# SUSTAINABLE DEVELOPMENT SUPPORTED BY LEAN TOOLS IN ASSEMBLY PROCESSES – A SYSTEMATIC LITERATURE REVIEW

## *Zrównoważony rozwój wspierany przez narzędzia lean w procesach montażu – systematyczny przegląd literatury*

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**Abstract:** Sustainable Development (SD) is necessary to implement in production processes in order to improve the economic aspects of enterprises and to protect workers and the environment. This paper demonstrates the needs to continue the research connected with sustainable development. The article deals with research works in the field of assembly and presents a systematic literature review looking for Lean Tools (LT) implementation to improve sustainable development of assembly processes. Topics discussed in the reviewed papers in the context of the research are identified as well as LT implemented were identified. Moreover, the influence on SD aspects presented in the studied papers was identified and the connections with the sustainability goals were indicated. Despite the fact that enterprises have shown interest in the discussed subject the impact of LT on SD aspects, i.e. ecological, economic and social, is not directly indicated in context on assembly. The presented quantitative analysis proves that the problem is not widely discussed in the literature. While the impact of LT on companies was studied in general, the research usually did not focus on the assembly process. On the basis of the conducted literature review, a gap was discovered that can be filled in future research by proposing an LT set that can be used in the organization to improve assembly lines and support SD. In future research, the authors intend to thoroughly analyse the aspects of LT implementation for SD by conducting research at selected assembly sites.
**Keywords:** Lean Tools, Sustainable Development, assembly process, systematic literature review

**Streszczenie:** Zrównoważony rozwój (SD) jest konieczny do wdrożenia w procesach produkcyjnych w celu poprawy ekonomicznych aspektów przedsiębiorstw oraz ochrony pracowników i środowiska. W artykule wskazano na potrzebę kontynuowania badań związanych ze zrównoważonym rozwojem. Artykuł dotyczy prac badawczych z zakresu montażu i przedstawia systematyczny przegląd literatury dotyczący wdrażania narzędzi lean w celu poprawy zrównoważonego rozwoju procesów montażu. Ustalano tematy poruszane w analizowanych artykułach w kontekście badań i zidentyfikowano wdrożone narzędzia lean. Ponadto zidentyfikowano wpływ na aspekty zrównoważonego rozwoju przedstawiony w badanych artykułach oraz wskazano związki z celami zrównoważonego rozwoju. Pomimo zainteresowania przedsiębiorstw omawianym tematem, wpływ narzędzi lean na aspekty zrównoważonego rozwoju, tj. ekologiczne, ekonomiczne i społeczne, nie jest bezpośrednio wskazywany w kontekście montażu. Przedstawiona analiza ilościowa dowodzi, że problem ten nie jest szeroko omawiany w literaturze. Chociaż ogólnie badano wpływ narzędzi lean na przedsiębiorstwa, badania zwykle nie koncentrowały się na procesie montażu. Na podstawie przeprowadzonego przeglądu literatury odkryto lukę, którą można wypełnić w przyszłych badaniach proponując zestaw narzędzi lean, który można wykorzystać w organizacji do usprawnienia linii montażowych w celu wsparcia zrównoważonego rozwoju. W przyszłych badaniach autorzy zamierzają dogłębnie przeanalizować aspekty wdrażania narzędzi lean dla zrównoważonego rozwoju prowadząc badania w wybranych procesach montażu.
**Słowa kluczowe:** narzędzia lean, zrównoważony rozwój, proces montażu, systematyczny przegląd literatury

## Introduction

Sustainable Development (SD) is widely discussed in the literature. In Web of Science database 78 165 papers can be found using as a keyword "Sustainable Development". About 80% of the papers are from the areas such as: environmental sciences and studies, green sustainable science technology, economics, management, engineering environmental, and energy fuels. Moreover, 208 papers present systematic literature review. More than 80% of them are connected with green sustainable science technology and environmental sciences. 4 of the papers presenting systematic literature review are in the group of engineering manufacturing and they discuss sustainability assessment in manufacturing organisations [8], integrated management systems [6], sustainable supply chain management [18] and issues connected with project management [30].

1% of the 78 165 papers are classified in the group of engineering manufacturing what shows how few research, comparing to other fields, were done in area of engineering manufacturing. Moreover, in this group only

18 papers can be retrieved when the word "assembly" is used in the searching process. These papers are connected with remanufacturing [15, 16], disassembly [21], Lean Six Sigma [29], Lean Design for eXcellence [2] and sustainable design [4, 10, 25], strategy for smart automation [31], intelligent systems [27], green productivity [24], products servicing [17] as well as composites, constructions, hole technologies, knowledge management and LCA (Life Cycle Assessment). This short search indicates that sustainability problems are not widely discussed together with assembly processes and Lean Tools.

The authors of this paper aimed to identify Lean Tools which support sustainable development in assembly processes. None of the mentioned papers answered the question how Lean Tools can support sustainable development. It is important to study this topic, since the LTs are simple and easy to be implemented in different environments and do not require high skills from employees who use the LTs. Moreover, if such simple tools can give a positive influence on SD this should be studied and supported. Currently, not all companies are already ready to implement high technologies and sophisticated tools. Still in many cases LTs are the best and maybe the only option. Therefore, the authors decided to develop a methodology and perform a systematic literature review to reach the papers discussing Lean Tools in SD context, in the area of assembly processes.

In the section entitled "Sustainable Development" the authors present what Sustainable Development is. Then, a short review of Lean Tools is presented. In section "Research questions and methodology", the work methodology and research questions are described. The section "Results analysis and discussion" shows the search results and discussion. The last section summarizes the work presenting conclusions and future work.

## Sustainable Development

Sustainable Development (SD) aims in meeting of economic and social needs without jeopardizing natural resources and the quality of environmental which are the basis of human health, safety, security and economic well-being [11]. The United Nations General Assembly adopted a set of 17 goals connected with sustainable development (https://www.un.org/sustainabledevelopment/).

Two of them are directly connected with assembly processes, namely:

- *Goal 9 – Industry, innovation and infrastructure* – innovations in assembly process such as, for example, augmented reality might facilitate the process [5], and
- *Goal 12 – Responsible consumption and production* – implementation of assembly process simulations can decrease a number of errors performed in the process, prevent reassembly and safe resources [22].

Other goals can be indirectly affected by proper organization of assembly processes. Other goals are: Goal 1 – End poverty, Goal 2 – Zero Hunger, Goal 3 – Good Health, Goal 4 – Quality Education, Goal 5 – Gender equality, Goal 6 – Clean Water and Sanitation, Goal 7 – Clean Energy, Goal 8 – Economic Growth, Goal 10 – Reduced Inequality, Goal 11 – Sustainable Cities, Goal 13 – Climate Action, Goal 14 – Protect Oceans, Goal 15 – Protect Biodiversity, Goal 16 – Peace, justice and strong institutions, Goal 17 – Partnerships.

Three SD aspects have been already mentioned: economic, social and environmental aspect. All of them can be analysed in relation to the assembly process. Economic aspects are connected with such work organization that only value added activities and other necessary activities are performed in the process. To improve this aspect a work stand can be also equipped with the tools which can speed up the assembly process so in the same amount of time more products can be assembled. This way there are no wastes in the process or the wastes are minimal and the process is completed in a minimum time. Social aspects are also connected with work organization which should be friendly for workers. Work organization is related to arrangement of work items on a work stand, use of user-friendly tools and proper organization of working time. Environmental aspect in assembly process are related to minimization of resources consumption, especially energy. Assembly methods are also important in the life cycle management because they determine possible future disassembly and reusing of a product components.

## Review of Lean Tools to be applied in assembly process

Lean Tools are to identify and eliminate wastes. In industry different lean tools are used to improve work organization [26]. Using the words "Lean Tools" a mental shortcut was applied. By Lean Tools the authors understand lean tools, techniques, methods and systems supporting lean manufacturing. The most popular of them which can be additionally implemented to support an assembly process, are [26, 27]:

- 5S to ensure order at the workplace,
- FIFO to ensure that products are processed in the specified sequence,
- 5Why? to identify source cause in case of problems appearing,
- Work Standardization to ensure process repeatability,
- Poka Yoke to prevent mistakes,
- Team Work to have the benefits of synergy effect,
- Kanbans to implement pull system and assemble only what is needed by customers,
- TPM to ensure that necessary equipment is always ready to be used in a process,
- Visualization enabling quick understanding of what is happening in the workplace,

- Value Stream Mapping to see the whole assembly process which can be realized in different steps and on different workstations,
- Just in Time to minimize inventory levels and in the same time ensure process continuity,
- Takt Time to dictate the pace of production,
- SMED for decreasing a changeover time and prepare fast a workstation for assembly process of other type of products,
- One Piece Flow, to decrease lead time,
- U-shape line to have in the same place input and output of the assembly process and short distance between workstations in case if more than one workstation is operated by one worker.

The question is whether the Lean Tools can support sustainable development and to what extent it is discussed in the literature in context of assembly processes.

## Research questions and methodology

In the study the following research questions were identified:

RQ1: How much sustainable development (SD) and lean tools (LT) are discussed in the literature in context of assembly process (AP)?

RQ2: Which are the topics mostly discussed in conjunction with sustainable development (SD) and Lean Tools (LT) in context of assembly process (AP)?

The work methodology contains the following activities: identification of keywords, development of a searching rule, selection of databases and adoption criteria, papers retrieval, analyses and discussion.

In the work tree databases were chosen to be searched: Web of Science, Scopus and Science Direct. The searching process is based on the keywords such as "Lean tools", "Sustainable Development" and "Assembly" as we as the words being the modifications of the mentioned keywords. During the article identification stage, the article title, abstract and author keywords were searched.

The presented searching rule was applied: (*"Lean tools" OR "Lean techniques" OR "Lean methods") AND ("Sustainable Development" OR "Sustainability" OR "Sustained Development" OR "Sustainable-Development" OR "Sustained Growth") AND "Assembly"*.

The search was focused on journal and conference papers as well as book chapters published in English. 16 different papers were retrieved what is a small number. This can mean that the topic is not widely discussed by the researchers. Several of the papers were registered in different databases, therefore it was necessary to eliminate duplicates to have the final number of 16 papers. These papers were the subject of further quantitative and qualitative analysis. The quantitative analysis concerned numbers of publications in years and type of publications. In the frame of qualitative analysis author keywords and available full texts were studied.

## Results analysis and discussion

This section presents the performed analysis. Figure 1 shows the interests on the analysed topic in time. The first paper was published in 2006. The analysis does not show a significant increase in interest in the topic.

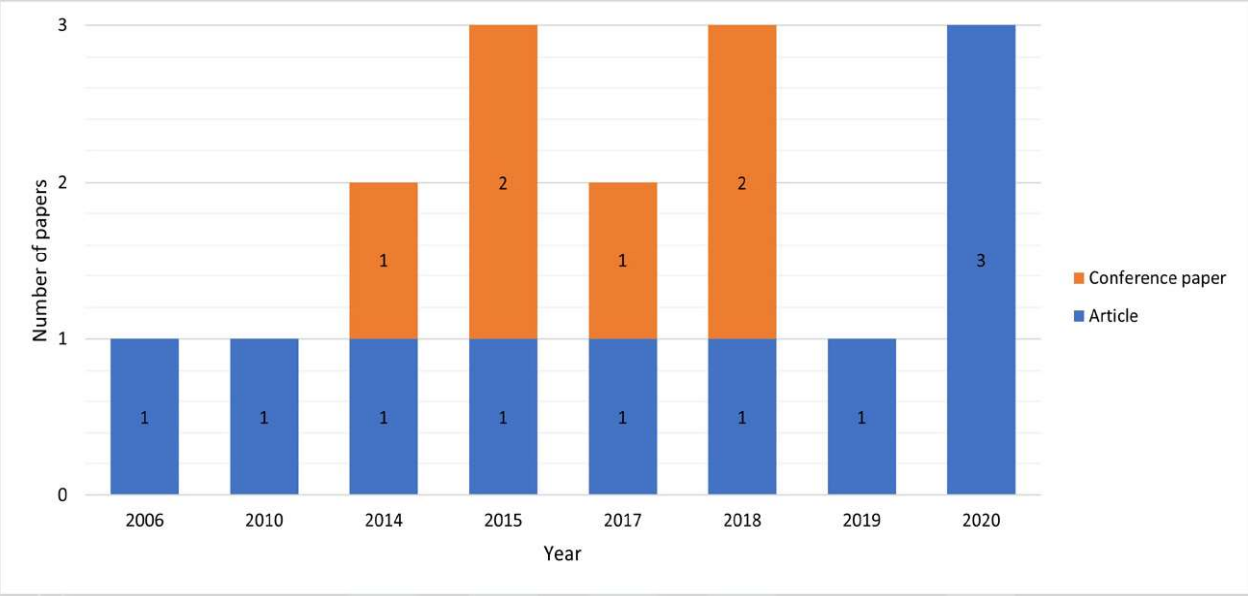


Fig. 1. Number of papers in years by type

In further analyses first, the author keywords coming from the publications were studied. 102 keywords were identified in all analysed papers and grouped to identify the discussed topics (Table 1). Among others, such issues as Lean Tools, Continuous Improvement, System, Sustainability, Economical Aspects, Environmental Aspects, Social Aspects, Optimization, Design, Lean, Construction, Layout and Supply chains were identified.

Table 1. Topics and keywords

| Topic | Keywords | Number of keywords |
|---|---|---|
| Lean tools | Lean Tools, Lean Tools, 5S, SMED, Value Stream Map (VSM), Value Stream Mapping, VSM, Value Chain, Waste Flow Mapping, TPM, Spaghetti Diagram, Standard Process, String Diagram, Bottleneck Process, Takt Time, Chalk Circle Exercise, DMAIC, Method, Digital Instructions | 19 |
| Continuous improvement | Continuous Improvement, Lean Process Improvement, Lead Time Reduction, Lean Transformation, Newly Elaborated Combined Improvement, Improvement Workshop | 6 |
| System | Lean Systems, Toyota Production System, Lean Project Delivery System, Last Planner System, Boeing Integrated Defense Systems | 5 |
| Sustainability | Sustainability Performance, Sustainable Development, Sustainable Manufacturing System, Sustainable Pallet, Social Sustainability, Enabler For Sustainability, Ingredients of Sustainability | 7 |
| Economic aspects | Cost Reduction | 1 |
| Environmental aspects | CO2 Emissions, Energy Management, Environmental Impacts, Environmental Management, Environmental Sustainability, Environmental System Analysis, Lean Energy, Material Efficiency, Green Lean, Green Manufacturing | 10 |
| Social aspects | Lean Culture, Societies and Institutions, Lean-Educated Workforce | 3 |
| Optimization | Multi-Objective Optimization | 1 |
| Design | Design Model, Axiomatic Design | 2 |
| Lean | Lean Manufacturing, Lean Manufacturing Environment, Lean Production, Lean, Lean Methodology | 5 |
| Construction | Lean Construction, Construction Industry | 2 |
| Layout | Facility Layout Design, Layout Enhancement, Industrial Plants, Plant Management | 4 |
| Supply chains | Supply Chains | 1 |
| Other | Apache Helicopters, Manufacturing Industry, COA Label, SLP, DEMATEL, Fishing Industry, GUI Interface, Real Case Study, Engineers, Production Engineering, Rapid Process, Server Manufacturing, Cell Manufacturing, Waste Management Services, Assembly, Small Scale Industry | 16 |

In the next step, the abstracts and the available full texts were analysed. One of the retrieved papers was on application of lean methods to improve surgical clinic experience. Another one, presented a case study from shellfish company. One paper investigated advantages coming from sustainable returnable packaging. Since, they were not connected with assembly processes they were excluded from the papers for further analysis.

Table 2 presents the retrieved papers and connected data such as the information about type of the paper and full text availability as well as the databases in which the papers are registered. Four papers are registered in Scopus, two papers are registered in Web of Science and thirteen papers are registered in Science Direct. Six papers are the conference publications published, among others, in Procedia Manufacturing (4 papers). Three papers are published in Journal of Cleaner Production. For 3 papers full texts were not freely available.

Table 2. Searching results

| Paper ID | Authors | Title | Journal / Publication | Paper type | Full text | Database |
|---|---|---|---|---|---|---|
| 01 | Kovács (2020) | Combination of Lean value-oriented conception and facility layout design for even more significant efficiency improvement and cost reduction | International Journal of Production Research | Article | No | Scopus Science Direct Web of Science |
| 02 | Kurdve (2018) | Digital assembly instruction system design with green lean perspective-Case study from building module industry | Procedia CIRP | Conference Paper | Yes | Scopus Web of Science |
| 03 | Saha et al. (2014) | Lean transformation for server manufacturing environment | IIE Annual Conference and Expo 2014 | Conference Paper | Yes | Scopus |
| 04 | James (2006) | It's all in the mind | Manufacturing Engineer | Article | Yes | Scopus |
| 05 | Barot et al. (2020) | Implementation of lean practices in water heater manufacturing industry | Materials Today: Proceedings | Article | Yes | Science Direct |
| 06 | Verma and Sharma (2017) | Sustainable competitive advantage by implementing lean manufacturing "A Case study for Indian SME" | Materials Today: Proceedings | Article | Yes | Science Direct |
| 07 | Oliveira et al. (2017) | Continuous improvement through "Lean Tools": An application in a mechanical company | Procedia Manufacturing | Conference Paper | Yes | Science Direct |
| 09 | Francis and Thomas (2020) | Exploring the relationship between lean construction and environmental sustainability: A review of existing literature to decipher broader dimensions | Journal of Cleaner Production | Article | No | Science Direct |
| 10 | Chiarini (2014) | Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers | Journal of Cleaner Production | Article | No | Science Direct |
| 12 | Fahad et al. (2017) | Energy Management in a Manufacturing Industry through Layout Design | Procedia Manufacturing | Conference Paper | Yes | Science Direct |
| 14 | Das (2018) | Integrating lean systems in the design of a sustainable supply chain model | International Journal of Production Economics | Article | Yes | Science Direct |
| 15 | Nujoom et al. (2019) | Drafting a cost-effective approach towards a sustainable manufacturing system design | Computers & Industrial Engineering | Article | Yes | Science Direct |
| 16 | Kurdve et al. (2015) | Waste flow mapping to improve sustainability of waste management: a case study approach | Journal of Cleaner Production | Article | Yes | Science Direct |

Based on the performed keywords analysis it can be seen that SD aspects (economical, ecological and social aspects), were widely discussed. However, only one keyword was assign to economic aspect. The sustainability aspects and connected topics discussed in the papers, identified after full texts reading, are presented in the Table 3. In the table the authors also presented a sustainability goals which can be supported by the actions presented in the papers.

Table 3. Sustainability aspects discussed in the papers

| Sustainable Development | | | Paper ID | Industry/Process | Supported sustainability goals |
|---|---|---|---|---|---|
| Ecology | Economy | Social | | | |
| - | Work efficiency with the standardized instructions | Standardized instructions to support workers and to ensure "easy jobs", equipment design, training system, ergonomics, safe work environment | 02 | Construction industry (building modules) | Equality promotion (G1) Reduced Inequality (G10) |
| Material utilization minimization (paper) by implementing dashboard enabled database system | Production cycle time reduction, minimizing rework activity time | Employee training, employees satisfaction assessment | 03 | Server manufacturing | Economic Growth (G8) Quality Education (G4) |
| - | - | Employee training, building awareness among employees, employee support and suggestion program | 04 | Aviation, car industry | Quality Education (G4) Decent Work (G8) |
| | Reduction of work in progress, cycle time and lead time | Standardizing work procedure Work conditions improvement | 05 | A water heater manufacturing | Responsible production (G9) |
| - | Reduction of the cycle time and cost | - | 06 | The CNC machining | Responsible production (G9) |
| Reduction of equipment replacements | Productivity improvement, better quality, less breakdowns, lower costs, reliable deliveries | Employees commitment, motivating working environments, greater safety, improved self-confidence of the employees | 07 | A mechanical company | Responsible production (G9) |
| Reduction of material flow, fuel consumption, emissions, carbon footprint, improvements in lighting system | Economic savings from less fuel and energy consumption | - | 12 | Manufacturing Industry Energy Management | Responsible production (G9) Quality Education (G4) Climate Action (G13) |
| Alternative materials, reduction of energy, water, waste and all other types of waste of non-renewable materials | improving overall effectiveness, cost reduction, elimination of production-related wastes | Training for employees, empowering employees, eliminating obstacles in material flow, organization of workplaces | 14 | Supply chain management | Responsible production in a supply chain (G9) |
| Carbon dioxide ($CO_2$) emissions, energy consumption, | Cost reduction | - | 15 | Warehouse area Factory Supplier area | Responsible production in a supply chain (G9) |
| Optimising of number and type of bins, fractions, optimizing of containers and equipment for separation, sorting and storage | The total operation costs, optimising of maintenance and cost of ownership/rent | - | 16 | Machine industry (manufacturer of trucks, buses, construction equipment and drive systems for marine) | Climate Action (G13) Responsible production (G9) |

***The paper 02 (Kurdve, 2018)*** is focused on work standardization. In the frame of the work digital assembly instructions were developed. The main motivation of the work was to ensure "easy jobs" as many workers being immigrants in Sweden have low education. The problem is to ensure a safety work environment and an efficient work by delivering simple work instructions covering reasonable amount of work and be even done by workers with physical handicaps. Visual work instructions are proposed as solutions of the mentioned problems.

***The paper 03 (Saha et al., 2014)*** is focused on waste elimination in server manufacturing process. The paper presents the process analysis in which lean tools such as fishbone diagram, process map, time study analysis, and employees satisfaction surveys were applied. The wastes existing in the process were identified and adequate countermeasures were proposed. An IT tool was designed to track the process. Then, a training for workers was performed. Next, a survey assessed the workers satisfaction with the new tool.

***The paper 04 (James, 2006)*** addresses issues related to employees' concerns when implementing changes. It shows how companies build awareness among employees through education, communication and employee involvement by empowering them to make decisions and by launching a suggestion system that is to encourage them to actively participate in the continuous improvement process.

***This paper 05 (Barot et al., 2020)*** looks for improvements in water heater manufacturing process. A company has to meet three basic customer requirements: timely delivery, good quality of the product and low price, with a strategy of continuous improvement. Company implemented value stream mapping, String diagram, 5S, TPM, Cellular manufacturing, standard work instructions to reduce non value added activities, cycle time and lead time.

***This paper 06 (Verma and Sharma, 2017)*** work presents a case study of implementation of lean manufacturing in a manufacturing company to identify non value added activities and eliminate wastes. The identified waste are related to equipment failures, bottleneck process, defects, waiting time, inventory and material handling. The above problems are analysed in concern with rejection control, inventory control, setup time and non-value added time. It has been found that the reason for non-value added activities are due to wrong handling material, long distance, defect and improper inventory.

***The paper 07 (Oliveira et al., 2017)*** suggests several lean tools, such as standard work, value stream mapping, 5S, visual management, Kanbans, line balancing, Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE), Single-Minute Exchange of Die (SMED), TQM that can be used to indicate the improvements and achieve productivity and profitability. Moreover, it is underlined that lean's purpose is to develop critical skills and competencies in organizations. The paper presents a case study connected with mechanical equipment manufacturing. It is worth to emphasize that the presented LTs can be additionally supported by, for example, digitalization, what can increase the efficiency. An example of LTs digitalization, nowadays quite widely implemented in industry, is connected with electronic Kanban system. In standard Kanban system the paper Kanban cards, as it comes from experience, can be lost, can be taken home by employee what disrupts work of the assembly process. This will never happen in electronic transfer of Kanban cards. An assigned number of the cards will always go around in a loop.

***The paper 12 (Fahad et al., 2017)*** addresses a very important issue regarding energy management, which is a big step towards green production and sustainable development. The main goal of Lean is to increase productivity, i.e. minimize costs and time, as well as analyse waste and use waste that has an impact on the environment. The conducted energy audit allowed for the categorization of the types and costs of energy consumption, the assessment of alternatives that can significantly reduce energy costs and the establishment of an application plan for energy saving projects.

***The paper 14 (Das, 2018)*** presents lean system applications in a supply chain design and planning to improve sustainability performances. The work identifies lean practices that can be applied in supply chain management. It also takes into account lean product development for assembly purpose.

***The paper 15 (Nujoom et al., 2019)*** describes the SMS (Sustainable Manufacturing Systems) system based on the MOO (Multi-objective optimization) model, which was developed in order to search for sustainable development between the economic and environmental aspects. The analysis concerns energy consumption and $CO_2$ emissions, and the research was conducted in three areas: supplier, warehouse and factory. The MOO model is based on the DEMATEL algorithm. The use of the algorithm makes it easier to make a decision when a compromise is found between minimizing the total cost required to establish the initial development and proper production, energy consumption and $CO_2$ emissions during operation. However, not in all cases it is possible to have access to data which can be used to create a mathematical model. Moreover, the model needs to be adequate to be applicable for a certain purpose. If it is not a case, simple LTs can be applied to improve a process. Although, the parameters will not be optimal the process will give better results. In many cases it is enough. Especially when continuous improvement is implemented and when in an assembly process there is a large variety and variability of the assembled products.

***In the paper 16 (Kurdve et al., 2015)*** described the analysis intended to find economically competitive environmental improvements on team, site and multi-site level, through best practice examples, and to define suitable performance indicators to secure implementation and continuous improvements. The collected data concerned the volumes and costs of treatment of waste fractions and costs of external services, while environmental and economic data from each site was used to validate and complement the supplier data waste analysis focusing the waste classification and the waste hierarchy. The research was carried out in 16 sites of two companies from the machine industry (trucks, buses, construction equipment, drive systems for marine).

Table 4. Problems discussed in the analysed papers; NP – number of papers

| Identified Problems | Paper ID | NP | Identified Problems | Paper ID | NP |
|---|---|---|---|---|---|
| **Bottleneck process** | 06, 16 | 2 | Maximum productivity | 15 | 1 |
| **Case study** | 02, 03, 05, 06, 07, 12, 15, 16 | 8 | Risk minimization | 15 | 1 |
| **Cellular manufacturing** | 05 | 1 | Layout | 05, 06, 07, 12 | 4 |
| **Continuous improvement** | 03, 04, 05, 06, 07, 12, 14, 15, 16 | 9 | Overproduction | 15 | 1 |
| **CO2 emissions** | 15 | 1 | Outsourcing | 14 | 1 |
| **Costs of production** | 12 | 1 | Optimization | 06 | 1 |
| **Creating partnerships with suppliers** | 14 | 1 | Unnecessary inventory | 15 | 1 |
| **Design of product** | 14 | 1 | Unnecessary movement of materials | 15 | 1 |
| **Depletion of natural resources** | 15 | 1 | Performance assessment | 03, 05, 06, 07, 12, 14, 16 | |
| **Economic savings** | 12 | 1 | Production planning | 06 | 7 |
| **Elimination of reworks** | 14 | 1 | Raw material | 14 | 1 |
| **Employees' concerns** | 04 | 1 | Reduction of stock | 14 | 1 |
| **Employee engagement** | 04, 05, 14 | 3 | Rejection control | 06 | 1 |
| **Energy consumption** | 15 | 1 | Rising energy costs | 12 | 1 |
| **Energy Management** | 12 | 1 | Supply chains | 06, 07, 12, 14, 16 | 1 |
| **Excess motion** | 15 | 1 | Training system | 04, 14 | 5 |
| **Green Manufacturing** | 12 | 1 | Traceability of mistakes | 02 | 2 |
| **Industry 4.0** | 07 | 1 | Quality problems documentation | 02 | 1 |
| **Information management** | 14 | 1 | Waste hierarchy | 16 | 1 |
| **Inventory control** | 06 | 1 | Wastes identification | 05, 06, 07, 12, 16 | 1 |
| **Material efficiency** | 16 | 1 | Waste segregation | 16 | 5 |
| **Material handling** | 16 | 1 | Waste in processing and the waste of rework | 14, 15 | 1 |
| **Materials Management** | 14 | 1 | Work assignment | 05, 06 | 2 |

The discussed topics are summarized in Table 4.

Table 5 presents Lean Tools discussed in the analysed papers with underlined in the papers positive effect of the environmental (EN), economic (EC), social (SO) aspects.

The presented tools, techniques and methods as well as systems such as TPM or TQM, have been applied in companies which realize assembly processes. Unfortunately, the researches presented in the papers not always are directly related to the assembly process and this process was just one of the processes analysed in the companies. Therefore, it is difficult to conclude that the positive effect of Lean Tools on SD came with

Table 5. Lean tools discussed in the analysed papers with underlined positive effect of the SD aspects: environmental (EN), economic (EC), social (SO); NP – number of papers

| Lean and other tools, methods, techniques, systems | Paper ID | NP | SD aspects |
|---|---|---|---|
| 5S | 05, 07, 14, 16 | 4 | EN, EC, SO |
| 7 wastes | 03, 06, 07, 12, 14, 16 | 5 | EN, EC, SO |
| Fishbone diagram, 5 Why, Root cause analysis, Cause of equipment failure | 03, 06, 16 | 3 | EN, EC, SO |
| Animated instructions, Digital instructions | 02 | 1 | EC, SO |
| Energy relation chart | 12 | 1 | EN, EC |
| LCA (Life Cycle Assessment) | 16 | 1 | EN, EC |
| Line balancing | 05, 07, 16 | 3 | EN, EC, SO |
| Customer satisfaction surveys | 03 | 1 | EN, EC, SO |
| Diagram Pareto, Diagram Pareto-Lorenz | 07, 16 | 2 | EN, EC, SO |
| EMA (Environmental Management Accounting) | 16 | 1 | |
| Gembutsu, Gemba | 07, 16 | 2 | EN, EC, SO |
| Flow chart | 16 | 1 | EN, EC |
| Jidoka | 16 | 1 | EN, EC |
| Just In Time | 07, 14 | 2 | EN, EC, SO |
| Kanban | 07 | 1 | EN, EC, SO |
| LR (Lean Relations) | 14 | 1 | EN, EC, SO |
| MFCA (Material Flow Cost Accounting) | 16 | 1 | EN, EC |
| MHA (Material Handling Analysis) | 16 | 1 | EN, EC |
| MOO (Multi-objective optimization) | 15 | 1 | EN, EC |
| MOPSO (Multi-Objective Particle Swarm Optimization) algorithm | 15 | 1 | EN, EC |
| MTBF (Mean Time Failures) | 07 | 1 | EN, EC, SO |
| MTTR (Mean Time to Repair) | 07 | 1 | EN, EC, SO |
| OEE (Overall Equipment Effectiveness) | 07 | 1 | EN, EC, SO |
| Poka Yoke | 02 | 1 | EN, EC, SO |
| Process map | 03, 04, 05, 06, 07, 14, 15, 16 | 8 | EN, EC, SO |
| SCs (Closed loop supply chains) | 14 | 1 | EN, EC, SO |
| SIPOC (Suppliers, Input, Process, Output, Customer) | 16 | 1 | EN, EC |
| SLP (Systematic Layout Planning), U-shape layout | 12 | 1 | EN, EC |
| SMED (Single-Minute Exchange of Die) | 07 | 1 | EN, EC, SO |
| SMS (Sustainable manufacturing systems) | 14 | 1 | EN, EC, SO |
| SOO (The single objective optimization) | 15 | 1 | EN, EC |
| SOP (Standard Operation Procedure) | 16 | 1 | EN, EC |
| Spaghetti diagram | 16 | 1 | EN, EC |
| Standardisation | 02, 03, 04, 06, 07 | 5 | EN, EC, SO |
| String diagram | 05, 16 | 2 | EN, EC, SO |
| Takt time | 06, 07, 14, 16 | 4 | EN, EC, SO |
| Teamwork | 02, 04, 07, 14, 16 | 5 | EN, EC, SO |
| TQM (Total Quality Management) | 07, 14 | 2 | EN, EC, SO |
| Time study analysis | 03, 06 | 2 | EN, EC, SO |
| TPM (Total Productive Maintenance), TPM check-sheet | 05, 07 | 2 | EN, EC, SO |
| WFM (Waste Flow Mapping) | 16 | 1 | EN, EC |
| VSM (Value Stream Mapping) | 05, 06, 07, 14, 16 | 5 | EN, EC, SO |
| Visual Management | 07 | 1 | EN, EC, SO |

their implementation just in assembly processes. They have rather given the positive effects on the companies. The obtained results can be compared to the work [7]. In the mentioned work the tools are analysed taking into account outcomes and effects of Lean Tools implementation on sustainability types. For example, standardization improves production rate what have positive influence on economic aspects and in the same time systematizes work, what, according to the authors, have additionally influence on environmental aspect. Moreover, standardization creates workforce driven collaborative environment what has positive influence on social aspects. The results obtained in this work confirm that standardization has positive influence on this three SD aspects also when assembly processes are discussed.

## Conclusions and future work

The main goal of the paper was to identify, based on a systematic literature review, how Lean Tools can support SD. First, in the paper the sustainable development together with the sustainability goals were defined. Then, a review of Lean Tools and their possible application in assembly process was presented. Then, a systematic literature review, focused on Lean Tools implementation towards sustainability improvements in areas connected with assembly process was performed. It was identified, that really few papers touch this problem and it is not sufficiently discussed in the literature how Lean Tools can affect sustainability of assembly processes. The retrieved papers, which were connected with the analysed topic were studied. The connected areas of research presented in the papers as well as applied Lean Tools were identified. Moreover, the connections with the sustainability goals were identified.

This paper contributes to the literature in presenting what Lean Tools are applied to improve manufacturing processes, especially assembly processes and how they can positively influence SD aspects. Moreover, it is presented what topics are discussed in the literature in this context. Additionally, it can be concluded that there is a gap discovered on the base of the performed systematic literature review which can be filled in future researches to present a set of tools which can be used in assembly process organization to improve positive effect of the Lean Tools implementation on assembly process SD.

Based on the performed analyses, it can be said that the topic needs to be further analysed. These few articles retrieved during the database search are not enough to present generalized conclusions concerning LT influence of assembly process sustainable development. The presented work is a part of a bigger studies. In future research the authors plan to analyse deeply what are the advantage of Lean Tools implementation for SD conducting researches in chosen assembly areas.

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