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ВЛИЯНИЕ БЕРЕЖЛИВОГО ПРОИЗВОДСТВА НА ОКРУЖАЮЩУЮ СРЕДУ: СИНЕРГИЯ ЭФФЕКТИВНОСТИ И ЭКОЛОГИИ

The article explores the relationship between Lean production methods and their impact on the environment. The mechanisms of reducing resource consumption, reducing emissions and waste generation, as well as the synergy of Lean principles with environmental management systems and ESG initiatives are analyzed.

Keywords: lean manufacturing, Lean, environmental management, sustainable development, ESG, waste (muda), emission reduction, decarbonization, resource efficiency, Toyota Production System.

Annotation

Against the background of stricter environmental legislation and rising raw material costs, the concept of lean production is being transformed, ceasing to be solely a tool for optimizing economic efficiency. This paper explores the fundamental correlation between Lean methodologies and their environmental impacts. An analysis of mechanisms that help minimize resource consumption, reduce emissions and waste generation is carried out, along with examples of the synergy between lean principles and environmental management systems as well as ESG initiatives.

Introduction: the new role of lean manufacturing

Historically, lean manufacturing has been viewed as a management paradigm whose main goal is to achieve maximum consumer value while reducing inefficiency at all stages of the production process. This philosophy, which originated in the Toyota Production System (TPS) in the mid-20th century, identified seven key categories of losses (muda): overproduction, waiting, unnecessary transport of materials, overprocessing, excess inventory, unnecessary motion of personnel, and production of defective products.

However, in the 21st century, in light of the deteriorating environmental situation and the transition to sustainable development principles, the role of Lean has undergone a transformation. Today it is becoming obvious that any reduction in production losses automatically leads to a reduction of the burden on the environment. As researchers rightly point out, "waste is a lost resource," and minimizing it is a common goal for both economists and environmentalists. Lean manufacturing provides an opportunity not only to reduce costs but also to make industrial companies more environmentally friendly – a strategy that becomes financially attractive without additional investments in "green" technologies.

Theoretical foundations: integration of Lean and ecology

From eight losses to environmental efficiency

The types of losses initially identified within the TPS concept are closely related to environmental problems. Jeffrey Liker's introduction of the eighth type of loss – "unrealized creative potential of employees" – became the starting point for forming a systematic approach, which is now successfully applied in the field of environmental protection.

Modern scientific thought identifies several aspects where the principles of Lean and environmental safety intersect:

- Energy: rational use of energy and energy-efficient production directly reduce the carbon footprint.
- Raw materials: striving for 100% utilization of raw materials and minimization of industrial waste reduces the need for natural resource extraction.
- Space: reducing storage space lowers the need for heating, lighting and area maintenance.
- Transportation: eliminating unnecessary material movements cuts CO₂ emissions from forklifts and freight transport.

The synergy of Lean and Green

Recent research has convincingly shown that lean and green manufacturing have more similarities than contradictions. Academic reviews covering the period from 2013 to 2024 confirm the existence of a strong synergistic effect. When these approaches are integrated, companies show better results than when they are implemented separately.

Moreover, the principles of lean manufacturing fit perfectly into the ESG (Environmental, Social, Governance) framework. The use of Lean tools, such as the Just-in-Time system and Total Quality Management, allows companies to improve their environmental performance in the long term. This is achieved by optimizing processes, which leads to lower energy consumption, reduced solid waste generation, and lower atmospheric emissions.

Practical mechanisms of environmental impact

1. Reduction of industrial waste

The Lean philosophy aims to reduce the volume of industrial waste, the disposal of which requires significant costs. This is achieved through constant cost assessment in all production processes and employee involvement in resource saving. For example, the Just-in-Time (JIT) principle helps avoid material spoilage in warehouses and consequently reduces the volume of waste requiring recycling.

2. Reducing water and energy consumption

Lean integration with environmental management systems (e.g., ISO 14001) yields measurable results. Studies conducted using the PDCA (Plan-Do-Check-Act) cycle show that the combined use of these approaches can significantly improve environmental performance. In one recent study, the efficiency of industrial water treatment was improved as follows:

- Chemical Oxygen Demand (COD) decreased by 68%;
- Biochemical Oxygen Demand (BOD₅) — by 60%;
- Concentration of heavy metals (Cu) — by 67%;
- Suspended Solids (SS) — by 65%.

These results were accompanied by a 90% improvement in work efficiency (productivity).

3. Reducing the carbon footprint

The active use of Value Stream Mapping tools makes it possible to identify not only time-related losses but also energy losses. Embedding sustainability metrics such as energy consumption, waste generation, and carbon emissions into the DMAIC (Define, Measure, Analyze, Improve, Control) framework allows for measurable improvements in process stability and environmental friendliness.

Examples of leaders: when thrift leads to a "zero footprint"

The impact of lean manufacturing on the environment is most clearly demonstrated by companies that combine the Lean concept with achieving Net Zero (zero carbon footprint) goals.

Schneider Electric (Wuxi, China)

The company's electrical plant in Wuxi is a prime example of a "sustainability beacon" according to the World Economic Forum. Thanks to the implementation of the Just-in-Time system, AI-optimized energy consumption, and a closed CO₂ tracking system, the company achieved zero Scope 1 and 2 emissions eight years ahead of schedule. The results are impressive: a 90% reduction in emissions, a 15% reduction in water consumption, and the use of 100% renewable electricity. Lean principles have made it possible to optimize flows and reduce energy consumption without loss of productivity.

BMW Group (Leipzig, Germany)

BMW's Leipzig plant demonstrates how lean manufacturing integrates with energy efficiency. Highly efficient production lines, energy-efficient heating and cooling systems, and the use of wind and solar energy have become possible by optimizing production flows and minimizing material movement. Reducing material waste here directly correlates with lower operating costs.

Nestlé (Veracruz, Mexico)

At the Nescafé plant in Veracruz, lean principles helped optimize the flow of materials and reduce downtime, which inevitably reduced energy consumption. Operating on 100% renewable energy, the company is actively implementing recycling and material reuse, minimizing the amount of waste sent to landfills.

Integration with management systems

To achieve maximum effect, modern enterprises integrate lean manufacturing with environmental management systems. Research highlights the need to move from formal control activities to proactive regulatory oversight methods. The objective integration of regulatory mechanisms allows company management to strengthen control over resources, determine the exact amount and composition of waste, and develop a corrective action plan to maintain ecological and economic balance.

Conclusion

The impact of lean manufacturing on the environment is fundamental and systemic. The Lean concept, originally aimed at economic efficiency, is today one of the most effective tools for achieving environmental sustainability.

Modern research confirms that any new users of Lean should consider its implementation simultaneously with "green" practices. This allows not only increased competitiveness through cost reduction but also compliance with strict environmental standards, avoiding fines and reputational risks.

Lean manufacturing is becoming a philosophy of non-linear management that adapts all processes to changing environmental factors. As the examples of world leaders show, the leanest factories are indeed the most environmentally friendly. This is the path to decarbonization of the economy that does not require sacrifices in productivity but rather enhances it.

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