Koukoulaki (2014).

Figures 7.17, 7.18 and 7.19 show our analysis results of the Lean practices effects overtime in MSD, stress and MSC respectively, where "n" represents the number of papers published in each year.

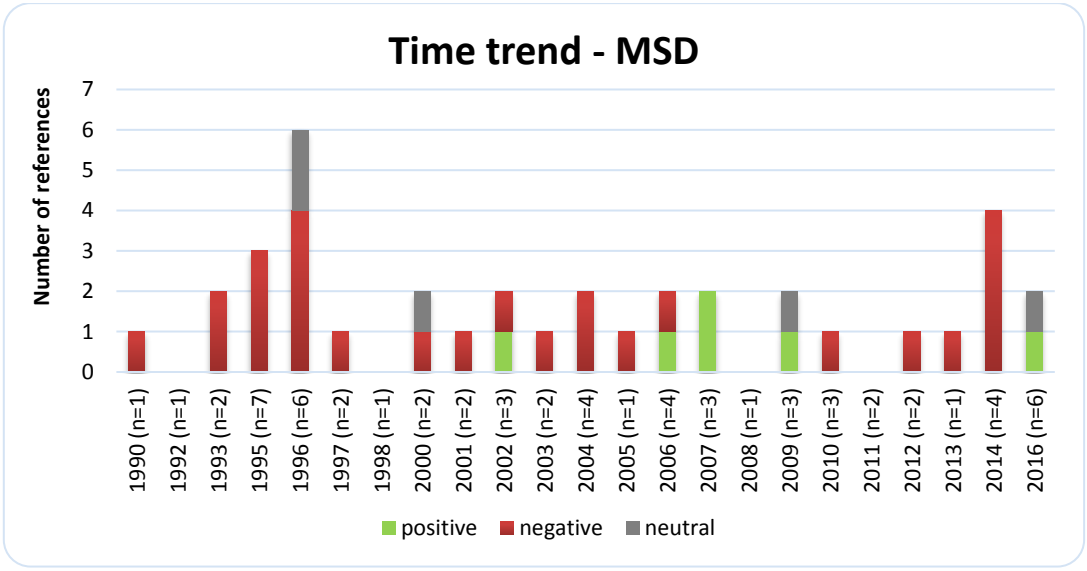

Figure 7.17-Effects on MSD in literature review according to article's publication year

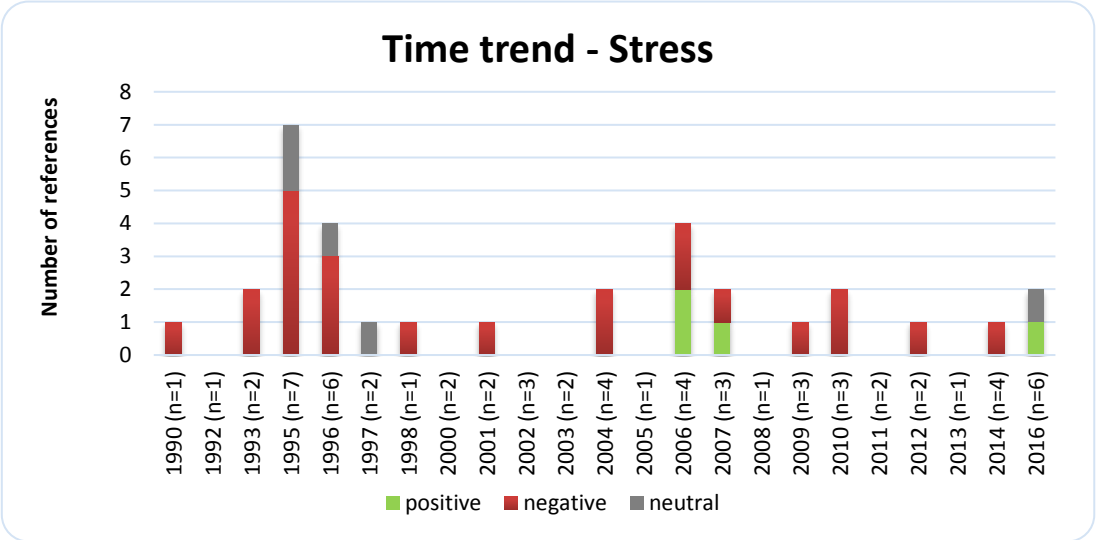

Figure 7.18-Effects on Stress in literature review according to article's publication year

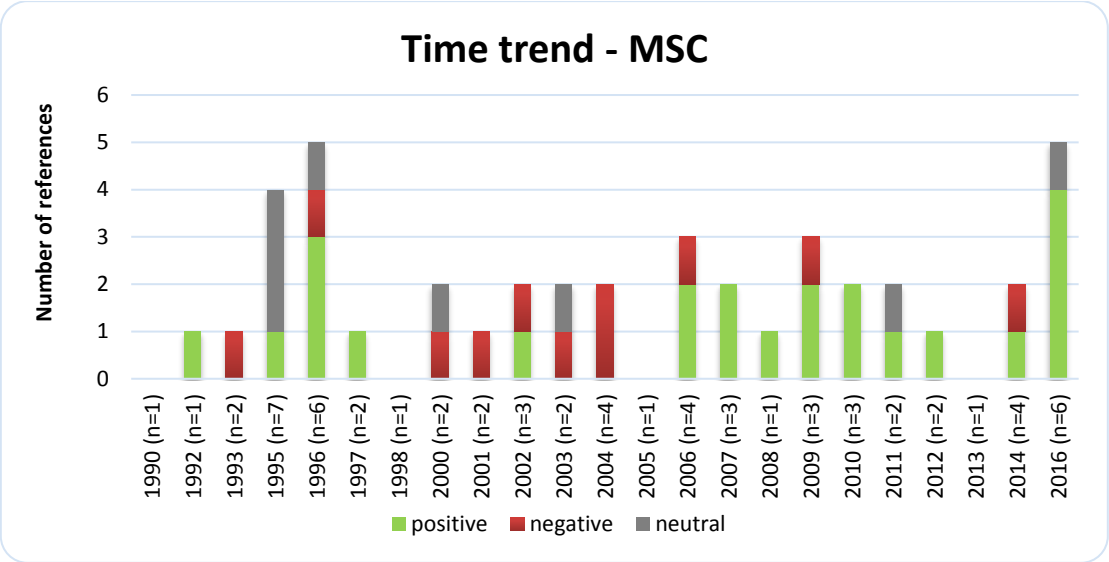

Figure 7.19-Effects on MSC in literature review according to article's publication year

Analysing between 1990 and 1997 our results shows that the studied effects were all negative in MSD and stress like Koukoulaki presented is his analysis. However, MSC effects are studied in this period and present mixed outcome contradicting Koukoulaki's trend analysis which says that in this time period this type of effect were not studied. Analysing the trend for 2000+, MSD, stress and MSC show mixed effects as also presented by Koukoulaki in his trend analysis, but with a slightly disagreement in the fact that the MSD effects were still studied in this period.

An analysis of the studies' trends in relation to the sector studied is done in Figure 7.20.

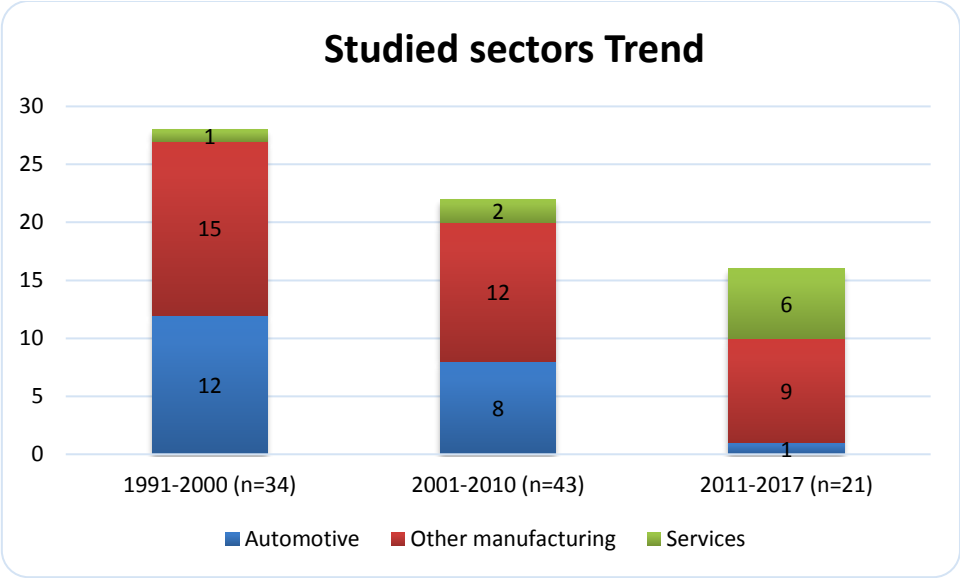

Figure 7.20- Studied sectors trend

Results show that in the first period the focus of the studies was on automotive and other manufacturing companies, which in the next years started decreasing while services sector started to become more studied. This might explain the results in chapter 7.2, where other manufacturing companies and services showed an increase in positive MSC effects in comparison to automotive sector since this type of effects only started to become the focus of the studies in other manufacturing companies and services sectors. Also, all the positive effects related to MSC in the first period (1991-2000) are related to other manufacturing companies.

Mullarkey et al. (1995) carried out an investigation in an electronics company in UK, on the effects of a two-phase introduction of JIT manufacturing practices on the perception of change. The surveys were carried out 1 month before JIT practices implementation and the other survey was done 5 months after the implementation. The results showed that the strategy taken by the company in its implementation of JIT has been extremely successful. It suggested that it is possible to introduce variety of JIT manufacturing practices into a batch production environment without adverse impact on the perceptions of the content of employees' jobs and their psychosocial wellbeing. The reason for this successful implementation was that the company took a highly developmental, human-centred, participatory approach to the introduction of JIT, by ensuring that employees were sufficiently multi-skilled and well-trained in the principles of TQM and team-working, before reducing inventory levels and introducing Kanban systems. Other companies, however, have been known to "dive in at the deep end", introducing teamworking, TQM and core JIT practices simultaneously as a part of a major organizational change. In such cases, it is possible that employees will experience greater difficulties associated with cross-training, human relations, and the greater vulnerability of the process under JIT. However, since the survey was only done 5 months after the JIT implementation, there remains the possibility that, with time, the positive effects observed may wear off.

Scott et al. (1992), conducted his study in a golf balls manufacturing company applying JIT in the USA and questioned 423 workers addressing job satisfaction. The results showed that levels of job satisfaction, an important determinant of commitment and motivation, tend to increase for workers as their JIT involvement increase. That is, the more they are involved with JIT practices, the more satisfied they are. Despite this positive analysis of JIT implementation, it is important to notice that this paper was published in a production and inventory management journal which was already analysed in chapter 7.4. This type of journals tends to create an illusion of the benefits of Lean on workers to favour cost and production solutions.

In the last period (2011-2017) several authors (Nahmens et al., 2012; von Thiele et al., 2017; Dierickx, 2016) reported that introduction of practices such as *Kaizen* increased job satisfaction. Bortolotti (2016) classified Lean in hard practices: setup time reduction, continuous flow, Kanban, autonomous

maintenance and soft practices: problem solving, multi-tasking training employees, top management leadership for quality, continuous improvement. He concluded that only soft practices improve workers commitment.

In conclusion, the results regarding the lean effects on workers studied trough time show a change of focus in the type of effect and show an improvement from mostly negative effects to mixed effects. The introduction of Lean practices in different sectors than automotive showed an increase in positive outcomes. The introduction of respect for people practices like job enrichment and training in more recent years increased the positive effects on workers. However, the main conclusion here is that the effects of Lean in workers depends more on company's management decisions than on the sector and country where it is implemented. Also, the partial implementation of Lean rather than its full implementation, may contribute to an increase in positive outcomes. An example of this strategy is found in Scandinavian companies which adopted Lean hybrid production systems. Another fact that may contribute to the increased positive outcomes trough time is the illusion companies create regarding the effects of Lean on workers to favour costs and production. Therefore, hypotheses seven is denied. H7: The concern of the lean effect on workers in relation to MSD, stress and MSC has been increasing over time.

8 Proposed interaction model between lean practices and effects on workers

Based on the results found in chapter 7 and the hypotheses analysis, an interaction model is proposed showing the relations between lean practices and risk factors for effects on workers MSD, stress and MSC. This model was inspired by Koukoulaki's (2014) model because it is the most complete and illustrative found in the literature focusing this study's subjects. The model's structure is composed by three columns, which in turn, the columns on the left and right were based on two models with the risk factors leading to psychological and psychosocial effects (Karasek & Theorell, 1990; Siegrist, 1996) and MSD effects (Bongers et al., 1993; Bernard & Anderson, 1997; Devereux et al., 1999; Punnett & Wegman, 2004; Silverstein et al., 1996) respectively and the central column show the main lean practices in the blue boxes found in each Lean pillar and their subsequent effects to job characteristics in the white boxes. The job characteristics result in exposure to the risk factors and effects in MSD's and psychological/psychosocial effects models. The green lines and boxes represent the risk factors for positive outcomes and the red ones represent the risk factors for negative outcomes. The model is illustrated in Figure 8.1.

JIT pillar practices like cycle time, causes intensification of work, control and demands, which is linked with MSD's risk factors like repetitive work and lack of recovery time, which ultimately contributes to an increase of stress. Manufacturing cells commonly found in JIT implementation also have the same effects on stress as cycle time. Although, they also increase multi-skilling which is linked with job enrichment known as a risk factor for increase of MSC.

Jidoka pillar practices such as work standardization reduces autonomy, which consequently creates an unbalance between job control and demands, increasing stress. This practice also increases work pace, consequently increasing MSD risk factors like repetitive work. Total Quality Management (TQM) creates pressure to come up with improvements which in turn increases psychological demands affecting negatively stress. On the other hand, *Kaizen* increases level awareness that increases the capacity to manage psychological issues, reducing stress.

Finally Respect for People pillar practices such as job rotation, reduces human effort, work intensification and pace, which in turn, increases recovery time, reducing the risk for MSD. Job rotation, also causes role breadth intensification, which is linked to job enrichment and consequently increase of MSC. On the other hand, role breadth intensification is also linked to an increase in cognitive demands which is related to increased stress. Workgroups is linked to job support which act as buffers to psychosocial risk factors. That is, if genuine support from team colleagues and supervisors is possible

within the workgroups of Lean. Although, workgroups can have negative effects in MSD when a team member is absent and the rest of the team members must do his work, increasing work pace and consequently decreasing recovery time.

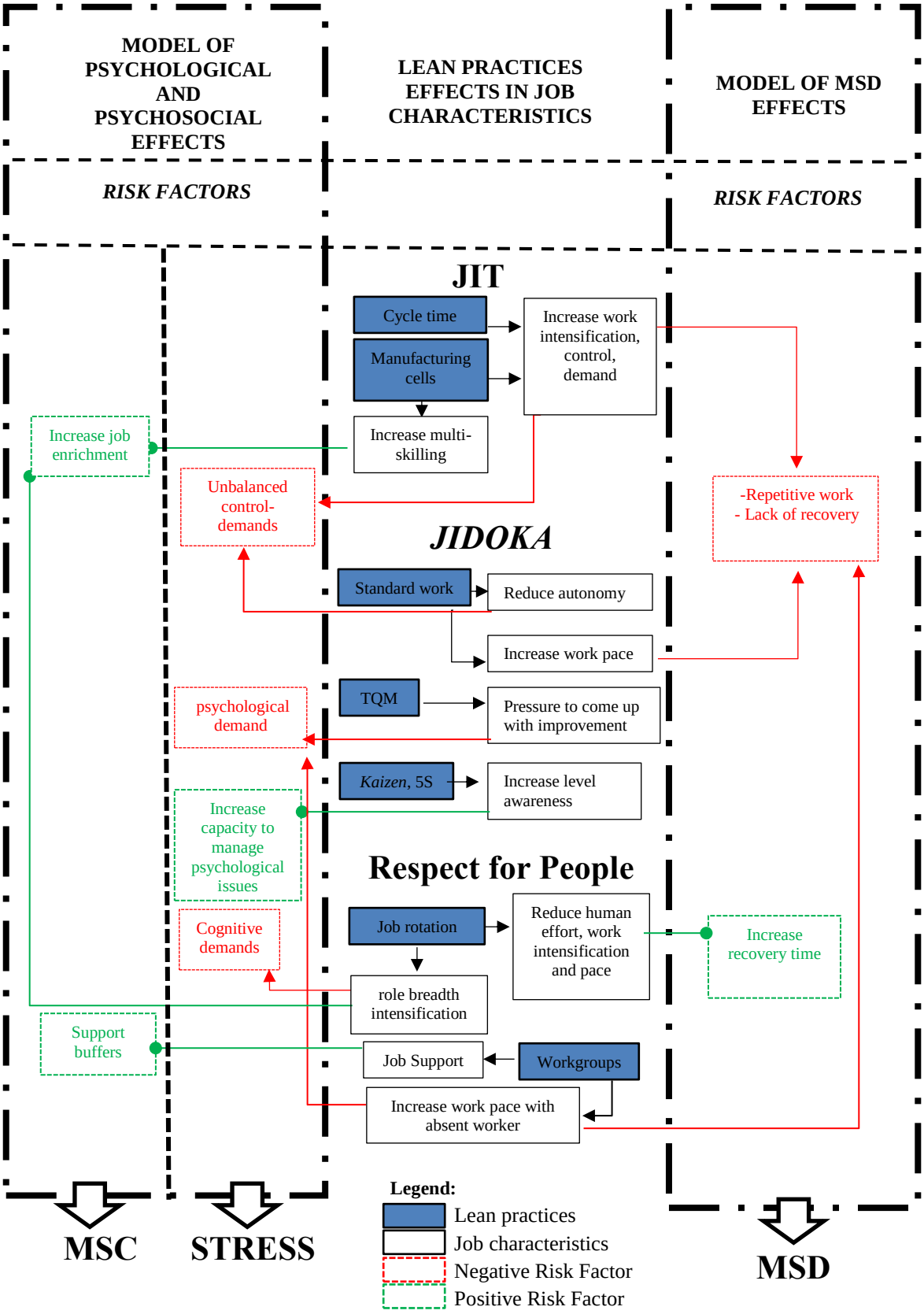

Figure 8.1-Proposed interaction model between lean practices and effects on workers.

9 Conclusions

This dissertation comprised an analysis of the last 26 years regarding the effects both positive and negative, of Lean Production Systems on workers, more exactly on musculoskeletal disorders, stress and psychological effects namely motivation, satisfaction and commitment. More than 50 papers studying the effects of Lean in automotive manufacturing, other manufacturing companies and services as well as in different countries were analysed. Despite the factors analysed in this dissertation, it is believed that there are others that can influence, such as the age and size of the company and the level of lean implementation. An attempt to study these factors was made but the lack of information regarding these factors in the literature did not allow them to be included in the analysis. Therefore, it is proposed that future studies and surveys collect and analyse these factors.

Overall findings indicate that the effects of lean production on workers are more evident in the automotive sector with increased stress and MSDs as well as in other manufacturing companies with an improvement in positive effects in relation to motivation, satisfaction and commitment. In services, the effects seem to be more positive. These positive effects describe motivation, satisfaction and commitment increase trough continuous improvement practices like *Kaizen*. Despite this results in services, the short amount of information found in this sector is not enough to take solid conclusions.

Several analysed studies showed contradictory outcomes in relation to the same lean practices implementations. The justification to these contradictions, is the perception of Lean and its implementation by companies as well as cultural factors. Lean was firstly created in Japan by Toyota and then applied in the western culture. The fact that Japan has a work culture of commitment to the company, hard work and group solidarity is a major determinant of the success of Lean in Japan, which is not found in the western culture. So, it is logical that the full application of Lean in western countries are expected to show more negative effects on workers. Despite this, some Scandinavian companies introduce hybrid forms combining aspects of lean and their earlier technological and organizational developments.

The Lean production pillar that seem to have the strongest association with negative effects on workers is JIT, including practice such as cycle time and manufacturing cells. It may be that these practices are causing intensification of work and an increase in control-demand which is linked to increased musculoskeletal disorders and stress but also to increased job motivation trough multi-skilling development in manufacturing cells. Results show that lean is not by definition harmful. Specific practice's characteristics can have negative effects on workers well-being. More important is what companies choose to implement from Lean. Respect for people practices are commonly forgotten by

companies or simply ignored, mostly in the automotive sector. The application of practices with intensification of work pace must be accompanied with trained and adjusted work teams, acting as buffers in MSDs trough introduction of recovery time when team members switch between different activities, can bring positive effects on lean production workers.

A comparison between papers published in Industrial journals and Organizational Health journals showed that Industrial type journals show more positive effects of Lean on workers. Despite this result, the truth is that this type of journals can create an illusion that lean production can lead to many benefits for workers, including empowerment and job control, which in fact is a strategy used by management to favour cost and production solutions. On the other hand, Organizational Health journals focus on the worker well-being, revealing the effects of Lean on them.

The analysis overtime of effects of Lean on workers showed the changing trends over a 26 years period. Effects of Lean evolved from a view that it is a 100% harmful production system to a system which can have mixed effects depending on cultural factors and most importantly the way it is managed and implemented.

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Appendix –Analysed papers investigating effects of Lean on workers

Author	Pub. Year	Lean practice analised			Effects on MSD	Effects on Stress	Effects on MSC	Country	Sector	Journal Type	Study design
		JIT	Jidoka	RfP							
Saurin & Ferreira	2009	assembly line, cycle time	TQM	macro-ergonomics approach for managing health and safety issues.	Pain/discomfort at a moderate level; unchanged by Lean	Moderately stressed, which had increased from Lean	Improved autonomy	Brazil	Manufacturing of harvesters (automotive)	Human Factors and Ergonomics in Manufacturing	Interviews, questionnaires, feedback meeting
Womack et al.	2009	JIT delivery of parts	leveled product mix (heijunka), quality systems (jidoka) including andon cords and error-proofing (poka yoke) devices, TPM, 5S, standardization , continuous improvement	work teams, job rotation	The Lean factory had reduced the number of injuries by 19% between 2000-2006		Repetitive work increased	USA	Car manufacturing	Human Factors and Ergonomics in Manufacturing	Comparison between 56 work stations in a Lean & traditional factory
					Lower use of force						

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		JIT	Jidoka	RfP							
Brown & O'Rourke	2007	JIT, reduced inventories			jobs with ergonomic stressors, intensification appears to result in an increase in the WMSD.	Increased individual stress		China	Shoe manufacturing	ocupation and environmental health	Case study: 27 questionnaires & focus groups (20 persons), no control group
						Stress was related to worry of not reaching set goals, unrealistic goal setting, too high work pace, too much work, unfair supervisor					

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		JIT	Jidoka	RfP							
Conti et al.	2006	Cycle time	TQM, continuous improvement	job rotation		low level of Lean, increased stress, while reduced stress at high level of implementation of Lean stress was reduced through participation, teamwork and support in the work situation	Increased participation Increased autonomy	UK	Manufacturing	Operations & Production Management	1391 questionnaires, assessed level of Lean (1-5) for 10 Lean tools & tested 21 hypothesis related to stress
Mehri	2005				Perceived work load was high			Japan	Car manufacturing		former employee of studied company. 75 interviews.
Brenner et al.	2004	JiT	TQM, teams and Quality Circles			Correlation between cumulative trauma disorders/ CTD and Quality Circles/ QC, and between CTDS & JiT				Economy and Society	Industrial setting, statistics from BLS

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		JIT	Jidoka	RfP							
Seppälä & Klemola	2004	JIT	TQM	teamwork		Increased perceived work pace and Increased stress for the white-collar workers	Increased perceived work control	Finland	Manufacturing companies	Human Factors and Ergonomics in Manufacturing	Cross-sectional study, 525 questionnaires, 4 companies
							Increased Qualification of the workforce (job enrichment) multi-skills requirements, job enlargement, participation and autonomy				

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		JIT	Jidoka	RfP							
Parker	2003	assembly lines, reduced inventories, "pull-production"	standardization	process development teams, Lean teams			Worker involvement in the workplace was reduced	UK	Automotive manufacturer	Applied Psychology	A quasi-experimental research design was used. Four groups were surveyed twice over a 3-year period.368 questionnaires
						No changes in workload or work related worry for lean team	Participation was unchanged for those participating in Lean-teams				
						workload or work related worry increased for assembly lines	Participation increased for the employees in the technical support group				
						Work related depression increased with assembly lines and standardization (+)	Reduced participation in the work process and usage of skills, and reduced autonomy (-)				

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Anderson - Connolly et al.	2002	restructuring, outsourcing, reduced inventories		simplified processes & cross-functional teams	Employees: Reduced health related to work intensity, competence and teamwork			USA	Manufacturing	Social Science	Longitudinal questionnaire study (1997 & 1999), 1244 questionnaires.
					Employees: Improved health related to autonomy						
					Management: Reduced health related to work intensity and autonomy						
					Management Improved health related to teamwork and work skill						
Bruno & Jordan	2002		quality circles, andon, kaizen	teamwork			The perceived work environment and job satisfaction was reduced	USA	Car manufacturing (Mitsubishi)	Labor and Society	Longitudinal study (1989 & 1997), over 1,000 questionnaires

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		JIT	Jidoka	RfP							
Lewchuk et al.	2001	JIT	kaizen	Workteams	Working with pain, exposure to muscular fatigue & WMSD			Canada	Car manufacturing companies	New Technology, Work and Employment	Comparing 4 companies of differing level of Lean implementation .
Jackson & Mullarkey	2000	cell manufacturing			Work related effort unchanged		Job satisfaction unchanged		Garment manufacture	Ocupattional Health Psychology	Comparing normal production line & cell manufacturing
Leclerc et al.	1998	JIT				Increase MSD in companies working with JiT		France	Assorted manufacturing companies	Occupational Environment Medicine	Cross-sectional study of JiT-production, with reference group
Adler et al.	1997			health and safety improvement	High frequency of reported injuries during launch of car model (-) Injuries reduced after ergonomic intervention program (-)			USA	Car manufacturing (NUMMI)	Industrial & Labor Relations	Longitudinal case study, investigating the ergonomic situation during launches of new car models in 1993 and 1995.

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		JIT	Jidoka	RfP							
Lewchuk & Robertson	1996	JIT			Working with pain similar in Lean & traditional companies			Canada	16 suppliers to car manufacturing companies	Work organization	1670 questionnaires
					Working with pain lower at companies initiating Lean						
					Perceived work load higher, and the perceived increase was higher, when comparing the Lean companies to the traditional companies						

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		JIT	Jidoka	RfP							
Jackson & Martin	1996	JiT assembly line (small batches, job rotation, simplified processes, pull production, inspection of own work			Work load higher with JiT	Psychological stress unchanged	Work satisfaction decreased with JiT	UK	Electronics manufacturing	Ergonomics	Comparison between JiT assembly line & traditional non-JiT line. 44 questionnaires before & after.
Nielsen	1996	sporadic implementation of JiT,	other Lean tools in parts of the factories		Physical work load unchanged		Integration of quality control in the normal job design was perceived as creating better job satisfaction	Denmark	6 manufacturing companies, 1 in process industry	Human Factors in Manufacturing	Interviews with persons from all levels of companies, observations from 3 companies, 150 questionnaires from 4 companies
Stewart & Garrahan	1995		continuous improvements	teamwork	Physical fatigue from work increased	Mental fatigue from work increased	Job satisfaction unchanged, or slight decrease	USA & UK	Car manufacturers	Work, Employment & Society	4 factories; 140 questionnaires

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		JIT	Jidoka	RfP							
Mullarkey et al.	1995	JiT	TQM			Stress showed no connection to JiT	Work satisfaction increased with JiT	UK	Electronics manufacturing	Operations & Production Management	65 surveys
Babson	1993	Lean bundle			workers believed that they would be injured/worn out before pension, with the current work intensity	Perceived work demands increased	Perceived work control decreased	USA	Car manufacturing (Mazda & Ford)	Labor Studies	Case study, 2380 questionnaires
Berglund	2010	cycle times	Kaizen	employee involvement, problem solving	Reduced cycle times increased work intesification		Increased job satisfaction, through employee involvement in work with continuous improvements and problem solving	Sweden		Work Science	Dissertation. Qualitative study, 3 companies working with Lean.
							Reduced job satisfaction, due to increased control and steering of the work				

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		JIT	Jidoka	RfP							
Brännmark	2010	value stream mapping, set-up time reduction	standardization, 5S	improvement groups		Increased stress		Sweden		Ergonomics	Conference paper. Qualitative & quantitative study (41 interviews, 82 questionnaires), 8 companies
Oudhuis & Olsson	2010		Continuous Improvement (CI), standardization	employee involvement, problem solving (PS)		Increased stress due to more monotonous and stressful work	Increased job satisfaction, through employee involvement in CI & PS	Sweden		Working life in change	Conference paper. Qualitative case study of large company implementing Lean.
						Increased workload, due to increased demands for working overtime	Reduced job satisfaction, due to standardization making work more boring				

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		JIT	Jidoka	RfP							
Andersson & Liljenvald	2009	JIT	TQM	group autonomy and employee			Increased job satisfaction, through increased group autonomy and employee empowerment	Sweden	manufacturing companies	Industrial and financial economics	Student thesis. Questionnaire study of common elements in manufacturing companies' Lean work.
Pettersen	2008		visualization & 5S	empowerment			Improved job satisfaction, due to improved communication between departments	Sweden		Science and Technology	Conference paper. Qualitative study, 2 companies implementing Lean.

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		JIT	Jidoka	RfP							
Eklund & Berglund	2007	Kanban, Paced line production	5S, continuous improvement,	Process orientation	Lowered workload, due to slower and more even work pace		Increased job satisfaction, through employee involvement in CI & PS	Sweden	one turbine manufacturer & one lift truck manufacturer	Ergonomics	Conference paper. Qualitative study, 2 companies implementing Lean. Deep interviews with 19 bluecollar workers
					Increased workload, due to demands to work more overtime and to work in shift, not just day time	Increased stress, caused by more monotonous work, assembly lines and increased work pace	Reduced job satisfaction, due reduced contacts with other employees				
Berglund	2007		steering, standardization	employee involvement, problem solving		Reduced workload, due to slower and more even work pace	Increased job satisfaction, through employee involvement in CI & PS	Sweden		Industrial Work Science	Student thesis. Qualitative study of company implementing Lean.
							Reduced job satisfaction from increased control, steering and standardization				

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		JIT	Jidoka	RfP							
Hunter	2002	cycle time, manufacturing cells			Decreased Human effort (work intensification, work pace)		Increased Qualification of the workforce (job enrichment) multi-skills requirements			Ergonomics	Using high-level, 3-D computer graphics simulation
					Decreased Risk of MSD development						
Bouville	2014		TQM, standardization	jobrotation, problem-solving	The perceived level of responsibility is associated with a lower level of health at work	problem-solving demand is associated with a worsening of health at work	job rotation is negatively correlated with intent to stay and job satisfaction	France		Human Resources Management	quantitative analysis carried out on a French national database (n = 24,486)
						quality management is positively correlated to health at work	standardization is associated with lower levels of job satisfaction ad intent to stay				

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Cullinane et al.	2014	JIT, Continuous flow, Reduced set-up times, Pull systems	TPM	Employee involvement		lean-specific job demands (i.e. production pace, problem-solving, accountability and task interdependency) are positively related to negative health-related outcomes (i.e. exhaustion)	Lean-specific job resources are positively associated with work engagement.	Ireland	multinational pharmaceutical manufacturer	Human Resource Management	data from 200 employees
Godard	2001	JIT	TQM, re-engineering,			more stressful work	JIT have negative effects in Job Satisfaction, and Commitment	Canada		Industrial and Labor Relations	data from a 1997 telephone survey of 508 employed Canadians

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Ha¨ renstam et al.	2004		standardization , TQM		The study found that a variety of trends in organizational change in contemporary working life have varying, yet overall negative associations with healthy work			Sweden		Work and Organizational Psychology	Data were collected within the confines of an interdisciplinar y Swedish study
Jackson and Mullarke y	2000	workflow integrtion	process simplification	team interdependenc e	Increase work pace		decrease of autonomy	UK	Garment manufacture	Ocupational Heath Psychology	Data from 556 employees

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		JIT	Jidoka	RfP							
Scott et al.	1992	JIT					motivation increase for production workers as their JIT involvement increases	USA	Golf balls manufacturer	production and inventory management	423 questionnaires adressing job satisfaction
							Supervisors and managers involvment in JIT pratices, have no effect in satisfaction				
Lindskog	2016		standardised work, 5S, and value stream mapping	visual follow-up boards,		None of the lean tools influenced employee and manager exhaustion	Standardised work and VSM significantly promoted engagement in development	Sweden	Healthcare	Hospital Administration	longitudinal quantitative study involving employees and managers in two hospitals and one municipality
							visual follow-up boards and 5S did not affect engagement in development				

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Nahmens et al.	2012		Kaizen event				increase in job satisfaction after Lean implementation	USA	Homebuilding Sector	Lean Construction	Company-wide questionnaires
							workers with more experience appear to have lower job satisfaction, there was no significant difference in job satisfaction between age groups				
Pagell et al.	2014	JIT	TQM, TPM	self-directed work teams	Increased use of JIT harms workers			USA	2 industries: manufacturing and logistics	Transactions on Engineering Management	The sample (150 facilities with +50 employees
					self-directed work teams improve safety and mitigates the negative effects of JIT						

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Shaikh et al.	2012		Kaizen event			Increases stress		UK	University experiment imitating automotive manufacture	Human Factors	Experimental task, 12 participants
Sprigg and Jackson	2006	Cycle time, workflow integration	standardization			the leaner the work environment, the higher was employee strain	less control over both the timing and methods aspects of their work	UK	Call center services (IT, financial services, retail, utilities, hotels and leisure, public/ voluntary sector, transport and travel, emergency services, and outsourcing)	Occupational Health Psychology	Using data from a sample of 823 call handlers from 36 call centers, these lean characteristics are examined in relation to the prediction of call handler job-related strain.
						a lean system was associated with lower control and higher work demands	they performed less varied tasks; and they had less opportunity to exercise their skills				
von Thiele et al.	2016		kaizen boards (continuous improvement)		Decreased discomfort	Increased mental health (Denmark)	increased job satisfaction (Denmark ans Sweden)	Denmark, Sweden	Postal service, Hospital	human relations	2 cluster-randomized, controlled participatory intervention studies

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Benders et al.	2016		Continuous Improvement (CI)			burnout risk decreased slightly	Job engagement did not change significantly	Holland	Training Hospital	Heealth planning and management	52 nurses survey measuring Job demands and Job resources
Dierickx	2016		poka-yoke, checklists, root cause analysis, 5S			5S (reduces stress)		Japan	Metal industry, bearing manufacturer	Dissertation in Business Engineering	multiple-case study, comprising five Japanese and five Belgian cases. each company was given a score for muda, muri and mura, based on the questionnaire and the visits
		U-cell	jidoka, poka-yoke, standard work, value stream map, 5S				commitment to improvement, skill development, intrinsic motivation multi-skilled and flexible employees	Belgium	Telecommunication: electronics production		
			standard work, root cause analysis, 5S principles				good relationship with employees, developing and sustaining a sense of trust, emphasis on people first, multi-skilled employees	Belgium	Metal industry: machining of castings and forgings		

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		JIT	Jidoka	RfP							
Schoutetten and Benders	2004	JIT, takt time	TQM, TPM, standardization, 5S, Kaizen management		Few problems with health/ physical reactions		Autonomy limited	Netherlands	Bike assembly	Economic and Industrial	Giant Europe Manufacturing B.V. (GEM),assembles about 300,000 bicycles a year. 63 surveys (1999)
					Need for resting higher		High dissatisfaction with work content				
							Work satisfaction limited				
							Support from supervisors or other departments had decreased				
Robertson et al.	1993	Lean bundle	Lean bundle	Lean bundle	Increase musculoskeletal disorders	increased Fatigue, stress, tension		Canada	Automotive manufacturer GM-SUZUKI	Occupational Health Psychology	Case study
S.K.Parker et al.	1995	JIT				increased Fatigue, stress, tension		UK	Automotive manufacturer	Occupational Health Psychology	35 employees prospective survey

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		JIT	Jidoka	RfP							
Fucini and Fucini	1990	Lean bundle	Lean bundle	Lean bundle	Increase musculoskeletal disorders	increased Fatigue, stress, tension		Canada	Automotive manufacturer (Japanese transplants)	Occupational Health Psychology	Case study
Graham	1995	Lean bundle	Lean bundle	Lean bundle	Increase musculoskeletal disorders	increased Fatigue, stress, tension		USA	Automotive manufacturer (Subaru-Isuzu)	Occupational Health Psychology	Case study
Mullarkey et al.	1995	JIT	TQM			No changes in stress	No changes in job satisfaction	UK	eletronics manufacturer	Occupational Health Psychology	56 manufacturers prospective survey
S.K.Parker et al.	1997	JIT	quality improvement	Multiskilling		No changes in stress	Increased job satisfaction	UK	chemical	Occupational Health Psychology	139 employee survey
Batt and Applebaum	1995	Modular manufacture			Increased workpace	Increased stress	No changes in job satisfaction	USA	Garment manufacture	Occupational Health Psychology	562workers in 6 plants in 3 companies
Moye and Rosenthal	1996		quality improvement	Teams	Increased workpace	Increased stress	Increased job satisfaction	USA	eletronics manufacturer	Occupational Health Psychology	72 employee survey
Bertelli	1996		quality program	Teams	Increased workpace	Increased stress	Increased job satisfaction	USA	aerospace	Occupational Health Psychology	80 employee survey

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		JIT	Jidoka	RfP							
Bortolotti	2016	**Hard:**Setup time reduction, Equipment layout for continuous flow, Kanban,	**Hard:**Autonomous maintenance,	**Soft:**Small group problem solving, Training employees, Top management leadership for quality, Continuous Improvement			soft practices improve employees' commitment		mechanical, electronics and transportation equipment sectors		survey in 278 facilities to test theoretical framework (effects of soft and hard lean tools on employee selection and commitment)
							hard practices don't increase their commitment				

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Koukoulaki	2014	JIT	Standardization, TQM, Poka-yoke	autonomous groups	JIT increases work load and time pressure, reduces breaks which contribute to MSD risk factors like High repetitiveness and lack of recovery	TQM increases pressure to come up with new quality improvement ideas and poka-yoke increases feeling of defects blaming increasing psychosocial demands and role overload	JIT increases work load and time pressure, reduces breaks which contribute to psychosocial risk factors like demands-resources-control imbalance			Applied Ergonomics	literature review across the last 20 years (1990e2013) and has included several studies on lean production effects in automotive manufacturing and other sectors (36 studies)
					Standardization increase work pace and working overtime contributing to MSD risks		Autonomous groups increses decision control and job support which consequently increase control at work and social support buffers				

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Shadur et al.	1995	JIT, pull production,	quality circles	teamwork, training, suggestions scheme		Increased stress		Australia	Automotive	Human Relations	200 employee survey
Sim et al.	2011			quality training, supervisory support , top management support			quality training contribute to job satisfaction	USA	manufacturing		151 surveys
							supervisory support enhanced career satisfaction				
							top management support is not related to career satisfaction				