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# ADVANCING LEAN METHODOLOGY ADOPTION IN SERBIAN MANUFACTURING SMES: EMPIRICAL INSIGHTS AND A STRATEGIC IMPLEMENTATION FRAMEWORK

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**Abstract**

As manufacturing industries become more competitive around the world, Lean methodology must be used to improve operations and keep the market stable. However, small and medium-sized businesses (SMEs), have a hard time fully implementing Lean because they don't have enough resources, and their organizations are stuck in their ways. This research provides an empirical analysis of the level of application of Lean in manufacturing SMEs in the Republic of Serbia. A structured survey was conducted in which 54 manufacturing SMEs took part, in order to determine the level of Lean adoption, the main obstacles in the implementation process and the influence of factors, such as company size, quality management system and product diversification. The Mann-Whitney U, the Kruskal-Wallis, the Chi-square test and a binary logistic regression were used for qualitative analysis. The results show that there is a strong link between ISO 9001 certification and Lean implementation. Larger enterprises are more likely to adopt Lean than smaller ones. The study presents a customized Plan-Do-Check-Act (PDCA) model for the Serbian SMEs, offering an approach to overcoming implementation barriers. Future research should be directed towards extending the analysis to the Western Balkans and comparing the results to support evidence-based industrial policy development.

*Keywords:* lean, small and medium enterprises, lean tools, production, survey, plan-do-check-act

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## 1. INTRODUCTION

The SMEs sector is the largest segment of the national economies with a great percent of the total number of enterprises, employing large numbers of people and significantly contributes to Gross Domestic Product (Milošević et al., 2019). In addition to encouraging the development of the economy, SMEs, as a major source of business skills, innovation, and employment, also contribute to the increase in employment, the competitiveness of the market and contribute to the acceleration of the transition process (Pedraza, 2021). The main comparative advantage of SMEs compared to large companies is their flexibility. They perform jobs that are not attractive to large companies, thus filling an empty space in the market, employing a large part of the workforce. By doing so, they influence the increase in employment (Jović et al., 2009).

In today's competitive business environment, SMEs are constantly looking for ways to improve their processes, reduce costs and increase customer satisfaction. Especially in periods of crisis and instability, SMEs are looking for new ways to solve the problems that have been caused. This approach is possible due to their ability to be agile and to offer the market a solution to the created problems in a short period of time (Ciravegna & Micheilova, 2022). However, these entities often grapple with challenges such as limited resources, intense competition, and rapidly changing market demands, which can hinder their growth and sustainability. For this reason, they must be focused on reducing costs and producing more products of high quality, in a short lead time. Lean methodology has emerged as a powerful methodology to boost efficiency and reduce waste, offering a lifeline to SMEs striving for improved performance. By focusing on the elimination of waste and the continuous improvement of processes, Lean principles can be particularly beneficial for SMEs that aim to strengthen their competitiveness (Driouach et al., 2019). Mihajlović et al. (2024) further show that digital platforms which quantify SWOT–TOWS factors through AHP facilitate rapid, participatory strategy formulation in manufacturing SMEs, reinforcing the need to embed data-driven tools alongside Lean.

There are many definitions of Lean methodology. In (Shah & Ward, 2007) Lean is defined as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability". Waste is any activity that consumes resources without adding value and the customer is not willing to pay (Henderson & Larco, 2003; Pavlović et al., 2014). This methodology is usually associated with large manufacturing companies. But in reality, Lean is not reserved only for large manufacturers, more and more SMEs take advantage of this methodology, because the core idea is to maximize customer value while minimizing waste, i.e. create more output with less input (Womack et al., 1990). According to (Rose et al., 2011) productivity can be improved 10-60%, lead time can be reduced from 8-50 %, and quality can be improved to 8-80%. Based on (Lathin & Mitchell, 2001; Ferdousi & Ahmed, 2009), as a result of implementing Lean, manufacturing companies can expect a reduction of 90% in lead time, 50% increase in productivity, 90% in inventories and 90% in the cost of quality.

### 1.1. Lean methodology and main Lean tools

Lean methodology is based on eliminating waste ("muda") and continuously improving processes to maximize customer value (Shah & Ward, 2007). To achieve this, many tools and techniques have been developed, and they are now widely used in SMEs. Key performance indicators (KPI) are used to track progress against goals and to support continuous improvement. Pareto analysis follows the 80/20 principle and helps identify the most critical causes of problems, so that resources are focused on the factors with the greatest impact. Takt time defines the rhythm of production in line with customer demand, reducing the risk of overproduction and excess inventory. Standard work sets repeatable best practices, reduces variability, and makes workforce training easier. Other Lean tools support production flow. Heijunka, or production leveling, smooths workloads to prevent bottlenecks and supports Just-in-Time production. Cellular manufacturing organizes workplaces into cells, minimizing transport and waiting time. Jidoka, or autonomation, ensures quality by stopping processes when an error occurs, preventing defective output. Value stream mapping (VSM) shows the flow of materials, information, and time, helping identify waste and opportunities for improvement. Several tools also focus on workplace organization and flexibility. The 5S method (Sort, Set in order, Shine, Standardize, Sustain) creates a clean, efficient, and disciplined work environment. Kanban provides visual signals to manage workflow and limit work in progress, which increases responsiveness. SMED (Single Minute Exchange of Dies) reduces setup times to under 10 minutes, making production more flexible in high-variety environments. Although originally designed for large manufacturers, these tools are increasingly adapted by SMEs. They reduce costs, improve quality, and strengthen competitiveness (Rose et al., 2011; Ferdousi & Ahmed, 2009). However, adoption levels differ depending on firm size, resources, and management support.

SMEs are a significant segment of Serbia's economy, and account for over 99% of the total number of business entities, generate around 2/3 of employment and turnover, 54.1% of GVA, and have a 43.2% share in the export in non-financial sector. 80% of the total workforce works in SMEs and the entrepreneurial sector (Republic institute of statistics, 2024).

While Lean implementation has been widely studied in large companies and some SMEs globally, research on Serbian production SMEs remains limited. Therefore, the primary objective of this paper is to understand its impact on efficiency, effectiveness, operational performance and competitiveness of those SMEs. The analysis of data from the survey aims to identify the extent to which Lean methods and tools are adopted in SMEs and the challenges faced during implementation. Understanding these factors can provide valuable insights for SMEs seeking to improve their efficiency and competitiveness in the market.

Additionally, the study applies binary logistic regression to quantitatively examine which structural and organizational factors (ISO 9001 certification, firm size, product assortment, and region) significantly predict Lean adoption, thereby strengthening the empirical foundation of the analysis.

Despite increasing interest in Lean

adoption globally, a clear research gap remains in understanding how Lean is implemented in resource-constrained environments such as Serbian SMEs. This study addresses this gap by exploring how structural factors (such as enterprise size and ISO 9001 certification) and knowledge-related factors (such as training and leadership support) interact to shape Lean methodology adoption. Accordingly, the central research question guiding this study is: How do structural and knowledge-related factors jointly determine Lean adoption intensity in Serbian manufacturing SMEs?

Numerous studies have examined Lean methodology adoption in SMEs, particularly the factors influencing successful implementation and typical barriers encountered. Shah and Ward (2007) provided foundational insight into defining Lean as a socio-technical system, emphasizing waste elimination and variability reduction. Rose et al. (2011) identified Lean best practices in SMEs and suggested that customized implementation approaches are necessary due to resource limitations. Alefari, Salonitis, and Xu (2017) discussed the important role of leadership in Lean adoption, while Ferdousi and Ahmed (2009) showed that Bangladeshi garment SMEs achieved significant productivity gains through Lean practices. In the context of Serbia and the Western Balkans, relevant studies remain scarce. However, Milošević, Mihajlović, and Stojanović (2019) explored SME failure factors, noting that structured management systems, such as ISO 9001, are important in operational resilience. More recently, Mihajlović et al. (2024) presented a digital SWOT-TOWS decision-support platform tested in manufacturing SMEs across Serbia and neighbouring CEE countries. Their findings confirmed that objective, data-driven tools enable SMEs to overcome strategic and operational ambiguity, aligning well with Lean's focus on systematic continuous improvement.

Recent findings have also highlighted the broader sustainability and institutional context within which Lean and other efficiency methodologies are integrated. For example, Elhassan (2025) showed that green technology innovation and green financing significantly contribute to reducing ecological footprints and $CO_2$ emissions in G7 countries, proving the importance of financial and technological enablers for sustainable industrial practices. Similarly, Prasetyo and Kistanti (2023) emphasized the potential of informal institutions in fostering green entrepreneurship and sustainable socio-economic development, pointing to the role of localized social norms and non-formal mechanisms in advancing sustainability transitions. These insights reinforce the relevance of aligning Lean adoption in SMEs with both formal standards (ISO 9001) and broader sustainability frameworks, thereby positioning Lean not only as an operational efficiency tool but also as part of a wider sustainability discourse.

Moreover, Salma, Anas, and Mohammed (2021) conducted a bibliographic review highlighting common difficulties SMEs face in Lean deployment, including resistance to change, lack of training, and underdeveloped quality systems. Arabi, Chafi, and El Hammoumi (2018) emphasized the influence of top management on Lean success in small-scale firms, proposing structured leadership engagement as a necessary precondition. These studies collectively form the theoretical and empirical foundation for this paper. By building on these findings, the present research investigates the specific

context of Lean adoption in Serbian manufacturing SMEs and proposes a PDCA-based implementation framework grounded in the challenges and enablers uncovered through survey data.

The novelty of this study lies in its potential to guide SMEs in strategic decision-making, supporting a culture of continuous improvement, and contributing to economic growth and sustainability, by proposing a customized Lean implementation framework, customized to the needs of SMEs in Serbia.

## 2. RESEARCH METHODOLOGY

This paper aims to investigate the state of the adoption and implementation of Lean methodology in Serbian SMEs. Research highlights that ISO 9001 certification creates the structural and procedural discipline necessary for effective Lean implementation. Certified SMEs typically display stronger process control, documentation practices, and continuous improvement routines, which align closely with Lean principles (Psomas et al., 2018). In emerging economies, ISO 9001 certification offers a formal, structured basis for Lean implementation by reinforcing continuous improvement and operational control. This integration aligns with the findings of Siegel et al. (2024), who proposed a comprehensive framework demonstrating the synergistic implementation of Green-Lean and sustainability initiatives in SMEs, thereby confirming the effectiveness of combined environmental and operational strategies. More recently, Susanto et al. (2024) confirmed that SMEs implementing ISO 9001 achieve greater readiness to adopt advanced management tools. Based on these findings, the following hypothesis is proposed:

H1: Manufacturing companies that have implemented the ISO 9001 standard apply Lean tools to a greater extent.

Firm size has consistently been identified as a determinant of Lean adoption. Larger organizations usually have greater managerial capacity, financial resources, and technical expertise to overcome implementation barriers (Ferdousi & Ahmed, 2009; Rose et al., 2011). Comparative research shows that Lean maturity levels are higher in medium and large enterprises than in micro- and small firms (Bhamu & Sangwan, 2014). Recent evidence also confirms that firm size moderates the adoption of sustainability-oriented practices, with larger SMEs better equipped to implement structured methodologies (Ahmadov, et al., 2025). Accordingly, the second hypothesis is formulated:

H2: The size of the organization has a greater impact on the implementation of Lean methodology.

Regional context strongly influences Lean adoption in SMEs. Firms located in peripheral or less developed regions often face structural disadvantages, including weaker institutional support, limited access to consultants, and lower integration into industrial networks. In Serbia, Milošević, Mihajlović, and Stojanović (2019) noted such regional inequalities in SME resilience and management practices. Mihajlović et al. (2024) similarly documented uneven digital and strategic capacities across Serbian and Western Balkan SMEs. More broadly, Guimarães et al. (2025) reported that Lean uptake correlates with regional industrial maturity, with peripheral areas lagging behind. Based on these insights, the following hypothesis is stated:

H3: Less than 40% of companies in Southern and Eastern Serbia implement Lean tools.

Product diversification increases production complexity and requires systematic approaches to maintain efficiency and responsiveness. Lean practices offer tools to handle such complexity by reducing waste and stabilizing processes. Empirical evidence shows that SMEs with broader product portfolios are more likely to implement Lean to balance flexibility and efficiency (Driouach et al., 2019). Liu et al. (2024) further showed that inventory leanness strategies are particularly relevant for firms with diverse operations. Thus, the final hypothesis is proposed:

H4: Companies with a broader product assortment exhibit a higher level of Lean methodology adoption.

To validate these hypotheses, a structured survey was conducted among enterprises in Serbia. The data collection method used for this purpose was a survey questionnaire carried out among enterprises belonging to the production sector. Of the 110 production enterprises to which the questionnaire was sent, 54 took part in this research, representing a response rate of 49%. The questionnaire consists of two sets of questions, whereby the questions from the first part are answered by all enterprises, while the questions from the second part are answered only by enterprises that use the Lean methodology. All questions in the questionnaire are in a close-ended form and translated into qualitative variables and quantitative variables containing Likert-type scale questions from 1 to 5. The Likert scale uses five answer options: 1) I completely disagree; 2) I disagree; 3) I partially agree; 4) I agree; 5) I fully agree. The first part of the question refers to general information about companies, such as the number of employees, which region of Serbia they belong to, characteristics of production programs and whether they apply the ISO 9001 standard.

The Mann–Whitney U test, Kruskal–Wallis test and Chi-Square test were used for qualitative analysis, and the results are presented in this paper. The Mann-Whitney U test was applied to compare differences between two independent groups when the dependent variable was ordinal or non-normally distributed, which was appropriate given the small sample size and Likert-scale data (Nachar, 2008). The Kruskal-Wallis test, an extension of the Mann-Whitney test, was employed for comparisons across more than two groups to assess whether median adoption levels of Lean tools differed significantly across enterprise size categories (McKight & Najab, 2010). The Chi-square test was used to examine associations between categorical variables, such as ISO 9001 certification and Lean adoption, providing insights into the dependence between structural characteristics and implementation outcomes (Abu-Bader, 2021). These non-parametric methods were selected because they do not require the assumption of normal distribution and are widely applied in SME and operations management research where survey data are typically ordinal and sample sizes are limited (Ferdousi & Ahmed, 2009; Rose et al., 2011).

Additionally, a binary logistic regression was performed with Lean adoption (0/1) as the dependent variable and firm characteristics (ISO 9001 certification, firm size, product assortment, and region) as predictors. Solver optimization in Excel was used to estimate the coefficients.

## 3. SURVEY RESULTS AND ANALYSIS

Table 1 summarizes the demographic characteristics of the surveyed SMEs.

The majority of the enterprises have implemented a Quality Management System (QMS) ISO 9001 (92.5%), and only 7.5% have not implemented this system. When asked if they are familiar with the Lean methodology, 47.2% of the enterprises answered yes, and out of the total number of surveyed enterprises, only 28.3% apply the Lean methodology in their processes. The majority of enterprises (90%) with over 250 employees apply the Lean methodology, while enterprises with the number of employees from 51 to 250 apply to a lesser extent (30%). Enterprises with less than 50 employees do not apply Lean methodology. The diagram in the Figure 1 visually shows the level of use of Lean tools in enterprises of different sizes - those with over 250 employees (red line) and those with 51 to 250 employees (green line). Values are shown in percentages. According to the survey, enterprises with 50 or less employees do not use Lean tools.

Lean tools usage is generally higher in larger enterprises, compared to smaller ones. The tools most utilized by enterprises with over 250 employees include: KPI (88%), Pareto Analysis (80%), Takt Time (80%), and Standard Work (75%). On the other hand, the tools that are used in the smallest percentage in these enterprises are: Heijunka (40%), Cellular Manufacturing (40%), and Jidoka (45%). Enterprises with 51 to 250 employees show significantly lower adoption rates for most Lean tools, with percentages ranging between 7% and 24%. Value Stream Mapping (21%), 5S Method (21%), and KPI's (24%) are the most commonly used tools in these types of enterprises. The least used tools are: Kanban (7%), Heijunka (7%), and SMED (8%). Diagram on figure 1 provides a clear picture of the different levels of implementation of Lean tools between large and medium-sized enterprises. Approximately one-third of the enterprises in Southern and Eastern Serbia apply the Lean methodology. If we compare data on enterprises that apply Lean

*Table 1. Demographic characteristics of the surveyed SMEs (N = 54)*

| Characteristic | Category | Frequency | Percentage |
|---|---|---|---|
| Firm size (no. of employees) | Up to 10 | 7 | 13.2 % |
| | 11–50 | 16 | 30.2 % |
| | 51–250 | 20 | 37.7 % |
| | >250 | 11 | 18.9 % |
| Region | Southern & Eastern Serbia | 36 | 67.9 % |
| | Šumadija & Western Serbia | 9 | 17.0 % |
| | Vojvodina | 6 | 11.3 % |
| | Belgrade | 2 | 3.8 % |
| Product assortment | Wide (>10 products) | 34 | 64.2 % |
| | Narrow (≤10 products) | 19 | 35.8 % |
| Production volume | High (large batch) | 29 | 54.7 % |
| | Low (small/medium batch) | 24 | 45.3 % |
| ISO 9001 certification | Yes | 49 | 92.5 % |
| | No | 4 | 7.5 % |

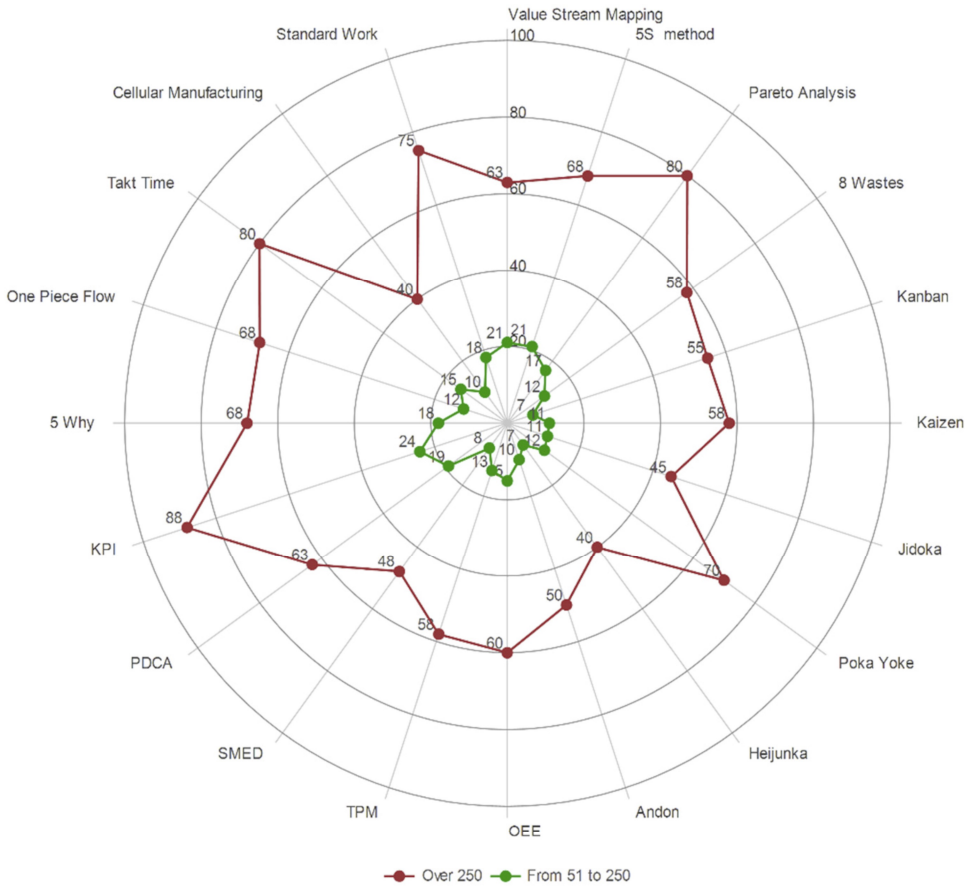


*Figure 1. The level of Lean tools utilization*

methodology and the characteristics of their production processes, we come to the conclusion that enterprises with a wide product range apply Lean methodology to a greater extent. Also, enterprises that produce large quantities of products have a higher percentage of Lean methodology application (38%), compared to enterprises with small quantities of products (17.3%).

As part of the survey, enterprises evaluated the benefits of applying Lean methodology, on a scale from 1 (lowest) to 5 (highest), with average scores for each category. The chart below (Figure 2) compares the perceived benefits between enterprises with more than 250 employees (red line), and enterprises with 51 to 250 employees (green line). Larger enterprises (over 250 employees) consistently report higher average benefits across all categories compared to smaller enterprises. The highest benefits for larger enterprise include: increasing customer satisfaction, and increasing productivity. The highest benefits for larger enterprise include: increasing customer satisfaction, and increasing productivity, while for smaller enterprises the biggest benefit is continuous process improvement.

The biggest difference in benefit ratings between these two groups is increasing employee satisfaction. Larger enterprises

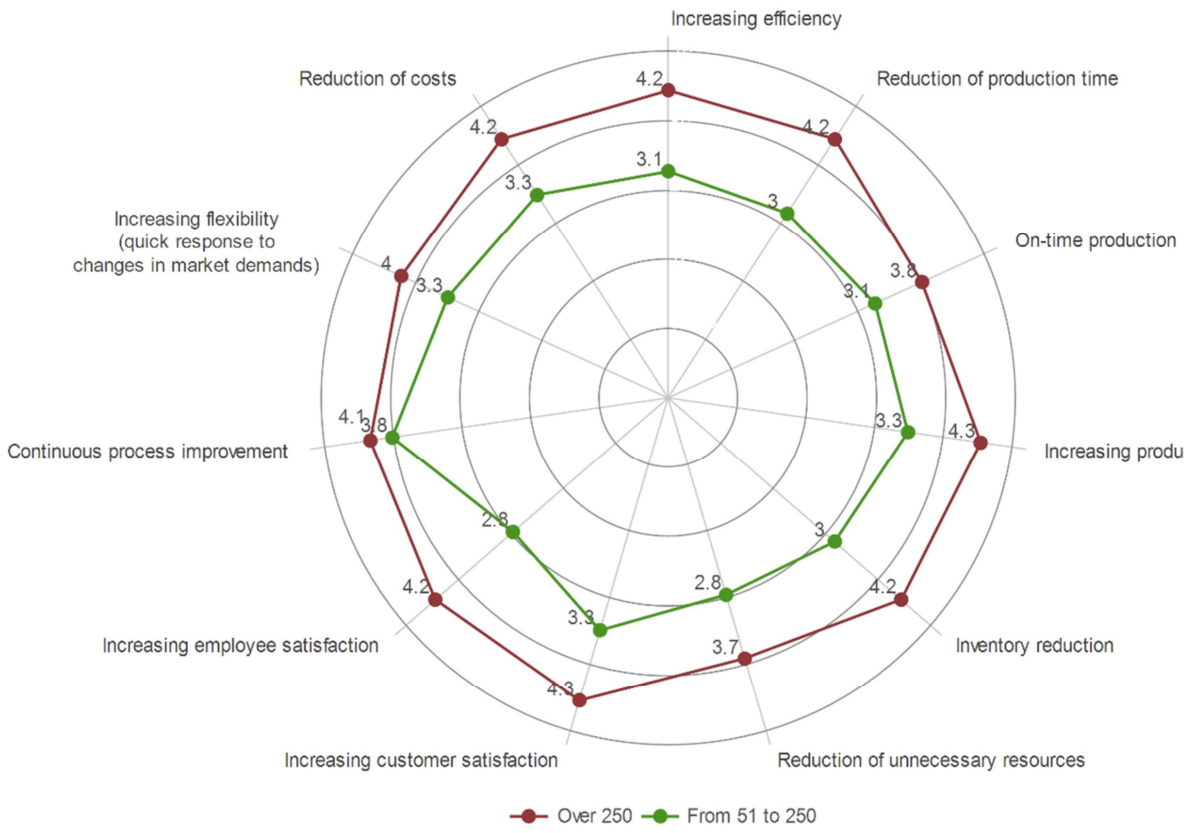


*Figure 2. The benefits of Lean tools utilization*

score significantly higher (4.2) compared to smaller ones (2.8), highlighting a notable gap. Larger enterprises appear to experience stronger benefits from implementing Lean methodology, likely due to their greater resources, scalability, and ability to adopt these practices more effectively.

## 4. PLAN DO CHECK ACT MODEL OF LEAN IMPLEMENTATION

This paper introduces the Plan-Do-Check-Act (PDCA) model of Lean implementation. The PDCA model offers a framework for Lean methodology implementation in manufacturing SMEs. Based on the survey data and observed practices, the following elaboration details each phase. The PLAN phase emphasizes strategic preparation for Lean implementation. The PLAN phase involves defining objectives, identifying KPIs, and addressing potential complexities in Lean implementation. Results indicate an average implementation level of 31.13%, revealing significant room for improvement. Key observations include that 30.57% of companies reported no issues with process complexity; 29.81% faced no challenges regarding a lack of knowledge about Lean implementation; and 30.94% received sufficient top management support. The highest-rated factor was the absence of problems in defining KPIs, with 33.21% agreement. These results highlight that most

companies struggle with top management involvement and understanding Lean principles during the planning stage. Improved training for leadership and clearer KPI frameworks could improve this phase. These results are summarized in Figure 3, which shows the distribution of SMEs by percentage agreement with PLAN-phase indicators. The x-axis shows the implementation percentage ranges, while the y-axis shows the number of enterprises. As can be seen, most SMEs cluster around the 10-20% range, indicating early-stage adoption.

The DO phase focuses on implementing Lean tools and practices, including regular training, leadership involvement, and internal communication. The average implementation level is 32.39%, slightly higher than the PLAN phase. Specific findings include: 36.60% of companies conduct regular employee training and update materials and procedures; only 27.92% reported no issues with the lack of skilled personnel; 29.81% of respondents faced no challenges with leadership; 31.32% noted that employee training posed minimal problems; and 32.08% faced no difficulties with communication within Lean implementation teams. The results suggest that while training is relatively well-established, gaps remain in leadership

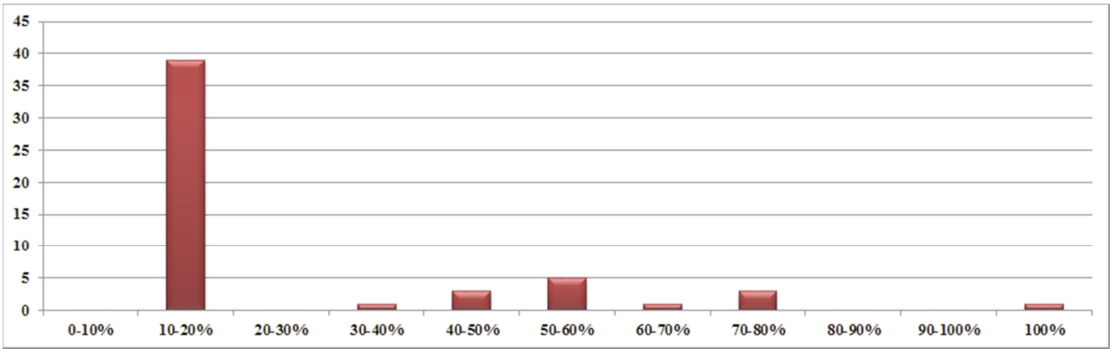


*Figure 3. Distribution of SMEs by reported challenges in the PLAN phase of Lean implementation. X-axis: percentage agreement with statements related to Lean implementation factors. Y-axis: number of SMEs.*

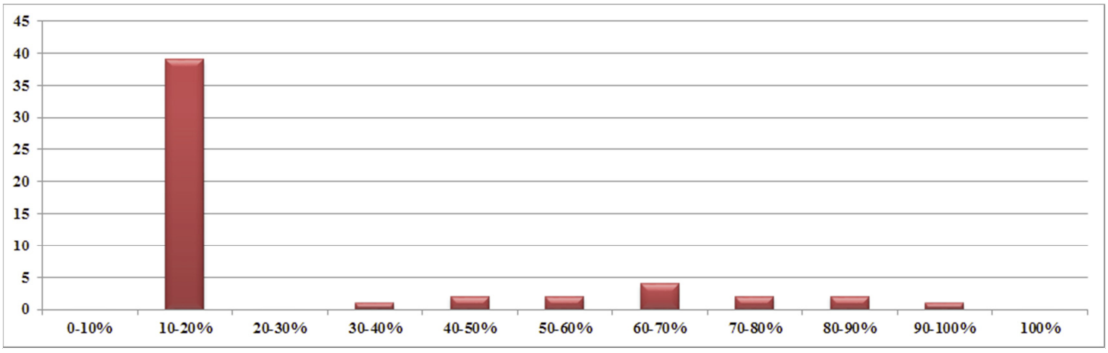


*Figure 4. Distribution of SMEs by reported challenges in the DO phase of Lean implementation. X-axis: percentage agreement; Y-axis: number of SMEs.*

engagement and workforce expertise. Addressing these gaps could lead to more consistent Lean application. The distribution of implementation percentages across SMEs is shown in Figure 4. Similar to the PLAN phase, most companies report low adoption (10-20%), though a small number reached higher levels (50-70%), particularly in training and internal communication.

The CHECK phase involves assessing the effectiveness of Lean implementation through KPIs and feedback mechanisms. This phase achieved the highest average implementation level at 34.15%. The main insights include: 28.68% of companies experienced no resistance to change from employees; 33.58% reported no issues with defining customer value accurately; 37.74% measure KPIs during or after Lean implementation; 36.60% of respondents indicated that the planned goals of Lean adoption were fulfilled. These findings reflect progress in monitoring Lean processes but emphasize the need for more comprehensive KPI frameworks and employee engagement strategies to overcome resistance. Figure 5 shows these findings, with most SMEs concentrated in the 10-20% category, but a notable minority achieving higher ranges (50–80%) in KPI monitoring and goal fulfillment.

The ACT phase focuses on sustaining Lean practices through periodic reviews and addressing systemic barriers. The average implementation level is 33.33%. Detailed results include: 32.45% of respondents experienced no employee resistance during Lean implementation; 32.83% faced no challenges with financial constraints; 34.72% reported no significant issues with IT resource availability. While financial and technological resources appear manageable, employee resistance and follow-through in Lean projects remain areas for improvement. Continuous improvement initiatives should focus on engaging employees and addressing organizational inertia. The overall distribution is shown in Figure 6, where again most SMEs cluster at 10-20%, but several reported strong adoption up to 100%, reflecting isolated cases of sustained Lean practices.

The PDCA model highlights the main strengths and weaknesses in Lean implementation among Serbian SMEs. PLAN and DO phases require a greater focus on leadership support, knowledge dissemination, and team communication to ensure effective preparation and execution. CHECK phase shows relatively strong

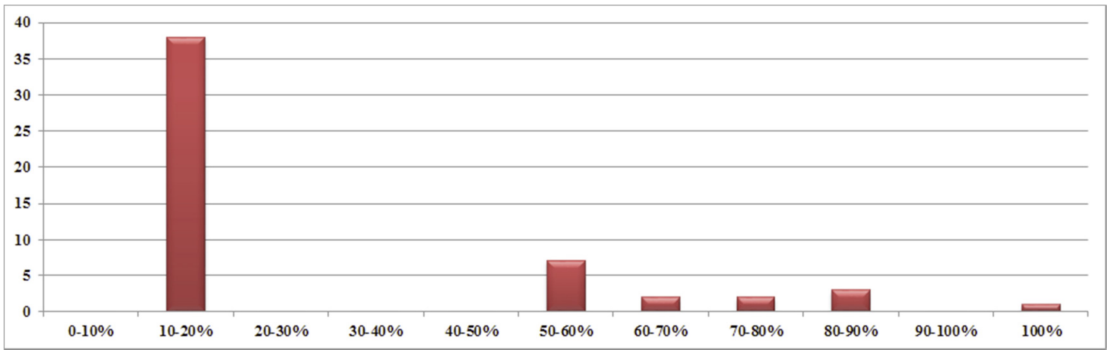


*Figure 5. Distribution of SMEs by reported challenges in the CHECK phase of Lean implementation. X-axis: percentage agreement; Y-axis: number of SMEs.*

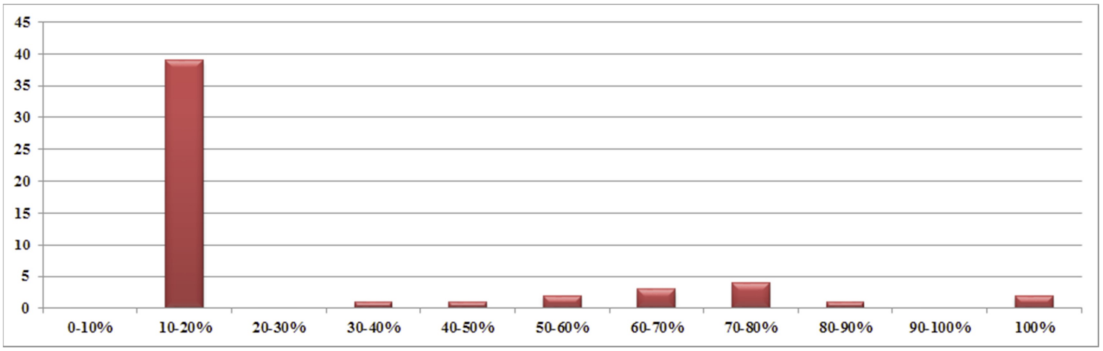


*Figure 6. Distribution of SMEs by reported challenges in the ACT phase of Lean implementation. X-axis: percentage agreement; Y-axis: number of SMEs.*

performance in KPI monitoring but still lacks comprehensive frameworks for assessing customer value and addressing resistance. ACT phase reflects the importance of resource availability but underscores the need for continuous engagement to maintain Lean practices. These insights can guide customized interventions for SMEs to strengthen Lean adoption and drive sustainable operational improvements. The PDCA model for Lean implementation provides a structured, iterative framework to systematically address challenges and improve operational efficiency in manufacturing SMEs. For policymakers, this model serves as a tool to design targeted programs and policies that address specific barriers, such as gaps in leadership, employee training, and resource allocation, which are evident from the survey results. By fostering initiatives to improve knowledge dissemination, Lean-related training, and incentivizing KPI monitoring, policymakers can accelerate Lean adoption in SMEs. For the industry, this model offers a clear roadmap for continuous improvement, enabling businesses to strategically plan, execute, monitor, and refine Lean practices. The novelty of this approach lies in its focus on data-driven insights specific to Serbian SMEs, highlighting regional and organizational challenges, and offering actionable recommendations customized to resource-constrained environments. This contextualized application bridges the gap between theory and practice, ensuring both the scalability and sustainability of Lean methodologies across diverse industries.

## 5. ANALYSIS OF CORRELATION BETWEEN ENTERPRISE PROPERTIES AND LEAN METHODOLOGY

The evaluation of the correlation between the degree of implementation of the Lean methodology and company characteristics was performed using the Mann–Whitney U test, the Kruskal–Wallis test and the Chi-Square test.

The results of the Mann–Whitney U test show that there is a significant difference in the level of implementation of the Lean methodology and whether companies have a certified quality management system or not. The level of implementation of the Lean methodology in enterprises with a certified quality management system (median=20%,

n=49) is 57) is significantly higher compared to those without a certified system (median=20%, n=4), with a z-score of 1.25 and a significant p-value (p=0.2113). Accordingly, H1 has been validated by the evidence gathered.

The analysis also considered whether the number of employees affected the level of Lean methodology implementation. Kruskal–Wallis test showed that larger enterprises had a higher median implementation level (66%, n = 8) than medium-sized (20%, n = 17) and small enterprises (20%, n=14), as well as micro enterprises (20%, n=5). The test returned a value of X2 = 13.7343 and a p-value= 0.0033, signifying a significant result for $p < 0.05$, thus confirming H2 that the size of enterprises influences the application level of the Lean methodology.

Companies that produce high volumes of products have a higher percentage of Lean methodology implementation, but the Chi-square test does not give a statistically significant difference. The Chi-square statistic is 2.6365, and the p-value is 0.104434. Therefore, the result is not significant at $p < 0.05$.

### 5.1. Logistic Regression Results

Logistic regression was conducted to examine which structural and organizational factors predict Lean adoption among Serbian SMEs. Firm size emerged as a significant determinant. Large firms (>250 employees) were about nine times more likely to adopt Lean methodology compared to small firms (≤50 employees) (OR = 9.00, β = 2.20). Other predictors, including ISO 9001 certification, product assortment, and region, did not show statistically significant effects in this sample.

*Table 2. Logistic Regression Table*

| Predictor | β (Logit Coefficient) | Odds Ratio (OR) |
|---|---|---|
| Intercept | 0.00 | 1.00 |
| ISO9001 | 0.00 | 1.00 |
| Size_51–250 | 0.00 | 1.00 |
| Size > 250 | 2.20 | 9.00 |
| Product Assort. | 0.00 | 1.00 |
| Region (SE) | 0.00 | 1.00 |
| High Volume | 0.00 | 1.00 |
| Top Management S. | 0.00 | 1.00 |
| Training | 0.00 | 1.00 |

Table 2 summarizes the regression results.

## 6. DISCUSSION

Based on the provided results, there is a significant correlation between ISO 9001 certification and the adoption of Lean methodology. Given that the majority of enterprises surveyed have implemented a QMS, it can be inferred that structured management systems, such as ISO 9001, support Lean adoption. The results confirm Hypothesis H1, as companies with ISO 9001 certification exhibit a higher level of Lean methodology adoption, suggesting that structured management systems contribute to Lean implementation.

Having in mind that, the survey results, as well as Kruskal–Wallis test confirm that company size is important in Lean adoption. Larger enterprises, with greater resources and operational complexity, exhibit a higher level of Lean methodology application compared to smaller firms. The trend observed aligns with previous literature (Van Dun et al., 2017; Arabi et al., 2018; Salma et al., 2021; Alefari et al., 2017), which suggests that SMEs face resource and knowledge barriers in Lean implementation.

The findings strongly support Hypothesis H2.

Lean methodology adoption remains low in Southern and Eastern Serbia, with only about one-third of enterprises implementing Lean practices. This pattern mirrors evidence from Morocco (Arabi et al., 2018), Algeria (Salma et al., 2021), India (Jadhav et al., 2015), and Indonesia (Nawanir et., 2016), where regional disparities in consulting support and uneven access to Lean expertise were shown to suppress SME adoption rates. Hypothesis H3 is confirmed, as Lean adoption in Southern and Eastern Serbia remains below 40%, highlighting regional disparities in Lean implementation.

The results indicate a positive relationship between product assortment and Lean adoption. Companies with a broader product range benefit from Lean principles in managing process complexity and efficiency, which explains their higher rate of implementation compared to firms with a narrow product portfolio. The analysis confirms Hypothesis H4, indicating that companies with a broader product range implement Lean methodology more extensively, likely due to the need for greater operational efficiency and process standardization.

The confirmation that ISO 9001 certification acts as a catalyst for Lean is the same as the results by Hicks and Matthews (2010) and Van Dun, Hicks & Wilderom (2017), who also reported that formalised quality systems raise process-discipline and data-visibility, thereby lowering organisational resistance. Likewise, the positive correlation between enterprise size and Lean maturity is consistent with Alefari, Salonitis & Xu (2017) and Arabi et al. (2018), both of whom emphasised leadership depth and training budgets as scale-related enablers. Then, in contrast, Nawanir et al. (2016) found Indonesian medium-sized manufacturers achieving >60 % Lean-tool utilisation, whereas our Serbian cohort reported only 28 %. Two factors may explain the gap: (i) Indonesian has benefited from coordinated national Lean-training subsidies since 2016, and (ii) its SMEs participate more actively in export-driven automotive supply chains that impose Lean standards. Similarly, Jadhav, Mantha & Rane (2015) observed meaningful Lean uptake even in Indian micro-enterprises, a result not replicated here. Follow-up interviews revealed that Serbian micro-firms rarely access industry associations that disseminate Lean know-how, suggesting an information-asymmetry barrier unique to the local ecosystem. Unlike earlier studies that stop at barrier identification, the present research contributes a quantified, PDCA-aligned road map validated on 54 Serbian SMEs. By integrating survey-derived bottleneck frequencies into each PDCA phase, we operationalise corrective actions with granularity that Arabi et al. (2018) and Salma et al. (2021) called for but did not supply.

## 7. CONCLUSION

Lean methodology is a powerful approach to boost efficiency and reduce waste, offering a lifeline to SMEs striving for improved performance. Therefore, Lean principles can be particularly beneficial for SMEs that aim to strengthen their market position and power.

The research was conducted to emphasize the impact of Lean methodology in Serbian production SMEs on efficiency, effectiveness, operational performance and competitiveness. The extent to which

methods and tools are adopted in production samples of SMEs and the challenges faced during implementation were highlighted. The obtained results point out the significance and potential to guide SMEs in strategic decision-making, support a Lean culture, and contribute to economic growth and sustainability. The results show that Lean tools usage is generally higher in larger enterprises, compared to smaller ones. The medium enterprises had significantly lower adoption rates for most Lean tools. Larger enterprises reported higher average benefits measured by increasing customer satisfaction and increasing productivity across all categories compared to smaller enterprises. While for smaller enterprises the biggest benefit is continuous process improvement.

This study is the first empirical analysis in Serbia to propose and validate a Lean adoption framework based on the PDCA cycle using real-world data from manufacturing SMEs. It bridges the gap between descriptive Lean maturity assessments and actionable process improvement models. By aligning adoption levels with structural and knowledge-related enablers, the findings contribute a practical and replicable roadmap for Lean transformation tailored to the constraints and capabilities of SMEs in emerging economies. An additional contribution of this study is the use of logistic regression analysis, which revealed firm size as the strongest predictor of Lean adoption. In particular, large firms (>250 employees) were about nine times more likely to adopt Lean practices than small firms (≤50 employees), while other factors such as ISO 9001 certification, product assortment, and region were not statistically significant. This quantitative evidence strengthens the empirical contribution of the paper and provides clearer guidance for policymakers and SME managers.

There are several limitations of the applied methodology in this work, primarily due to the sample size and geographic limitation. The sample of 54 SMEs is relatively small, compared to the other studies that often include hundreds or thousands of respondents, which may limit the statistical power of the tests and the general validity of the conclusions. The research is focused only on production SMEs in Serbia. This means that the results cannot be automatically generalized to other countries, especially those with different economic, organizational and cultural contexts in which Lean is applied. The method of data collection, which implies the use of questionnaires, can also represent a certain disadvantage because they rely on the self-assessment of respondents, which can lead to subjectivity and potentially inaccurate representations of the actual state of Lean methodology implementation.

Future research in this area could be focused on a comparative analysis of industrial practice in the countries of the Western Balkans. In this way, a research gap would be filled and significant comparable data would be obtained that can be useful to industrial policy makers at the national and supranational level.

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# УНАПРЕЂЕЊЕ ПРИМЕНЕ LEAN МЕТОДОЛОГИЈЕ У ПРОИЗВОДНИМ МАЛИМ И СРЕДЊИМ ПРЕДУЗЕЋИМА У СРБИЈИ: ЕМПИРИЈСКИ УВИДИ И СТРАТЕШКИ ОКВИР ЗА ИМПЛЕМЕНТАЦИЈУ

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**Извод**

Са порастом конкурентности производних индустрија на глобалном нивоу, примена Lean методологије постаје неопходна ради унапређења пословних процеса и очувања тржишне позиције. Међутим, мала и средња предузећа (МСП) суочавају се са значајним изазовима у потпуној имплементацији Lean концепта услед ограничених ресурса и организационе инертности. Ово истраживање пружа емпиријску анализу нивоа примене Lean принципа у производним МСП у Републици Србији. Спроведено је структурисано анкетно истраживање у којем су учествовала 54 производна МСП, са циљем утврђивања степена усвајања Lean концепта, идентификације кључних препрека у процесу имплементације, као и испитивања утицаја фактора као што су величина предузећа, постојање система менаџмента квалитетом и диверзификација производног програма. За квалитативну анализу примењени су Ман-Витнијев U тест, Краскал-Валисов тест, $\chi^2$ тест и бинарна логистичка регресија. Резултати указују на постојање снажне повезаности између сертификације ISO 9001 и имплементације Lean концепта. Већа предузећа показују већу вероватноћу усвајања Lean методологије у односу на мања предузећа. У раду је предложен прилагођени модел Планирај-Уради-Провери-Делуј (енг. Plan-Do-Check-Act – (PDCA)) намењен МСП у Србији, који представља систематски приступ превазилажењу препрека у имплементацији. Будућа истраживања требало би усмерити ка проширењу анализе на регион Западног Балкана и компаративном сагледавању резултата, у циљу подршке развоју индустријских политика заснованих на доказима.

*Кључне речи:* Lean, мала и средња предузећа, Lean алати, производња, анкета, Планирај-Уради-Провери-Делуј

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# APPENDIX

**A survey on Lean methods and tools implementation in small and medium-sized enterprises**

Dear Sir/Madam, the purpose of this survey is to analyze the representation of Lean methodology in small and medium-sized enterprises. The collected data will be used only for statistical purposes and will not be publicly displayed.

The questionnaire consists of two sets of questions, whereby the questions from the first part are answered by all companies, while the questions from the second part are answered only by companies that use the Lean methodology.

***Part 1***

The questions from the first part of the questionnaire, are answered by all companies. Please answer all questions.

1. Company name
2. The company's core business
3. Number of employees
    a. Up to 10
    b. From 11 to 50
    c. From 51 to 250
    d. Over 251
4. To which region of the Serbia does your company belong?
    a. Beograd
    b. Vojvodina
    c. Šumadija & Western Serbia
    d. Southern & Eastern Serbia
5. The production program of your company is characterized by
    a. Wide product range (over 10 types of products)
    b. Small product range (up to 10 types of products)
6. The production program of your company is characterized by
    a. Low production volume (small and medium batch programs)
    b. High production volume (large batch programs)
7. Do you have a certified ISO 9001 quality management system?
    a. Yes
    b. No
8. Are you familiar with the Lean methodology and its methods and tools?
    a. Yes
    b. No
9. Does your company use Lean methodology?
    a. Yes
    b. No
10. If you do not use Lean methodology, do you plan to implement it in the future?
    a. Yes
    b. No
    c. Maybe

**Part 2**

The questions from the second part of the questionnaire are answered only by companies that use or have applied the Lean methodology. Please answer all questions.

11. How long has your company been using Lean methodology?
    a. Less than 1 year
    b. 1-2 years
    c. 2-3 years
    d. 3-4 years
    e. 4 and more years

12. The number of employees who received Lean methodology training
    a. 0-5
    b. 5-10
    c. 10-15
    d. 15-20
    e. 20 and more

13. Your company uses the following Lean methods and tools
    *(Likert scale: Not applicable; Implementation has just started; Partially implemented; Implemented extensively; Fully implemented)*
    a. Value Stream Mapping
    b. 5S method
    c. Pareto Analysis
    d. 8 Wastes
    e. Kanban
    f. Kaizen
    g. Jidoka
    h. Poka Yoke
    i. Heijunka
    j. Andon
    k. OEE
    l. TPM
    m. SMED
    n. PDCA
    o. KPI
    p. 5Why
    q. One Piece Flow
    r. Takt Time
    s. Cellular Manufacturing
    t. Standard Work

14. If you use any other method or tool, which is not given in the previous question, please list them here:

15. Please rate the accuracy of the following statements
    *(Likert scale: I completely disagree; I disagree; I partially agree; I agree; I fully agree)*
    a. The company regularly carries out employee training
    b. The material for trainings and work procedures is regularly updated
    c. There was no resistance from employees during the implementation of the Lean methodology

16. When implementing the Lean methodology, you had no problems with the following:
*(Likert scale: I completely disagree; I disagree; I partially agree; I agree; I fully agree)*
    a. Process complexity
    b. Lack of professional personnel
    c. Lack of knowledge about how to implement Lean
    d. Lack of leadership
    e. Lack of training for employees
    f. Insufficient top management support
    g. Lack of finances
    h. Lack of IT resources
    i. Employee resistance to change
    j. Lack of communication within the Lean implementation team
    k. Lack of value or incorrect definition of customer value
    l. Difficulties in defining KPIs

17. Please mark one answer in each line
*(Likert scale: Not at all; Very little; Average; To a great extent; Completely)*
    a. Do you measure KPIs during or after implementing Lean methodology?
    b. To what extent has the Lean methodology implementation plan been fulfilled?

18. Please rate the following benefits from the application of Lean methodology in your company on a scale from 1 to 5, where 1 is the lowest and 5 is the highest
    a. Increasing efficiency
    b. Reduction of production time
    c. On-time production
    d. Increasing productivity
    e. Inventory reduction
    f. Reduction of unnecessary resources
    g. Increasing customer satisfaction
    h. Increasing employee satisfaction
    i. Continuous process improvement
    j. Increasing flexibility (quick response to changes in market demands)
    k. Reduction of costs

19. Which Lean tool/method was the most difficult to implement?

20. Do you plan to continue implementing the Lean methodology in your company?