

EMBRACING THE SYNERGY OF ARTIFICIAL INTELLIGENCE WITH LEAN AND SIX SIGMA METHODOLOGIES

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ABSTRACT

Lean and Six Sigma are two methodologies using each other synergies to optimize processes by elimination of waste. While Six Sigma is focusing on reduction of variations, lean is focusing on optimization by reduction of waste. Combining them provides a powerhouse approach that makes processes both fast and high quality. Synergies between Six Sigma and Lean methodologies exist even without including any support from Artificial Intelligence. As the complexity of the tasks performed by artificial Intelligence are more deepened with this current article we tested successfully some part of the Six Sigma Methodologies. Our intention was to prove that even these well-known optimization processes which until now were working well with old digitalization solutions can be improved further by instructing Artificial Intelligence to run the process steps.

KEY WORDS

artificial intelligence, automation, digitalization, six sigma

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INTRODUCTION – LEAN AND SIX SIGMA METHODOLOGIES

Understanding Lean and Six Sigma Lean is a methodology focused on maximizing value while minimizing waste. Originating from the Toyota Production System, it is widely used across various sectors to enhance efficiency and quality. Key principles of Lean include:

- Value Creation – Define what is valuable from the customer's viewpoint.
- Value Stream – Map all steps in a process, eliminating those that do not add value.
- Flow – Ensure that value-creating steps occur in a smooth, uninterrupted sequence.
- Pull – Produce only what the customer needs, reducing overproduction.
- Perfection – Continuously improve processes to achieve perfect value with zero waste.

Lean aims to create more value for customers using fewer resources by consistently improving processes. It finds applications in diverse fields such as manufacturing, healthcare, and services.

Six Sigma is a methodology designed to enhance business processes by minimizing defects and variability. Introduced by engineer Bill Smith at Motorola in 1986, Six Sigma utilizes statistical methods and data analysis to identify and eliminate defect causes, ensuring consistent quality and efficiency. The structured approach it follows is known as DMAIC:

- Define – Identify the problem and project goals.
- Measure – Collect data to assess current performance.
- Analyse – Determine root causes of defects and issues.
- Improve – Implement solutions to address root causes.
- Control – Monitor improvements to ensure they are sustained.

Lean and Six Sigma can work synergistically by combining their strengths to improve both efficiency and quality. This integrated methodology is often referred to as Lean Six Sigma. Here is how they complement each other:

- Lean emphasizes eliminating waste and enhancing process flow, aiming to create more value with fewer resources by removing non-value-added activities.
- Six Sigma focuses on reducing process variability and defects, employing statistical tools and a structured problem-solving approach (DMAIC) to improve quality.
- By integrating Lean and Six Sigma, organizations can achieve comprehensive process improvements. Some ways they work together include:
- Value Stream Mapping – Lean's value stream mapping identifies waste and inefficiency, while Six Sigma tools reduce variability in these areas.
- Continuous Improvement – Lean principles encourage ongoing improvements, and Six Sigma provides the methodologies to measure and sustain these improvements.
- Project Selection – Lean projects can quickly tackle visible waste, whereas Six Sigma projects address more complex issues requiring detailed analysis.

This combined approach allows organizations to enhance productivity, quality, and customer satisfaction more effectively than using either methodology alone [1-3].

HOW LEAN SIX SIGMA SUPPORTS TECHNOLOGY ENHANCEMENTS

Technology enhancements generally complement, rather than contradict, Six Sigma. In fact, integrating advanced technologies like Artificial Intelligence (AI) and machine learning with Six Sigma methodologies can significantly bolster process improvement efforts. Here are some ways technology can support Six Sigma:

- Data Analysis – AI and machine learning can swiftly and accurately analyze vast amounts of data, identifying patterns and anomalies that human analysis might overlook.

- Efficiency – Automation tools streamline processes, reducing manual effort and minimizing errors.
- Real-Time Monitoring – Technologies like Internet of Things enable real-time process monitoring, allowing for immediate adjustments and continuous improvement.
- Customer Insights – AI facilitates the collection and analysis of customer feedback, ensuring improvements align with customer needs.

By leveraging these technologies, organizations can enhance the effectiveness of their Six Sigma initiatives, leading to improved quality, efficiency, and customer satisfaction.

Lean Six Sigma can play a crucial role in preventing the failure of digitalization efforts by ensuring that technology implementations are efficient, effective, and aligned with organizational goals. Here's how Lean Six Sigma can assist:

- Value Stream Mapping – Lean Six Sigma employs value stream mapping to visualize and analyse information and material flow, helping identify inefficiencies and areas where digital solutions can be most effective.
- Root Cause Analysis – Thorough root cause analysis by Lean Six Sigma identifies underlying issues hindering digital transformation, ensuring technology solutions address real problems rather than just symptoms.
- Continuous Improvement – Lean Six Sigma fosters a culture of continuous improvement, ensuring digitalization efforts are ongoing processes rather than one-time projects, helping organizations adapt to changes and continuously optimize digital solutions.
- Metric-Driven Decisions – Lean Six Sigma emphasizes using metrics to measure performance and drive improvements, ensuring digital initiatives align with business objectives and deliver measurable benefits.
- Customer Focus – Lean Six Sigma prioritizes customer value, ensuring digital solutions enhance customer satisfaction and effectively meet their needs.

By integrating Lean Six Sigma principles into digital transformation efforts, organizations can maximize the value from technology investments, reduce the risk of failure, and achieve sustainable improvements [2-4].

HOW CAN DIGITAL TRANSFORMATION ENHANCE LEAN AND SIX SIGMA METHODS

Digital transformation has significantly enhanced Six Sigma methods by integrating advanced technologies to improve efficiency, accuracy, and effectiveness. Here are some key ways digital transformation is impacting Six Sigma:

- Integration with AI and Machine Learning – AI and machine learning enable predictive analytics, allowing teams to identify and address potential issues before they occur. These technologies also automate data analysis, making it faster and more accurate. In our next chapter we tested the utilization of Artificial Intelligence on real data and presented the accurate and detailed result provided by AI.
- Real-Time Data Analytics – Digital tools provide real-time data collection and analysis, enabling continuous monitoring and immediate process adjustments. This helps maintain high-quality standards and quickly address deviations. Working with Artificial Intelligence represents significant productivity increase, in some minutes AI can provide the desired complex analyse and present detailed description of the conclusion. Human interpretation of the result provided by Artificial Intelligence is still needed, however this human intervention is only fine tuning and much less time consuming compared to old way of working with Lean and Six Sigma methodologies.

- **Advanced Software Tools** – Modern software tools for process mapping, simulation, and statistical analysis make Six Sigma methodologies more accessible and effective, helping visualize processes, identify bottlenecks, and implement improvements. Six Sigma always relied on digital solutions offered advanced software tools. By involving Artificial intelligence most of the statistical analyses can be processed in real time, much faster. Combining the software tools with Artificial Intelligence could improve productivity by faster answer on simpler task and keeping the old way of visualization for more complex data structure.

AI can significantly enhance Lean methodologies by offering advanced tools and capabilities that streamline processes, reduce waste, and improve decision-making. Here's how AI can support Lean:

- **Data-Driven Decision-Making** – AI quickly and accurately analyses vast amounts of data, helping organizations make informed decisions based on real-time insights.
- **Predictive Analytics** – AI-powered predictive analytics forecast future trends and potential issues, allowing organizations to proactively address problems before they arise.
- **Process Automation** – AI automates repetitive and time-consuming tasks, reducing manual effort and minimizing errors, aligning with Lean's goal of eliminating non-value-added activities.
- **Real-Time Monitoring** – AI enables real-time monitoring and visualization of processes, providing instant feedback and allowing for immediate adjustments to maintain optimal performance.
- **Root Cause Analysis** – AI performs advanced root cause analysis, identifying underlying issues more effectively and suggesting targeted improvements.
- **Continuous Improvement** – AI supports continuous improvement by constantly analysing data and providing insights for ongoing process optimization.

By integrating AI with Lean methodologies, organizations can achieve greater efficiency, reduce waste, and enhance overall process performance [5-7].

REGRESSION ANALYSE PROVIDED BY GEMINI

We used Gemini to analyse real data of a Hungarian production company, (the company). Similar tests require a contract including confidentiality clauses with the Service provider of the Artificial Intelligence. For confidentiality reason we do not provide the name of the company and we do not provide any data including exact name of the articles and name of the files. The data analysed by Gemini are not recent, but this does not influence the result of the test and the conclusion of this article.

After providing the Sales and Material consumption data to Gemini, even without asking anything, Gemini analysed and summarized the information. We received a top 5 articles sold and consumed. As next steps Gemini offered to calculate the margin and provide a trend analyse. We can agree that this initial part has nothing to do yet with Six Sigma methodology, however it is a huge improvement to old way of analyse in Microsoft Excel.

As a next step we were interested to analyse the dependency of the sales to the material consumption. Six Sigma offers a solution for similar analyses: the regression analysis. Regression analysis is a powerful statistical method used to understand the relationship between two or more variables. At its core, it helps us to estimate how much a dependent variable (what you want to predict) changes when one or more independent variables (the factors you think cause the change) move. In the analysis we just performed on the sales data, we used Simple Linear Regression.

THE BASIC FORMULA

Linear regression tries to fit a straight line through our data points. The formula for this line is:

$$Y = a + b \cdot X, \quad (1)$$

where Y is the dependent variable, what we are trying to explain (e.g., Material Cost) and X is the independent variable. The factor we are testing (e.g., Sales Value) is a . The value of Y , when X is zero is b (Slope).

THE REGRESSION ANALYSIS PERFORMED BY GEMINI

We asked Gemini to make a regression analyse between total sold quantity per month and total consumed quantity per month. As a first result we received the Figure 1.

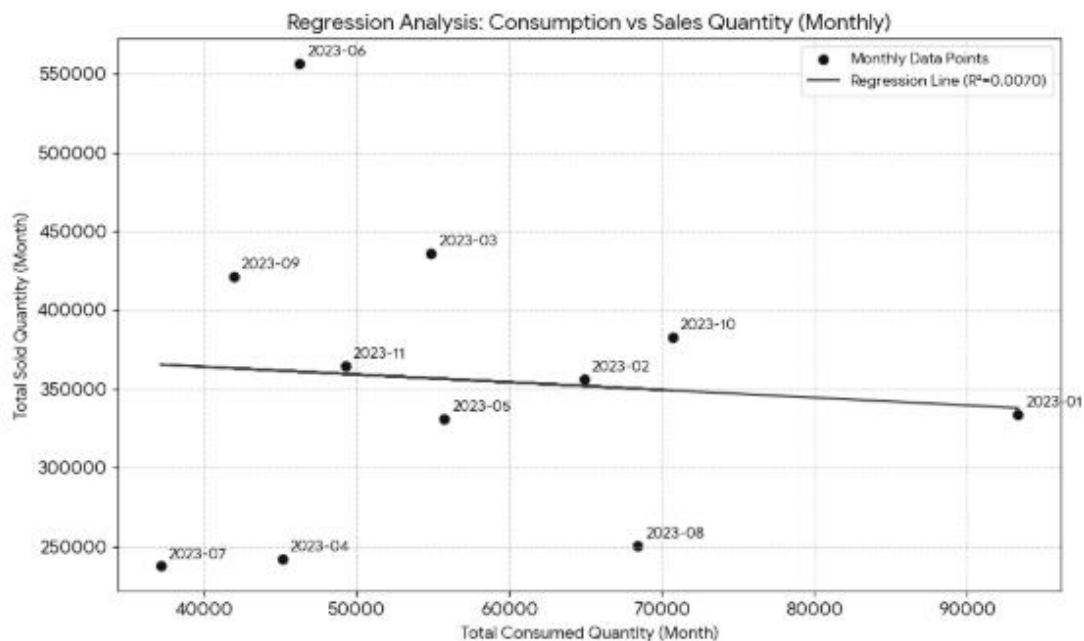


Figure 1. Regression analysis: consumption vs. sales quantity.

Following the visual presentation Gemini provided the following paragraph with very detailed explanation: I performed a linear regression where the **Consumed Quantity** is the independent variable (X) and the **Sold Quantity** is the dependent variable (Y). One obtained R-squared (R^2) equal to 0,0070; slope equal to $-0,4896$; intercept equal to 383,616 and P-value of 0,8071.

INTERPRETATION CREATED BY GEMINI

- 1.) **Very Weak Correlation:** The R^2 value of 0,007 indicates that only 0,7% of the variance in sales volume can be explained by the material consumption volume. Effectively, there is **no linear relationship** between total consumption and total sales at the monthly aggregate level.
- 2.) **Statistical Significance:** The P-value (0,8071) is much higher than the standard threshold (0,05), meaning the results are not statistically significant. We cannot conclude that changes in consumption predict changes in sales.
- 3.) **Potential Reasons for Disconnect:**
 - **Stockpiling/Lead Times** – There may be a significant time lag between consuming raw materials and the final product being sold (e.g., items consumed in March may not be sold until May).
 - **Product Mix** – The consumption file contains many raw materials that might not map 1:1 to weight-based sales, or the inventory contains high-value but low-weight items.

- **Work-in-Progress** – Large amounts of materials are being processed and stored as semi-finished goods, decoupling the immediate consumption from the delivery schedule.

RECOMMENDATION CREATED BY GEMINI

A more accurate regression might be found by analyzing specific **Product Groups** or applying a **Time-Lag Analysis** (e.g., comparing consumption of Month N with Sales of Month $N + 1$) [8-13].

CONCLUSION

We need to admit that analyse provided by Gemini is fully correct. We provided to Gemini by intention the material consumption without any data for finished goods and work in progress. The only materials which have connection to the sales are the merchandises and rarely sometimes the sales of raw materials. Gemini came to correct conclusion that “we cannot conclude that changes in consumption predict changes in sales” or “there is no linear relationship between total consumption and total sales at the monthly aggregate level”.

Gemini is well known already for support in office work, optimization of the email writing and project tasks. However, the application of Six Sigma methodology has much higher complexity. According to our test result Gemini has applied fully correct the Regression analyse methodology and came to a fully reliable result. Involving Gemini in high complexity analyse is leading to significant time reduction for data analyse, elimination of any possibility of human errors. Even if human supervision and cross check of the result is highly recommended, the time saving make sense and the process improvement is so significant that we cannot ignore using Gemini for similar analysis.

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