Modern Approaches to the Implementation and Use of Lean Production Models

Alexey Popov*

Ural State University of Economics, Yekaterinburg, Russia

Abstract. In an environment of rapid change, efficient production and resource management are becoming a fundamental necessity to ensure sustainable development of enterprises. In this regard, economic entities are increasingly turning to models of rational production. This article substantiates the relevance of using these models and provides an analytical review of modern approaches to their implementation and use. The article examines the key principles, advantages and disadvantages of the main models, including JIT, TQM, Six Sigma, ERP, and others. The strengths and limitations of each model are emphasized. The article highlights the advantages of the models, in particular, increase in efficiency, reduction of costs, improved product quality. The article also examines the disadvantages, which include the complexity of implementation and the need for cultural change. The article discusses a number of key problems associated with the implementation of lean production models, which include insufficient training of personnel and difficulties in adapting to changing market conditions. At the same time, the article points to prospects in the use of modern technologies, such as digitalization and automation, to improve production processes. It is concluded that the use of rational production models is promising. It will improve performance, reduce costs, improve social and environmental effects and ensure sustainable growth not only of the enterprises themselves, but also of industries and the economy as a whole.

1 Introduction

The use of rational production models by business entities at the present stage remains a pressing scientific and practical problem for several key reasons. In an increasingly fierce and global competitive environment, choosing the most efficient and optimized production model can have a significant impact on a company's competitiveness in the global market. Permanently changing market conditions require companies to quickly adapt to new requirements and changes in demand. Rational production models allow you to quickly respond to changes and effectively manage resources. Limited resources such as raw materials, energy, labour and capital require sustainable use, which is becoming increasingly important for the sustainability of companies and for reducing their environmental impact. Technological innovation, characterized by rapid changes in

*Corresponding author: prepodpopov@yandex.ru

technologies including artificial intelligence, Internet of Things, automation and digital transformation, provides new opportunities to optimize production and create more flexible and efficient production processes. Increased requirements for environmental responsibility of companies are tightening legislative requirements in the field of resource conservation and environmental protection; accordingly, rational production models can help reduce the negative impact of production processes on the latter. Increasing quality requirements due to demanding consumers pose the task to rational production models to improve the quality and reliability of the products. The trend of increasing customization demonstrates that in some industries the demand for customized products and services is growing significantly, and therefore sustainable production models are helping to meet this demand and provide customers with customized solutions. Based on these factors, choosing the best production model remains a key challenge for companies seeking to remain competitive, efficient and sustainable in today's business environment. This problem remains the focus of attention of researchers and practitioners in the field of production management and operations management. The most significant developments in this area are described by world-famous scientists J. P. Womack, D. T. Jones, D. Ross, under whose authorship the work "The Machine That Changed the World" was published, and who are the founders of the concept of lean manufacturing [1]. With regard to quality management, which is the result of rational production, the following authors are worth mentioning: the Japanese scientist K. Ishikawa, the author of the concept of "Seven Tools of Quality Management" [2], J. M. Juran, the founder of the concept of "Three-Stage Quality Management Cycle" [3], W.E. Deming, author of "14 Key Principles of Quality Management" [4]. It is impossible not to note the works of P. Hines and N. Rich developing the issues of lean manufacturing [5], M. E. Porter, the author of the "Value Creation Chain" concept [6], as well as R. J. Schonberger, a researcher in the field of lean manufacturing and the author of the work "World-Class Manufacturing : Lessons in simplicity in practice." [7] Among the Russian researchers who address these issues are O. G. Turovets [8], A. V. Pykhtina [9], A. E. Brom [10], etc. Some dissertations on the problem, in particular, by A. S. Kuzmin [11], V. Yu. Bazhina [12] are of scientific interest as well. However, in light of significant changes in the conditions for conducting economic activity at the present stage, these issues need timely updating. Thus, the purpose of this work is to dwell upon the modern approaches to the use of rational production models in the context of ongoing changes and to identify promising directions for the development and application of these models.

2 Materials and Methods

This study was related to modern approaches to lean production in the field of industrial engineering. This choice is due to the relevance of the study in the context of modern challenges and requirements for production processes. To carry out the research, a review of current scientific articles and other publications of foreign and Russian researchers, materials of dissertations in the field of rational production and related fields was carried out. The opinions of experts in the field of rational production and quality management, the experience of using rational systems by corporations General Electric, Toyota, Motorolla and others, according to open sources, are considered. The research methodology included the use of traditional scientific methods, including review, description and grouping, as well as special methods, such as critical analysis, identification of strengths and weaknesses and extrapolation.

In this work, rational production models will be understood as mathematical, statistical or analytical models developed to describe and optimize production processes and operations in industrial organizations. They are formalized systems that model various aspects of production, such as resource allocation, inventory management, production

planning, quality management, logistics and others. Lean manufacturing models are used to analyze and optimize business processes to achieve optimal productivity, reduce costs, improve product or service quality, and make informed decisions based on data and analytics. These models may include various optimization techniques, statistical analysis, and other tools that predict results and evaluate the impact of various factors on manufacturing operations.

3 Results and Discussion

When preparing this work, an analysis of the most well-known models of rational production in the world practice was carried out, identifying their strengths and weaknesses. The results are presented in Table 1.

Table 1. Critical analysis of popular lean production models

Model	Essence	Advantages	Disadvantages
Just in time (JIT)	A method of inventory management and production developed in Japan. The main idea is to minimize inventories of raw materials and finished products in order to reduce storage costs and optimize production processes. Products are produced only at the moment when customers require them	- Reduced storage costs, which is important in conditions of lack of resources and limited warehouse space; - Faster response to demand changes; - Improved quality management; - Shortening of the production cycle and increase in productivity; - Reducing of losses from product obsolescence	- High dependence on suppliers, delivery delays can cause downtime; - The risk of shortage of goods due to the lack of possibility of prompt additional release; - Instability during changes; - Difficulties in quality management; - High implementation costs
Total Quality Manage-ment (TQM)	A management methodology focused on improving the quality of products and processes. With the TQM model, all levels and employees of the organization must participate in the process of improving the quality of products or services, the goal is continuous improvement	- Product quality improvement, reduction of flaws and complaints; - Greater motivation and involvement of the employees; - Cost reduction; - Higher customer satisfaction; - Process-oriented approach; - Improved risk management	- Difficult to implement, requires significant effort, resources and time; - Impossibility of widespread application; - Difficulties in changing quality due to unclear criteria; - High costs of training and program development; - Probability of delayed results
Six Sigma system	A model for improving production and business processes that seeks to minimize defects and inconsistencies in products or services. The main goal of Six Sigma is to achieve a level of quality at which the likelihood of defects is	- Quality improvement, reduction of flaws and deviations from standards; - Cost reduction; - Focus on the client; - Strengthened control and monitoring; - Efficiency increase, optimization of	- Complexity of implementation; - Impossibility of widespread application, especially for companies with variable processes; - Need for experts; - Focus on statistics; - Not always quick results

	close to zero	processes; - Measurability of results	
Lean production system (Lean production or lean manufacturing)	A production management methodology aimed at eliminating all types of "garbage" (waste) in the production process. This method was developed based on the Toyota production system and aims to increase production efficiency	- Reduce costs due to the elimination of unnecessary operations and tools; - Productivity increase - Better quality management; - Production flexibility; - Better inventory management; - Reducing downtime of workers and equipment	- Difficult implementation, time costs; - Impossibility of widespread application; - Employee resistance; - Difficulties in measuring culture; - Risk of redesign requiring additional resources
Flexible Manufacturing System (FMS)	An automated manufacturing system designed to provide flexibility and efficiency in manufacturing operations. The main goal of FMS is to allow quick and easy changes in production processes, as well as to increase productivity and product quality	- Flexibility of production without the need to reconfigure equipment; - High level of automation, increased productivity; - Reduced production time; - Reduction of errors and defects; - Reduced warehousing costs	- High implementation costs, requiring significant investment; - Difficulty of maintenance; - Dependence on technology; - Difficulty in measuring production processes; - The system is not always economically feasible
Integrated automated production (Computer-Integrated Manufacturing, CIM)	An integrated production process management system using computer technology. Combines design, planning, management and monitoring of production operations in a single automated environment	- Productivity increase; - Improvement of inventory management; - Higher product quality; - Improved business process management; - More accurate planning and forecasting; - Reduced risk of errors	- High implementation costs; - Difficulty of implementation; - Dependency on technology; - Difficulties in measuring the system; - The need for highly qualified personnel; - Not always suitable for small companies due to high costs
Enterprise Resource Planning (ERP)	An integrated information system designed to manage all business processes and resources in an organization, including finance, production, inventory management, human resources and others	- Business processes integration; - Centralized data storage; - Efficiency increase; - Qualitative approach to decision making; - Improved inventory management; - Strengthened financial control; - Compliance with standards and regulations	- High implementation costs; - Difficulty of implementation; - Dependence on suppliers; - Does not always take into account the specifics of a particular organization; - Employee resistance; - Data security risks

The list of models given in Table 1 is not exhaustive. Modern realities dictate the need to refine and improve the existing models, as well as develop new ones.

The implementation of lean manufacturing models may face various problems and challenges that may make it difficult to successfully apply them. The main problems include:

- Complexity of models: Rational production models can be difficult to implement, especially in large and complex manufacturing organizations. Understanding and implementing such models requires highly qualified and trained personnel.
- Lack of data: Models require access to large amounts of data, including historical data on production, demand, quality and other factors. If data is not available or not accurate enough, it can skew the simulation results.
- Environmental Variability: External factors including changes in market conditions, technological innovation and political changes can influence the effectiveness of rational models. Predicting and accounting for such factors can be challenging.
- Employee resistance: The introduction of new production models may cause resistance among employees, especially if they believe that the models may change their working conditions or threaten their jobs.
- Technical Issues: Hardware and software issues, system incompatibility, and other technical issues may complicate the implementation and use of models.
- Cost of implementation: Developing and implementing sustainable production models may require significant investment in technology, training and research. This can be financially taxing for the company.
- Uncertainty of results: All models are based on simplifications and approximations of real production processes. Therefore, there is uncertainty about how accurate the simulation results will be.
- Change Management: Effective implementation of lean production models requires good change management to ensure staff are prepared for new processes and ways of working.

Successful implementation and use of lean manufacturing models requires consideration of these challenges and development of strategies to overcome them. This may include training staff, collecting more accurate data, adapting models to a changing environment, and providing leadership and support from company management.

The process of introducing lean production models should include the stages shown in Fig. 1.

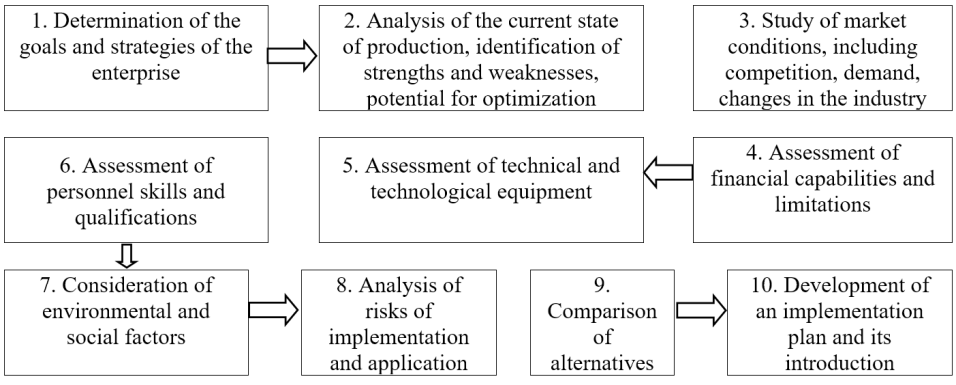

Fig. 1. Scheme and sequence of implementation of lean production models

The introduction and use of sustainable production models in industrial engineering has significant prospects and can lead to a number of beneficial results. The most important ones include:

- Increased production efficiency, expressed in the optimization of production processes, which will increase productivity and reduce production costs. This is especially important in industrial engineering, characterized by the production of high-tech and expensive products.
- Modeling and control of production processes make it possible to more effectively manage product quality, which can reduce the number of flaws, manufacturing defects and lead to a reduction in complaints.
- Reducing the time for the development and production of innovative types of products. This facilitates faster response to changes in market conditions and customer needs.
- Rational models contribute to greater accuracy of analysis and controllability of multifunctional production complexes, which is important to ensure their reliability and efficiency.
- Modeling and optimization of production processes lead to a reduction in the negative impact on the environment, increasing environmental sustainability and safety, which is one of the trends in the development of modern industry.
- Optimizing production using rational models can make engineering enterprises more competitive in the market, which contributes to profit growth and business expansion.
- Modeling and data analysis can help identify potential areas for innovation and new product development, which can expand the product portfolio and increase revenue.

Overall, lean manufacturing models provide a variety of tools and techniques that can significantly improve manufacturing operations in mechanical engineering. They can help businesses become more flexible, efficient and competitive, which is key to success in this industry.

4 Conclusion

This article analyzed the implementation and use of lean manufacturing models, covering a variety of methodologies and approaches aimed at optimizing production processes and resource management. Sustainable production models play a critical role in improving enterprise efficiency, reducing costs, improving product quality and business sustainability. Each model considered has its own unique advantages and limitations, and the choice of the appropriate model depends on the specifics of the enterprise, its goals and market conditions. It is important to emphasize that the successful implementation of a lean production model requires not only an understanding of its principles, but also a systematic approach to changing business processes and training personnel.

Lean manufacturing models are a valuable tool for improving the operational performance of enterprises in various industries. The choice of model must be justified by and based on the goals and strategy of the enterprise, as well as on an analysis of the current situation and resources. It is important to note that models are not universal, and successful implementation requires adaptation to specific conditions and needs. The question of constantly updating and improving models in response to changing market requirements and technological innovation remains open.

Despite limitations and challenges, sustainable production models remain a key element of operations management and can contribute to sustainable growth and development of enterprises. At the same time, their updating and development is the direction of further scientific research and practical implementation in this area.

References

1. J. P. Womack, D. T. Jones, From lean production to lean enterprise, Harvard business review, **72**, 2 (1994)
2. K. Ishikawa, J. H. Loftus, *Introduction to quality control*, 98 (1990).
3. J. M. Juran, *Juran on leadership for quality* (2003)
4. W. E. Deming, Improvement of quality and productivity through action by management, National productivity review, **1**, 1 (1981)
5. P. Hines, N. Rich, The seven value stream mapping tools, International journal of operations & production management, **17**, 1 (1997)
6. M. E. Porter, The five competitive forces that shape strategy, Harvard business review, **86**, 1 (2008)
7. R. J. Schonberger, Japanese production management: An evolution — With mixed success, Journal of operations management, **25**, 2 (2007)
8. O. G. Turovets, V. N. Rodionova, The concept of implementing the principles of lean production, the organizer of production, **3(62)** (2014)
9. I. G. Pykhtin, A. V. Gostev, Conceptual model of building a database structure of resource-saving agrotechnologies, Agriculture, **7** (2018)
10. A. E. Brom, E. V. Eliseeva, Mathematical model of production organization based on resource conservation, Mechanical engineering and computer technologies, **05** (2013)
11. S. A. Kuzmin, *Development of a resource-saving system in the design of footwear production* (2010)
12. V. Y. Bazhin, *Justification of resource saving in the technology of aluminum production in high-ampere electrolyzers with burnt anodes* (2012)