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Enhancing Production Efficiency of Oil Product at a Petroleum Company Through Lean Six Sigma and Continuous Improvement

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This study aimed at improving the production efficiency of a petroleum company in Jordan, hereinafter called JOPEL, through the application of Lean Six Sigma (LSS) principles. The Define, Measure, Analyze, Improve and Control (DMAIC) methodology was used to decrease the variability of oil product weights under strict filling requirements. The initial process analysis using statistical process control tools indicated that the process was highly unstable and had performance gaps. Root cause analysis indicated that the main causes of the variation were machine calibration problems and poor communication among the production workers. Targeted improvement actions were undertaken, such as improved process monitoring, equipment calibration practices and structured communication procedures. These interventions led to better process stability, improved process capability and reduced variability. The study recommends institutionalizing the communication framework, formalizing accountability for calibration activities, and adopting early warning systems to support sustainable performance improvements. Results reveal that a framework based on Lean six-sigma methodology offers a practical path for sustainable process stability, quality improvement, and operational excellence in oil refinery and similar process-based manufacturing industries.

Keywords: Continuous improvement, DMAIC, Lean six sigma, Process variability, Production efficiency improvement

Introduction

Although technology may make it easier to collect and analyze data, many companies struggle to perform in-depth analyses or may misinterpret the data, leading to incorrect conclusions. The absence of these data analysis skills often results in decisions being made based on intuition, highlighting the importance of adopting data-driven approaches. Companies strive to reduce manufacturing costs and continuously improve processes to maintain growth and competitiveness, particularly in the Middle East, where economic challenges are constant. In particular, the industrial sector in Jordan needs to discard old practices and replace them with new techniques such as Lean Six Sigma (LSS) to facilitate continuous improvement and reduce waste. Adopting LLS practices at JOPEL enhanced production of lubricants for automotive sector via reduced cycle time, improved quality, and expanded production capacity. This minimizes costs and boosts profitability.

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Many different industries have made significant money from automotive to healthcare with successful LSS implementations. The biggest companies have seen a return of 1% to 2% of their annual sales and smaller companies have seen returns of 3% to 4%. In recent times, organizations have adopted lean methodologies to improve their competitiveness in the market by reducing waste and focusing on customer value.[1,2] Lean is about improving quality and reducing costs through streamlining processes and eliminating waste. It defines 8 types of waste and encourages continuous improvements in quality and productivity. Historically, lean has proven its worth through historical figures such as Henry Ford and Toyota by reducing waste and optimizing efficiency.[3,4] Lean can be applied to the manufacturing and service industry and it affects many aspects of operations such as process design and inventory management. It deals with issues such as overproduction, redundancies and waiting times to improve overall efficiency and minimize resource usage.[5] At the same time, Six Sigma has become a popular methodology for improving efficiency, productivity and error reduction by eliminating operational variation.[6] Sigma stands for

standard deviation and Six Sigma sets the benchmark for optimal quality with a defect rate of 3.4 per million units.[7] The natural curve idea was conceived by Carl Friedrich and adopted by Walter Shewhart in the 1920s. Six Sigma was formalized at Motorola when Bill Smith and Mikhel Harry responded to competitive pressures from Japan in 1979.[(8)]It improves problem solving by reducing defects and variability, and therefore improves revenue and reliability of services.[9,10] Six Sigma strategy relates to improving long-term performance, deeply ingrained in the cultures of large corporations such as General Electric, where it emphasizes the importance of high quality delivery.[11] The objective of this organized approach is to reduce variability and attain strategic objectives with a laser focus on satisfying the customer-specified standards.[12] Lean Six Sigma combines the focus of lean on waste reduction with the focus of Six Sigma on minimizing variability and is helping companies to achieve greater success. This synergy has led to increased operational efficiency, improved product quality, improved customer satisfaction and reduced costs.[9,10] Maytag and Allied Signal are among the first companies to use the integration.[13] Lean Six Sigma is designed to enhance processes by eliminating waste while also enhancing quality and delivery[14] directly targeting critical quality problems to reveal great opportunities for improvement.[15] Successful organizations such as Toyota and General Electric aim for a defect rate of 3.4 per million opportunities (DPMO).[16] The DMAIC (Define, Measure, Analyze, Improve, and Control) approach is critical to pushing process improvements.[17] Tools like Ishikawa diagrams are used to determine the root causes, while control charts track performance, allowing distinguishing random variation from specific errors.[18,19] The case study is a Jordanian petroleum company named JOPEL. This company was founded in 1977 in a partnership with Shell and its oil plant had a production capacity of 15,000 tons per year, which has since been doubled to 30,000 tons. It holds a 45% share of the Jordan market. In contrast, the oil-packaging department has problems with inconsistent filling of 25-liter gallons that has led to reduced productivity. The research aims to decrease waste and increase efficiency and to keep pace with advances in lubricant manufacture across the world through measure and reduce variability, assess the process capabilities, implement recommendations for continuous improvement, and to compare current and future states via Lean Six Sigma tools to inform management decisions.

The current work is different from prior Value Stream Mapping (VSM) and DMAIC research because it extends the application of LSS to the petroleum industry, incorporates automation, and communication strategies, that make it a valuable reference for continuous improvement in process driven industries outside traditional manufacturing.

Clearly, although the methodology of LSS is a basis of manufacturing in general, its application in the high-risk oil sector is a major unexploited opportunity. This study closes the gap by developing a standard DMAIC framework incorporating specialized automation and calibration strategies for lubricant blending. This research goes beyond traditional planning and provides a unique and practical roadmap for improving accuracy and efficiency in process-intensive industries.

The current work extends research on VSM and DMAIC methodologies, with its distinct contributions across several dimensions summarized in Table 1.

Problem Formulation

The methodology for conducting research in this project mostly entails using the Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) methodology combined with Lean tools, specifically Value Stream Mapping (VSM), in relation to JOPEL

Table 1 — Contributions and differences of the paper compared to existing VSM and DMAIC studies

Dimension	Contributions compared to previous studies
Integration of lean six sigma in a petroleum production context	• LSS integrates waste reduction with SPC.[14,19] Previous applications include household appliance manufacturing.[6,12] This study extends LSS to petroleum production.
Addressing variability and control with a unique calibration approach	• DMAIC applied to improve production performance,[10] while SPC support process monitoring.[18] This study integrates weight checking with an alarm system to discover filling deviations.
Use of automated systems to reduce variability	• Improvement requires reliable measurement and continuous monitoring.[18,20,21] This study introduces systematic calibration tracking, assigned structured responsibilities to strengthen process accountability.
Value Stream Mapping (VSM) focus with process capability analysis	• VSM and SPC supports improved production flow[1,3,4] this study combines these approaches to evaluate filling-weight performance.

production line with the purpose of improving the quality of packed oil in terms of weight variation reduction. Performance measures will be specified in the Define step. The Measure step implies the systematic gathering of data, which will continue throughout some months of observation. Afterward, collected information will be analyzed through descriptive statistics and control charts in order to evaluate process capability and baseline sigma level.

Materials and Methods

In this study, the methodology is a combination of positivism with the use of statistics along with the DMAIC approach of Six Sigma that concentrates on the quantitative side.[20] Information on the weight of the oil fill is collected on the production line that is under consideration. The researcher makes a number of interviews with the production manager, machine operator, as well as other people working in the production and quality control departments to understand existing problems and create solutions at the improve stage. The registered tracking system is utilized in the JOPEL's compliance with ISO 9001 standards as a quality management system, and the generated information is an essential part of the data to be analyzed by the researcher. During the research stage, 112,057 pieces have been produced. The expected population proportion is defined to be 0.5, and the margin of error is estimated as 4.5%. In the course of the study, 95% confidence level is used, corresponding to the z-score value of 1.96.[(21)] In the present case, both qualitative and quantitative data will be involved into the study. The latter includes fill weight measurements made at certain intervals that are compared to the target values. The methodology of the present study is described in Table 2, which

Table 2 — Summary of DMAIC methodology: Tools, activities, and objectives for process improvement

Stage	Tool	Tool Description	Activities	Purpose
Define	Flow chart	A visual representation of a process or workflow.[21]	- Identify variability in weights of the product - Develop project charter - Define project scope - Map out production process	- Clarify the problem - Set project boundaries - Understand overall production flow
	Project charter	Defines a project's objectives, scope, stakeholders, roles, responsibilities, goals and expectations.[13]		
	High-level process map	Illustrating the main steps and identifying key areas for improvement.[2]		
	Project scope	Outline objectives, deliverables, and limitations, and project boundaries.[14]		
Measure	Cause and effect diagram	Visualizing root causes across various categories.[18]	- Data collection - Construct Current Value Stream Map (CVSM) - Estimate defect rates	- Quantify the variability in weight - Identify inefficiencies in the process - Identify waste in the process
	Value stream Map	Visualizing the flow of materials and information required to bring a product or service from start to finish.[1]		
Analyze	A boxplot	Display the distribution of a dataset through its quartiles.[21]	- Perform statistical analysis on the collected data - Identify root causes of variability - Construct Future State Value Stream Map (FVSM)	- Determine key factors contributing to process instability - Derive proposed solutions through FVSM
	Control charts	Identifying trends, variations, or out-of-control conditions that need corrective actions. [6]		
	Descriptive statistics	Main features of data, such as mean, median, and standard deviation.[12]		
	Histogram	Representation of data distribution, provides a quick visual summary.[7]		
	Process capability analysis	Measures a process's ability to produce products that meet design specifications consistently.[21]		
Improve	Brainstorming solutions	Creative thinking and open discussion among team members. [9]	- automated weight checking - Enhance calibration. - Strengthen teams' communication	- Reduce variability and human error - Streamline process through automation
	Value stream Map (VSM)			
Control	Control plan Control charts	Monitor and maintain process performance.[11]	- performance Monitoring - Documentation and calibration - Training and maintenance	- Sustain improvements and Translate it into procedure

consists of the DMAIC phases with the description of their tools and tasks, and presents the whole methodology of the study.

LSS, the DMAIC methodology and VSM are widely used to improve processes and operational performance. LSS brings together two complementary approaches: Lean, which focuses on reducing waste and improving workflow, and Six Sigma, which aims to reduce process variation and improve quaility.[13,14] Their combined use provides a structured way to address operational problems and improve efficiency. Applications in bearing manufacturing and household appliance production illustrate the relevance of systematic improvement methods to manufacturing performance.[6,12] The study employs VSM to analyze and optimize process workflows, aligning with the results of Deokar *et al.*[1], which demonstrated its benefits in the automotive industry. LSS, DMAIC methodology, and VSM have been identified as effective approaches for process improvement.[9] This can be justified with the help of references that demonstrate the effectiveness of these approaches in various industries. LSS combines Lean approach, which concentrates on waste reduction, and Six Sigma, which aims at variability minimization. The use of both Current and Future State VSM ensures that improvements are strategically planned and measurable.[9] According to AL-Tahat[22] continuous improvement influence by the integration of digital tools and LSS into non-traditional sectors. Another feature of the flexibility of DMAIC is illustrated by its implementation. For example, AL-Tahat and Nsour[23] have shown that LSS-DMAIC techniques can be adjusted to suit the needs of the pharmaceutical industry in terms of quality and efficiency. It should be noted that just like the petroleum industry, the pharmaceutical industry operates under strict standards in terms of safety and quality. In addition, the use of lean techniques is not restricted to manufacturing processes but can be used in service and public sectors. The research by AL-Tahat and Alharbi[24] on the education sector indicates that lean management techniques are universal and applicable in any organized process and are not limited to manufacturing only. All these methods fit the guidelines set forth by Montgomery who emphasized the necessity of these tools to ensure process stability and quality control.[21] Lastly, a self-checking of products' weight with alarm system to minimize human interference is suggested in order to increase quality monitoring in the process. It reflects the conclusions of who proved how automation could help in increasing efficiency in chemicals production.[10] It shows how the chosen methodology is in line with the existing researches and practice; it can be stated that these methods reflect the modern industrial practices. While this study utilizes a widely known framework, such as DMAIC, it goes beyond the conventional approaches by personalizing the method to meet the unique challenges of the particular industry, namely petroleum production. Unlike other papers focused only on general manufacturing, this study implements LSS in order to improve product weight variability that did not receive significant attention in previous scholarly works. Key advancements include the use of an automatic weighing system together with an alarm system.

Problem Solution

This segment offers a concise discussion on the experimental findings; their interpretation as well as the conclusions that can be drawn from experiments, with an emphasis on the steps for their implementation of the DMAIC based LSS.

Define Phase

Defining the Product the Production Process and the Scope

The product under investigation designated S3 plus 50, is an oil product characterized by a density of 0.901 to 0.902 g/cm^3, a target filling weigh of 22.538 kg, and allowable filling tolerance ±0.15 kg. The customer and progresses through several steps place the order before sending it to the production lines. The production-order flow at JOPEL, from receiving the customer's order to imitation the actual production processes is illustrated in Fig. 1. After the

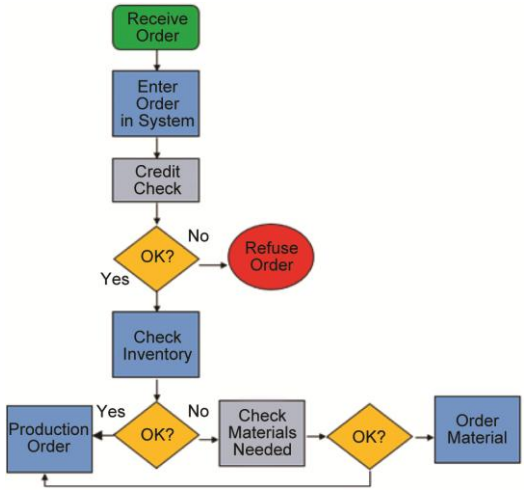

Fig. 1 — The flow chart from receiving customer's order to the actual production request in JOPEL

production process, the production order goes to departments; the blending department examines the availability of raw materials in the required quantity. After the detection and sampling process in accordance with the process map (Fig. 2), the quality control department gives an approval for the packaging process. The request to package the product is sent to the final packaging department. The team analyses the packaging requirements and makes preparations, which include several steps such as calibration, adjustment, and lubrication.

Three nozzles are used to fill the gallon within less than a minute; after filling, the gallon goes through the conveyor belt to be taken to the printer where vital details like the time of production, date of production, serial number, and batch number are printed. After this process, the capping process takes place using one head. Then, the 25-liter gallon is moved to the induction sealing machine and squeezer. After the leakage test, the gallon is weighed to confirm that it meets the required limits. Finally, a semi-automatic handler is used to move the finished product to the pallet. The flow process map of the product from receiving customer's order to the actual production request in JOPEL is given in Fig. 2. Performance measures related to this process map are tabulated in Table 3.

The current study mostly concentrates on filling weight, which is considered the most variable element throughout the observation period through measuring techniques. The Target Filling Weight (T) is taken as 22.538 kg, while the tolerance is ± 00.150 kg. In consequence, the Upper Specification Limit (USL) will be 22.688 kg, whereas the lower specification limit (LSL) is equal to 22.388 kg. It is revealed that the packed weight of the product sometimes reached the LSL (22.388 kg) and even went below this limit as non-conformity. Consequently, it caused delays and disruptions in the manufacturing process.

Project Charter

Scope of the project, objective, important stakeholders, members of the team participating in this research, and other aspects of the project are described in the project charter, which is presented in Table 4.

Measure Phase

Measure Phase involves developing the Current Value Stream Map (CVSM), as well as defining the

Table 3 — Performance measures for the product under study

Measure	Value
Target filling weight	22.538 kg
Tolerance of filling weight	± 00.150 kg
Target filling volume	25 Liter

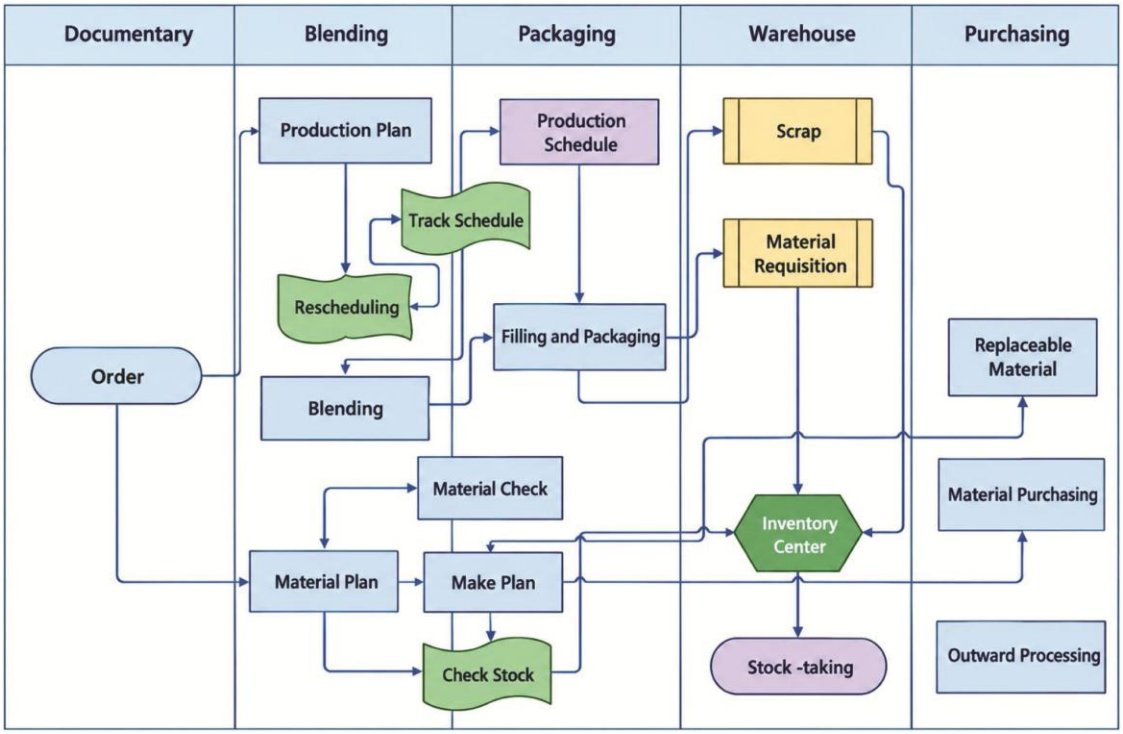

Fig. 2 — The flow process map from receiving customer's order to the actual production request in JOPEL

Table 4 — The project charter (Note: Fields have been left blank to ensure confidentiality and protect privacy)

Project Title	Measuring evaluating and reducing the variation on filling weight of the 25-Liter gallons under study
Sponsoring Organization	JOPEL Company
Team Members	Title / Role /Contact (Phone, E-Mail) JOPEL General Manager (+962000000000) Production Section Head (+962000000000) Blending Section Head (+962000000000) Head of SHEQ (+962000000000)
Key Stakeholders	
University of Jordan	Prof. Dr. Mohammad D. AL-Tahat, (+96265355000, altahat@ju.edu.jo)
University of Jordan	Prof. Dr. Sa'ed Musmar (+96265355000, s.musmar@ju.edu.jo)
Date Chartered	—
Project Start Date	—
Target Completion Date	—
Revision Number: 001—	
Project Mission Statement	
Problem Statement	• This study aims to pinpoint the major issues with the filling weight of JOPEL's oil product, which leads to recurrent delays in production and issues with quality compliance. The necessity for manual adjustments in calibration disrupts the efficiency of the production line and creates difficulties for the company and its clients in meeting product standards and delivery schedules.
Business Case	• This initiative addresses the issue of variable filling weights in JOPEL, which results in operational delays and quality discrepancies. By working to create consistent filling weights, the project seeks to streamline processes, enhance customer satisfaction, and bolster JOPEL's competitive position in the industry.
Project Scope	• The focus of this research is to investigate the causes of discrepancies in filling weights within JOPEL's oil production line, with particular attention to how these differences lead to delays in operations.

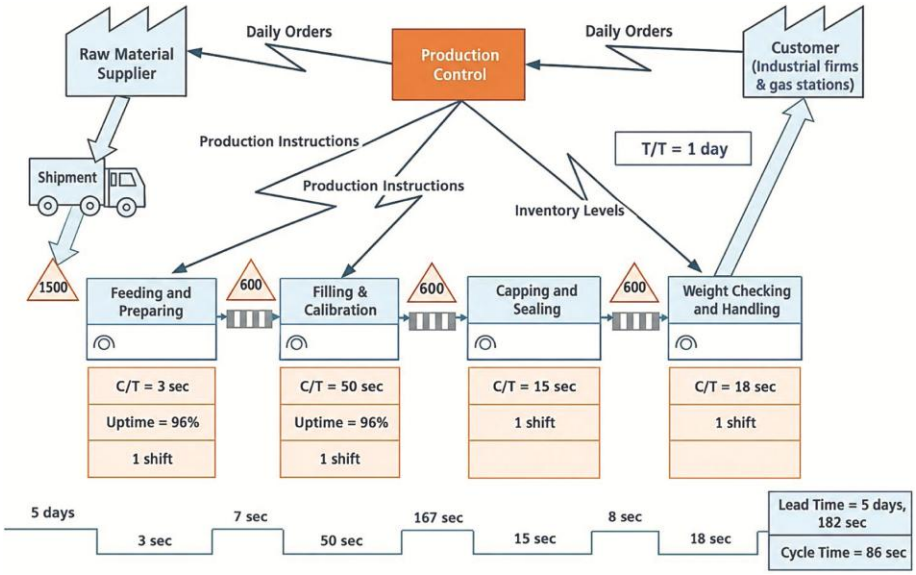

Fig. 3 — A visual representation of the CVSM for this production line

root cause of variability of the product. The CVSM is illustrated in Fig. 3; the total cycle time of the system is 86 seconds. The total lead-time is equal to 5 days and 182 seconds. What is important is that considerable part of 167 seconds of lead-time is taken because of the delays between actual fillings and capping. This delay results from the need for calibration caused by the variations of the filled volumes. As it can be seen from Fig. 3, the problem of volume variations has prolonged the total lead-time, especially the period between filling and capping, equal to 167 seconds. CVSM illustrates the influence of the variability of the volume of filling of the product on value added time and total lead-time.

The data for the creation of the CVSM was obtained through direct observations.

Frequency of Defects Analysis

A defect is defined as a product whose measured filling weight falls outside the specified limits of 22.538 kg ± 0.150 kg, corresponding to LSL of 22.388 kg and an USL of 22.688 kg. The measurement and the average defect percentages recorded over a five-month production period are presented in Table 5. The results indicate noticeable variation in the defect percentages across the sample.

Cause and Effect Diagram

The fishbone diagram in Fig. 4 illustrates the potential causes of filling- volume variability. In total, there are six main categories, which determine variability in the filling volume of the oil product: measurement, materials, methods, machinery, workers and environment. Moreover, in each of the categories, the root causes can be found. Furthermore, work speed, shift change and lack of communication in case of problems on the production line may contribute to this problem.

Analyze Phase

The collected production data are analyzed using descriptive statistics, as presented in Table 6. Control charts are then developed to identify nonconforming points and determine when they occur. Finally, the Future Value Stream Map (FVSM) is developed is developed to present the proposed improved process.

Table 5 — Defect counts and percentage of defective products from a five-month production sample

Month	Number of defects	Total production	Percentage of defects (%)
1	1,201 unit	18,761 unit	6.40%
2	1,731 unit	19,670 unit	8.80%
3	807 unit	17,928 unit	4.50%
4	1,175 unit	18,561 unit	6.33%
5	1,145 unit	18,461 unit	6.20%
Average	1,212 unit	18,676 unit	6.45%

Table 6 — Summary of descriptive statistics for the filling weight

Measure	Value
Sample size (n)	5
Number of samples (N)	118
Total number of individual measurement (N×n)	590
Mean (μ)	22.5091 kg
Standard deviation (σ)	0.1050 kg
Variance (σ^2)	0.0110 kg
Maximum value (Max)	22.850 kg
Minimum value (Min)	22.060 kg
Average of ranges ($\bar{R}$)	0.19 kg

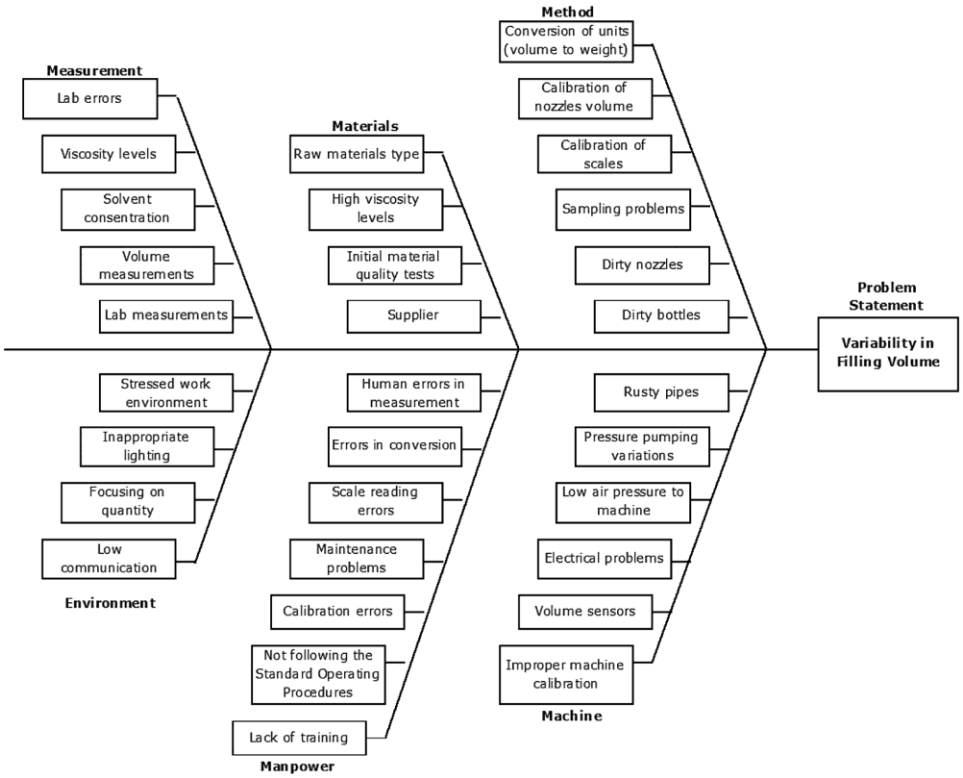

Fig. 4 — Cause and effect diagram for the volume's variability problem

Outliers were also detected using the boxplot method in the filling weight data set, as illustrated in Fig. 5 below. All samples apart from the first one have outliers. The first sample, which was collected at the beginning of the workday, had a mean value almost equal to the target value. The second sample has three outliers and an average value that is higher compared to the first sample. Third sample has an average value that is lower compared to the previous ones and two outliers less than the acceptable values. Fourth and fifth samples, collected later in the day, contain six and four outliers, respectively, less than the minimum values. It can be concluded that earlier samples in the day are more reliable.

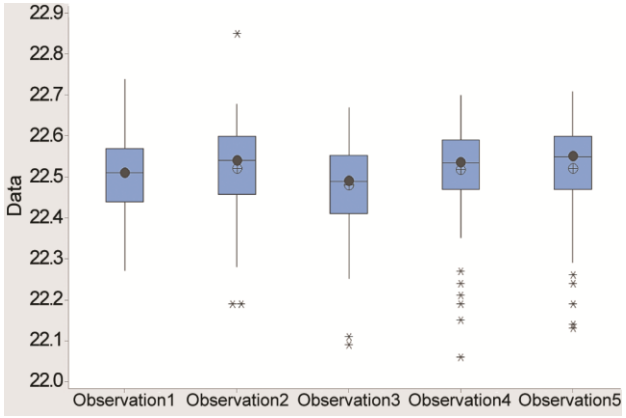

Fig. 5 — Boxplot for the filling weight dataset under analysis

The X-bar and R charts in Fig. 6 illustrates the process variation, X-bar chart monitors the average filling weight over time, whereas the R chart depicts the sample range values from each sample. It is evident that there are at least 10 points that violate control chart rules on the X-bar and R control charts. In general, the X-bar and R control charts are out of control, reflecting high variability and the existence of out-of-control points requiring improvements. From the X-bar control chart and R chart, one can notice that the filling process is out of control since some points have violated the Upper Control Limit (UCL), some points lie under the Lower Control Limit (LCL), and there are some consecutive samples reflecting shift in mean upwards and downwards. There are 16 consecutive samples under the Centerline (CL) and 14 samples over CL. The main reasons include increased work pressure in mid-month where production planning is more active than at the beginning and end of the month. In addition, there is not enough time allocated for the preventive maintenance of equipment on production lines, which may lead to some small defects and calibration problems. One more reason for such a high amount of out-of-control points on X-bar and R charts can be the sample size in the conducted study. Histogram of the obtained observations (Fig. 7(a)) demonstrate a left-skewed curve with concentration on the minimum values, which explains the greater amount of out-of-

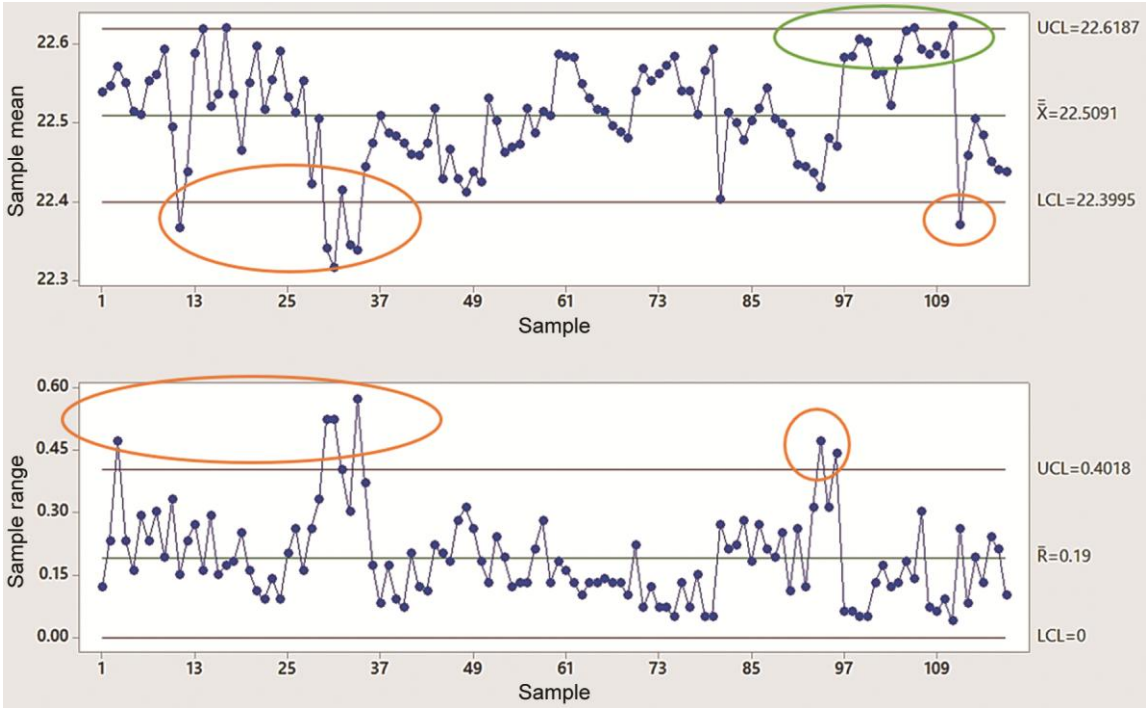

Fig. 6 — The X-bar and R control chart for the weight of filling in

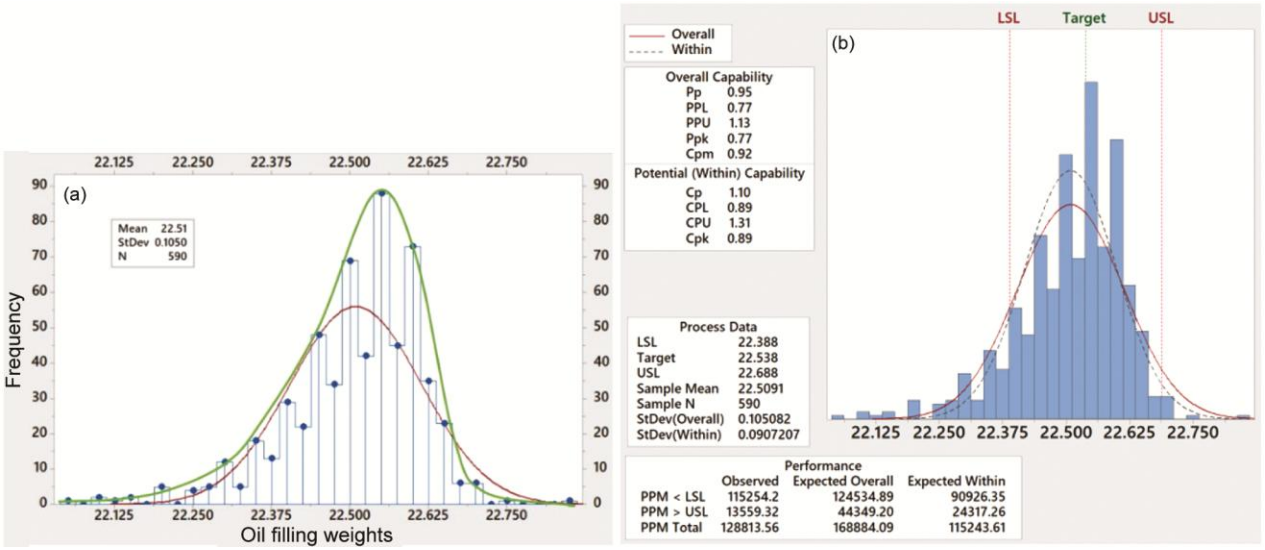

Fig. 7 — Histogram of oil filling weights for collected data and the process capability analysis results

control points under LCL on X-bar chart. Process capability analysis (Fig. 7(b)) results in capability ratio (Cp) = 1.10, overall capability (Pp) = 0.95, Defects Per Million Opportunities (DPMO) = 128,813.56, and the corresponding process sigma level = 2.63. Thus, there is a defect rate of 12.88%, yielding 87.12%.

Improve Phase

Major concerns in this phase are improving communications from the production to the maintenance teams, improving calibration procedures, and automating things to avoid having human involvement at all costs. Other recommendations include increased frequency of calibration and specific people assigned the task of doing this. Implementing these recommendations is expected to reduce lead-time, defects, and costs, while providing a foundation for further improvement.

Strengthen Production and Maintenance Communication

Establishing clear communication channels with managers and supervisors is recommended to ensure timely responses and effective resolution of operational issues. For instance, any detected variability in the filling process should be promptly escalated to production and maintenance supervisors to for corrective action. Prolonged issues, such as a five-month delay, are detrimental, especially for high-demand products. Effective communication between teams fosters proactive problem-solving, allowing potential issues and anticipated errors to be shared and resolved swiftly, which leads to faster solutions and better decision-making.

Improve Calibration Process and Accountability

Regular calibration of packaging machines is essential due to their intensive use and the influence of operating conditions, because of the high usage of machines and the impact of such factors as operating conditions, vibrations, pressure variation, and material properties such as viscosity, density, and temperature. The continuous calibration process needs to be done by the production staff. Now, the calibration process takes place only at the beginning of the production. However, the adjustments of the calibration values and the checks of the machine pressure and filling nozzles need to be done several times during one batch. To address calibration issues, it was recommended to recalibrate the filling volume and pressure after every 2500 liters of production.

Future Value Stream Map (FVSM)

Enhance communication within the production team about changes in volume and improve calibration process is expected to bring positive effects on efficiency. With less human intervention in volume calibration, the dependency will be transferred to automated packaging instead of manual calibration. In order to make the above-mentioned improvements clearer, FVSM shown in Fig. 8 is developed. It takes considerable amount of time to manually calibrate the volumes of oil. Improved communication is expected to reduce the total lead-time from 5 days and 182 seconds in the CVSM to 5 days and 30 seconds in the proposed FVSM.

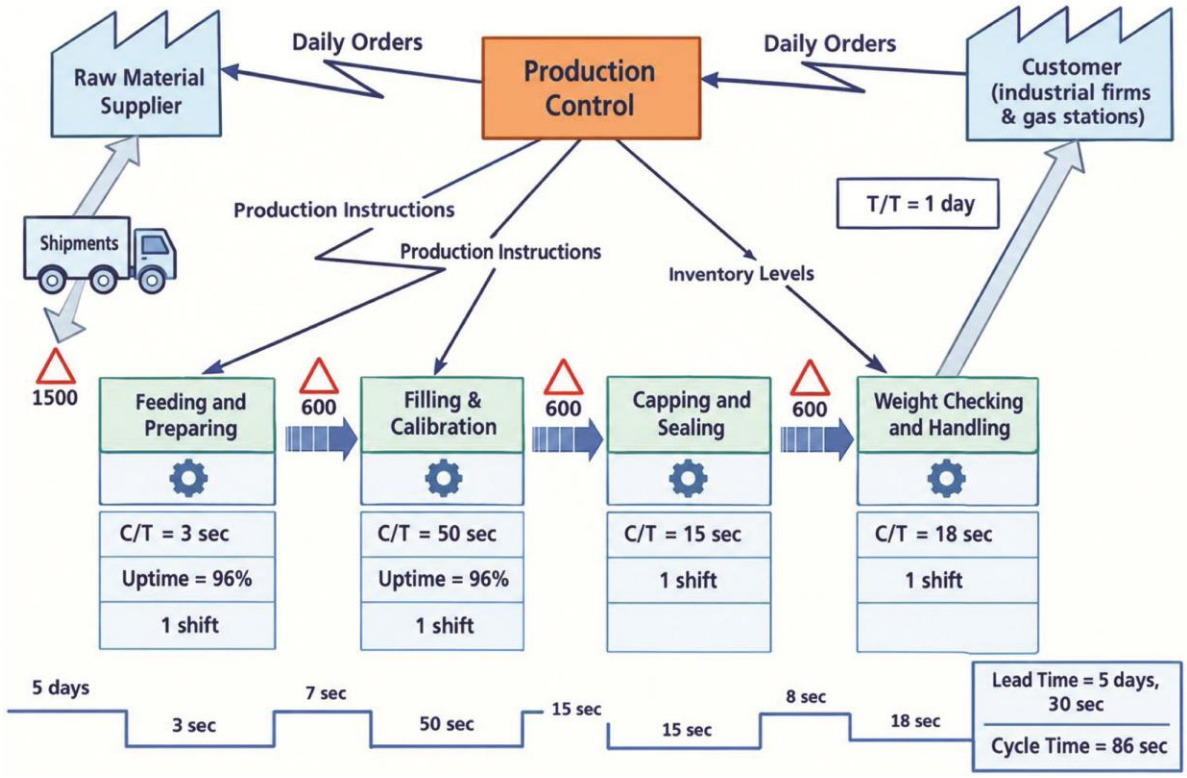

Fig. 8 — Future value stream map for oil products in packaging line

Table 7 — Descriptive statistics for post improvement data

Measure	Value
Sample size (n)	5
Number of samples (N)	51
Total number of individual measurement (N × n)	255
Mean (μ)	22.5430 kg
Standard deviation (σ)	00.0881 kg
Maximum value (Max)	22.7900 kg
Minimum value (Min)	22.3000 kg
Average of ranges ($\bar{R}$)	00.2130 kg

Data Collection and Post-improvement Analysis

After implementation of the improvements, new data were collected to analyze the process performance. The descriptive e statistics for the post-improvement data is presented in Table 7. The mean filling weight increased to 22.543 kg, closer to the target of 22.538 kg, while the standard deviation decreased from 0.1050 to 0.0881 kg, indicating reduced variability. The observed filling weights ranged from 22.30 kg to 22.79 kg. As seen from Fig. 9(a), there are no out-of-control points in the post-improvement X-Bar and R charts. Process capability analysis shown in Fig. 9(b) results in the following data: capability ratio (Cp) equals 1.10, overall capability (Pp) equals 1.13, DPMO equals 70,588.24, and that is, the process sigma level is 2.97. This represents an approximately 46.5% reduction in the defect rate, from 6.45% to 3.45%.

Control Phase

The recommended changes should be implemented, and monitored regularly to verify that the identified problems have been solved and that the improvements are sustained in both the short and long term. Effective communication is essential for sustaining LSS by improving coordination among weight checkers, supervisors, operators, production staff, and team leaders. Daily documentation of calibration responsibilities also strengthens accountability and enables managers to identify the person responsivities for calibration.

Validating Process Improvements and Methodology Outcomes

The study combined statistical analysis, root cause identification, and post-improvement validation to assess LSS effectiveness and sustainability

1. The study relied on past production records and current data to quantify the variation in oil filling volumes. Statistical tools such as control charts ($\bar{X}$-R), descriptive statistics, and process

capability were used to assess the process stability and performance.

2. Interviews were conducted with production supervisors, machine operators, and quality control personnel. Fishbone (Ishikawa) diagram was used to analyze the main causes of variability such as machine calibration and ineffective communication.
3. The post process improvement data analysis indicated an improvement in process stability. The processes sigma level improved to 2.97 under JOPEL standards and 4.16 under JSMO standards.
4. The improved process was monitored over an extended period to assess the sustainability of the results, and recommendations were developed for ongoing monitoring and maintenance of the improvements.

Discussion of Improvement Outcomes and Cross-Industry Comparisons

The degree of improvement gained through the increase in Sigma score from 2.63 to 2.97 and decreasing defect levels from 6.45% to 3.45%, is quite a big step for any organization. Though the main focus of research carried out in the general manufacturing field is waste minimization, it can be noted that improvement in the Cp of JOPEL from "incapable" 0.95 to compliant 1.13, is quite similar to those seen in the automotive industry[1], however, they solve different problems. Having implemented automated alarming system and calibration procedure, JOPEL has reached the level of performance, which shows the reduction in defects by 46% and provides much more advanced stability compared to that of traditional standards of quality. The comparison between the initial and improved systems is presented in Table 8, while Table 9 compares the finding from JOPEL with related applications in other industries. The outcomes of LSS implementation at JOPEL are consistent with those that have been seen through LSS success in other technically demanding and regulated fields including pharmaceuticals, whereby standardization of complicated procedures is vital for quality purposes.[22]

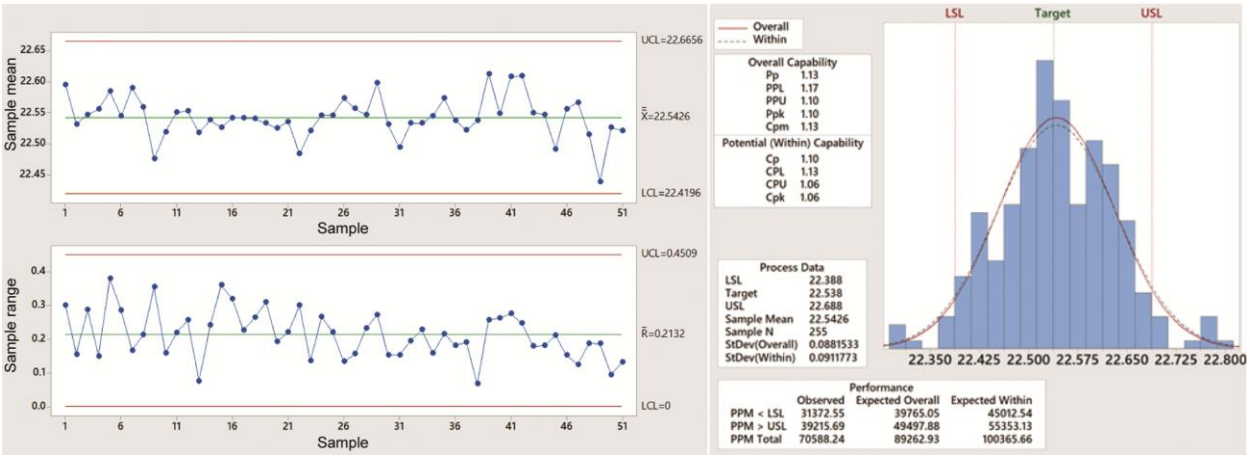

Fig. 9 — Post-improvement phase:(a) The X-Bar and R charts;(b) Process capability analysis (the weight of filling)

Table 8 — Comparison of initial and improved systems

Aspect	Initial system (before improvement)	Improved system (after lean six sigma implementation)
Mean filling weight	22.5091 kg (below target)	22.5430 kg (closer to target)
Standard deviation	0.1050 kg (high variability)	0.0881 kg (reduced variability)
Defect rate	6.45%	3.45%
Sigma level	2.63 (low process capability)	2.97 (improved process control)
Process capability (Cp)	0.95 (not meeting quality standards)	1.13 (improved capability)
Lead time	5 days, 182 seconds	5 days, 30 seconds
Control charts	Multiple out-of-control points	No out-of-control points
Calibration frequency	`Inconsistent, manual adjustments	Scheduled recalibrations every 2,500 liters
Automation	No automated quality checks	Automated weight-checking system
Communication & accountability	Lack of structured communication between teams	Established clear reporting system and accountability for calibration
Overall process stability	Unstable, frequent variations in filling weights	Stable, with reduced defects and controlled variations

Table 9 — Specific points of comparison between JOPEL and other industries

Metric	JOPEL result	Industry parallel	Discussion note
Sigma level	2.63 → 2.97	Pharmaceuticals	Both require high precision to avoid costly rework or safety risks.
Defect rate	46.5 Reduction	Automotive	Mirrors the waste reduction seen in Toyota-style Lean applications.
Process capability(Cp)	0.95 → 1.13	General manufacturing	Shifts the process from "Incapable" to "Marginally Capable/Acceptable."
Innovation	Automated alarms	Digital revolution	Aligns with AL-Tahat[22] regarding digital disruption in LSS.

Conclusions

This study demonstrated the practical application of LSS to improve filling-weigh performance in a petroleum product packaging process. The implemented interventions reduced process variability and defect rates while improving process capability and lead-time. Combining statistical process control with documented calibration procedures, automated weight checking, and clearer communication helped address operational weaknesses and strengthen process monitoring. The findings highlight the value of integrating analytical tools with practical measures to improve production performance. However, the study was conducted at a single facility over a five-month period, limiting the extent to which the findings can be generalized to other production environments, Future research should examine the long- term sustainability of improvements, assess their economic benefits, and evaluate their applicability across multiple petroleum facilities and product lines. Future integration of real-time data analytics and automated process monitoring could also strengthen early defects detection and support more proactive quality management. The purposed approach may be adapted to other process-based manufacturing industries facing similar challenges in quality control, processes variability, and operational efficiency.

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Contribution of Individaul authors

Mohammad D. AL-Tahat and Sa'ed Awni Musmar conceived the research idea, defined the overall objectives of the study, and provided oversight and critical insights during data analysis. Hisham M.s. Alghwiri collected the data, analysed and ensured data integrity, executed the statistics. Mohammad D. AL-Tahat prepared this manuscript.

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Conflict of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article

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