Integrating the Lean concept in sustainable manufacturing development

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Abstract. In the current context of climate change in the world, it is increasingly necessary to implement strategies and ways of action to adapt industrial companies to sustainable production. The implementation of the Lean concept has a particular impact on creating added value, by reducing wastage, production waste and improving efficiency in order to obtain products/services of higher quality. Through a new approach, the authors propose the use of Lean techniques to develop sustainable manufacturing with an impact on the environment and their implementation in the production sectors. The main objective of the paper is to highlight the opportunities and challenges of Lean Manufacturing in the context of sustainable development. At the same time, the application of Green Manufacturing concept is the development of products/services/processes that save energy, natural resources, with beneficial effects on the environment. A starting point in the analysis will consist of the detailed study of the literature regarding the use of this two concepts, the limits that still occur in their implementation and the finding of a methodology for networking them. The results will demonstrate that integrating the two dimensions will lead to increased performance of the system and to the development of a sustainable company.

1. Introduction
The development of advanced production systems now involves profound changes that will affect both the basic technique and the management, organization and quality assurance techniques. The establishment of advanced production systems has been achieved in highly industrialized economies (such as Japan, USA, Germany, etc.), with the current development prefiguring profound mutations and transformations. The implementation of the concept of Industry 4.0 in the context of sustainability will, according to studies currently underway [1 - 3], have an important impact on the creation of added value in the industrial environment, together with the emergence of new opportunities related to the development of sustainable production, the characteristics of each company.

Competitive environment forces increasingly more organizations, industrial companies to review, restructure and redirect activities to achieve competitive advantage in terms of sustainable development. The concept of Lean manufacturing, as a new philosophy, successfully applied in the field of increasing production efficiency, can be developed and implemented together with the concept of Green manufacturing. Integration of the two dimensions can lead to increased competitiveness, the performance of the organization and, last but not least, the development of sustainable companies.
The Lean concept was developed by Taiichi Ohno in the 1950s and later developed by Shigeo Shingo and was first applied in the automotive industry, within the *Toyota Production System* (TPS), [4].

Lean philosophy was developed in the West by Womack and Jones (2003) [5], who considered this type of management as "an antidote against waste - any human activity that does not bring value". Currently there are two organizations that implement this management philosophy: Kaizen Institute Ltd. (Masaaki Imai, Switzerland, 1985) [6] and the Lean Enterprise Institute (J.P. Womack, USA, 1996) [7]. By efficiently applying Lean tools and techniques, the system has been rethought, the processes in the value chain have been controlled and improved to increase performance, the speed of processes and to minimize waste. To meet customer demand not only through Lean objectives, companies are rethinking modern manufacturing processes in terms of sustainable products / services ecologically sustainable, respecting government environmental regulations. At present, organizations have a proactive role in designing recyclable products, as well as developing cleaner production services and processes. Thus, the green paradigm has emerged as a philosophical and operational approach to reduce the negative environmental impact of an organization's products and services, as well as to improve the ecological efficiency of their operations, while at the same time fulfilling their financial goals [8].

1.1. The importance of research

EU waste management policies aim to reduce the impact of waste on the environment and health and to improve resource efficiency in Europe. The long-term goal is to turn Europe into a recycling society, avoiding waste and using inevitable resources as much as possible. According to Eurostat statistics [9] of 2014 and updated in 2017, total waste generated in the EU-28 by all economic and household activities amounted to 2 503 million tonnes; this is the largest quantity registered for the EU-28 in the period 2004-2014. It is noted that relatively large quantities of waste were generated in Romania, which requires the implementation of new methods of sustainable management and development.

The share of different economic activities and households in total waste generated according to the source [9] is shown in figure 1. At EU-28, in 2014, construction contributed 34.7% of the total, followed by extractive industry (28.2%), manufacturing (10.2%), water and waste (9.1%) and households (8.3%); the remaining 9.5% was waste generated by other economic activities, especially services (3.9%) and energy (3.7%).

![Figure 1. Waste generation by economic activities and households, EU-28 (%). Source Eurostat [9].](image-url)
Also, 891 million tonnes of waste was generated in the EU-28, [9] except for the major mineral waste, equivalent to 36% of the total amount of waste generated (table 1). It is noticed that the production activity registered a relatively high level of waste, of 184.1 million tons, while the evolution over time recorded a decrease of 32.2%.

Table 1. Quantity of waste in different economic sectors in the EU (Eurostat source, [9]).

|                     | 2004 (million tonnes) | 2006 (million tonnes) | 2008 (million tonnes) | 2010 (million tonnes) | 2012 (million tonnes) | 2014 (million tonnes) | Rate of change% 2004-2014 |
|---------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|--------------------------|
| Total               | 941.1                  | 942.3                  | 903.4                  | 875.2                  | 884.2                  | 890.8                  | -5.3                     |
| Agriculture, forestry and fishing | 63.1                  | 57.4                  | 46.2                  | 21.7                  | 22.3                  | 19.7                  | -68.7                    |
| Mining and quarrying | 10.4                  | 7.1                   | 10.1                  | 8.0                   | 7.8                   | 7.9                   | -24.1                    |
| Manufacturing       | 271.4                  | 250.5                 | 236.6                  | 202.8                 | 190.5                 | 184.1                 | -32.2                    |
| Energy              | 92.2                   | 100.0                 | 88.8                   | 81.9                  | 93.6                  | 90.7                  | -1.6                     |
| Waste / water       | 110.9                  | 110.2                 | 130.1                  | 149.0                 | 178.7                 | 208.0                 | 87.7                     |
| Construction        | 39.3                   | 45.2                  | 38.7                   | 50.9                  | 60.1                  | 61.8                  | 57.2                     |
| Other sectors       | 148.8                  | 160.9                 | 140.6                  | 146.5                 | 122.0                 | 115.0                 | -22.7                    |
| Households          | 205.0                  | 211.0                 | 212.3                  | 214.4                 | 209.3                 | 203.5                 | -0.7                     |

Worldwide, as a result of studies in the USA, it is noted that manufacturing processes currently generate the largest amount of waste; the power consumption of the production system is 23% of total USA energy consumption [10]. As a result, one of the priority strategies for the development of sustainable production will have to be waste reduction, which will generate a favourable impact on the environment while reducing energy consumption and emissions.

Based on the literature [4, 5, 6, 7] and the remarkable results achieved by implementing the concept of Lean in various companies [11, 12], this research will identify opportunities to incorporate techniques and tools of Lean with current concept of Green manufacturing for the purpose of sustainable development. It will develop a methodology, an integrated model of sustainable practices, Lean and Green manufacturing, which will open future research directions.

2. Lean manufacturing vs. Green manufacturing

Lean manufacturing involves a team-based approach to identifying and eliminating losses, activities that do not add value through continuous improvement, ensuring a continuous flow of product / service, responding to customer demand, with the goal of perfection. Green Manufacturing focuses on eliminating waste and emissions. Developing organic production is often costly [10, 13, 14]. Applying new regulations and methodologies in the field of sustainable manufacturing involves the adoption of a new organizational culture by employees. Lean lines up perfectly with the organizational structure, culture and performance evaluation system to create long-term results. Although there are currently studies to develop the Lean concept integrated with the Green manufacturing concept [8, 10, 15], there is no methodology and no deployment practice in companies. Activities unsustainable that industrial companies should pay particular attention are: the waste of resources and high emissions from production, quality still inadequate products, the large number of defects / rejects and therefore increased number of reprocessing, the emergence waste correlated with the dissatisfaction of employees and customers. Application methods and tools to improve leading to eliminating waste in manufacturing simultaneously with regulations on development and protecting the environment can have a positive impact on reducing costs and emissions for long periods of time [10].

Strategies to implement Lean and Green Manufacturing concepts were analysed in several studies and recent research, observing that they can be implemented both sequentially and simultaneously [15, 16]. In the paper [17], the research was geared towards applying the Kaizen concept resulting in an improvement in environmental aspects with an environmental impact. This approach has resulted in a reduction in resource use by 20% and energy flow by 5%. A detailed research [18] analyses extensively (through 58 scientific papers) the possibility of integrating Lean and sustainable manufacturing.
2.1. Lean manufacturing. Economical Sustainable

Economic sustainability is linked to strategies to manage their resources in a way that results in financial benefits for a long time. Lean manufacturing practices are among the practices that are necessary for economic sustainability [10]. Lean concept is considered a business strategy with the main objective to increase customer satisfaction through better use of resources.

Research in the papers [19] states that Lean manufacturing is the most popular investment choice among companies that invest to remain competitive, flexible and profitable. By applying the Lean strategy in manufacturing systems, the effectiveness of the implemented system has been demonstrated, resulting in a number of benefits: reducing the direct and quality costs by 5-20%, reducing the waiting times by 80%, processing speeds, reducing production unfinished (WIP) and 50-80% finished product stocks, increase in operating profit by about 5%, waste reduction, productivity improvement, operational performance and quality, production flexibility, efficient use of labour, space and production capacity.

Lean Management methods can be summarized in three concepts: waste reduction / losses, maintaining quality of products / services and accelerating production. To implement the Lean concept, it is necessary to know the specific tools: Mapping Process, Value Stream Mapping (VSM), Six Sigma, 5S, Cellular Manufacturing, Kanban System, JIT Concept, Kaizen Continuous Improvement, Standardization, TQM (Total Quality Management), TPM (Total Preventive Maintenance), etc.

2.2. Green manufacturing. Sustainable manufacturing

Sustainability or sustainable development is generally defined as "development that meets the needs of today's generation, without compromising the ability of future generations to meet their own needs". Sustainability has three dimensions, namely economic prospects, ecological balance and social responsibility [20].

The paper [21] suggests that "a sustainable company is one that generates profits for its shareholders, while protecting the environment and improving the lives of those with whom it interacts". Also referred to as sustainable manufacturing, Green manufacturing has as major concern the consequences of production activities and the entire life cycle of the product on the environment. In another view of this concept there is a set of strategies, practices and behavior, to prevent, reduce and / or eliminate the negative impact on the environment [22, 23].

The synergy between the two Lean and Green manufacturing concepts [24] can be achieved from the waste patterns identified in the two systems (figure 2).

![Figure 2. Forms of waste identified by Lean manufacturing & Green manufacturing.](image-url)
The main operational activities [10] for waste reduction are: product redesign, replacement, reduction, recycling, remanufacturing, return, stock control, domestic consumption, reduction of transport, and reduction of defects.

Among the advantages of Green manufacturing can be listed: saving valuable resources, economic incentives, energy efficiency and environmental benefits by reducing waste and harmful emissions, competitive advantages, quality and reliability.

3. Implementation methodology

The identification and measurement of mass and energy flow, followed by the continuous improvement of the environmental value flow, is now a reflection, given the increasing environmental concern. These activities are similar to Lean Management principles to ensure information flows, material and energy continue in industrial processes. The integrated Lean & Green Manufacturing model will analyse the mass and energy flows of a plant as a final customer and will analyse the impact on sustainable development, [14]. The Lean Manufacturing and Green Manufacturing concept integration and implementation scheme is outlined in figure 3, where we can see the synergies between Lean thinking and the continuous improvement of the environment.

![Figure 3. Lean & Green Manufacturing integrated implementation scheme.](image)

The main stages of implementing a Lean & Green Manufacturing integrated model involves:

- identify the flow of values by identifying critical points that require improvement;
- identification of the environmental aspects and the impact of the value flow in manufacturing, according to the standards in force (ISO 14001);
- measuring the flow of environmental values, by identifying data about the environmental process;
• analysis of productivity in resource use and potential impact on the environment;
• lean management, organizing the team by involving the specialists, the managers;
• improving environmental value flows by identifying waste disposal opportunities;
• implementing plans for continuous improvement of the environment for strategic business projects; the improvement opportunities identified by the lean application will be integrated into the continuous improvement plan for the environment.

The implementation of Lean tools in production leads to the development of economic sustainability, through the efficient use of resources and the achievement of impressive benefits. Lean practices tend to lead to green results, being the first step in developing a green company.

4. Conclusions
Although it does not directly aim to reduce environmental impact, Lean methodology can provide environmental benefits by improving the environment while increasing productivity. The fundamental principle of Lean thinking, continuous improvement and employee empowerment creates opportunities for the development of sustainable green industries by reducing waste and emission elements that characterize Green manufacturing.

In the new integration concept for the development of sustainable manufacturing, Lean aims to link the core production targets, such as cost reduction and production times, to Green manufacturing waste disposal targets that affect the environment. It thus tends to interlink the objectives of the three pillars of sustainable development: economic sustainability, sustainable manufacturing and social sustainability. Although recent studies show a synergy of the two concepts, there is no common methodology yet, an agreement on their inter-implementation. In the development of a sustainable company, Lean and Green Manufacturing can mean an innovative. A future research activity is required to investigate real links, overlaps, advantages and disadvantages, positive impacts and even gaps, development and implementation of the Lean & Green Manufacturing concept, by developing an integrated model applicable to various organizations.

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