

# An Approach for the Integration of Non-ergonomic Work Design as a New Type of Waste in Lean Production Systems

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**Abstract.** Nowadays, Lean Production Systems are an industry standard implemented to achieve the objectives set by the management. The overall goal is to reduce costs and delivery time as well as to increase quality. By reducing waste, production processes are improved and, in turn, help to achieve these objectives. However, mostly technical or organizational changes are being made. Human Factors and Ergonomics is not seen as a potential for waste so far although non-ergonomic work causes high costs for companies. The paper outlines four different approaches for integrating non-ergonomic work in the framework of Lean Production Systems.

**Keywords:** Human factors · Ergonomics · Lean production systems

## 1 Introduction

Lean Production Systems (LPS) are commonly implemented in German companies and can be seen as an industry standard nowadays [1]. They are used to coordinate individual subsystems within the company and aim at reducing costs, increase quality and, as a result, improve the company's overall competitiveness. In order to achieve these aims, processes that do not contribute to value-adding are identified and considered as waste. These non-value-adding processes often relate to technical or organizational processes such as transportation, waiting time or inventory. However, many studies examining the impact of lean production on social systems indicated that they can have a negative effect on the employees [2]. The typical lean production is often characterized by the lifting and carrying of heavy loads, static postures or repetitive activities which all have a significant impact on employees. Being exposed to those impacts result in musculoskeletal disorder and psychosocial risks [3]. For example, according to a calculation of costs arisen for the absence time of ill workers by Federal Institute for Occupational Safety and Health (BAuA) Germany, about 130 million days of incapacity to work were caused by musculoskeletal disorder in Germany 2015. As a consequence, this high number of days of incapacity to work led to a production loss of €14.1 billion [4]. Given the fact that non-ergonomic work has great potential to

contribute to the overall aim of LPS by boosting productivity, it is hardly perceived as waste. Therefore, possibilities to implement non-ergonomic work design as a new type of waste in Lean Production Systems have to be identified.

## 2 Work Stress and Human Factors and Ergonomics

The perspective towards the role of human work has drastically changed over the past decades [5]. In the early 20<sup>th</sup> century, employees were seen as a necessity during the production process. There was no responsibility or actions taken to keep or even improve the workers' health. In case of an accident, the worker was replaced. Over the past decades, the fundamentals of work ethics changed and the importance for workers' health and employer responsibility increased. Nowadays, the awareness for health and work-life-balance are important aims for most individuals as well as companies in order to stay as long as possible in the company.

However, production processes have a great impact on the health of the employee and result in work stresses which affect the employee. A work stress is defined in the DIN EN ISO 6385 as the total of external conditions and requirements in a work system which affect a person's physiological and /or psychological condition [6]. A work stress is not automatically a negative impact on health. It can even positively affect human health because an underchallenge of an employee can, for example, lead to a feeling of monotony and in the worst case cause illnesses [7]. Therefore, an overload as well as a underchallenge of the employee has to be avoided. Due to the diversity in personal performance prerequisites, the same work stresses lead to different strains. According to Hardenacke et al., five skills can be affected by working stress. These are endurance, cardiovascular system, perception and reaction, sensitivity and commitment as well as creativity [8]. Through the individual response of a person to a stress, various illnesses can be caused, whereby the so-called strain can be both physical and psychological. If, for example, the requirements for the employee are continuously increase by an improved production process, the stresses for the latter may become uncontrolled, which in the worst case can lead to the incapacity to work and, thus, the employee's absence times [9]. Therefore, it has to be questioned to which extent adaptations of the working system can be made without causing more stresses for the employee. If, for example, walking distances are reduced by reducing inventories or transport activities, this can lead to a reduction in load changing, thus increasing the risk of musculoskeletal disorders. In addition, endurance is less stressed by the elimination of walkways. This may be advantageous, but a minimum should be maintained to activate the cardiovascular system. The risk of cardiovascular disease, such as a heart attack, is also increasing here. Furthermore, by eliminating unnecessary processing steps and superfluous movements, compensating movements can be eliminated, which eliminates a load change and promotes musculoskeletal disorders. In addition to the physical stress, psychological stresses can arise. These are caused, for example, by work intensification or pressure to perform and can lead to a burnout in the extreme case [10].

Work-related musculoskeletal disorders are common and mainly caused by a lack of movement, lack of exercise or overload. This affects people who work on the

computer as well as in the production [11]. For 2012, it is shown that musculoskeletal disorders are generally among the four greatest impacts on the populations health [12].

The manufacturing sector is characterized by high physical workloads, such as the lifting and carrying of heavy loads. As an example, the Federal Institute for Occupational Safety and Health in Germany has carried out a calculation of the economic costs related to incapacity for work for 2015 [4]. Today, the manufacturing sector is above average for with 17 days of incapacity to work per employee per year, with a large proportion of these days caused by musculoskeletal disorders. Taking into account the fact that, on average, the highest payment is paid in the manufacturing sector, this sector has the highest production loss costs of €5.13 billion per year [4].

Due to this imminent development, it is of utmost importance to focus on the health of employees. In order to achieve this objective, Human Factors and Ergonomics provides suitable methods and tools, with the focus on the prevention of occupational stresses [13]. Human Factors and Ergonomics is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design and optimize well-being and overall performance [14].

The ergonomic workplace design is a core element of these preventive measures [15]. The design of work systems, places, products and processes are made according to criteria, which are characterized by physiological performance and psychological conditions of humans as well as their measurements [3]. Thus, new illnesses of the musculoskeletal system or an exacerbation of an existing musculoskeletal disorder can be avoided. Despite these well-known solutions, methods of Human Factors and Ergonomics are not applied adequately [3, 14]. In a review of leading experts for Human Factors and Ergonomics, four reasons were identified: limited applicability of the methods and tools, multidisciplinary, unclear communication to the external world, and lack of awareness of the problem [14]. Above all, the lack of awareness of the problem is a decisive factor in under-estimating the importance of Human Factors and Ergonomics [16]. Only the attainment of a knowledge for a problem leads people to seeking solutions. With the emerging awareness of the problem, it is to be achieved that health is maintained by preventive methods. Once this awareness has been created, this will lead to a health-conscious behavior, which will affect both the profession and private activities [3, 17]. In order to counter this lack of awareness of the problem, competences in the field of Human Factors and Ergonomics has to be developed.

### 3 Lean Production Systems

In modern production plants, workstations and processes are designed according to the principles of Lean Production Systems. LPS have the target to consider the aspects of technology, organization and humans equally [18]. The definition of a Lean Production System is stated in the VDI 2870 as “an enterprise-specific, methodical system of rules for the continuous orientation of all enterprise processes to the customer in order to achieve the objectives set by the enterprise management” [1, 19]. Generally, the focus is on technical and even more on the organizational process design. In order to reach higher efficiencies and, consequently, to be more competitive, elimination of wasteful

activities in all company processes is the major target in LPS [14, 19, 20]. In this context, waste can be seen as all kinds of non-value-adding activities that do not contribute to the product in terms of increasing the customer value. In LPS seven different kinds of waste can be distinguished:

- Over production
- Waiting time
- Transportation
- Over processing
- Inventory
- Motion
- Defects and touch up [19].

As shown in Fig. 1, an LPS consists of different elements. On the first level, an enterprise has to define targets. In most cases, target dimensions stand for the strategic targets of an enterprise and are quality, costs and time. Since strategic targets affect the entire organizational structure they need to be referred to all enterprise processes. Enterprise processes are the second element in a LPS. Within the third element of a LPS, the strategic targets are executed. On this level, an LPS consists of different Principles that define a coherent overall framework. Each principle leads to defined methods and tools which can be used in order to achieve the targets. Methods and tools are the fourth element in a LPS [19].

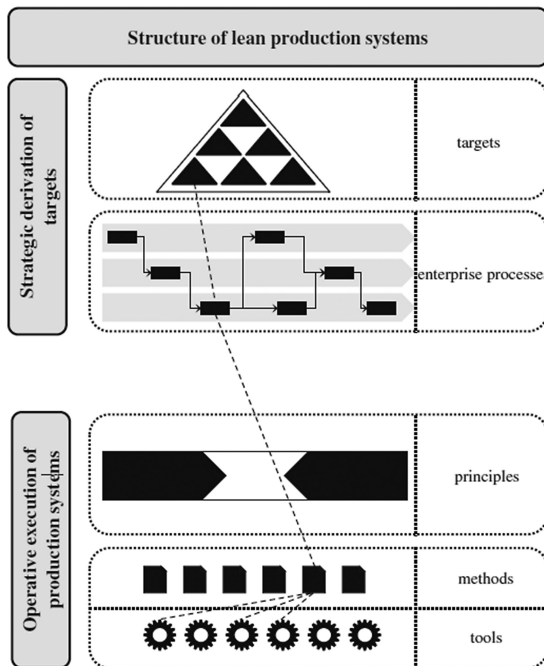


Fig. 1. Structure of lean production systems [19]

In the following the structure of a LPS is explained with an example. The top target of a manufacturing company is to improve the quality. Therefore, Sub-targets are sustainable process mastery in manufacturing and assembly-friendly product design. For this purpose, relevant manufacturing processes need to be defined, e.g., for turning, milling or grinding. As to achieve the strategic target, a suitable principle is “zero-defects-production”. The principle combines methods and tools that are used to re-duce the number of defects that are passed to the next production step and to ensure a high product and process quality. Especially Six Sigma, automation, Poka Yoke and 5x Why are methods of this principle [19].

As it is mentioned above, LPS are used to comprehensively and continuously design enterprise processes. The processes are optimized to lower costs, save time or improve quality. However, methods of human factors and ergonomics are not consequently implemented in all elements of an LPS. Mostly, they are just used as methods and tools in different principles. As an example, the 5S-Method includes the cleaning of the work station. This is an important prerequisite for Human Factors and Ergonomics because it focuses the safety of the work station. However, it is not perceived as part of Human Factors and Ergonomics but to LPS. Therefore, it is assumed that there is only little awareness for Human Factors and Ergonomics in industry. In the next section, different options for the integration of Human Factors and Ergonomics in LPS are being presented.

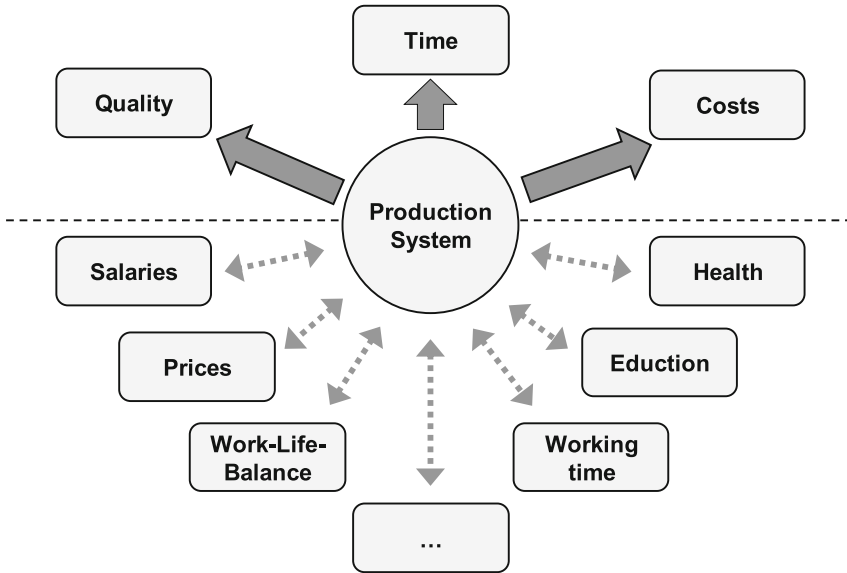
## **4 Human Factors and Ergonomics in Lean Production Systems**

As shown in the previous section, Human Factors and Ergonomics is a crucial factor for companies to secure employees health. It is an important mean for companies to employ healthy and motivated employees in order to stay competitive.

Lean Production Systems have the target dimensions quality, time or costs [19]. However, the way in which the product is produced is often not recognized, but has considerable implications for employees and the Society. For example, industrialization triggered such substantial changes in society that they, retrospectively, are considered technical revolutions. The change in the mode of production and thus of the production systems, has a significant influence on the quality of life and prosperity of a society [1].

Usually, the overall strategic targets of a company are to reduce costs as well as time and to improve quality. However, this is just the tip of the iceberg. Figure 2 shows different aspects which have influences on those strategic targets.

Salaries have an impact on production systems because they ultimately can reduce or, mostly, increase costs for staff. Therefore, solutions have to be found that help to compensate higher costs like automation or staff reduction. Changes like prices for resources, work-life balance, working time, education and health can have similar effects on production systems. As mentioned in Sect. 2, musculoskeletal disorders also have a significant impact on production systems [2]. However, the effects do not only work one way. Many studies over the past 20 years showed that LPS also have effects on employees. As to use the example of the LPS introduction, the zero-defects-method can not only lead to the improvement of quality but also to the work intensification for



**Fig. 2.** Social relevance of production systems [1]

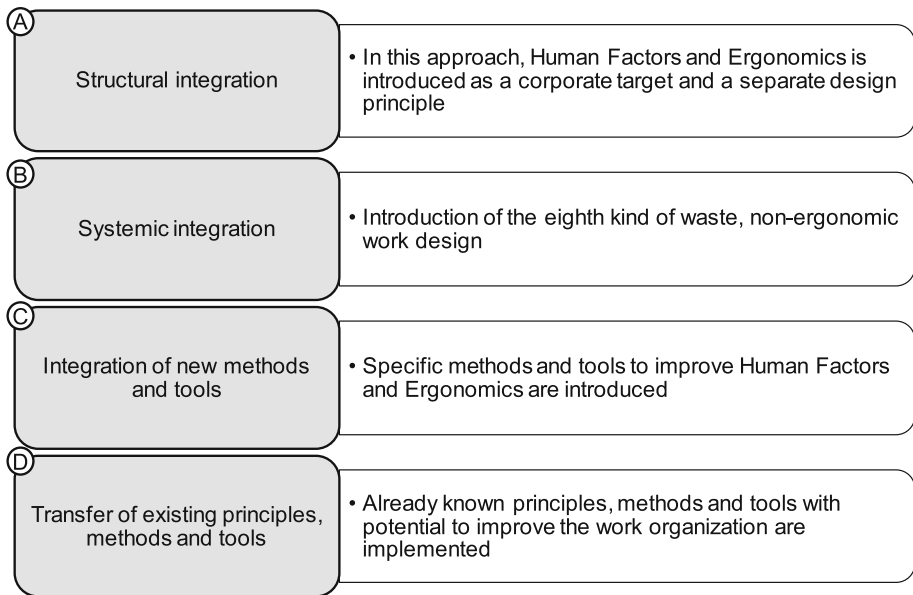
the employee. This effect can be caused by increased process controls which can e.g. lead to a reduction of hidden breaks for the employee. If the worst case occurs, the work stress increase causes an illness for the employee and results in a long-term absence.

The example shows that LPS not only have positive effects. The studies concerning the impact of LPS on musculoskeletal disorders and psychosocial risks showed that those effects are mostly negative [2, 21]. As mentioned earlier, specific lean methods lead to an intensification of work. Therefore, compensation like additional buffers or work breaks have to be considered to avoid the negative impacts. Human Factors and Ergonomics offer several methods and tools compensate the intensification of work for the employee. For a successful integration, those methods and tools have to be integrated in an overall structure. The existing LPS framework as an industry standard can be used as a basis to implement Human Factors and Ergonomics successfully. In the next section, different possibilities are shown to implement Human Factors and Ergonomics in LPS.

## 5 The 9<sup>th</sup> Pillar in LPS

An analysis of existing LPS has shown that Human Factors and Ergonomics is not consequently implemented [13]. For the analysis, 20 LPS with about 800 methods were evaluated with the focus of the degree of implementation of ergonomic methods. The result was that only 23% of these methods consider Human Factors and Ergonomics. Therefore, the awareness for and implementation of Human Factors and Ergonomics

has to be raised because it can create immense benefit by improving employee health as well as reducing the overall costs for enterprises. As shown in the previous section, LPS represent an industry standard in German companies and are used to give a framework for the implementation possibilities. Therefore, according to the four elements of LPS, four implementation possibilities developed. Those can be used to adapt LPS to the need of creating awareness for Human Factors and Ergonomics as well as to sensitize for musculoskeletal disorders. In the development of the solutions, particular attention was paid to the effects of the interaction of LPS in order to achieve a lasting improvement. Figure 3 shows the approaches for the sustainable integration of Human Factors and Ergonomics in LPS.

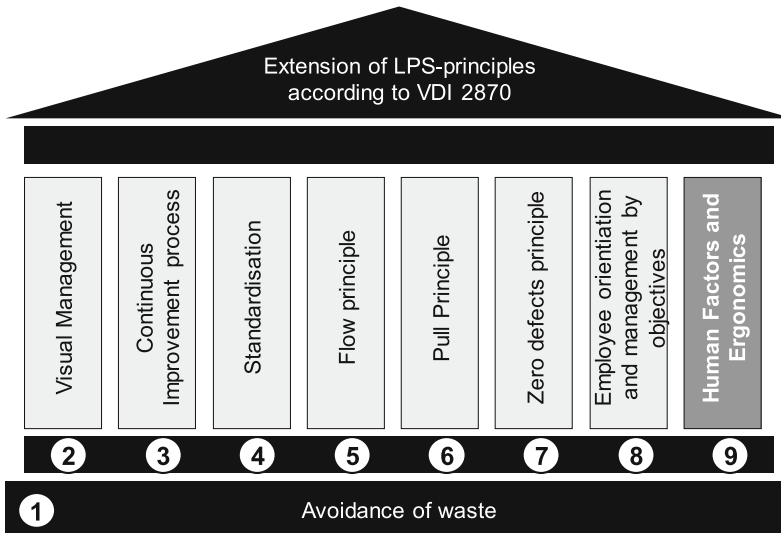


**Fig. 3.** Different approaches to implement human factors and ergonomics in LPS

In a structural integration, for Human Factors and Ergonomics a new corporate target and a separate design principle is integrated into the LPS. This creates the pre-requisite for bundling new methods in a design principle and ensuring a systematic application. However, in order to ensure a regular application of the design principle and the methods contained, the Human Factors and Ergonomics must also be anchored in the company's objectives. This is the only way to pass through the cascade from the target to the tool.

Furthermore, the structural integration is of particular importance because the structure of a LPS is usually visualized and seen as a symbol for the entire LPS. For this reason, the structure is usually depicted in company presentations and other marketing tools. Thus, the structural integration also leads to an improved perception of Human Factors and Ergonomics. As a consequence, all employees are obliged to life

and secure methods of Human Factors and ergonomics. Therefore, it leads to a higher awareness on all levels from management to the shop floor. Especially managers need to not only implement these methods but also to become role models and to encourage other managers and employees to do the same. The most common forms of visualizing a LPS are the house, the circle and the product of the company [21]. Figure 4 shows the structural integration using the example of the VDI Guideline 2870.



**Fig. 4.** Extension of LPS-Principles according to VDI Guideline 2870

The next approach proposes a systemic integration of Human Factors and Ergonomics in the LPS. In particular, the adaptation of the design principle “avoidance of waste” is an option since this is the basis for the other design principles. The focus of waste prevention is the elimination of any activities that do not contribute to the added value of the customer [4]. In the future, it will no longer be sufficient to consider the avoidance of waste only from the customer’s point of view. Rather, aspects such as the health of the employees must also be focused. Accordingly, it is necessary to expand the seven types of waste. A possible extension is to add Human Factors and Ergonomics. Thus, the principle is kept more general in order to cover all aspects of the field.

The integration of new methods and tools into the LPS structure is necessary for the operational implementation of Human Factors and Ergonomics. This enables employees and managers to implement Human Factors and Ergonomics in their daily working routines. A study of different LPS showed that only very few methods have been anchored in the LPS for the purpose of improving non-ergonomic work [13]. In particular, methods for assessing and improving ergonomics can be integrated. Such methods are already used in companies today. However, they are not an integral part in LPS and are therefore not effective. In recent years, the European Assessment Worksheet (EAWS) has become a standard for industry in the assessment of ergonomics [22].



In addition to the EAWS, other methods besides ergonomic assessment like appropriate work design or occupational health management should be integrated into the LPS.

The idea of the fourth integrational approach is to transfer existing LPS design principles, methods and tools to Human Factors and Ergonomics. An important prerequisite for this approach is the enlargement of the concept of waste, which has been explained above. As a result of this extension, methods for avoiding waste can also be used in a targeted manner to shape human work (e.g. PDCA, 5× why or benchmarking). But other methods can be applied as well. By using Poka Yoke, for example, employees can be not only assisted to not produce accidental mistakes, but also to avoid lifting heavy loads. The conventional 5S method is also well transferable. By adding another S in the sense of sorting, selecting, keeping clean, making sure, standardizing and self-discipline there would be an extension to 6S. Thereby, an improvement of the work safety would be achieved.

Not only methods, but also design principles can be transferred. The design principle of standardization is particularly suitable. The transfer would not only determine the best processes in terms of quality, time and costs, but also take into account the criteria of Human Factors and Ergonomics. A zero-defects principle could also be conceived, which would combine methods and tools that would contribute to a continuous reduction of the days of incapacity to work.

## 6 Conclusion

Musculoskeletal disorders have a great impact on the productivity of companies. As a result, a consistent and sustainable human work design is required. Today, modern companies often design their workplaces and processes according to the principles of LPS, which in recent years have more and more developed to a standard in industry. LPS focus mainly on monetary aspects such as quality, time and costs when it comes to work design. Other aspects like Human Factors and Ergonomics are only considered little. Therefore, even though Human Factors and Ergonomics can contribute to the economic aspects by reducing days of incapacity to work, there is no awareness for this. As to raise awareness and implement Human Factors and Ergonomics in LPS, four different approaches for the sustainable integration were presented in this article. The first approach provides for the integration of Human Factors and Ergonomics into the structure of the LPS. In addition, a systemic integration of Human Factors and Ergonomics as well as the integration of new methods and tools are presented. The transfer of existing design principles, methods and tools forms the fourth part of the solution approach. By implementing Human Factors and Ergonomics into LPS, not only the awareness of all organizational members is being raised but also a systematic implementation is created. Therefore, it is integrated in an overall framework and is harmonized with the other enterprise targets.

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