



GENERAL PROBLEMS OF THE MODERN RESEARCH AND INNOVATION POLICY

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EVALUATION OF INNOVATIVE MANAGEMENT METHODS IN COMBINATION WITH DECARBONIZATION STRATEGIES: INTERACTION EFFECTS AND RECOMMENDATIONS FOR DOMESTIC ENTERPRISES

Introduction. *The integration of innovative management methods with corporate sustainability strategies has become increasingly relevant across business sectors.*

Problem Statement. *The challenge is to evaluate management methods when combined with decarbonization approaches to ensure both efficiency and environmental responsibility.*

Purpose. *This study has investigated the impact of combined production management methods on key performance indicators of enterprises, including their advantages and disadvantages, application frameworks, managerial implementation, cultural aspects, and capacity planning under emission reduction requirements.*

Materials and Methods. *A mixed-methods approach has been employed, combining qualitative and quantitative techniques to analyze innovative practices. Information-search, analytical, and comparative methods, along with cost-benefit and decision tree analysis, have been applied to develop practical recommendations.*

Results. *A comprehensive comparative analysis of innovative production management methods — specifically Lean Manufacturing, Total Quality Management (TQM), Six Sigma, the Theory of Constraints (TOC), and Just-in-Time (JIT) — has been presented. The study has examined similarities and differences across 20 criteria in both international and domestic enterprises, enabling decision-makers to gain deeper insight into their foundations. It has been demonstrated that integrating decarbonization with efficiency-focused methodologies optimizes resource utilization. Practical recommendations for improving production processes have been developed, taking into account industry-specific characteristics and current operational challenges. Cost-benefit and decision tree analyses have confirmed the robustness of the proposed recommendations.*

Conclusions. *The proposed approach has contributed to aligning sustainability objectives with profitability in manufacturing enterprises. The findings have provided a foundation for further research in innovation management and for the development of practical solutions aimed at cost optimization, quality improvement, and enhanced customer satisfaction in the manufacturing sector.*

Keywords: innovative methods, lean manufacturing, cost savings, entrepreneurship, globalization, sustainability.

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Organizations constantly need innovation and improvement in management methods due to rapid technological progress and continuously changing consumer expectations. The desire for increased productivity, good quality, and sustainable operation has led enterprises to study various innovative management methods. Approaches such as Lean Manufacturing, TQM, Six Sigma, TOC, and Just-In-Time principle have gained popularity as the most critical approaches for achieving operational excellence and ensuring economic sustainability [1]. These methodologies are of great importance. Nowadays, companies face the challenges of globalization, they should be flexible and adapt to different market conditions and competitive pressure. Such adaptation often involves adopting continuous improvement strategies that not only optimize processes but also raise work efficiency and improve the economic component of the organization as a whole. These methodologies are particularly relevant for Ukrainian manufacturers, especially given the profound economic disruptions caused by the ongoing war. Ukraine's economy contracted by approximately 30% in 2022 [2], mainly due to the invasion's impact on export routes, infrastructure, and industry. For manufacturing companies, this context of crisis and uncertainty means that adopting innovative management techniques becomes critical for maintaining competitiveness and survival. Implementing continuous improvement strategies can help optimize limited resources, boost production efficiency, and reduce costs during these challenging times.

Lean manufacturing focuses on eliminating waste and optimizing efficiency, while Six Sigma focuses on reducing variability and improving quality. Total Quality Management aims to meet customer needs, involve all staff in the decision-making process, and monitor results. The Just-In-Time system reduces storage costs and allows businesses to respond to changes in demand quickly. Theory of Constraints provides a framework for identifying and eliminating bottlenecks in production processes, thereby improving productivity [3]. It is important to mention that lean principles can be

adapted to help domestic and international enterprises reduce their level of emissions without compromising productivity. Consequently, such an approach allows businesses to take effective actions toward growing demands for sustainability from their stakeholders [4]. Linking lean production and decarbonization supports both regulatory compliance and global climate goals as per the Paris Agreement [5]. Furthermore, it is becoming progressively well-liked by enterprises planning to contribute to global sustainability efforts, according to the United Nations Sustainable Development Goals, in particular Climate Action, Goal 13 [6]. By incorporating these goals into enterprise strategies, organizations can gain a competitive advantage and reduce their environmental impact simultaneously.

Many researchers have revealed the potential for synergy between these methodologies, suggesting that an integrated approach can bring significant benefits [7, 8]. For example, combining Lean manufacturing principles, Six Sigma and Theory of Constraints improves production systems by eliminating shortcomings and creating a culture of continuous improvement. Moreover, the growing emphasis on environmental friendliness in business practices has prompted organizations to rethink their operational strategies. Sustainable manufacturing practices (SMP) have become a critical component of these changes as companies increasingly realize the importance of environmental attitudes and social responsibility [1]. SMP can be effectively integrated with traditional management and economic practices, creating a more holistic approach to improving operational efficiency that meets consumer values, expectations, and trust. Careful analysis and study of the existing literature and empirical data, this article is intended to give a complete picture of the effectiveness of analyzed innovative management methods in various conditions. Comparing the experience of international and domestic enterprises, we strive to identify best practices and critical factors that contribute to successful implementation. This analysis revealed the various applications of

these methodologies and show organizations' challenges in their willingness for excellence. Consequently, it provides some guidance to better understanding of how innovative management practices can contribute to improving the efficiency and sustainability of an organization, considering growing competition rate in the global market. As the business evolves, the findings of this comparative analysis will serve as a valuable source for practitioners and academics, guiding future efforts to improve management practices and achieve long-term success. The manufacturing sector has seen considerable changes, with various approaches emerging to boost productivity, quality, and sustainability. In this research analyzed important insights from recent studies on integrating continuous improvement strategies, such as Lean Manufacturing, Total Quality Management, Six Sigma, Theory of Constraints, and Just-In-Time, and examines their effects on organizational performance and economic sustainability. De Jesus Pacheco explores the convergence and divergence of TOC, Lean Manufacturing, and Six Sigma, highlighting their complementary elements [7]. The study identifies comparative criteria that reveal how these methodologies can be integrated to improve manufacturing systems. This integration is crucial, as it allows organizations to leverage the strengths of each approach while addressing their limitations. Similarly, Arnheiter and Maleyeff argue for the integration of Lean and Six Sigma, suggesting that a combined approach can overcome the shortcomings of each methodology when applied in isolation [9]. This perspective is echoed by Bendell, who emphasizes the need for a holistic approach to process improvement, advocating for the compatibility of Lean and Six Sigma practices [10]. Hami and Muhamad investigate the role of sustainable manufacturing practices (SMP) in enhancing economic sustainability [1]. Their findings indicate that internal SMP positively affects economic sustainability, with process innovation serving as a mediator. This underscores the importance of integrating sustainability into continuous improvement strategies, as organiza-

tions that adopt environmentally and socially responsible practices can achieve better economic performance. Nordin and Deros address the challenges of implementing Lean Manufacturing, attributing low success rates to inadequate change management [11]. They propose a framework for organizational change management that links it with Lean implementation, emphasizing the need for a structured approach to facilitate successful transformations. Lleo, Viles and Lomas highlight the significance of middle managers in fostering a culture of continuous improvement [12]. Their study identifies specific trustworthy behaviors that boost employee engagement and commitment, indicating that effective managerial practices are crucial for the success of continuous improvement initiatives. Sale and Inman [8] present empirical data comparing the performance of firms using traditional manufacturing, JIT, and TOC. Their results indicate that companies adopting TOC see the most significant performance gains, while JIT does not notably surpass traditional methods. This finding suggests that organizations should carefully evaluate which methodology best fits their operational objectives. Dametew et al, analyzes the challenges faced by the basic metal industry in Ethiopia, pinpointing issues like inadequate supply chain systems and outdated technology [13]. They recommend an integrated continuous improvement model that combines TQM, JIT, and Supply Chain Management (SCM) to boost global competitiveness. Theoretical insights from Nave and Dettmer shed light on the foundational concepts of Lean, Six Sigma, and TOC, emphasizing the importance of a deep understanding of these methodologies for effective implementation [6, 14]. Additionally, Permana, Purba and Rizkiyah, conduct a systematic review of TQM, confirming its ongoing relevance in enhancing business performance and customer satisfaction across various sectors [15].

Integrating continuous improvement methodologies offers significant potential for improving manufacturing performance and economic sustainability. However, successful implementation hinges on a solid grasp of each methodology, effec-

tive change management and a focus on employee engagement. This research investigates the synergies among these approaches and their applicability across different industries to further enhance organizational performance. Furthermore, adopting these strategies becomes even more crucial in the context of the current global crises, such as the war in Ukraine. For Ukrainian manufacturing companies struggling with disrupted supply chains and economic instability, the need to optimize production efficiency and resource utilization is heightened. Companies can enhance resilience, maintain competitiveness, and reduce the risk of financial losses by continuously improving processes.

This article aims to comprehensively study and evaluate innovative methods by comparative analysis of their applications at both international and domestic enterprises, connecting a decarbonization strategy with production principles of enterprises for a powerful approach to sustainability and efficiency. The purpose of the study – evaluate and compare innovative management methods applied within international and domestic enterprises, aiming to identify best practices and critical factors for successful implementation across different organizational. The effectiveness of Lean Manufacturing, Total Quality Management, Six Sigma, the Theory of Constraints and Just-In-Time has been assessed by applying four steps approach proposed by authors. This approach represents set of four main objectives of the research:

Step 1. Examine the core principles, strengths, and limitations of Lean Manufacturing, TQM, Six Sigma, TOC, and JIT.

Step 2. Compare how these methodologies are applied within enterprises, highlighting differences in implementation strategies and outcomes.

Step 3. Identify critical success factors and best practices that enable the effective implementation of decarbonization strategies across diverse organizational contexts, ensuring alignment with enterprise goals and sustainability objectives.

Step 4. Evaluate the recommendations to identify best practices that enhance environmental sustainability and operational efficiency.

A mixed-methods approach is used in this research, integrating qualitative and quantitative research methods for a comprehensive understanding of innovative practices. The proposed approach enables a more profound analysis by combining numerical data with valuable insights from industry practice. The detailed steps of the applied methodology are as follows:

1. Compile a list of credible primary and secondary sources related to Lean Manufacturing, TQM, Six Sigma, TOC, and JIT, ensuring a broad coverage of foundational and contemporary works.

2. Organize collected materials by themes such as implementation strategies and industry-specific applications to streamline analysis.

3. Conduct a thorough literature review to identify areas where information is insufficient, inconsistent, or underexplored, highlighting gaps in current Lean Manufacturing, TQM, Six Sigma, TOC and JIT research.

4. Utilize comparative analysis to evaluate the effectiveness of various approaches and methodologies, drawing distinctions in their impact across different settings.

5. Synthesize findings to formulate actionable conclusions and provide recommendations for both future research and practical applications within the research field.

6. Conduct assessment for the proposed suggestions and identify limitations.

The basic principle of lean manufacturing is to eliminate waste and create value for the customer. De Jesus Pacheco explores the synergy between the TOC, Lean and Six Sigma and argues that integrating these methodologies can provide a comprehensive framework for improving productivity [7]. Lean also aims to improve efficiency, Six Sigma seeks to enhance quality by reducing process variability, and TOC identifies and manages performance constraints. This synergistic approach allows organizations to optimize various efficiency aspects, increasing their competitiveness in today's market. The integration of Lean and Six Sigma attracts special attention. Hami emphasize that organizations that use rational production

methods improve environmental performance and achieve better economic results [1]. Dametew proves that an integrated approach that includes sustainable development in an enterprise’s strategy increases its competitiveness [13]. Employee support is one of the main factors for successful production transformation. The introduction of lean manufacturing requires not only technical changes but also cultural shifts within the organization [11]. The authors strongly recommend investing in staff training to ensure the practical application of Lean Techniques [1, 6, 9–11]. Each method has its separate approach to improving productivity and quality, influencing certain aspects of the production process and providing special tools and ways to achieve the goals of a particular organization.

We start with step 1 – examine the core principles, strengths, and limitations of Lean Manufacturing, TQM, Six Sigma, TOC, and JIT. The Table 1

compares these methodologies overview by using specified criteria. The selection of these 20 characteristics is based on a comprehensive literature review, emphasizing key performance indicators commonly used to evaluate and compare management methodologies in production settings [8].

Authors proposed to use this criteria set: 1 (idea), 2 (objectives), 3 (goals), 4 (focus), 5 (prime effects), 6 (indicators of performance management), 7 (stability requirements for deployment), 8 (application steps), 9 (complexity of implementation), 10 (inventory required), 11 (effect on the variability), 12 (contributions), 13 (process details), 14 (control on production), 15 (planning on production), 16 (distribution of knowledge), 17 (culturally dominant aspects), 18 (managerial style and level of implementation), 19 (disadvantages), 20 (data requirements).

Each characteristic, such as “Objectives,” “Goal,” “Focus,” and “Prime Effects” provides an essential

Table 1. Matrix of the Criteria Sets from 1 to 5 and Their Characteristics

Criteria/Methods	1	2	3	4	5
Theory of Constraints	Identify and manage constraints to improve system performance	Maximize throughput by focusing on the system’s weakest point	Improve overall system efficiency by managing bottlenecks	System bottlenecks that limit production flow	Improved throughput and resource utilization
Lean Manufacturing	Eliminate waste and increase value by focusing on activities that add value to the customer	Maximize productivity and efficiency, reduce waste, and improve customer satisfaction	Achieve a streamlined, cost-effective production process with minimal waste	Waste reduction (such as overproduction, waiting, inventory)	Cost savings, faster production cycles, and customer satisfaction
Six Sigma	Use statistical tools to reduce defects and improve process control	Reduce process variation to improve product quality	Achieve near-perfection in process quality, targeting 3.4 defects per million	Statistical analysis to reduce variation and enhance process control	Reduced defects, higher quality, and improved customer satisfaction
Just-In-Time	Reduce waste by producing items only as they are needed	Minimize inventory and reduce lead time	Align production closely with demand to reduce storage costs	Inventory minimization and response to real-time demand	Cost savings, reduced waste, improved flexibility
Total Quality Management	Foster a quality-centric culture that permeates every aspect of the organization	Consistently meet or exceed customer expectations	Improve quality in all facets of production and business operations	Quality at every step, from product design to final delivery	Enhanced product quality, customer satisfaction, and employee involvement

Source: developed by the authors.

Table 2. Matrix of the Criteria Sets from 6 to 10 and Their Characteristics

Criteria/ Methods	6	7	8	9	10
Theory of Constraints	Throughput, inventory levels, operating expense	Requires an understanding of system constraints	Identify constraint, exploit it, subordinate other processes, elevate constraint, repeat	Moderate; depends on clear identification of constraints	Optimized inventory, limited to prevent bottlenecks
Lean Manufacturing	Cycle time, inventory levels, defect rates, customer satisfaction	Requires stable processes to identify and remove non-value-adding activities	Identify waste, map value streams, create flow, establish pull, and pursue perfection	Moderate to high; requires commitment and cultural shift	Minimal; focuses on reducing excess inventory
Six Sigma	Defect rate, sigma level, process capability	Requires well-defined processes with identifiable variations	Define, Measure, Analyze, Improve, Control (DMAIC)	High; requires trained personnel and extensive data analysis	Focus on minimizing variation in inventory quality
Just-In-Time	Inventory levels, lead time, order fulfillment	Requires a stable, reliable supply chain	Demand forecasting, production scheduling, inventory control	Moderate to high; depends on demand predictability	Minimal; only as needed for immediate production
Total Quality Management	Customer complaints, defect rates, employee engagement	Requires stable processes for consistent quality monitoring	Customer focus, leadership, continuous improvement, employee involvement	High; affects entire organization and requires strong leadership	Inventory optimized based on quality standards

Source: developed by the authors.

Table 3. Matrix of the Criteria Sets from 11 to 15 and Their Characteristics

Criteria/ Methods	11	12	13	14	15
Theory of Constraints	Reduces bottleneck-related variability	Increased throughput, reduced lead times, optimized resources	Focused on continuous improvement at the bottleneck level	Constraint-based production control	Planning around the constraint's capacity
Lean Manufacturing	Reduces variability by standardizing processes	Cost reduction, improved product quality, faster response times	Involves continuous improvement and employee engagement	Standardized work processes and constant flow	Pull-based system; production based on demand
Six Sigma	Significantly reduces variability in processes	Quality improvement, efficiency gains, and cost reduction	Structured, data-driven approach to problem-solving	High level of statistical control over production processes	Focus on defect prevention and process optimization
Just-In-Time	Reduces inventory variability, but may increase production variability	Lower inventory costs, reduced storage space	Responsive, demand-driven production scheduling	Production closely aligned with customer orders	Demand-based, minimizing lead times
Total Quality Management	Decreases variability through standard quality practices	High-quality products, customer loyalty, brand reputation	Employee-driven quality improvements; process-focused	High control over each process to maintain quality	Long-term quality-focused planning

Source: developed by the authors.

vision of the strategic and operational priorities of each methodology [10, 14]. These criteria are widely discussed across foundational works in mentioned methodologies, serving as primary factors that impact efficiency, quality, and adaptability in production. The chosen characteristics offer a balanced view, addressing not only the implementation complexity and cultural aspects but also specific technical factors like “Inventory Required” and “Effect on Variability,” which are crucial for production environments, especially in production companies. Limiting the criteria to 20 ensures a manageable yet thorough analysis, encompassing strategic and operational dimensions without overwhelming the comparison with excessive details.

Tables 1–4 summarize main business ideas towards improvement decisions in production management and deliver sustainable growth in an increasingly complex business environment.

By analyzing these aspects, we can identify each approach’s strengths, limitations, and potential

applications. In addition, this data provides insight into industry-specific applications, helping organizations choose and combine methods that best suit their economic needs and market demands. Furthermore, this comparative review can be a basic guide for companies looking to improve their production processes. Organizations should consider adapting these approaches to meet industry requirements and the challenges that companies set for themselves. For example, Lean and Six Sigma can create a reliable, high-quality production system, while TOC and JIT can adapt to highly volatile industries. Arnheiter and Maleyeff emphasize that Lean’s focus on optimizing processes and reducing waste is effectively combined with Six Sigma’s data-driven approach to improving quality [9]. While Jin et al., also discuss the integration of TOC and Six Sigma to improve production processes, pointing out significant improvements in productivity and quality [16]. That research also highlights the importance of sustainability.

Table 4. Matrix of the Criteria Sets from 16 to 20 and Their Characteristics

Criteria / Methods	16	17	18	19	20
Theory of Constraints	Localized to team managing constraints	System-focused, efficiency-driven culture	Operational level, constraint-driven	Limited scope, potential neglect of non-bottleneck processes	Moderate; requires data on bottlenecks and system flows
Lean Manufacturing	Collaborative; encourages sharing of improvement ideas	Customer-first mindset, continuous improvement culture	All levels involved, with a focus on continuous improvement	Initial setup costs, requires cultural change, may reduce flexibility	High; requires real-time data to track waste and performance
Six Sigma	In-depth training in statistical methods (e.g., Green Belt, Black Belt)	Data-driven, improvement-focused	Project-based, often requires expert oversight	Resource-intensive, may be too rigid, and high training costs	Very high; relies on accurate, extensive data collection
Just-In-Time	Relies on shared demand and inventory information	Efficiency-focused, customer-responsive	Decentralized, production-level emphasis	Vulnerability to supply chain disruptions, requires demand stability	Moderate; relies on accurate demand and inventory data
Total Quality Management	Cross-functional; encourages knowledge sharing on quality	Quality-focused culture and customer-centric values	Top-down leadership with broad employee involvement	Slow to implement, requires culture change, potentially costly	Significant; requires comprehensive data on quality metrics

Source: developed by the authors.

This combination not only improves operational efficiency but also contributes to the formation of a culture of continuous improvement, where employees always have the opportunity to identify and solve problems. TQM principles can be integrated to support a culture where continuous improvement and quality are priorities. Sila and Ebrahimpour point out that TQM needs to be adapted to local cultural conditions for effective implementation [17]. Organizations that integrate TQM into their operational strategies can better meet customer expectations [15]. TQM also demonstrates significant flexibility in different cultural contexts. The relationship between total Relationship Management (TRM) and TQM, noting that customer and Supplier Relationship Management is a key component for achieving high results [18]. Middle management is critical in stimulating employee engagement, which significantly increases engagement in improving initiatives [12]. Just-in-time is also a critical approach, which increases operational efficiency by aligning production with customer demand. Barkhordari and Denavi investigate the impact of JIT in the ceramic industry, emphasizing that JIT not only reduces the cost of inventory that needs to be harvested but also increases production flexibility [19]. Aradhye shows the effectiveness of JIT applications in the service sector, which illustrates the adaptability of the methodology to any of industries [20].

As a step 2 of the authors' approach, the following recommendations can help businesses in various industries effectively implement these production methods. These recommendations, which consider the unique characteristics of different sectors, provide advice for applying these methodologies to meet industry requirements and improve overall operational efficiency. These recommendations serve as a practical basis for industry leaders who strive to innovate and optimize their production processes, which in turn will reduce costs and improve product quality. This individual approach not only facilitates the selection and integration of appropriate production methods but also supports the sustainability and adapta-

tion of the company. The recommendations are composed in a Table 5.

The implementation of Lean, TQM, Six Sigma, TOC, and JIT methodologies creates a strong synergy that significantly benefits all kind of industries by enhancing their adaptability to adapt for market demands and promoting stable growth.

Based on this analysis authors proceed to step 3. By optimizing resource utilization, Lean and JIT principles lead to increased productivity and reduced operational costs. Six Sigma and TQM enhance product quality through the defect reduction and quality control mechanisms, ultimately improving customer satisfaction. The flexibility provided by Lean and JIT enables companies to respond swiftly to changing customer needs, ensuring competitiveness in dynamic markets. Lastly, the emphasis on continuous improvement ingrained by TQM and Lean fosters a culture of innovation and high standards, driving sustained organizational development.

Hence, it is noticeable that using a comprehensive approach to implementing Lean, TQM, Six Sigma, TOC, and JIT methodologies allows enterprises to achieve operational excellence. The challenges that we can see nowadays, require businesses to be flexible, customer-oriented, and meet environmental requirements. The integration all of these methodologies contributes to forming a sustainable business model that can achieve high-quality standards, efficient use of resources, and providing a competitive advantage in a dynamic market.

All of these together focus on optimizing processes by minimizing waste and improving efficiency, thus aligning with the decarbonization strategies of enterprises. Consequently, applying Lean, TQM, Six Sigma, TOC and JIT methodologies would facilitate enterprises decrease emissions by synchronizing production with demand, hence avoiding overproduction with the related carbon costs.

Step 4 focuses on implementing the synergy of all the methodologies mentioned before for a hypothetical Ukrainian manufacturing company, businesses can outline key actions, timelines, costs,

potential and possible challenges. All the costs provided in the table are based on general industry benchmarks and common costs associated with similar implementations. Since this is a hypothetical scenario, the exact costs can vary based on factors like the size of the company, location, the specific vendors or consultants chosen, and external conditions. As per the Lean Institute Ukraine, ERP pricing: Understanding the costs involved, Accounting services fees in Ukraine, Six Sigma certifications & quality management courses and Lean Yellow Belt training [30–34]. We will con-

Table 5. Recommended Methodologies across Different Industries

Industry	Recommended approach	Applications and examples of usage
High-Precision Manufacturing (aerospace, pharmaceutical)	Integration of Six Sigma and TQM to achieve high-quality standards	Boeing and Pfizer have implemented Six Sigma and TQM for rigorous quality control in their production processes [21, 22]
Consumer goods and retail	Lean and JIT provide adaptability to local market demand, and TQM contributes to customer satisfaction	Toyota and Unilever use Lean and JIT to streamline inventory and adapt quickly to market needs, enhancing customer satisfaction [23]
Mechanical Engineering and automotive industry	A combination of Lean, Six Sigma, and TOC is effective for mechanical engineering and automotive companies. Lean minimizes material and time loss while providing flexibility, while Six Sigma improves quality control and reduces defects. TOC, focusing on eliminating “bottlenecks,” ensures maximum performance, especially in mass production environments. This integrated approach helps to increase productivity and reduce costs, which allows companies to remain competitive in high-tech industries	Ford and General Motors utilize Lean, Six Sigma, and TOC to boost productivity and ensure operational efficiency [24]
Food Processing and FMCG (Fast-Moving Consumer Goods)	The use of JIT and Lean is relevant for food processing enterprises and FMCG. These methods help to respond quickly to market demand, minimizing inventory and preventing losses due to rapid product spoilage. Combining TQM principles helps ensure stable product quality, increasing consumer confidence and brand loyalty	Nestle and Procter & Gamble (P&G) apply Lean and JIT to optimize responsiveness and reduce waste, maintaining quality through TQM [25, 26]
High-tech industries (Electronics, IT)	The benefit from the integration of Lean and TQM can reduce the time needed to bring the product to market and ensure stable quality. Lean avoids excessive inventory, which is especially important for components with a short life cycle, while TQM ensures compliance with high-quality standards. Six Sigma can also be used to optimize processes and reduce defects, minimizing the risk of product returns and increasing brand confidence	Intel and Samsung combine Lean and TQM to shorten cycle times and meet high quality standards in electronics production [27, 28]
Primary industries (metallurgy, mining)	Integration of TOC, JIT, and sustainability principles is essential for major industries. TOC allows optimizing resource usage by focusing on constraints in the production chain, while JIT helps reduce storage costs and promotes production flexibility. Integrating sustainable practices, such as reducing emissions and optimizing energy costs, not only increases efficiency but also positively impacts the company’s environmental reputation, which is important for attracting investors and maintaining social responsibility	Rio Tinto and ArcelorMittal have applied TOC to manage production constraints and JIT to streamline inventory, minimizing storage costs. Additionally, both companies have incorporated sustainable practices, with Rio Tinto focusing on emissions reduction and ArcelorMittal implementing energy optimization measures [29]

Source: developed by the authors based on [21–29].

sider the medium business with a staff of about 50–200 people (Table 6).

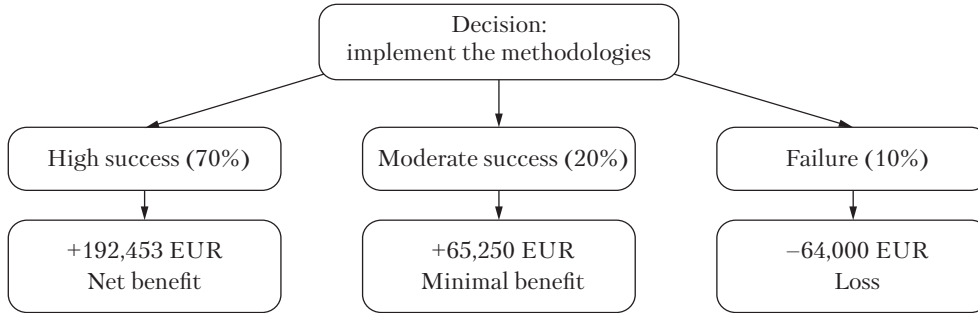
Applying the considered example with a hypothetical typical medium size business firm we find these helpful practical insights mentioned below in priority order. An operational audit is a foundational step in assessing current processes and identifying inefficiencies. Following this, Lean and Just-In-Time principles can be integrated through targeted training and workshops, fostering a culture of waste reduction and streamlined

production. Six Sigma initiatives, mainly through Yellow Belt certification, enable employees to understand and apply data-driven approaches to minimize process defects and variations. The cultural integration of TQM is crucial for promoting continuous improvement and employee engagement, which can be achieved through dedicated workshops and communication strategies. Implementing modern IT infrastructure, such as ERP systems, facilitates real-time inventory management and enhances operational agility. Lastly, es-

Table 6. Action Plan and Cost Analysis for the Integration Method

Proposed action	Estimated time of implementation	Cost (Euro)	Potential effects	Challenges in implementation
1. Conduct an Operational Audit (Assess current inefficiencies, gaps in quality, production bottlenecks)	2–4 months	3,000–5,000 (consultancy)	Provides initial data for Lean, Six Sigma, and TQM implementation	Requires management buy-in and employee time usage (non-working hours)
2. Lean and JIT Implementation (Improving production flow to minimize waste and inventory) and align these principals with decarbonisation strategy of an enterprise	4–6 months	5,000–10,000 (training, certifications, software tools)	Cost reduction in production by up to 15–20% Directly impacts the carbon footprint via fewer usage of resources Synchronizes production with demand and avoid overproduction with the associated carbon costs – decreases enterprises emissions	Requires staff training, possible resistance to change, requires time to deliver visible results
3. Six Sigma Project (Initial Phase, reduce defects and variations)	6–12 months	7,000–15,000 (training, pilot project costs)	Potential reduction in defect rates by 10–15%, improving product quality	Requires hiring certified Six Sigma experts or upskilling employees (gain new certificates)
4. TQM Cultural Integration (Build continuous improvement culture)	Ongoing, starts after another methodology	2,000–3,000 (workshops, communication plans)	Increased employee engagement and productivity, better quality outcomes	Building a culture takes time, could meet resistance without managerial assist
5. IT Infrastructure, ERP systems (Integrate enterprise resource planning systems to monitor inventory and production in real time)	8–12 months	20,000–30,000 (system purchase, setup, updates)	Real-time data improves decision-making and production flexibility	High initial cost, may require staff training
6. Continuous Monitoring and Feedback Loops (Implement data-driven review systems to monitor performance)	Continues	500–1,000 per month (data analytics, reports)	Long-term operational optimization, reduction in defects, improved customer satisfaction by 10–15%	Ongoing cost, may require external expertise to interpret results

Source: developed by the authors.



Decision tree of methodology implementation
 Source: developed by the authors.

tablishing continuous monitoring and feedback loops using data analytics tools ensures that key performance indicators related to quality and productivity are consistently tracked, allowing for ongoing adjustments and improvements in processes. Together, these initiatives can create a comprehensive framework for sustained operational excellence.

Using data in the table above we can perform a cost benefit analysis to evaluate whether implementing the synergy of these methodologies is justified. We will use the Net Present Value (NPV) method, where we project the costs and benefits over a 5-year period and discount them to the present value using a discount rate. The discount rate of 8.6% was used as the expected inflation rate for 2024 based on National bank of Ukraine Inflation report [35].

We have kept the discount rate fix for these 5-year period. Assuming production costs are approximately 200,000 EUR (based on author’s estimations and approximate calculations from Table 3). It is expected that the introduction of Lean and JIT will save from 30,000–40,000 EUR by reducing production costs by 15–20%. Six Sigma initiatives can reduce the costs associated with defects by 5,000–7,500 EUR, expected reduction in defect rates 10–15% (assuming the costs associated with defects are approximately 50,000 EUR annually). TQMs efforts to create a culture of continuous improvement can increase productivity, which is estimated to result in savings of 25,000 EUR (if the revenue from production is

500,000 EUR annually, savings will be about 5%). The domestic company can expect average annual savings of 35,000 + 6,500+25,000 = 66,250 EUR by improving efficiency, reducing costs and improving quality. Let’s assume an initial investment of 64,000 EUR as a maximum cost (Table 3), time frame is 5 years, and discount rate is 8.6%.

The basic formula for NPV is presented below [36].

$$NPV = \sum \frac{B_t - C_t}{(1+r)^t} - C_0, \quad (1)$$

where NPV – Net Present Value; B_t – benefits in a year; C_t – costs in a year; r – discount rate; C_0 – initial investment; t – number of years.

For each year, the effective benefit after accounting for the annual cost will be:

$$B_t - C_t = 66,250 - 1,000 = 65,250 \text{ EUR.}$$

The following step is to present the NPV calculation over 5 years (Table 7).

Table 7. Five-Year Financial Projection

Year	Benefits, EUR	Discount factor	Discounted Net Benefit	Discounted Net Benefit, EUR
2024	65,250	1.086	$65,250/(1+0.086)^1$	60,155
2025	65,250	1.176	$65,250/(1+0.086)^2$	55,487
2026	65,250	1.276	$65,250/(1+0.086)^3$	51,001
2027	65,250	1.388	$65,250/(1+0.086)^4$	46,712
2028	65,250	1.513	$65,250/(1+0.086)^5$	43,096

Source: developed by the authors.

According to the Table 7, total discounted net benefits = 60,155 + 55,487 + 51,001 + 46,712 + 43,096 = 256,453 EUR. Applying (Formula 1), *NPV* for the proposed project (suggested recommendations (Table 6), will be equal as following $NPV = 256,453 - 64,000 = 192,453$ EUR. Consequently, based on this hypothetical example, the positive *NPV* justifies the implementing of the synergy of the proposed methodologies and makes it useful for further implementation by domestic firms.

A simplified representation of the decision tree is presented in Figure.

To derive the expected monetary value (*EMV*) of the decision to implement, we can calculate it as follows presented [36].

$$EMV = (P_{success} \cdot Benefit_{success}) + (P_{partial} \cdot Benefit_{partial}) + (P_{failure} \cdot Loss_{failure}), \quad (2)$$

where $P_{success}$ – Probability of full implementation success; $Benefit_{success}$ – Monetary benefit if the implementation is fully successful; $P_{partial}$ – Probability of partial success; $Benefit_{partial}$ – Monetary benefit if the implementation is partially successful; $P_{failure}$ – Probability of failure; $Loss_{failure}$ – Monetary loss if the implementation fails.

Applying Formula 2, we identified that $P_{success} = 0.7$, if the implementation is successful, the company gains a net benefit of +192,453 EUR; $P_{partial} = 0.2$, if the implementation has limited success, the net benefit is +65,250 EUR. $P_{failure} = 0.1$, if the implementation fails, the company incurs a loss of -64,000 EUR.

According to Formula 2.

$$EMV = (0.7 \cdot 192,453) + (0.2 \cdot 65,250) + (0.1 \times -64,000) = (134,716) + (16,050) - (6,400) = 141,366 \text{ EUR}$$

The Expected Monetary Value is approximately 141,366 EUR suggests that, average implementing the methodologies is likely to yield a positive financial outcome over time. The *EMV* of implementing the methodologies is significantly higher than not implementing them. Therefore, the decision tree analysis supports the conclusion that

it would be beneficial for the company to move forward with the implementation.

Hence, it is noticeable that the integration of an enterprise decarbonization strategy with proposed production approach can enhance the effectiveness of both ideas. Lean, TQM, Six Sigma, TOC and JIT methodologies emphasizes the optimization of efficiency via the reduction of waste, while decarbonization covers strategies aimed at reducing greenhouse gas emissions and fostering environmental sustainability. Consequently, aligning these two proposed approaches, enterprises can achieve substantial economic and environmental benefits via synergistic effects. Those together can be considered as one of the practical recommendations for enterprises to reduce their carbon footprints and contribute to sustainable development without sacrificing efficiency.

Authors have applied the four steps approach and the findings show that innovative production management methods Lean manufacturing, TQM, Six Sigma, TOC, and JIT described in the study shows how each method provides certain advantages and solves specific production tasks. While these methods are unique in their focus, tools, and approach to implementation, they also have synergistic potential, as they can all be integrated to achieve comprehensive performance and quality improvements. An important aspect is the adaptability of these methodologies to different industrial environments, which indicates that best practices are highly dependent on industry requirements. The results show that combining these approaches is most effective in industries that require high precision, such as aerospace or pharmaceuticals, and in rapidly developing industries, such as consumer goods manufacturing, where flexibility and adaptability are paramount. The cost-benefit analysis indicates that implementing the synergy of methodologies yields a positive *NPV* of 192,453 EUR and an Expected Monetary Value of 141,366 EUR, justifying the investment due to the anticipated annual savings of approximately 66,250 EUR. This adaptability also shows that these methodologies, primarily combined, pro-

vide resilience in the face of global market fluctuations and supply chain disruptions.

However, any potential implementation for domestic enterprises can run into problems such as the following:

1. Cultural resistance to change: implementing new methods often necessitates significant changes to the organizational culture. Employees and managers accustomed to traditional approaches may refrain from adopting new practices due to fears of job loss, misunderstandings, or skepticism about the effectiveness of these methods. This resistance can lead to challenges in the implementation and adoption process.

2. High implementation costs and resource limitations: implementing methodologies like Six Sigma often requires extensive data collection, statistical analysis, and additional training, such as green or black belt certification, with costs ranging from €7,000 to €15,000. Smaller enterprises with limited budgets may struggle to allocate these resources. Similarly, the implementation of methodologies like Theory of Constraints and Just-In-Time requires investments in improved planning systems, delivery speeds, and enhanced supply chains, which can strain financial resources. Implementation costs for Lean and JIT are estimated between €5,000 and €10,000, further burdening small businesses.

3. Complex integration and skill development: effectively integrating multiple methodologies, such as combining Lean manufacturing with Six Sigma or TOC, requires careful coordination to ensure processes complement each other. This complexity can lead to ambiguity in roles and responsibilities. Moreover, methods like Six Sigma and Total Quality Management demand specialized skills in statistical analysis, quality control, and project management. Organizations may need help sourcing or developing personnel with these competencies, necessitating extensive and costly training programs.

4. Dependence on leadership support and continuous improvement: ongoing leadership support is crucial for fostering a culture of continuous im-

provement. Inconsistent backing from management can undermine the effectiveness of initiatives like TQM and Lean. With sustained support, employees may gain enthusiasm for new methods, resulting in improved relevance and better accountability for performance.

5. Supply chain vulnerabilities: JIT and TOC methodologies are highly reliant on stable and responsive supply chains. Disruptions due to market volatility, logistics challenges, or external crises can severely impact the effectiveness of JIT, which requires stringent inventory control. Additionally, TOC depends on reliable supply to prevent bottlenecks; any delays can significantly reduce the system's overall efficiency.

6. Challenges in data collection and analysis: Six Sigma and TQM mainly depend on accurate data and substantial data volumes for measuring and improving processes. Inadequate data collection systems or poor data quality can impede effective decision-making, leading to inaccurate conclusions and complicating the overall implementation process.

The evaluation of innovative management methods in combination with decarbonization strategies has proven to be critical for domestic Ukrainian enterprises, particularly under wartime conditions. The conflict has intensified challenges such as resource scarcity, demand fluctuations, disrupted logistics, and workforce constraints. By selectively adapting and integrating innovative production methodologies, Ukrainian companies have been able to strengthen resilience, enhance operational efficiency, and mitigate the heightened economic risks of war. These approaches have also provided a strategic advantage, enabling firms to adapt rapidly to uncertain market dynamics while supporting national economic stability during and after the conflict.

The authors have applied a four-step approach, and the findings have shown that integrating multiple methodologies maximizes their benefits, fosters dynamic production systems, and simultaneously reduces emissions. Alignment with enterprise decarbonization strategies has built resili-

ce by reducing dependence on resource-intensive processes and has offered a roadmap for maintaining long-term compliance and competitiveness.

This study has highlighted the importance of tailoring production management methods to the requirements of specific industries. The recommendations have been substantiated through cost-benefit and decision tree analyses. However, long-term projects have not been considered in the decision-making process, representing a limitation of the proposed framework. Lean Manufacturing, TQM, Six Sigma, TOC, and JIT have all been identified as valuable tools for improving efficiency, quality, and adaptability under modern competitive conditions. By identifying best practices and critical success factors, the study has laid the foundation for strengthening the competitiveness

of domestic manufacturing and enabling rapid responses to market shifts. Moreover, the integration of sustainability principles into management practices has been shown to enhance the long-term viability of enterprises.

The scope of this research has not extended to service industries or the use of renewable energy in production, as the focus has been on emissions reduction in manufacturing processes. Future studies should examine the effects of these implementations on efficiency, cost reduction, innovation, and employee engagement, as well as the role of advanced technologies such as artificial intelligence in optimizing methodologies (Lean, Six Sigma, and TOC). Such research will further support enterprises in improving production processes while adapting to evolving challenges in the global economy.

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ОЦІНКА ІННОВАЦІЙНИХ МЕТОДІВ УПРАВЛІННЯ У ПОЄДНАННІ З ПІДХОДОМ ДО ДЕКАРБОНІЗАЦІЇ: ЇХНЯ ВЗАЄМОДІЯ ТА РЕКОМЕНДАЦІЇ ДЛЯ ВІТЧИЗНЯНИХ КОМПАНІЙ

Вступ. Проблема інтеграції інноваційних методів управління та стійкості компаній наразі є актуальною у різних галузях господарювання.

Проблематика. Однак вона вимагає ретельного аналізу та оцінки методів управління у поєднанні з підходом до декарбонізації.

Мета. Оцінювання впливу комбінованих методів управління виробництвом на ключові показники ефективності компаній, їх переваги та недоліки, структуру застосування, реалізацію на рівні управління, культурні аспекти, а також планування виробничих потужностей у контексті зменшення викидів.

Матеріали й методи. Дослідження застосовує змішаний підхід, поєднуючи якісні та кількісні методи для кращого розуміння інноваційних практик. Застосовано інформаційно-пошуковий, аналітичний, порівняльний методи, а також підрахунок результатів для формулювання рекомендацій.

Результати. Подано всебічний порівняльний аналіз інноваційних методів управління виробництвом, зокрема *Lean Manufacturing*, *Total Quality Management (TQM)*, *Six Sigma*, *Theory of Constraints (TOC)* та *Just-In-Time (JIT)*. Розглянуто подібності та відмінності між інноваційними методологіями управління в міжнародних та вітчизняних підприємствах (20 критеріїв), що дозволяє приймаючим рішення краще зрозуміти їхні основи. Запропоновано інтегрувати декарбонізацію з методами підвищення ефективності виробництва, оскільки обидва аспекти зосереджені на оптимізації використання ресурсів. Подано практичні способи покращення виробничих процесів, враховуючи специфіку галузі та поточні завдання. Проведений аналіз витрат і вигод, а також аналіз дерева рішень підтвердили запропоновані рекомендації.

Висновки. Розроблений підхід сприяє досягненню цілей стійкості та підвищенню прибутковості підприємств, що працюють у виробничій галузі. Отримані результати можуть слугувати основою для подальших досліджень в управлінні інноваціями та пошуку практичних рішень для оптимізації витрат і покращення якості продукції, що в кінцевому підсумку підвищує задоволеність клієнтів виробничих компаній.

Ключові слова: інноваційні методи, бережливе виробництво, економія витрат, підприємництво, глобалізація, сталий розвиток.