Management and Production Engineering Review
Volume 15 • Number 1 • March 2025 • pp. 1–25
DOI: 10.24425/mper.2025.153927

Technological Changes and Innovations in Manufacturing and Assembly Processes in Industrial Production of Incubators

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Received: 25 February 2024
Accepted: 01 December 2024

Abstract
The paper focuses on creating a proposal for an innovative solution for technological changes in manufacturing and assembly processes in industrial production of incubators. The aim of the paper is to point out how the manufacturing and assembly processes can be made more efficient so that capacity of industrial production of incubators is maximized, enterprise resource planning is fully integrated with production plan and overall evaluation of machinery efficiency is acceptable to all business subjects involved and creates potential for economic added value. The empirical methods used were TOC method, data mining-based analysis, analysis of internal documents, process benchmarking, FMEA, Lean manufacturing, Kaizen, process audit, Six Sigma, guided interview, Pareto analysis, Ishikawa diagram, Practice, 5 Whys method and 8D report method. The application part of the paper describes changes and innovation in production of industrial incubators concerning increased efficiency of assembly processes targeted at product quality. By optimizing production of incubators in compliance with customer preferences, life functions of new-born babies were improved. According to analysis of input data implementation of investment projects concerning changes in mass production and assembly of machinery benefits of projects were upgrading manual manufacturing to semi-automatic. Increased performance and streamlining of manufacturing and assembly processes in integration with an increase capacity of production stations enabled reducing operating costs of main production activity by implementing cost-saving measures. This contributed to promoting competitiveness of industrial and production enterprises and stabilizing their position in national and international market by integrating strategic, commercial, labor, and other business development and growth opportunities. Key innovations and technological changes create potential for economic added value and stable growth. A better understanding and implementation of optimization scientific research methods in production processes has potential to ensure long-term competitiveness of industrial and manufacturing enterprises on the global market. Ambitions of further research is application of SMED (Single Minute Exchange of Die) in Lean manufacturing, which enables synchronization of production flows and reduction of machine working hours with an emphasis on waste minimization, operator space optimization and rejection rate reduction of non-value operations at machine changes.

Keywords
Innovation, technology, industrial engineering, production processes, investment projects.

Introduction

Technological upheavals transform industrial ecosystems, demonstrating revolutions in constantly reducing costs and increasing production volumes. Industry 5.0 aims for a more sustainable future and the integration of intelligent systems and robots into human work with an uncertain future of resources. The development of technologies, especially the Internet of Things and big data in an automated industrial environment, is integrated with an ecological perspective of environmental goals, such as carbon neutrality, waste recycling and use of biodegradable materials, whose values ??benefit from maximum efficiency, minimal impact and high performance in production. Like Industry 4.0 and Industry 5.0, the aim of business success is equipment and availability of machinery, autonomy of unattended robotized workplaces, ability of machines to imitate human abilities, allowing technical systems to respond to environment, solve problems and eliminate causes with aim of achieving formulated goals with support

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of Big Data, which allows data sets to be captured, managed and processed by software means. The efficiency and intelligence of systems enhance industrial and manufacturing processes in managing operational efficiency and determining whether it is realistic to improve economic performance (Vaníčková, 2023).

Although technological progress is optimized by an emphasis on recruitment, retention, and resilience of human talent and skilled workers, tension between technology and business process innovation cannot be denied. The increasing complexity and sophistication of innovative industrial automation solutions requires acquisition of advanced knowledge and professional skills in relevant industry sectors ([x]Enderwick & Buckley, 2020).

Modern technologies gave rise to the emergence of new scientific disciplines as innovations are often integrated with customer requirements and technology users, including strategic partners and key suppliers. Competition based on innovative and research activities enhancing improvement in life cycles of industrial and manufacturing enterprises stimulates environment for generating added value and economic profit potential for business entities oriented towards participation and cooperation with strategic, business, and social partners and customers (Althoff et al., 2019; Li et al., 2019).

Business innovation is based on continuously seeking and finding new opportunities and improving existing ones to meet future needs and wants of potential customers by improving quality and reliability of products/services and reducing calculated costs including development of technologies applied in organizational strategies of corporate structures (Tiewtoy et al., 2024). The identification of trends and economic cycles are difficult to predict assuming that individual countries/continents are undergoing transformation changes in trends of inflation, global trade, labor share, as they participate in innovations and changes related to shift from transformation into transaction management.

Measuring OEE and reporting production output enables monitoring of non-productive times in production, as it is not possible to improve production processes and find it acceptable but also optimistic, innovative, and cost-saving measures that are not linked to control and supporting systems. Low labor productivity, breakdown rate of machinery and production equipment, instability, and increase in OEE (Overall Equipment Effectiveness), poor internal quality, customer complaints, and unreliability of supply chain are major factors affecting production continuity.

The present paper deals with changes and innovation of manufacturing and assembly processes in industrial production of incubators integrated with reorganization and changeover of machinery. The main paper of research is transformation of outdated production processes into modern, innovative and competitive systems that support long-term sustainability and economic performance of industrial and manufacturing enterprises. The benefits of paper are technological changes and innovation of manufacturing and assembly processes of industrial incubator manufacturing lines, which have not been upgraded for 10 years. The added value of paper is increasing efficiency and production capacity, optimization of manufacturing and assembly lines with aim of increasing work productivity and workstation availability, reduction of operating and production costs, reorganization of machinery and processes with an emphasis on cost efficiency, strengthening competitiveness, modernization of production processes for purpose of a better position on international and local markets, ensuring compliance with resource planning and production plan, effective enterprise resource planning (ERP) and alignment with master production plan. Quantification of economic added value that innovations bring, for example higher production volume, profitability and reduction of losses from inefficient processes.

Literature Review

The state of uncertainty related to limited human resource capacity, strategic, business and other opportunities is often hampered by a lack of financial and investment resources for business development (Muharam et al., 2020; Kassa & Getnet, 2022; Seňová et al., 2021).

Innovation can be seen as a combination of values and traditions related to a given company, such as company's reputation and goodwill, as stated by (Caputo et al., 2018; Linder & Seidenstricker, 2018), position in regional market, longevity and quality of products and services (Kgobe & Ozor, 2021), as well as experience in meeting needs of existing and potential customers (Udiyana et al., 2018). Innovation can thus be introduced effectively and transparently, as innovation process in an organizational chart identifying problems and uncertainties of an investment project at each stage of project life cycle in synergy with managerial decision-making promotes development of innovations and eliminates potential risks and solutions of which improve functionality and efficiency of business processes (El Kadiri Boutchich & Gallouj, 2023; Gorecki & Núñez-Cacho, 2022; Lewandowska-Ciszek, 2022).

The carrier of modern innovations is innovation process, which is transformed into value of a new product available at a reasonable price and acceptable quality

(Ali & Frimpong, 2020; Bulut et al., 2022; Elamir, 2020; Greve & Seidel, 2015). Product innovation can be characterized from perspective of their functionality and generation of values, principles, or technical solutions (Krol & Sokolov, 2022; Maroušek et al., 2023; Odei & Appiah, 2023; Zhang et al., 2019), impact on occupational health and safety, reliability, comfort, and product design (Pokojski et al., 2019; Trojan et al., 2020).

Innovation of products, services, and processes can be achieved by better penetration into existing market by increasing sales volume and capturing new market segments (Hensen & Dog, 2020; Nymark et al., 2020; Pekarčíková et al., 2020; Salim et al., 2020), improving products and services by adding new features and functions (Cannas & Gosling, 2021), simplification, reliability, and material efficiency (Espíndola et al., 2019; Ghodoosi et al., 2018), increased sales performance and number of customers (Tsai & Huang, 2019), higher profitability (Rogulenko et al., 2021), streamlining sales through social networks, information and communication technologies (Sit & Lee, 2023; Yuan et al., 2021; Winter, 2023) and moving into other emerging markets selected on basis of geographical clustering to adapt products and processes to local conditions or exclusive representation of new products for existing and potential customers (Chi et al., 2015; Simanová & Sujová, 2022). The dissemination and implementation of innovative designs and methodologies are beneficial if offering opportunities for development of business and growth of industrial and manufacturing enterprises (Alochet et al., 2023; Hallam et al., 2018; Hernandez-Vivanco et al., 2018; Ling et al., 2022; Yang et al., 2018).

The turbulent environment of changes and challenges, risks and opportunities emphasizes better fulfilment of corporate goals and potential results of production plan by evaluating assigned tasks according to scope, quality and benefit with the lowest possible expenditure of resources/volume of funds/bid price or the lowest costs in life cycle of incubator production with an emphasis on the sustainability of smart industrial production and development of manufacturing sector by transforming production, supply and distribution, increasing flexibility of supply chains, resilience to risks, adaptation to changes in customer behavior. By identifying weaknesses, deficiencies and reserves in production and assembly processes, proposals for innovative solutions for developing more resilient flexible production against fluctuations can be modelled in close cooperation with efficient and talented people engaged in operational activities.

Economically rational management, i.e. economically, efficiently and purposefully contributes to elimination of waste, elimination and prevention of risks by taking advantage of opportunities that have an impact on the improvement of production and assembly processes, product quality and specification of control activities in production of industrial incubators.

Challenges to innovation include work injuries associated with material handling and machinery operations, as well as poorly designed internal occupational health and safety guidelines (Chi et al., 2015).

Innovation integrates a company's reputation, goodwill, regional market position, longevity, product quality, and ability to meet customer needs (Linder & Seidenstricker, 2018; Hallam et al., 2018; Hernandez-Vivanco et al., 2018).

Disseminating and implementing innovative designs and methodologies fosters business growth in industrial and manufacturing enterprises (Hallam et al., 2018; Hernandez-Vivanco et al., 2018).

Innovations are characterized by their functionality, technical solutions, and value creation, addressing occupational health and safety, reliability, comfort, and design (Espíndola et al., 2019; Pokojski et al., 2019; Zhang et al., 2019).

Streamlining sales through social networks and ICT enhances market reach (Tsai & Huang, 2019) addressing production and assembly weaknesses, with innovation implemented in multiple phases due to increasing complexity (Ali & Frimpong, 2020; Nymark et al., 2020; Pekarčíková et al., 2020; Salim et al., 2020).

Financial uncertainty, resource limitations, and strategic challenges stifle innovation efforts (Muharam et al., 2020).

Innovation involves transforming initial stimuli into valuable, reasonably priced products (Elamir, 2020).

Simplified and user-friendly innovations attract customers, while overly complex products or services decrease consumer interest (Kassa & Getnet, 2022).

Managerial decision-making integrated into innovation processes helps mitigate risks, enhance functionality, and improve business efficiency (Lewandowska-Ciszek, 2022).

Inadequate occupational health and safety regulations and poorly equipped workplaces continue to hinder innovation (Simanová & Sujová, 2022).

Risk factors for innovation in production processes include workplace injuries and dysfunctional safety protocols (Winter, 2023).

Strategic decisions in innovation are essential for developing efficient, transparent business processes (El Kadiri Boutchich & Gallouj, 2023; Gorecki & Núñez-Cacho, 2022).

A commitment to quality fosters tangible economic benefits: Market Penetration and Expansion: High-quality products enhance customer trust, enabling better market penetration and capture of new segments (Hensen & Dong, 2020).

Improved Profitability: Quality-focused innovations lead to higher sales volumes and profitability, as customers value reliable and functional products (Rogulenko et al., 2021).

Resource Optimization: Emphasis on material efficiency reduces waste and lowers production costs, contributing to economic and environmental sustainability (Ghodoosi et al., 2018).

Customer Loyalty: High-quality offerings strengthen brand reputation, fostering long-term customer relationships and competitive advantage (Vaníčková, 2021).

If evaluation of 3E criteria (economy, effectiveness and efficiency), management of production risks and business results are not systematically analyzed and thoroughly assessed, erroneous management decisions and systemic failures can be anticipated. These challenges are integrally connected with production, technical, economic, financial, personnel, and organizational problems that substantially increase innovation costs in production and assembly processes, extend life cycles of incubator production, and ineffectively prevent resource wastage.

Strategic balance underscores importance of fostering a culture of innovation and continuous improvement across all stages of production and organizational decision-making (Vaníčková, 2024).

A high-quality production economy serves as a foundation for innovation and sustainability in business. By integrating quality with economic efficiency, organizations can achieve greater profitability, enhance customer satisfaction, and secure a competitive edge in the global market. Combining product and service innovation with process innovation in a synergistic effect, the "more for less" relationship is stimulated, as argued by (Guillen et al., 2020; Katato et al., 2020).

Increasing production flow by identifying bottlenecks in synergy with application of TOC (Theory of Constraints) method enables realistic identification and elimination of problems and causes of product flow, seen Table 1.

Table 1
Increasing product flow

Steps	Description	Methods
Finding bottleneck	Identification of a bottleneck that prevents system permeability	Contemporary problem tree, simulation, workshop, imaging
Systematizing bottleneck	Securing material tray from a bottleneck	Kanban, FIFO stack
Bottleneck implementation in manufacturing and assembly processes	Work as fast as you can or wait	Kanban
Intensity of restrictions	Increasing system throughput in a bottleneck	Quality and variability reduction in manufacturing and assembly processes, selection of alternative solutions for partial processes
Return to step 1	Finding a new bottleneck and removing its constraints	

Source: (Košturiak & Chaž, 2008, own elaboration).

Corporate strategy is important for prosperity of an enterprise, as it is a tool for both growth and survival of business (Krishnan et al., 2019; Mesquita, 2016). New competitors influence pricing policy regardless of considering profitability of enterprises (Kalmykova et al., 2018; Tomczak, 2022). Given ever-changing market environment and turbulence of business life cycles, it is essential to promote innovation strategies that aim to generate benefits quantifiable in terms of economic, social, and environmental value integrated with parameters of time and location for business development and growth (Ottonicar et al., 2020; Shah & Guild, 2022; Zhao et al.,2023). Strategic, systemic, gradual and systematic innovation of business system, as well as entry and expansion of enterprises into new markets can be achieved (Berić et al., 2018) by creating a new product or service (Moro et al., 2021; Tsai & Huang, 2019), expanding an additional segment in an existing market (Schipper & Silvius, 2018), as well as by increasing customer's cost share (Haldar, 2019; Riquero et al., 2019).

Improving product and service competitiveness and introducing new technologies into corporate processes can stimulate labor productivity to higher performance and cost minimization (Dobrosavljević & Urošević, 2019; Gancarczyk, 2016; Kuś & Grego-Planer, 2021).

In terms of importance and benefits of proposed system intended for the target group of newborns, see Fig. 1, an analysis of internal documentation monitoring handling of sterile material is created. The industrial incubator houses a component called regulator, which cannot be disassembled non-destructively after manufacturing and assembly process, as a press-

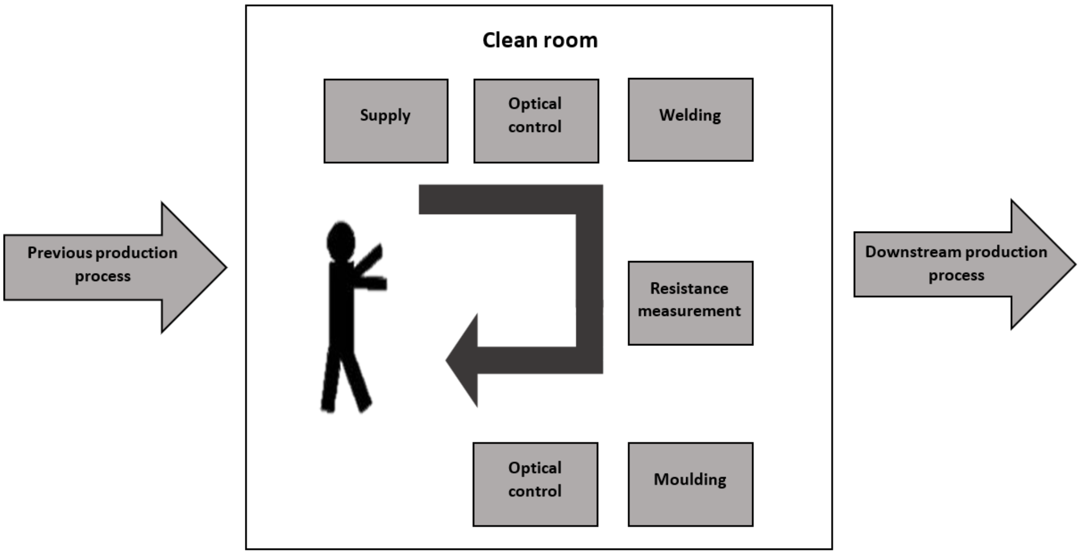

Fig. 1. Block diagram of regulator production, Source: (Author, 2024).

ing technology is used in production processes, which does not enable rebuilding of production equipment (Villalonga et al., 2021). In view of this fact, the component must be manufactured in an environment with increased demands on safety, hygiene, and cleanliness. Other components are not in direct physical contact with users, and therefore, it is undesirable to produce other components in production and assembly areas with these increased demands compared to standard production and assembly operations requirements.

As seen in Fig. 1, in clean rooms, individual activities are performed in the following order: Supply, Optical control, Welding, Resistance measurement, Molding and Optical control. These activities are systematically linked and interrelated, as they represent a part of inputs and outputs of production program, the so-called Previous production and Downstream production. The innovation of production and assembly processes of value-generating activities in mass production of incubators can reduce negative consequences caused by limitation of production capacity resulting from obsolete layout of manufacturing and assembly lines (El Ahmadi & El Abbadi, 2022; Hayes et al., 2022; Hees et al., 2017; Sahoo, 2019).

The implementation of technological changes can contribute to achieving financial costs quantified in measurable units of economic ratios.

Figure 1 presents an illustrative example of a regulator producing a component in a clean room. In the environment of the production hall, the parameter of cleanliness is not technically considered. Based on this fact, a clean room of 100 m^2 was built in the production hall, fulfilling the following parameters:

- The production and assembly line handling components wear protective clothes, protective gloves, and a hygiene hat to prevent contamination of products by fibers from normal clothing, palm sweat, and hair falling out.
- Controlled ventilation. Air humidity control by reducing corrosion inside regulator is one of issues addressed by innovative solutions.
- Controlled entry of staff by entering clean room through cloakroom, where disposable gloves, hygiene hats, and a work gown are key criteria supporting monitoring of measurable values of individual parameters.

Controlled entry into clean room cannot be made through door opened between production hall areas. Therefore, entry is relocated into the cloakroom through door open to clean room. The reason for this rebuilding is to ensure higher airflow that captures impurities (see Fig. 2. The principle of controlled entry into clean room) are undesirable outputs and unfulfilled expectations imported from analysis of internal documents.

Figure 2 shows a graphical representation of entry through cloakroom door to clean room. Controlling access to clean rooms is costly in terms of maintenance and servicing, as it increases production costs by:

- Special treatment of air humidity and impurity control.
- Regular work and protective aids for operators of assembly and manufacturing lines, such as disposable hygiene hats, protective work smocks, protective clothing and gloves, and other work aids, such as shoes.
- Constant maintenance of clean room.

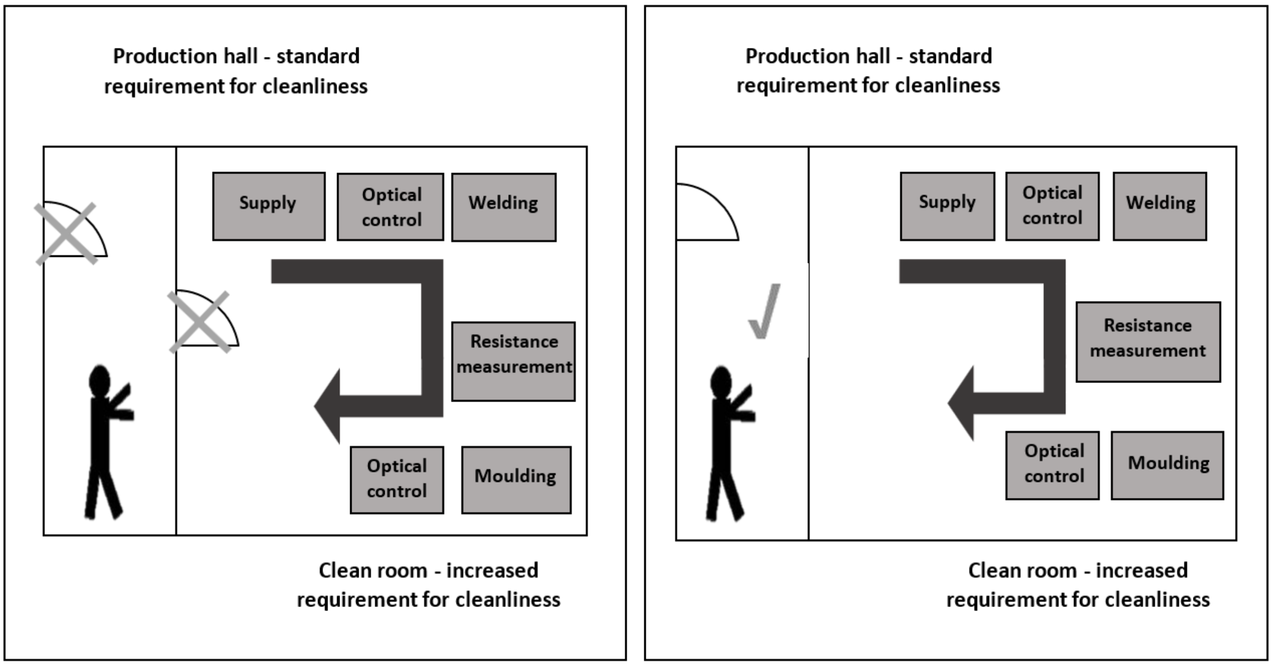

Fig. 2. The principle of controlled entry into clean rooms, Source: own elaboration.

- Inspections of entry systems.
- Presence of service staff at each workstation.

Within any operation in a clean room, operators of production and assembly line must manually grasp component in a glove and transport it to the production station. Due to the frequency of component production between 6 production stations, 3 production and assembly line operators are required at the same time and the same place, see Fig. 3.

The three operators of manufacturing and assembly lines jointly ensure the Supply, Optical control, Welding, Resistance measurement, Molding and Optical control operations, as shown in scheme of mass production of incubators, which presents individual operations and sub-activities carried out within production and assembly processes.

Figure 4 shows links within production of industrial incubators from clean rooms to assembly of internal parts of incubator, which are part of complete electrical installation, parameter control/testing, and packaging/shipping.

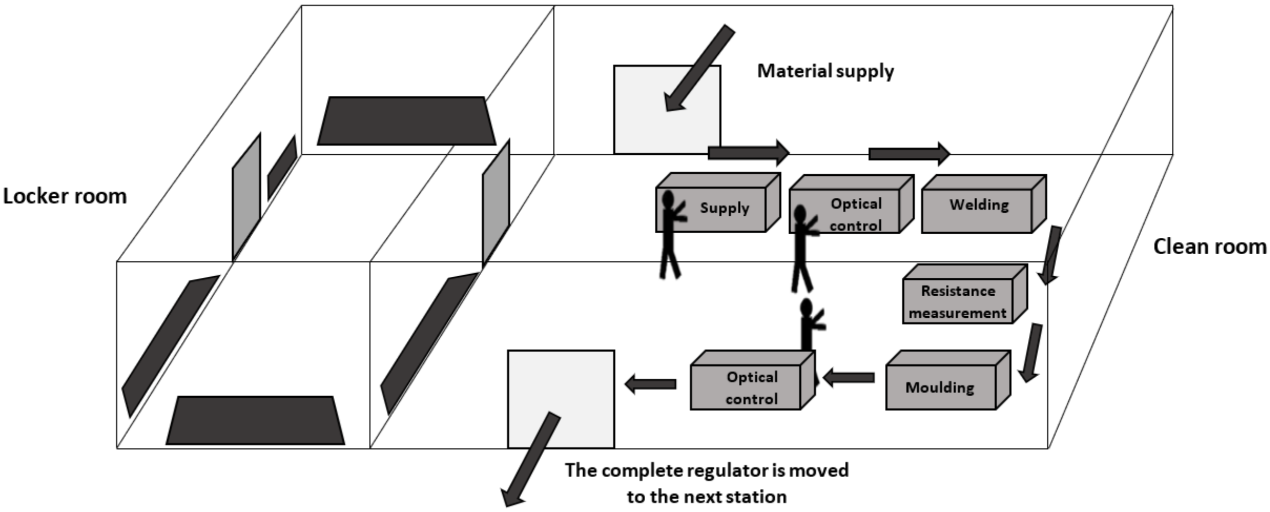

Fig. 3. Clean room with entrances and cloakroom manned by 3 production line operators, Source: own elaboration.

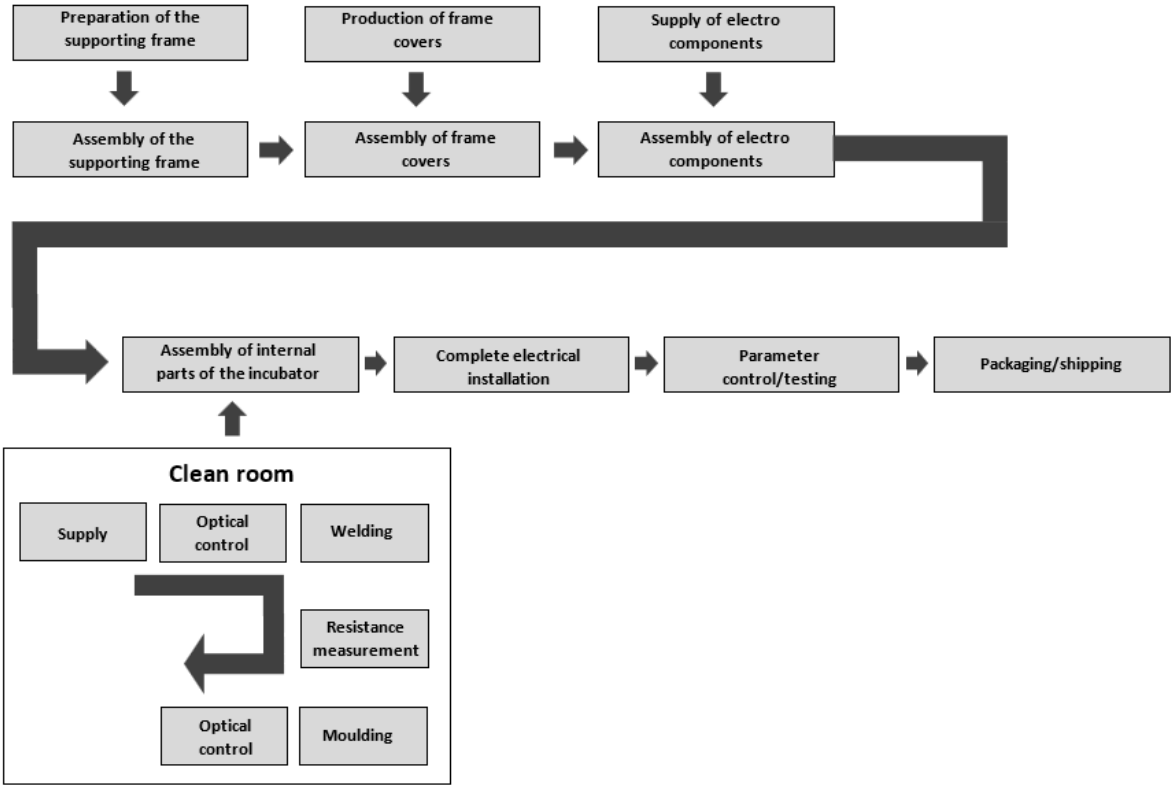

Fig. 4. Schematic of mass incubator production, Source: own elaboration.

Data & Research methods

Data collection

Data mining is important and beneficial in terms of more efficient use of targeted and controlled acquisition of data and reliable information that increase ability of companies to respond more flexibly and adapt to new or innovative conditions and opportunities for development of business in sector, with emphasis on maximization of utility and profit from source data for purposes of strategic planning and rational managerial decision-making in a knowledge-based advanced economy and society.

In the analytical part of paper, data mining analysis was used with analysis of internal documents. Visualization software is used to graphically represent and interpret outputs of individual data on effect and added value of innovations of manufacturing and assembly processes in mass production of industrial incubators. The workflow in corporate processes was monitored in the case of production operations listed on electronic board in the form of planned and executed work activities and sub-activities integrated with life cycles of investment project arranged in columns. Speeding up manufacturing and assembly processes, as well as improving design of individual operations makes complex material handling and material flow rationalization systems, which operate more efficiently on principle of Lean manufacturing and Just-in-Time, or Just-in-Case more transparent, while achieving better parametric values of measurable indicators. By agile programming, shared communication is streamlined in production rationalization, with an emphasis on increasing production and optimization of investment production costs.

Outcomes, causal conditions, and research design

Based on theoretical background, scientific and research findings and assumptions, the following research questions and a hypothesis were formulated:

Q1: At which stages of manufacturing and assembly processes are the highest parametrized values achieved?

Q2: Which activities of machinery production and assembly processes are the least frequent?

Q3: What defects have been eliminated during the implementation of work operations in manufacturing and assembly processes?

Q4: What conceptual solutions are more effective in increasing productivity and minimizing investment production costs?

H1: Reorganization of machinery to produce industrial incubators reduces technology downtime while maintaining parameters of increased cleanliness of production stations.

The research problem was formulated as causal aimed at increasing availability of production stations by reorganizing machinery. The causal conditions identify factors influencing reorganization of machinery to maximize utilization of production stations. The research design is focused on monitoring processes of changes to machinery in industrial production of incubators. Considering production efficiency and cost-effectiveness of input costs and costs incurred, growth in business and development in industrial and process engineering, capacity reserve of manufacturing and assembly lines was calculated, along with utilization of production stations in integration with innovation of manufacturing and assembly processes of machinery to confirm/refute relationship between increase in productivity and reduction of investment production costs.

The research objectives include:

- Current capacity of manufacturing and assembly lines.
- Utilization of production stations.
- The cost of clean room maintenance.
- The way of utilization of clean room area.
- Further utilization of manpower in case of clean room cancellation.

Research methods

Selected scientific research and application methods for obtaining knowledge, answering research questions and scientific research background include TOC, data mining analysis, analysis of internal documents, process benchmarking, FMEA, Lean manufacturing, Kaizen, process audit, Six Sigma, guided interview, Pareto analysis, Ishikawa diagram, Best Practice, 5 Whys, and 8D report.

TOC (the Theory of Constraints) enables identification and elimination of process bottlenecks. In practice, this method can be used in industrial engineering in workplaces with a low capacity of manufacturing and assembly lines that do not meet efficiency standards in the long term. The aim of this method is to identify causes of constraints and to find an optimal solution for material inventory necessary to ensure manufacturing and assembly processes while not limiting or compromising continuity of production and assembly line capacity and availability of production stations.

Data mining and internal document analysis were used to obtain data and information applicable to implementation of technology changes. The information and data obtained are presented in the analytical part of paper (Chapters 4.2 and 4.3. Not numbered).

Process benchmarking is used to analyze and compare identified manufacturing and assembly processes through describing and stimulating functionality and efficiency of processes to improve and streamline individual operations and activities that show direct and potential impact on development of operational activities of an industrial and production enterprise. Benchmarking consists in determining the competitive position of industrial and production companies in national or international markets in comparison with other business entities based on the amount of operating costs and number of employees operating in relevant sector. The aim is diffusion of expertise and professional experience in core and supporting corporate processes contributing to improvement of management activities and processes within operational activities. Process benchmarking is a dynamic process that needs to be continuously updated and adjusted in line with changing conditions and market needs in the business sector.

The FMEA (Failure Mode and Effect Analysis) is a method based on systematic identification of real defects of product/industrial incubators or processes, which have a negative effect on reduction or elimination of causes of actual defects by documenting their impact on manufacturing and assembly processes. Within production processes, FMEA is primarily used for identification of possible failures of manufacturing lines, as well as for implementation of new technologies into production or optimization of production processes.

Lean manufacturing is a method used by industrial and manufacturing enterprises to eliminate non-value-creating activities and point to individual changes and innovations aimed at improving and simplifying production processes to reduce investment production costs, increase margin and profit on product sales. Seeking alternative resources and possible savings or constraints required by production and manufacturing processes represents key themes of acceptable solutions integrated with production efficiency. Complete reorganization of manufacturing and assembly lines by means of moving material is mission of internal logistics of industrial and manufacturing enterprises, with benefit of saving time and reducing operating costs, especially in terms of direct wages in synergy of increasing availability of production stations and capacities of manufacturing and assembly lines. The method facilitates the adaptation of production processes to changing market conditions and needs and customer preferences. Acceptance of Lean manufacturing principles and their adaptation to specific needs of enterprise with regular revision represent essential activities to innovative corporate processes supporting stability, growth of enterprise, and business development.

In case of incremental improvement, in manufacturing and assembly processes, it is beneficial to implement Kaizen method in designing improvement proposals. The implementation of Kaizen method requires mentoring and leadership of employees to ensure continuous improvement of work processes. The application of method is based on continuous monitoring and measuring of partial results in line with an agile approach in changing market economies and customer preferences.

The method of process audit analyses complex processes or selected sections of corporate processes. Process audit consists in systematic assessment and evaluation of corporate processes, with aim to define, document, and implement production and non-production processes in line with established standards and norms, and contributes to mapping and identifying potential improvement and streamlining of partial activities and processes that can be implemented more effectively. In practical terms, process audit represents an important tool to classify and maintain the high level and quality of corporate processes and sub-processes.

Six Sigma contributes to elimination of losses in production of industrial incubators resulting from implementation of system innovations of operational activities within manufacturing and assembly processes. Six Sigma is used in various industrial and manufacturing sectors, since it offers a systematic approach to identifying and eliminating errors, minimizing process variability, and increasing product quality. Using analysis of internal data obtained from databases of internal documents combined with observation method in operating areas of industrial and manufacturing enterprises, it is possible to reduce errors and eliminate processes variability. Using this managerial method, it is possible to improve quality of processes within value-creating activities, because by reducing defects, errors, and negative effects, we can reduce waste in production, increase speed and productivity of investment projects integrated in 30% cost savings. The revision of production processes and analysis of machinery performance quantified in measurable units enables identification of potential risks and financial impacts on comprehensive evaluation of benefits of manufacturing and assembly processes of value-creating activities in mass production of industrial incubators.

Guided interviews with experts in industrial engineering enables focusing on selecting sophisticated solutions for transfer of innovations from custom manufacturing to industrial production. This method can be beneficial if it is systematically structured and targets key competencies and skills necessary for successful transfer of engineering innovations into manufacturing processes. The structured questions are focused on accomplishment of company goals and project goals with an emphasis on teamwork of experienced and new employees. Through a guided interview, experts can communicate information and share experience and approaches to solving sub-problems using best practices. In industrial and process engineering, where technical knowledge and skills are critical, methods of guided interview with employees can promote and develop advanced technical skills. Discussion on investment projects, development trends in sectors and innovation challenges are part of substantive and guided interviews in intergenerational social groups.

Pareto analysis, also known as 80/20 Rule, is a method used for identification and prioritization of key factors of a phenomenon, problems, defects, or causes that have a significant impact on overall performance or product quality. The application of Pareto analysis in business practice shows causal consequences of losses in production process efficiency. Prioritizing sophisticated solutions to identified problems contributes to optimization of business processes by enhancing efficiency of value-creating activities.

The Ishikawa diagram is an analytical technique for displaying and analyzing cause and effect. Due to its versatility, it is most often used in processes of production quality management for identification of causes of poor quality and addressing consequences with implementation of corrective measures to improve manufacturing and assembly processes. In industrial engineering, the Ishikawa diagram is used to analyze root causes of manufacturing processes hindering achievement of machinery efficiency, e.g., to detriment of product quality.

Best Practice, 5 Whys, and 8D report are used for elaborating final report (see Conclusions). Best Practice verifies effectiveness of methodological procedures and techniques by demonstrating consistency of alternative solutions in form of communication on benefits and potential of investment projects and leadership of working teams to meet investment project objectives and corporate goals. In industrial engineering, the method is used to identify, document, and implement best practices and corporate strategies that contribute to achieving and meeting expected outcomes. Best Practice can be effectively used in disseminating professional experience and skills implemented in managing performance and efficiency of business processes and sub-activities through benchmarking, studying successfully implemented investment projects, or consultations with experts from practice. The implementation of Best Practice in industrial and process engineering supports the development of strategic design solutions to effectively use best practices and techniques and achieve favorable results in production, project management, and operational activities of industrial and manufacturing enterprises.

The 5 Whys method prevents making rash decisions by identifying root causes and assessing depth of a problem by five iterations of asking Why? Which contributes to the elimination of product defects and undesirable failures of machinery and manufacturing lines in industrial and process engineering. It helps identify root causes of failures and enables taking measures to increase reliability and availability of machinery and prevention of failures. Suitable application of this method increases effectiveness of individual steps and sub-procedures in eliminating problems by proposing innovative solutions and making recommendations to improve and refine processes and activities in industrial and process engineering.

To comprehensively address problems in 8 disciplines of integrated quality management systems, it is appropriate to use 8D report method, which aims to identify, and document causes of faults/malfunctions and to propose acceptable, immediate, corrective, and preventive measures to prevent recurrence of faults and defects. The method is used within a structured approach to identify root causes of problems and implementation of corrective measures related to product quality, urgent production failures, or other difficulties identified in business processes. The 8D report method is based on philosophy of continuous improvement of business processes. The analysis of root causes and implementation of preventive measures can enable achieving long-term improvement of processes and sub-activities.

The Theory of Constraints, analysis of internal documents, and data mining analysis are specified in detail in chapter Theoretical Framework. TOC enables identification of problems of specific products – industrial incubators shown in Tab. 1. The results of analysis of internal documents are presented in Fig. 1 and 2. Figure 3 Clean room with entrances and cloakroom manned by 3 production line operators and Fig. 4. Scheme of mass production of incubators, relationships between production activities and manufacturing and assembly processes are illustrated in Tab. 2 and 3 Capacity analysis of production station are based on results of process benchmarking and TOC.

FMEA enabled formulation of partial conclusions considering capacity of manufacturing and assembly lines and utilization of production stations by eliminating root causes that have a significant impact on reduction of number of products (industrial incubators) in total volume of production due to defects incurred. Lean manufacturing provided information for calculation of operating costs and costs of clean room maintenance, see Tab. 4. In Tab. 5 Built-up area of production stations was compiled based on data obtained through implementation of Lean manufacturing and Kaizen in manufacturing and assembly processes. The results of application of Six Sigma are presented in Tab. 6.

The guided interviews with representatives of industrial and manufacturing enterprises were conducted in shared spaces for a period of 2 months, with a frequency of 1 meeting a week. These meetings stimulated employees for closer cooperation and higher productivity. The results of internal document analysis and process audit are presented in Tab. 7. The proposed innovative solutions for manufacturing and assembly processes are based on the Pareto principle, and benefits of Kaizen are reflected in value-creating activities. These include streamlining production, reducing waste, and improving the quality of products (industrial incubators), which have a positive impact on increasing profitability, prosperity, and competitiveness of industrial and manufacturing enterprises.

Figure 5 illustrates the modified controller production station, showcasing proposed improvements in manufacturing and assembly processes in conjunction with process audit.

Figure 6 and Tab. 8 further describe innovated manufacturing and assembly processes and production capacity of upgraded manufacturing and assembly lines. These changes are based on results of Theory of Constraints, with bottlenecks process eliminated to increase capacity of manufacturing and assembly lines. The increased production volume is supported by data obtained through the Ishikawa diagram.

Table 9 shows the usability of manufacturing and assembly process stations, which were compiled to promote quality of industrial incubators. As seen in Tab. 10 and Tab. 11, the quantification of initial and operating costs of investment projects demonstrates the effectiveness of Lean manufacturing principles. The success of Lean management improvement project was confirmed by maximizing utilization of production stations, increasing number of produced units per minute, and reducing investment and operating costs.

Increased speed was achieved by streamlining workflows and removing inefficiencies, leading to a reduction in production time. The design improvements in production steps and machinery optimized operational throughput. The application of Lean Manufacturing and Just-In-Time (JIT) principles ensured efficient resource use without excess, reducing costs and improving overall performance. Additionally, improved parametric values, such as efficiency, throughput, and cost reduction, were measurable outcomes of these changes.

Results and Discussion

The analytical part of paper presents investment projects using a concrete example in mass production of industrial incubators designed to support life functions of newborn babies. The innovative change in manufacturing and assembly processes from custom to mass production is implemented by reorganizing machinery used. The production departments of industrial enterprises collected statistical data and information on number of industrial incubators produced and cost of human operator downtime, which is affected by pauses in capacity of manufacturing and assembly lines and utilization of production stations.

Based on capacity of manufacturing and assembly lines, utilization of production stations, and empirical data analysis, calculated capacity reserve of production stations is 33%. The analysis of internal state shows a link between technological pauses caused by physical transfer of regulator to component assembly station, for which time losses related to clean room shutdown (periodic inspection twice a year) are identified, as well as technical errors identified in past but not corrected. Tab. 2. Production line capacity utilization presents capacity of production stations and usability of manufacturing lines in %. Both Tab. 2 and 3 (Capacity analysis of production stations) were compiled using empirical methods applied to process benchmarking and TOC for machinery reorganization through innovation of manufacturing and assembly processes.

Table 2
Production line capacity utilization

Capacity of production stations	**Number of pieces produced (pcs)**	**Currency exchange**	**Usability of manufacturing lines (%)**
7	4	Morning	57
7	5	Afternoon	71
7	5	Night	71

Source: own elaboration.

Table 3 analyses the capacity of production stations.

The highest values of production capacity were measured at production station before entry of regulator from clean room to electrical component assembly, where connectors are crimped and soldered manually. It is lengthy manufacturing and assembly processes in which there is a time delay in the assembly station for internal components of industrial incubators, as confirmed by FMEA. The findings obtained enable answering the first research question.

Table 3
Capacity analysis of production stations

Production stations	**Capacity of production cycle stations (%)**
Preparation of support frame	20
Mounting of supporting frame	0
Manufacture of frame covers	25
Mounting of frame covers	12
Supply of electrical components	0
Assembly of electrical components	15
Assembly of inner part incubators	30
Complete electrical installation	3
Testing	32
Packaging/expedition	0

Source: own elaboration.

Cost of cleaning room operation and maintenance

Due to the higher costs of maintenance and operation of clean rooms, input costs were calculated. The data necessary for the implementation of changes in manufacturing and assembly processes and subactivities (see below) were quantified in line with Lean manufacturing method, see Tab. 4:

- Costs of the production station operators in clean room (anti-static smocks with special coating in compliance with the ISO 5 norms designed for clean rooms/production areas, PVC dot knit gloves, hygiene hats with mesh, safety equipment).
- Air circulation costs (installation of an air handling systems to protect the operators and internal environment of industrial and manufacturing enterprises and products (industrial incubators).
- Costs of clean room air tightness ensure 100% functionality of the HVAC system with electronic sensors, with a lifetime of up to one calendar year. Emphasis is put on cleanliness of air passing through multi-stage filtration. To prevent microbial contamination of air filters, it is advisable to change filters regularly and sanitize clean rooms.
- The costs of maintaining structural walls and regular measuring of airtightness of clean rooms have an impact on the costs of clean room operation and maintenance.
- Costs of cleaning cleanable and storage area of clean room and cost of clean room operation and maintenance.

- Cost of monitoring air handling data (air change rate in m^3/day and throughput of filter in % assuming 100% efficiency).

Note: If the percentage falls below 85%, filters must be replaced immediately.

The following Tab. 4 provides an overview of cleaning room operation and maintenance costs.

Table 4
Clean room operation and maintenance costs

Item	**Annual costs (CZK)**
Protective equipment	100 000
Cost of air treatment	650 000
Labor costs of operators	1 100 000
Regular service	300 000
Revision control	50 000
Total	2 320 000

Source: own elaboration.

Utilization of clean rooms

The analysis of unused space according to capacity of manufacturing and assembly lines, see Tab. 2 shows that the least used production station is assembly line for assembling electrical components,

With an identified reserve of approximately 20%, see Tab. 3. The data obtained provides answers to the second research question.

The overview of clean room operation and maintenance costs including built-up area of manufacturing and assembly lines and production stations is presented in Tab. 4 and 5. About spatial arrangement of stations in production hall, rational solution is to move production stations for assembly of electrical components. When testing constructive designs in manufacturing and assembly lines, work performance requirements of production operators were considered. An ineffective variant of conceptual design was adaptation of production station staff, which has a direct impact and effect on decision-making of line workers in process of production. planning, assembly, and covering of support frame. The aim was identification of undesirable economic impact of operating costs on integrated activities, such as relocation and design of production stations. The obtained results and findings concerning utilization of clean room are useful for implementation of innovations in manufacturing and assembly processes applied to strategic decision-making in a comprehensive concept (see DSS – Decision Support Systems).

Table 5 below shows built-up area of production stations and spatial arrangement of production stations in m^2. This table was compiled based on information obtained through application of Lean manufacturing and Kaizen.

Table 5
Built-up area of production stations

Production stations	**Spatial arrangement of production stations (m^2)**
Preparation of support frame	150
Mounting of supporting frame	90
Manufacture of frame covers	130
Mounting of frame covers	160
Assembly of electrical components	85
Assembly of inner part incubators	95
Complete electrical installation	65
Testing	45
Packaging/expedition	130

Source: own elaboration.

Reorganization of machinery

Innovation of production and assembly processes in case refers to cancellation of clean rooms by relocating manufacturing and assembly lines closer to production stations. The output of reorganization of machinery is a reduction of technology downtown while maintaining parameters of production station cleanliness. The formulated hypothesis was confirmed. Table 6 Model situations for location production stations presents relocated production stations, cost, and length of upgraded manufacturing lines processes based on process audit and Six Sigma implemented in manufacturing and assembly processes.

The reliability of obtained data and results was discussed with experts in industrial and engineering enterprises in the form of guided interviews. The feedback was obtained through structured questions and answers with discussions. Responsibility for manufacturing and assembly processes was given to the production department. Technical support was provided by the technology department. The quality of products (industrial incubators) and selection tests were coordinated by representatives of the quality department. The R&D department was responsible for product design.

Table 6
Model situations for location production stations

Relocated production stations	**Cost (EUR)**[*]	**Length of upgraded manufacturing lines processes**
Preparation of support frame	6,38	6,38
Mounting of supporting frame	3,83	6,17
Manufacture of frame covers	5,53	7,23
Mounting of frame covers	6,81	7,45
Assembly of electrical components	3,62	3,19
Assembly of internal parts incubators	4,04	4,04
Complete electrical installation	2,77	4,68
Testing	1,91	5,74
Packaging/ expedition	5,53	5,96

[*] The Exchange rate of the Czech koruna according to the CNB (Czech National Bank) as of 1 May 2023 is CZK 23.505/Euro. The euro is rounded up to two decimal places. Source: own elaboration.

Using FMEA (Failure Mode Effects Analysis) method in manufacturing and assembly processes, failures in production were identified, which had an adverse effect on reduction of effectiveness of production and assembly processes. This approach could minimize defects and improve overall efficiency and reliability of production and assembly processes.

As a result, the measures implemented may lay the foundation for long-term process optimization and increased competitiveness in the market. The aim was to take measures to eliminate defects in production and the assembly of components to reduce losses to the lowest acceptable level. The reorganization of manufacturing and assembly lines took place before actual production of components in cooperation with staff of industrial and manufacturing enterprises participating in evaluation of results. The primary goal was to find and establish optimal solutions to reduce the occurrence of defects identified. The criteria for assessing the occurrence of defects that have a negative impact on the occurrence of additional defects were designated as RPN (Risk Priority Number). They took effect on allocation of time and funds invested in design of individual solutions to eliminate inconsistencies and defects identified. The measurable values on a scale from 1 to 10 (1 being the lowest value) reflected severity of defects occurrence.

In accordance with analysis of input data, or analysis of internal documents and process audit, see Tab. 7, unused capacity of production stations was quantified in% and operating area of production station was monitored. Within analysis of identified defects and failures in production and assembly of components combined with FMEA (Failure Mode Effects Analysis) method, a model situation was tested with aim of assessing alternative design solutions to incomplete utilization of production stations (with a value of up to 15%) and unoccupied space of 100 m^2.

The production station for assembling internal parts of industrial incubators will be reorganized in line with FMEA method and results obtained, since values exceeded 30% (the threshold value is 15%).

The application of FMEA method in production and assembly processes helped identify defects and failures in assembly of electrical components and defect monitoring was implemented. Thanks to innovations in reorganization of machinery and transformation of manufacturing and assembly processes, there were identified defects occurring in assembly of electrical components during transport of component frames to station of assembly of internal components in production of industrial incubators. The defects identified enabled answering the third research question. As a countermeasure, devices are installed that send signals on a board in production station area operating on principle of activation of acoustic signal.

Innovation of production and assembly processes of machinery for producing industrial incubators

The proposed solution based on application of Kaizen, process audit, Pareto analysis, and Best Practice is to upgrade production stations of 6 regulators set in automatic, not manual mode and cancel clean room. The transport between production stations is ensured only by 3 production and assembly line operators, whose main task is handling covers during transport of material. The innovation is in implementation of special covers made of transparent plexiglass to ensure protection and security of production and assembly line operators to eliminate damage to property of industrial and manufacturing enterprises, as well as damage to health of staff. The special covers are designed to allow ventilation that regulates air hu-

Table 7
Analysis of data input

Production stations	**Unused capacity of production stations (%)**	**Criterion (%)**	**Conform**	**Space required (m^2)**	**Criterion (%)**	**Conform**
Preparation of support frame	20	≤ 15	Yes	150	100	No
Manufacture of frame covers	25		Yes	130		No
Mounting the frame covers	12		No	160		No
Assembly of electrical components	15		Yes	85		Yes
Assembly of internal parts of incubators	30		Yes	75		Yes
Complete electrical installation	3		No	110		No
Testing	45		Yes	135		No

Source: own elaboration.

midity around machinery, thus increasing efficiency of air handling system. These integrated design solutions represent the answer to the fourth research question.

A logical change is the application of automatic conveyors between machines, whereby grippers and vacuum suction cups controller move material onto conveyor belt located between production stations equipped with optical sensors. The optical sensors send signals to control units to center position of production components when material is being pressed. Based on comparison of time necessary to handle physical transport of material to automatic transfer, time savings were demonstrated resulting from reduction of costs of manual handling, as seen in Fig. 5 designed in context of process audit aimed at elimination of problems and causalities occurring in manufacturing and assembly processes.

As seen in Fig. 5, individual processes in order Supply, Optical control, Welding, Resistance measurement and Optical control are closely related to each other. The creation of a handling station eliminates the need for two production operators, where the remaining one deals with optical control without necessity of wearing special protective gloves and equipment, as operations do not require use of special covers (effectiveness of innovative design solutions was confirmed by Kaizen method). Relocation of production parts and machinery to operator's location is unfeasible.

The removal of air handling unit, which mixes a specific amount of air depending on size of room, can be also considered economically beneficial. The modification of controlling production stations resulted in a reduction in the number of operations, which has a positive effect on purchasing air handling systems

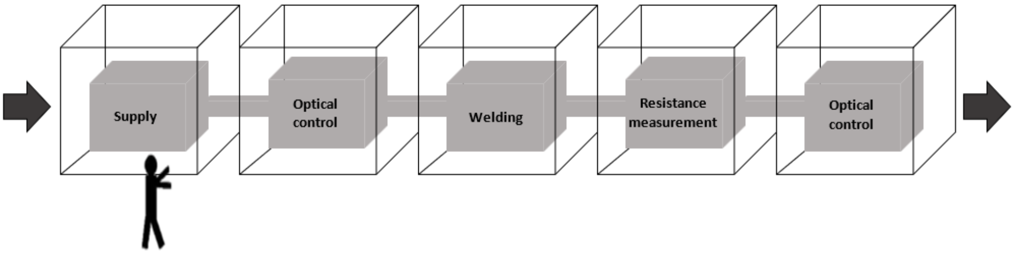

Fig. 5. Modified controlled production stations, Source: own elaboration.

with higher performance, reflected in funds savings in areas of maintenance and servicing of production stations. Monitoring air quality inside production stations and the tightness of protective covers remains unchanged. The transparent covers enable operators to look inside at any moment and in the event of errors displayed on control panel, to eliminate identified defect immediately. The added value of manufacturing and assembly processes is mounting of a door through which operators can easily enter internal spaces after turning off machinery, see Fig. 6.

Figure 6 shows two innovative changes (see white rectangles above) – Assembly of electric components and Production of the regulator. As part of innovations, cleaning room was cancelled and parts of manufacturing and assembly lines to produce regulators were rebuilt. The effectiveness of proposed solution was verified using Pareto analysis, which emphasizes rule that 20% of selected activities generate 80% of profit. As a replacement for cancelled clean rooms, two production stations intended for assembly of electrical components are used (in the original process, there was only one such station). Due to time-consuming production and assembly activities, specifically crimping and soldering cable bundles, production cycles were often slowed down, as frames from previous production stations piled up at entrance. Therefore, other production stations were added to ensure a smooth and even distribution of production components flow.

Analysis of modified production and assembly processes

Using analysis of modified manufacturing and assembly processes, capacities of innovative manufacturing and assembly lines were measured, including time necessary for production, utilization of production station and calculation of production costs of investment projects.

Capacity of upgraded manufacturing and assembly lines

During a three-shift operation, the capacity of upgraded manufacturing and assembly lines was monitored, and number was increased to 6 industrial incubators/1 shift. Regarding increased production and assembly to 33% capacity reserve was increased by 15% as well. In Tab. 8 the TOC method was used to calculate capacity of manufacturing lines, number of pieces produced, currency exchange, and utilization of manufacturing lines, which assess the number of manufactured pieces of industrial incubators per given

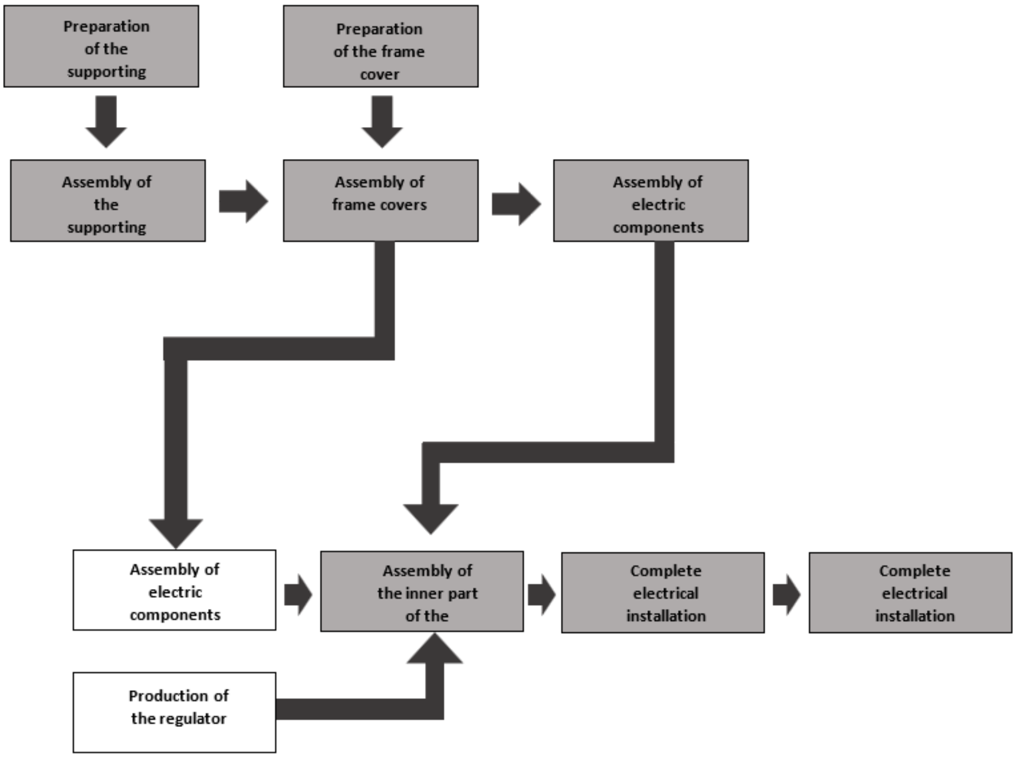

Fig. 6. Innovated manufacturing and assembly processes, Source: own elaboration.

unit of time with work efficiency, which has an impact on performance and has a potential for expanding production output.

Table 8
Production capacity of upgraded manufacturing and assembly lines

Capacity of manufacturing lines	**Number of pieces produced (pcs)**	**Currency exchange**	**Usability of manufacturing lines (%)**
7	6	Morning	85
7	6	Afternoon	85
7	6	Night	85

Source: own elaboration.

Time required for manufacturing and assembly processes

The time required for manufacturing and assembly processes was reduced from the original 75 min to 50 min, with production volume of 5 units/1 shift compared to the original 3 unit/1 shift. When producing 4 units, calculated time saving was 50%, with a reduction by 37.5 min/1 shift. The synergy between capacity of manufacturing and assembly lines and time required for production and assembly processes was confirmed in line with TOC in technical project management and continuous improvement of sub-activities in industrial and process engineering.

Utilization of production stations

By streamlining complex production and assembly processes in line with the Ishikawa diagram, time consumption was reduced, and utilization of production stations connected to each other was increased, as capacity of manufacturing and assembly lines is now fully utilized, see Tab. 9.

Calculation of investment projects production costs

The effectiveness of implementation of Lean manufacturing in industrial and manufacturing

enterprises were confirmed in appreciation of input costs of machinery reorganization in first quarter of 2023 by starting pilot operation, see Tab. 10. The appreciation was quantified by ratio of input costs and production operations.

The second category in which costs were assessed is operating costs. The requirements of occupational health and safety were considered through the air handling system implemented with the intention of reducing the number of present persons/production operators in clean rooms. The manufacturing and assembly lines were covered with special covers and monitored every 30 minutes by authorized production operators. The operating costs of individual operations are presented in Tab. 11.

The added value of investment projects in industrial and process engineering is streamlining production and assembly processes, which represents a cost-effective solution through reduction of operating costs and in-

Table 9
Usability of manufacturing and assembly processes stations

Production stations	**Production cycle capacity (%)**
Preparation of support frame	10
Mounting of supporting frame	0
Manufacture of frame covers	10
Mounting of frame covers	12
Supply of electrical components	0
Assembly of electrical components	10
Assembly of inner incubator pats	10
Complete electrical installation	3
Testing	12
Packaging/expedition	0

Source: own elaboration.

Table 10
Quantification of initial investment cost projects

Operations	**Cost (EUR)***
Preparatory phase	4254,41
Dismantling the clean room	2127,21
Conversion of controller station	51052,97
Mounting of controller station	6381,62
Construction of second station of electric component	13614,12
Process settings	4254,41
Total	81684,75

*The Exchange rate of the Czech koruna according to the CNB (Czech National Bank) as of 1 May 2023 is CZK 23.505/Euro. The euro is rounded up to two decimal places.
Source: own elaboration.

Table 11
Quantification of operating investment cost projects

Item	**Cost (EUR)**[*]
Cost of air treatment	6381,62
Regular service	6381,62
Revision checks	2127,21
Total	14890,45

[*] The Exchange rate of the Czech koruna according to the CNB (Czech National Bank) as of 1 May 2023 is CZK 23.505/Euro. The euro is rounded up to two decimal places.
Source: own elaboration.

creasing volume of sales of products (industrial incubators) integrated with expected value-creating results.

The research results are subject to consideration of changes in Theory of Constraints (TOC) procedures, which do not provide a solution to find bottlenecks. Through Drum-Buffer-Rope (DBR) method, it is realistic to determine bottleneck affecting overall speed of production system to identify limitations in work-in-process and inventory, including overloading of production system.

Measuring labor intensity in cycle times is integrated with a production plan aimed at limiting and using unlimited resources with excess capacities is subject of innovation of methodological procedures and research solutions that consider a wide range of production risks. Classification of bottleneck as a risk of lack of input material is a partial, not a complete solution to change and innovation of manufacturing and assembly processes integrated with all operational activities.

In accordance with PUSH strategy, Kanban system and Lean manufacturing and Just-in-Time, not by blocking bottlenecks according to Theory of Constraints, it is possible to streamline production of industrial incubators, improve manufacturing and assembly processes at all production stations and reduce inefficient activities by shortening times and downtime in preparation and organization of production of industrial incubators.

Conclusions

Production planning using dynamic simulation planning contributes to the higher efficiency of production processes, as algorithms used enable making multicriteria decisions on reduction of inventory in production processes, including shortening continuous production time and meeting customer expectations by satisfying demand for individual products. Industrial and manufacturing enterprises use various software tools and parametrization of production data applicable for streamlining processes of capacity and material planning and systematic production scheduling. The application of advanced tools of effective production planning enables industrial and manufacturing enterprises to reduce volume of work-in-progress components and input components, thus ensuring continuity of production based on actual customer needs and requirements. With use of effective and proven production planning tools, it is possible to reduce inventory in entire production processes by twenty to sixty percent, shorten production time by forty percent, increase labor productivity by thirty percent, and meet customer requirements by almost one hundred percent, as confirmed by author's experience in low and middle management of manufacturing and engineering enterprises and in electrical industry. The creation and rationalization of solution is risky in aggregate time, as it can be longer than one year in production planning for a new database; therefore, when implementing a production planning system, a flexible model prototype is used, which enables production planners to use principles and procedures of individual proposals for changes and innovations by removing erroneous data and replacing them with valid data.

The paper presents integrated proposals of construction proposals for innovations of production and assembly processes of machinery used in production of industrial incubators. Regarding the increase in prices in industrial incubator manufacturing and predicting demand for quality and functional products, demand for innovative products can be expected to increase, including impact on localization of production.

Based on input analysis, critical areas of defects were identified, which have an impact on increase in operating costs and reduced effectiveness of production and assembly processes of machinery. Theoretical knowledge, scientific and research findings, and assumptions in systemic concept of strategic approach implemented in change proposals and innovative solutions of investment projects had a positive impact on increasing efficiency of production and assembly processes of machinery to produce industrial incubators and a positive impact on reducing investment production costs.

The objective of the paper was implementation of technical innovation into manufacturing and assembly processes by increasing capacity of manufacturing and assembly lines, saving physical space in production halls, and reducing the cost of production station operation. The paper deals with processes innovation in industrial production of incubators by reorganizing manufacturing and assembly lines. The partial objective was to point out how manufacturing and assembly processes in production of industrial incubators can be made more efficient by evaluating economic value added to business processes, which has potential for economic profit. The selected scientific and research methods were TOC, analysis of internal documents, process benchmarking, FMEA, Lean manufacturing, Kaizen, process audit, Six Sigma, guided interviews, Pareto analysis, Ishikawa diagram, Best Practice, 5 Whys, and 8D report. As part of identifying research problems, four research questions and a hypothesis, were formulated.

Answer to first research question Q1: At which stages of manufacturing and assembly processes are the highest parametrized values achieved? The highest value of production capacity was measured at production station waiting for entry of regulator from clean room into assembly of electrical components, which are manually crimped, and connectors soldered. During manufacturing and assembly processes, it is important to optimize business processes so that use of machinery and production equipment, automation of manufacturing lines, monitoring of key performance indicators (KPI), and control activities are effective. If problems or defects are identified, corrections are made by eliminating their causes and implementing prevention measures to prevent occurrence of future problems. Documentation of the entire process with obtaining feedback is key to stabilization and sustainability of business processes and continuous improvement of individual activities. By analyzing empirical data and measurement results of individual activities, it is possible to identify key areas of improvement in core, supporting, and management processes.

Answer to second research question Q2: Which activities of machinery production and assembly processes are the least frequent? The least utilized section of production stations is assembly of electrical components, where identified utilization of its capacity was 20%.

Answer to third research question Q3: What defects have been eliminated during implementation of work operations in manufacturing and assembly processes? The identified defect was transport of frames to assembly of internal parts of components in production of industrial incubators.

Answer to fourth research question Q4: What conceptual solutions are more effective in increasing productivity and minimizing investment production costs? Innovative solutions include covering frame with a cover made of transparent plexiglass to ensure protection and security of works/production operators to eliminate damage to property of industrial and manufacturing enterprises and to health of workers.

The formulated hypothesis was as follows: Reorganization of machinery to produce industrial incubators reduces technology downtime while maintaining parameters of increased cleanliness of production stations. The innovative measure was cancellation of clean rooms by transferring manufacturing and assembly lines closer to production stations. The relocated production stations are shown in Tab. 6.

The theoretical part of paper specifies steps and description of methods used to increase product flow. For a better understanding of benefits and potential of description, a block diagram of regulator production is illustrated in Fig. 1 and 2, which show principle of controlled entry into clean room integrated with an increase in operating costs, e.g., by special treatment of air humidity and removal of impurities, as well as revision control of input systems in presence of production station operators. Regarding the frequency of production of components between 6 production stations, the number of production and assembly line operators was reduced by 50%, i.e., to 3. In the application section of paper, innovative changes in manufacturing and assembly processes is presented in the form of a shift from customs to mass production. Based on internal state of manufacturing and assembly processes of machinery, time loss resulting from shutdown of clean rooms was calculated, see Tab. 2 and 3. The highest capacity of manufacturing and assembly lines was measured at the production station waiting for entry of regulator from clean room to assembly of electrical components. Given spatial arrangement of production stations in production halls, rational solution was to move assembly of electrical components into industrial production of incubators to verify effectiveness and benefits of stimulation model identifying built-up area of production stations with spatial arrangement of production stations in m^2. An innovation in manufacturing and assembly processes of machinery was cancellation of cleaning room by transferring manufacturing lines closer to production stations, see Tab. 6. The design of construction solutions was consulted with representatives of industrial and manufacturing enterprises in the form of guided interviews and discussions with obtained feedback. This enabled identification of failures and defects that showed an adverse effect in the form of reduced efficiency of machinery. The intention of corrective measures was to eliminate actual defects in production and assembly of components to the lowest possible measurable level. The aim was to find an optimal solution to identified problems and causes of failures and defects in production and assembly of components and an independent assessment of unused capacity of manufacturing and assembly lines and production stations calculated at 15% of free space of 100 m^2. The innovative solutions were implementation of a special cover made of transparent plexiglass for protection and security of workers/production operators in industrial and manufacturing enterprises. A simple and feasible innovation was the application of automatic conveyor belts between individual machines using grippers and vacuum suction cups used to transport material on conveyor belts to production stations. The modification of control production stations enabled a reduction in the number of production operations, which has a positive effect in the form of purchase of an air handling system with higher operating performance. Clean rooms were replaced by assembly stations for assembly of electrical components. Due to the time-consuming nature of production operations, other production stations were added, the purpose of which was even and smooth distribution of production flows of components. Along with modification of production and assembly machines, several partial measurements were implemented, concerning use of capacity of manufacturing and assembly lines and utilization of production stations integrated with calculation of costs of clean room operation and maintenance.

The benefits and potential of investment projects are differentiating enterprises from their competitors in an innovative way through reorganization of machinery and rebuilding of manufacturing and assembly lines. These changes enable production of industrial incubators with full utilization of production station capacity, creating economic benefits and resource efficiency that drive value creation. The effectiveness of integrated design proposals was confirmed by monitoring modified production and assembly processes for machinery used in industrial production of incubators. The results demonstrated not only immediate improvements but also potential for long-term gains, including increased throughput, minimized downtime, and enhanced scalability. Moreover, analysis of current and future utilization of production stations and capacity of manufacturing and assembly lines indicates that these changes support sustainable development goals by optimizing resource use and reducing waste, thereby reinforcing enterprise's competitiveness in a rapidly evolving industrial landscape.

The implementation of integrated design solutions to innovation of manufacturing and assembly processes of machinery in industrial engineering has many effects on industrial and manufacturing enterprises and primary sectors, since integration of manufacturing and assembly processes can increase overall production efficiency. The automation and optimization of manufacturing and assembly processes using modern technologies have an impact on optimization of operating costs. The integration of proposals and innovative solutions enables easier monitoring and control of product quality during entire production processes, which contributes to reducing defects and increasing quality of products. The integration of proposed solutions enables greater production flexibility to produce demand. The ability to respond promptly to changes in product demand, adapt to new trends and challenges in industrial and process engineering, or to implement new product series in industrial production of incubators are key aspects of strategic, continuous and systematic implementation of proposed changes and innovations in business processes and sub-activities, since integration of technology in production contributes to reducing losses in complex evaluation of individual production cycle phases.

The automation of activities and data monitoring enables rapid detection and correction of identified problems. Modern technologies and integrated systems facilitate the work of permanent employees and motivate them to better concentrate on more complex tasks and activities influencing labor productivity. Due to automation of machinery and optimization of manufacturing and assembly processes, it is possible to reduce total costs of production and assembly, e.g., by reducing energy consumption, better use of available materials, more efficient use of labor, etc. Integrated systems can reduce the time necessary for development, testing and introduction of products into production.

Implications

Although input costs of investment project are high, see Tab. 10, profitability of investments in innovation of manufacturing and assembly processes in industrial production of incubators was confirmed by an increase in production capacity and higher utilization of production stations. Considering the market price of industrial incubators, cost savings after transformation of machinery in the first year are estimated at EUR 42.544,14. The operating costs were reduced by EUR 23.824,72. The total cost saving after reorganization was EUR 66.368,86 /1 calendar year. In 2024, in which initial investment in reorganization of machinery is not calculated, predicted annual savings in operating costs are EUR 6.299.

Integrated design solutions for manufacturing and assembly processes innovation in industrial engineering are beneficial and value-creating especially in terms of their application in process of streamlining manufacturing and assembly processes in industrial engineering. Optimization of manufacturing processes, automation of machinery, and synchronization of operational activities increase process efficiency.

Monitoring and controlling product quality contributes to reducing the occurrence of defects and increasing product quality. Integrated design solutions enable rapid adaptation to design and changes in demand for products or technologies in synergy with flexibility of primary sector, industrial and manufacturing sectors. Integrated systems facilitate coordination between production cycles and development phases for products by offering more agile entry of new products into national and international markets. The implementation of robotics and production automation promotes the speed and accuracy of monitored processes. The application of integrated design solutions requires through preparation of planning and implementation of investment projects in all phases of project life cycle, as it creates opportunities and potential of value added of processes and activities, production flexibility, and enhanced competitiveness of industrial and manufacturing enterprises in production and non-production processes.

Currently, most industrial and manufacturing enterprises invest their funds in reorganization of machinery in process of closing traditional production by introducing new production or expanding existing production with an emphasis on introducing innovative practices and technologies for selected activities and products. The purpose of the paper is to determine the benefits and potential of a proactive and systemic approach to product and process innovations implemented in technological changes and innovation in manufacturing and assembly processes.

The primary objective is to upgrade production processes and eliminate losses in measurable parameters that have an impact on reduction of volume of product stock and shortening working hours to streamline and improve manufacturing and assembly processes and sub-operations. To prevent further downtime and a decrease in productivity, the aim is to achieve the best results in the shortest possible time. The reorganization of machinery is processes that require changes and innovations of operations and sub-operations, which need to be clearly defined and standardized.

Changes in production and working procedures are often time-consuming, downtimes are longer than usual time allocated to these operations. The needed change is the technical rebuilding of machinery, during which manufacturing and assembly lines are stopped and do not generate products, i.e., do not allocate capital.

The process of globalization by transfer to glocalization enables selling products all over the world, including faraway countries and localities with cheaper labor. To a certain extent, the market determines selling price, which enables a reduction of production costs due to profit from sales of products, with quality of products remaining at the same level. The application of industrial engineering methods and Lean manufacturing enables increasing effectiveness of processes, as well as efficiency of machinery. In automotive, a common phenomenon is that several types or series of products are manufactured by some manufacturing and assembly lines. Thanks to rebuilding machinery, e.g., replacing some tools or fixtures, whose benefits are reflected in calculation of purchasing price of manufacturing and assembly lines, reducing space for production operators, and waste of products, it is advisable to implement new investment projects into manufacturing and assembly processes.

Limitations

The limitations of paper include ambiguous definition of sub-processes in production and assembly, which can significantly influence the amount of fixed costs within total costs of an industrial or manufacturing enterprise. This lack of clarity can lead to challenges in identifying inefficiencies, accurately allocating resources, and optimizing production processes. Moreover, it may hinder the ability to develop precise cost models and forecasts, which are essential for strategic planning and decision-making. Addressing these ambiguities through more detailed process mapping and analysis could not only enhance cost management but also improve the overall competitiveness and adaptability of enterprise in dynamic market conditions. The degree of operating leverage affected by mechanization, automation, and robotization has an impact on production volume and amount of operating earnings. In conjunction with the application of the 5 Whys method, it is possible to maintain a position on national or international markets and remain competitive in industrial engineering, assuming analysis of primary causes of technical and human failures to identify defects with the aim of eliminating consequences and creating proposals of innovative, smart, and multi-purpose measures with a higher added value of manufacturing and assembly processes.

The systematic, continuous improvement of corporate processes and comprehensive solutions to key problems and causal consequences are subject of integration of production processes quality and production management systems. Enterprise resource planning (ERP) systems are targeted at corporate resource planning, whose application now shows a lower added value of corporate processes, as indicated by the 8D report method. Traditional ERP systems do not integrate supply chains, thereby disrupting a holistic approach to the system, without which it is impossible to specify benefits of sub-processes and their connection in core and controlling processes. Real-time quality control of products (industrial incubators), frequent technological changes, and adaptation to new trends and strategic forecast in innovation and strategic management of selected branches of technical and mechanical fields must respond to current and future needs of industrial production by absorbing technological changes and innovations aimed at long-term economic prosperity and manufacturing sustainability.

The proposed solution is to divide industrial and manufacturing enterprises into parts producing new products and invest in research and development, technology construction, conceptual design of production systems, and distribution to customers. Supporting activities deal with innovations and implementation of products into business and corporate processes and individual operations through functional systems applicable to implementation and expansion of new practices and creative solution proposals in manufacturing and assembly processes.

Further research directions

Further research could focus on empirical application of a Lean manufacturing method, SMED (Single Minute Exchange of Die), by dividing production into smaller units of manufacturing and assembly processes with a direct impact on synchronization of production flows, e.g., by shortening the time necessary for machinery changeover. This method aims to reduce the time needed to change tools or set up machines, which will speed up production processes and increase efficiency. To reduce the time needed to change tools or set up machines, which will speed up production processes and increase efficiency.

Other directions of research

Division of production into smaller units

Research should explore division of production and assembly into smaller units, which would have a positive effect on synchronization of production flows. This approach can help reduce production lead times and improve production station utilization.

Increasing capacity of production lines

Research aimed at increasing capacity of production and assembly lines should be part of efforts to increase efficiency and reduce downtime in production. Improving capacity can lead to more efficient use of available resources and a reduction in the time required to produce products.

Reduction of material stocks

Another direction is research aimed at reducing material stocks, which contributes to optimization of production processes and reduction of costs associated with material storage. Less inventory means faster material flow and lower storage costs.

Automation and Robotization

Research should also include automation and robotization of production processes, which helps to increase efficiency and reduce human error. The use of advanced technologies such as robots and automated systems can significantly improve production quality and speed up production.

Integration of Advanced Technologies

Further research could also investigate the integration of advanced technologies such as automation, IoT (Internet of Things), and AI-driven analytics in production and assembly processes. These technologies can enhance real-time monitoring, predictive maintenance, and decision-making, resulting in more synchronized and efficient operations. By leveraging these innovations, enterprises can further reduce downtime, optimize resource utilization, and gain valuable insights to refine their production strategies.

Improving manufacturing and assembly processes and control activities by introducing digital technologies into production, automation and robotization of machinery enables creating a portfolio of opportunities and challenges for technological advancement and growth of industrial and manufacturing enterprises in developing market economies.

The potential benefits and expectations in adapting to new market conditions and customer requirements, however, remain largely unexplored and unaddressed in a systematic manner. This gap highlights the need for a structured approach to understanding and leveraging market dynamics and evolving consumer preferences. Systematic analysis could uncover opportunities to innovate products, optimize production processes, and create value-driven solutions tailored to emerging demands. Furthermore, addressing this issue would help enterprises enhance their competitiveness by aligning their capabilities with market trends, reducing time-to-market for new products, and fostering stronger customer relationships through a proactive and responsive approach to changing requirements.

Acknowledgments

The paper is part of the project IDUPS22039 The importance of quality and innovative benefits for creating and increasing added value in business processes.

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