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Lean and Six Sigma Methodologies for Process Improvement

Quality and Business Improvement (ACMA4004)

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1 Introduction

Process improvement refers to systematic principles utilised by organisations to enhance operating efficiencies. To ensure continuous improvement of operations, companies strive to achieve greater operational excellence by implementing key methodologies.

Application of identification, analysis and improvement implementation techniques is fundamental in optimising quality and performance across industry sectors. A consistent and collaborative approach to these principles is critical in achieving optimum efficiency, also elevating business agility and competitiveness.

The purpose of this report is to examine the different methodologies that are employed by organisations worldwide, in particular Lean and Six Sigma. The objective, to compare the methodologies, defining the differing strategies and tools deployed by each continuous improvement technique.

The report will seek to explore adopted cases of each continuous improvement strategy in industry. Analysis will focus on the implementation of each methodology, including factors such as cost, resource and cultural influences and the results that each systematic technique has provided.

Finally, the research will present the basis for continuous process improvement opportunities at Dragon LNG. Potential enhancements across the business will be identified and the appropriate technique (Lean or / Six Sigma) will be elected to form a relevant continuous improvement recommendation.

1.1 Introduction to Methodologies

Lean is a process improvement method focused on eliminating waste and maximising value. Originating from the Toyota production system, Lean identifies nonvalue adding activities, such as excess motion, waiting and overproduction. It then implements an action to remove the nonvalue adding activity to improve efficiency. Its five principles include defining value, mapping the value stream, creating flow, using pull systems and pursuing continuous improvement. Common tools include 5S, Kaizen, and Kanban. Lean is used across industries to deliver more value with fewer resources. (Team, 2022)

Six Sigma is a quality management approach that reduces defects and process variation using data-driven methods. Developed by Motorola and popularized by GE, it follows the DMAIC cycle: Define, Measure, Analyse, Improve, Control. The goal is to achieve near-perfect results, with fewer than 3.4 defects per million. Practitioners are trained at various belt levels and use tools like control charts and process capability analysis. Six Sigma is widely used in manufacturing, healthcare and services to boost quality and consistency. (Six Sigma Online, 2024)

2 Principles Background

2.1 Lean

“In 1801, a man by the name of Eli Whitney pioneered a new manufacturing method. He had successfully demonstrated the concept of interchangeable parts” (English, 2019). Eli Whitney was the first person to successfully mass produce interchangeable parts in relation to firearm production. Prior to Eli Whitney’s successful interchangeability breakthrough, parts and components of firearms were bespoke, requiring manufacturing of a custom engineered part on component failure.

During the early 1900’s Henry Ford heavily contributed to Lean by introducing the moving assembly line, which revolutionised mass production. His focus on standardisation, workflow continuity and waste reduction laid the groundwork for Lean principles. Ford's methods greatly influenced later systems, including the Toyota Production System, which expanded on his efficiency driven manufacturing concepts. (Six Sigma Daily, 2019)

As already referred to, The Toyota Production System (TPS), developed by Taiichi Ohno, is the foundation of modern Lean manufacturing. Ohno emphasised eliminating waste, improving flow and respecting workers. TPS introduced concepts like Just-in-Time (JIT) and Jidoka (automation with a human touch), creating a flexible, efficient production model that transformed global manufacturing practices. (Walker, 2024)

Finally, in 1990, the publication ‘The Machine That Changed the World’ introduced the term "Lean production," comparing Toyota’s efficient system to traditional mass production. It highlighted Lean’s superiority in quality, cost, and flexibility. Influencing industries worldwide to adopt Lean principles for continuous improvement and waste reduction. (Womack, 2025)

2.2 Six Sigma

Initially, Walter Shewhart pioneered statistical quality control in the 1920s, introducing control charts to monitor process variation. His work laid the foundation for Six Sigma by emphasising data driven decision making and consistent quality, influencing later methodologies focused on reducing defects and improving performance.

Six Sigma was later developed at Motorola in the 1980s by engineer Bill Smith, who sought to reduce variation and defects through statistical analysis and measurable quality control. Recognising its potential, Mikel Harry, a senior engineer at Motorola, helped formalise the methodology, introducing the DMAIC framework, Define, Measure, Analyse, Improve and Control, which became the foundation of Six Sigma projects.

Motorola's implementation led to dramatic improvements in product quality and cost savings, earning the company the first Malcolm Baldrige National Quality Award in 1988. In the 1990s, Jack Welch, then CEO of General Electric, famously adopted Six Sigma enterprise-wide, investing heavily in training and making it a core business strategy. Under Welch’s leadership, GE reported billions in savings and significantly improved operational performance. This high-profile success propelled Six Sigma into mainstream business practice across manufacturing, healthcare, finance, and technology sectors. (Six Sigma Online, 2024)

3 Continuous Improvement Principles

3.1 Lean

As illustrated in Figure 1, the 5 lean principles that became prominent, after the publication of Lean Thinking, Womack and Jones (1996). The principles refined from an earlier publication by Womack and Jones, The Machine That Changed the World (1990). (Weigel and Weigel, 2000)



Figure 1 - 5 Lean Principles (PlanetTogether, 2021)

An important function of lean, is the identification of waste or 'Muda'. Waste can be further analysed and therefore classified into a particular type of waste. The DOWNTIME acronym represents the classification of waste in lean (Pannell, 2025).

Figure 2 details the 8 different types of waste, a key component of lean continuous improvement principles. The foundations can be applied in real world applications at Dragon LNG. Nonvalue adding activities have been identified coinciding with motion waste. A summary of the issue:

Current responsibilities of the shift supervisor require the administration and authorisation of between 10-20 work permits per 12-hour day shift. The shift supervisor office is located approximately 20 metres from the permit office, along a corridor with no direct visibility. During a 12-hour shift, the supervisor will travel between the permit office and shift supervisor office to fulfil responsibilities, with an average accumulation travel motion of 15 minutes per shift.

Under Lean Kaizen principles the waste classifies as 'Muda' – Waste caused by activities that use resources, but do not add value to the customer, or in this instance the employer.

Further analysis of the waste, using the 'Downtime' 8 sources of 'Muda' principle, determines the issue as 'Motion' waste – Unnecessary movements by people. There is also indirect associated 'Waiting' waste, due to hesitance of travelling back to the shift supervisor office from the permit office, as another employee potentially may arrive for another permit, causing the supervisor to wait, even though there is no certainty an employee will arrive for authorisation of a permit.

'Non utilised talent' waste has also been recognised as an indirect effect, as the wasted motion time has the potential to be far greater utilised for the shift supervisor, perhaps self-development training could be taken advantage of during this identified 15-minute period of waste.



Figure 2 - DOWNTIME waste (Skhmot, 2017)

Lean philosophies incorporate many different tools and techniques to assist in the continuous improvement journey. Figures 3 -10 graphically represent the various fundamentals of Lean that can aid improvements throughout an organisation.

5S originated in the manufacturing sector and was designed to help clean and organize workspaces. However, its benefits aren't limited to environments with heavy machinery. Even in an office setting or home workspace, cleanliness and organisation can significantly boost efficiency and focus. The principles of 5S are versatile and can enhance productivity in virtually any type of work environment.



Figure 3 - 5S (Team, 2022)

Bottleneck analysis identifies process slowdowns, their causes, and solutions—often solved by streamlining, reallocating resources, or prioritizing improvements.

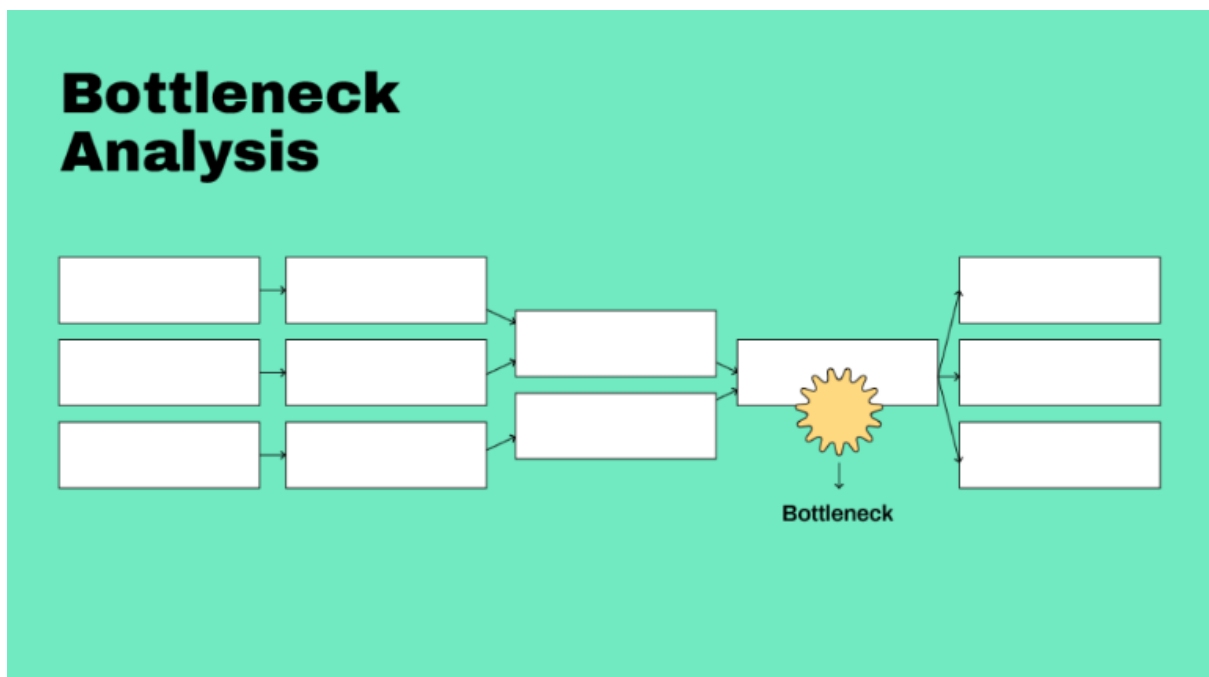


Figure 4 - Bottleneck Analysis (Team, 2022)

PDCA (Plan-Do-Check-Act) is a continuous improvement cycle used to test, analyse and refine changes in processes, products or organisational workflows.

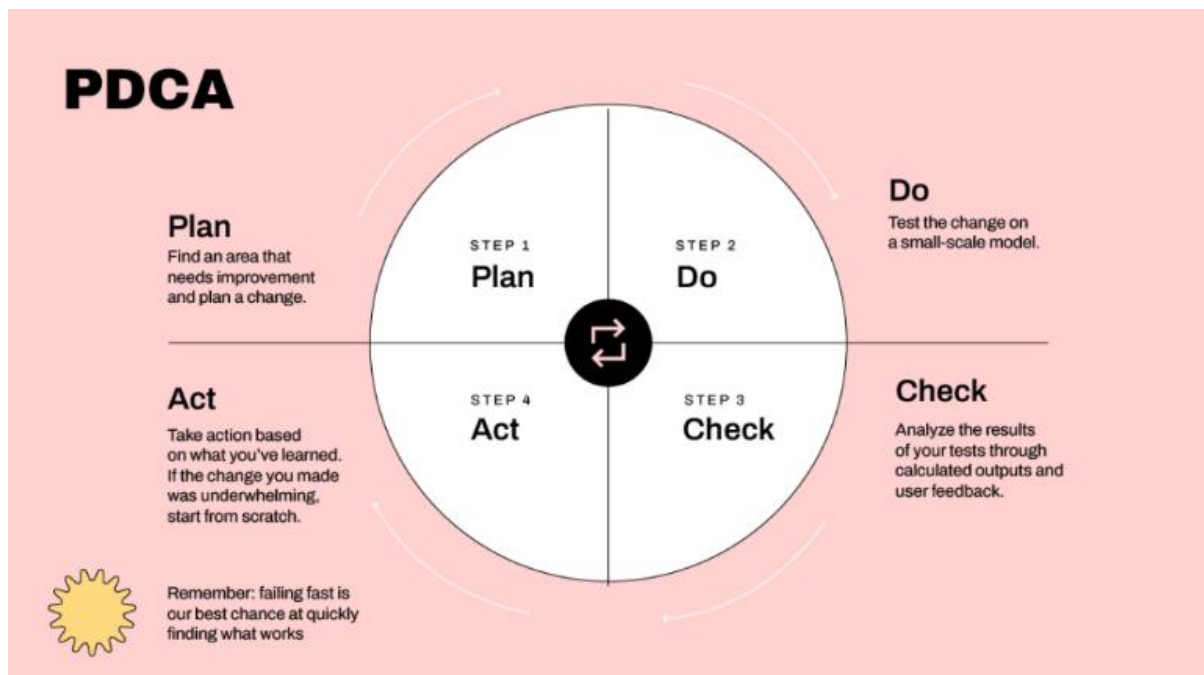


Figure 5 – PDCA (Team, 2022)

Kaizen, meaning “continuous improvement,” a key fundamental in Lean Management. It involves identifying problems, analysing processes, testing improvements, implementing changes and reviewing results, ensuring the engagement of employees across all departments.

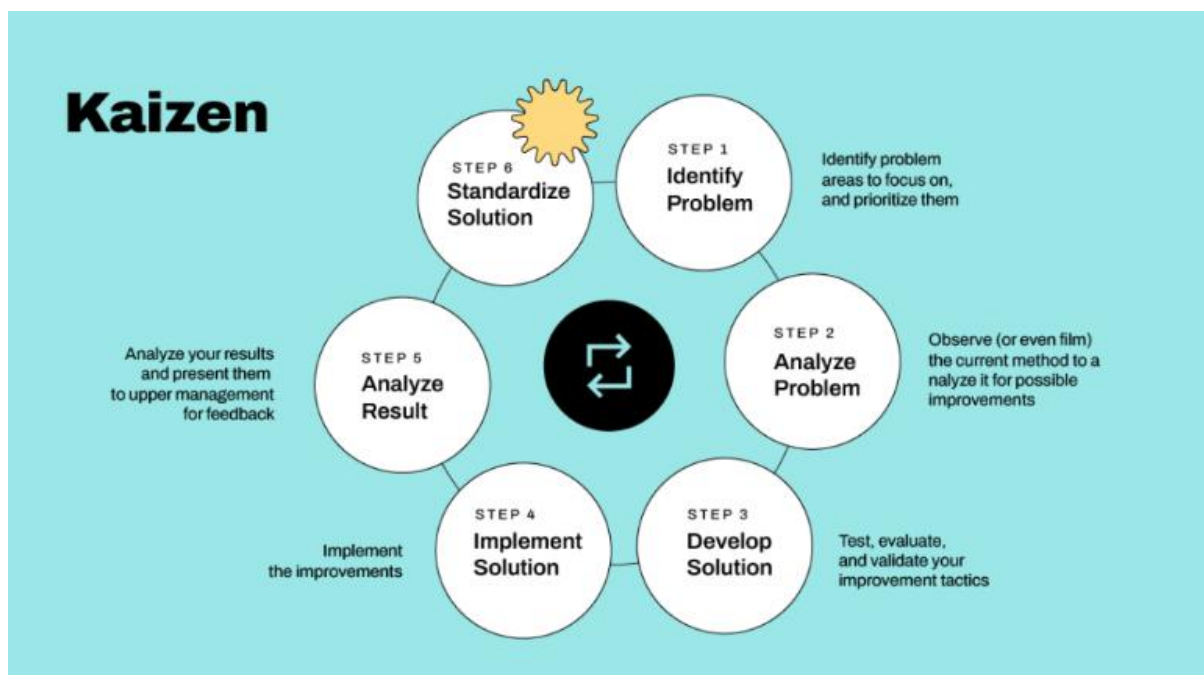


Figure 6 – Kaizen (Team, 2022)

Poka-yoke or error proofing is a preventive technique used to minimise mistakes before a process begins. It ensures proper conditions are in place to reduce human error, inefficiency and rework. By identifying issues, gathering data, uncovering root causes and implementing safeguards, organisations can improve reliability and streamline operations. With practice, applying poka-yoke becomes increasingly effective and intuitive.

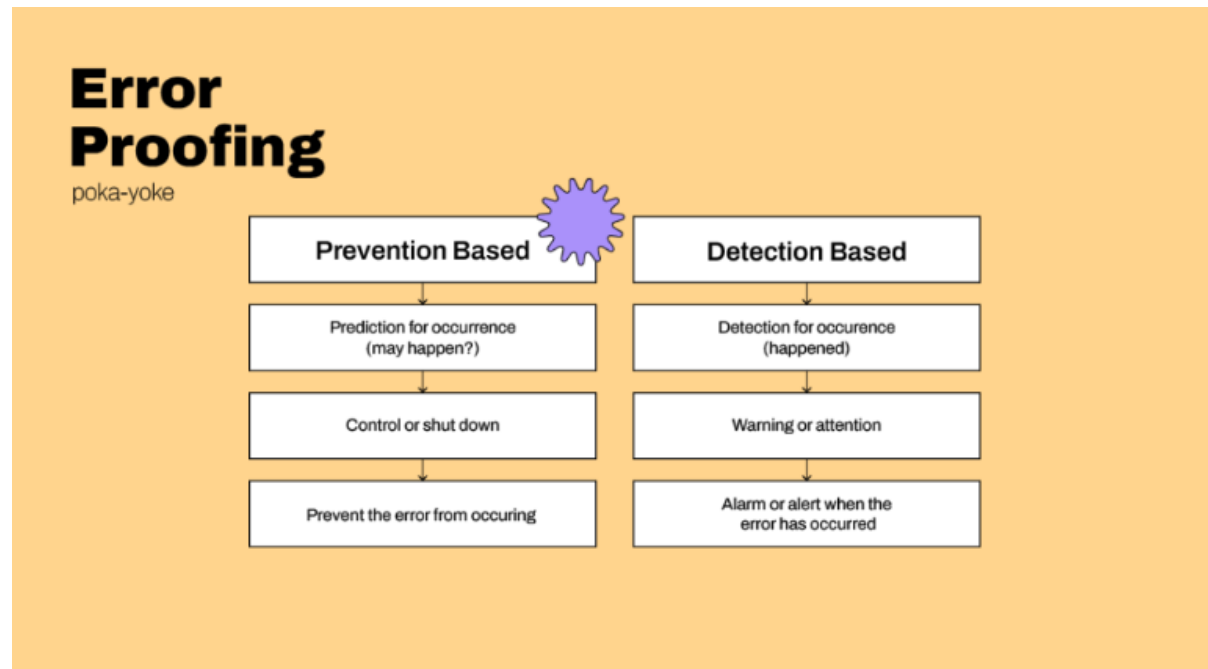


Figure 7 - Error Proofing (Team, 2022)

Root Cause Analysis (RCA) is a problem-solving method used to identify the underlying reasons for defects or issues, aiming to address the true cause rather than just the symptoms.

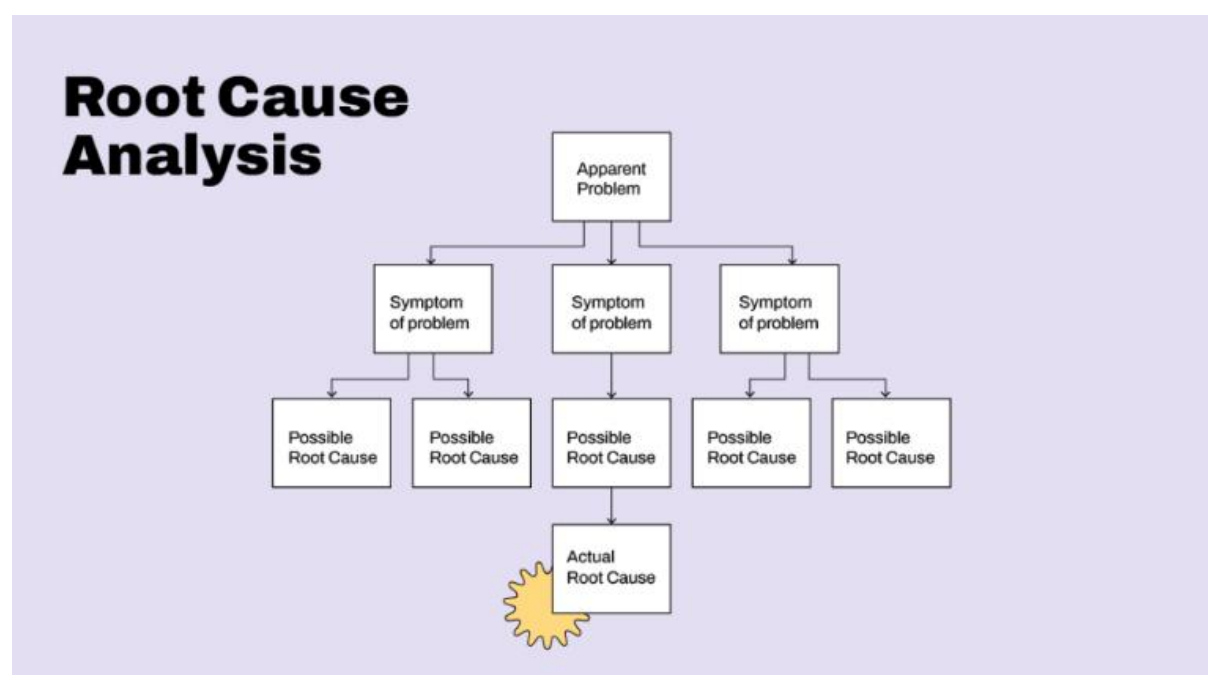


Figure 8 - RCA (Team, 2022)

SMED (Single-Minute Exchange of Die) aims to reduce changeover time to under 10 minutes, boosting efficiency, even in corporate tasks like meetings or information sharing.

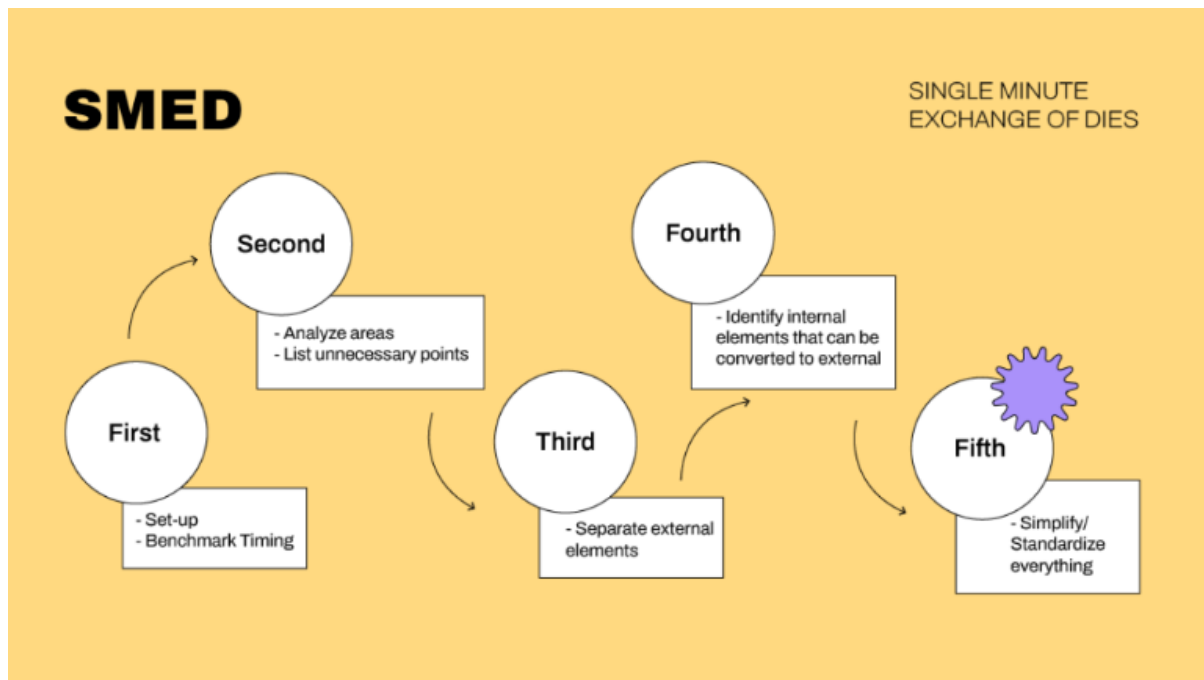


Figure 9 – SMED (Team, 2022)

Standardised Work is a straightforward but highly rewarding tool which involves thoroughly documenting procedures to identify best practices and task durations, by utilising shared editable documents for team collaboration. Team members contribute and refine the content of a procedure seeking to continually improve the standard work process.

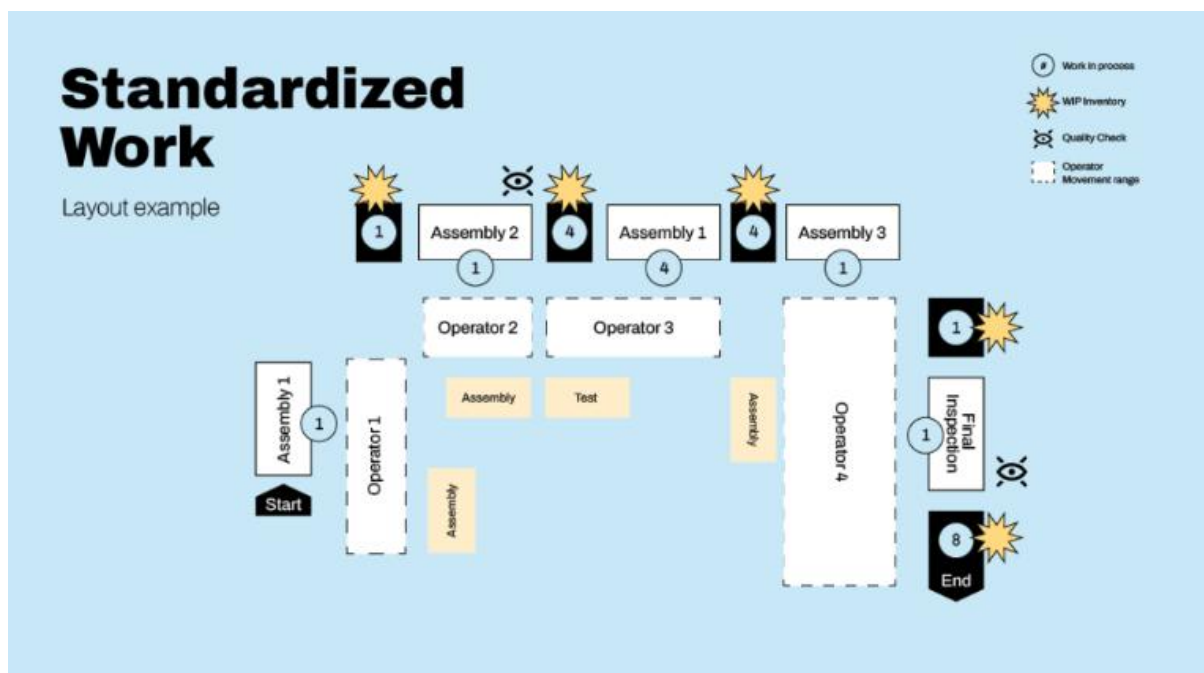


Figure 10 - Standardised Work (Team, 2022)

Value Stream Mapping visually outlines all steps in a process to identify waste, streamline workflows and improve efficiency by distinguishing value-adding from non-value-adding activities.

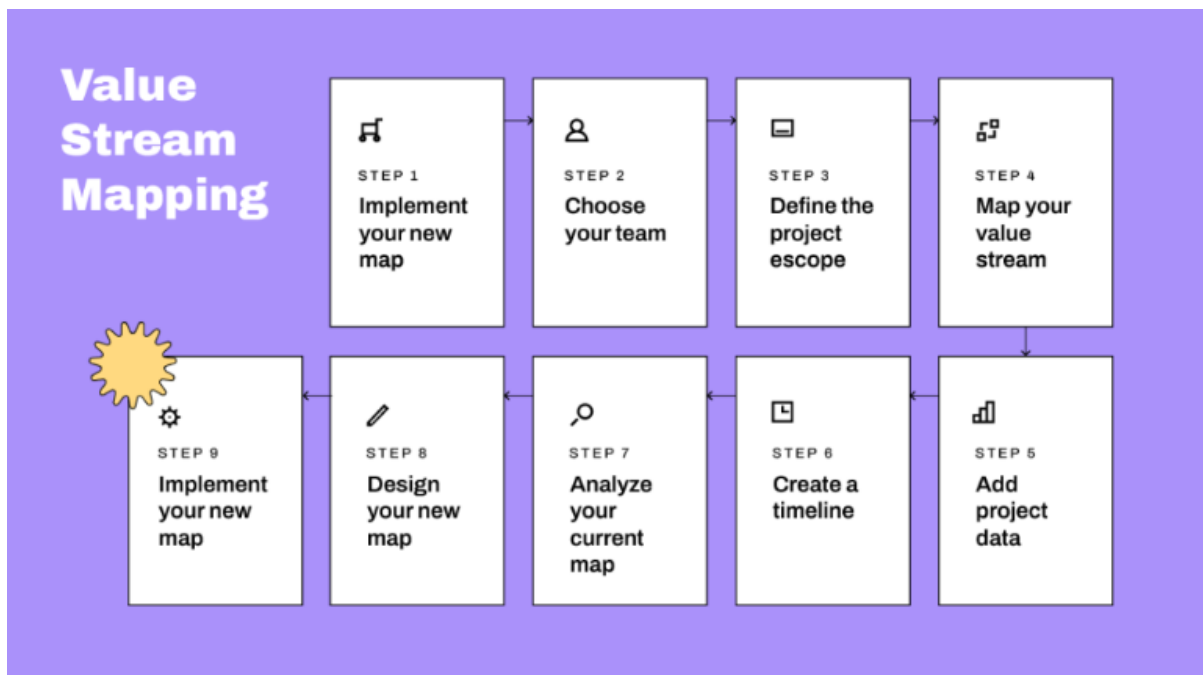


Figure 11- Value Stream Mapping (Team, 2022)

3.2 Six Sigma

Here are the key principles of Six Sigma, focused on reducing variation and improving process quality:

1. **Focus on the customer** – Identify and measure what is critical to quality (CTQ) from the customer's perspective.
2. **Data-driven decision making** – Use statistical methods and data analysis to identify and eliminate defects.
3. **Remove Variation** – Aim to improve processes by reducing variation and defects to achieve near-perfect performance (3.4 defects per million opportunities).
4. **Process Focus** – Utilisation of visual tools such as graphs and flow charts to illustrate process and make informed decisions.
5. **Continuous improvement** – Strive for ongoing refinement and optimization of processes.
6. **Equip and involve people** – Organisational buy in from the top down, all employees need to be invested.

(DeLadurantey, 2024)

3.2.1 DMAIC Methodology

Figure 12 depicts the absolute fundamental element of Six Sigma, the DMAIC process. DMAIC provides a framework for a continuous improvement project, where required enhancement of process variability has been identified, or excessive defects have been deemed an issue.

During the initial define phase the problem is clearly defined along with project goals and customer requirements. Identification of the scope of the project, key stakeholders and the value the improvement will bring to the business are outlined. Tools like project charters, SIPOC diagrams and Voice of the Customer (VoC) analysis can be utilised to verify the definition of the problem.

The measure phase involves collecting data to understand current performance and establish a benchmark, to which an improvement will be measured against. The focus is on identifying the key process metrics that will be used to evaluate the potential improvement and the scale of the enhanced metrics, if successful. Accurate measurement is critical, so tools such as process maps, data collection plans and statistical analysis are used.

In the analysis phase, the objective is to examine the key data to identify the root causes of the problem. Statistical tools and root cause analysis techniques such as cause and effect diagrams (Ishikawa), Pareto charts and hypothesis testing are used to pinpoint where and why defects or inefficiencies are occurring. On completion of RCA, the required solutions are developed and implemented to address identified causes. System redesign, updated workflows or changes to process parameters may form solutions. Tools like brainstorming,

design of experiments (DOE) and pilot testing help validate solutions before full-scale implementation.

The control phase, which is the final part of the DMAIC framework, aims to ensure that the improvements are sustained over time. Control plans, monitoring systems and standard operating procedures (SOPs) are established to maintain the new process performance. Tools like control charts and ongoing audits are used to track results and prevent regression. (Six Sigma, 2025)



Figure 12 - DMAIC process (Six Sigma, 2025)

An opportunity for the application of the DMAIC methodology at Dragon LNG would be to reduce LNG in tank pump discharge pressure fluctuation. To define the problem, currently one of the four LNG pumps has an increased pressure swing on the pump discharge in comparison with the remaining three pumps.

A measurement of data could be retrieved from historical control chart data (trend), motor current control chart and discharge temperature control chart. Historical vibration data analysis would also be a viable metric to measure.

Detailed analysis of the measurement metrics identified to be carried out. The metrics should provide sufficient data to allow root cause analysis to be performed and identification of issues verified.

Formulation of an improvement plan can then be established. The improvement could detail the necessary upgrade of existing pump, control valve adjustment or electrical fault.

Dependant on the improvement implementation, the control phase of the process will ensure that the required running of the pump, will be within its safe operating limits. A revised standard operating procedure could be created to confirm the pump is operated responsibly and standardisation is aligned across shift operations teams. Continuous monitoring of the pump parameters can be achieved through control charts, providing real time assurance that the pump improvement plan has been successfully implemented.

3.2.2 DMADV Methodology

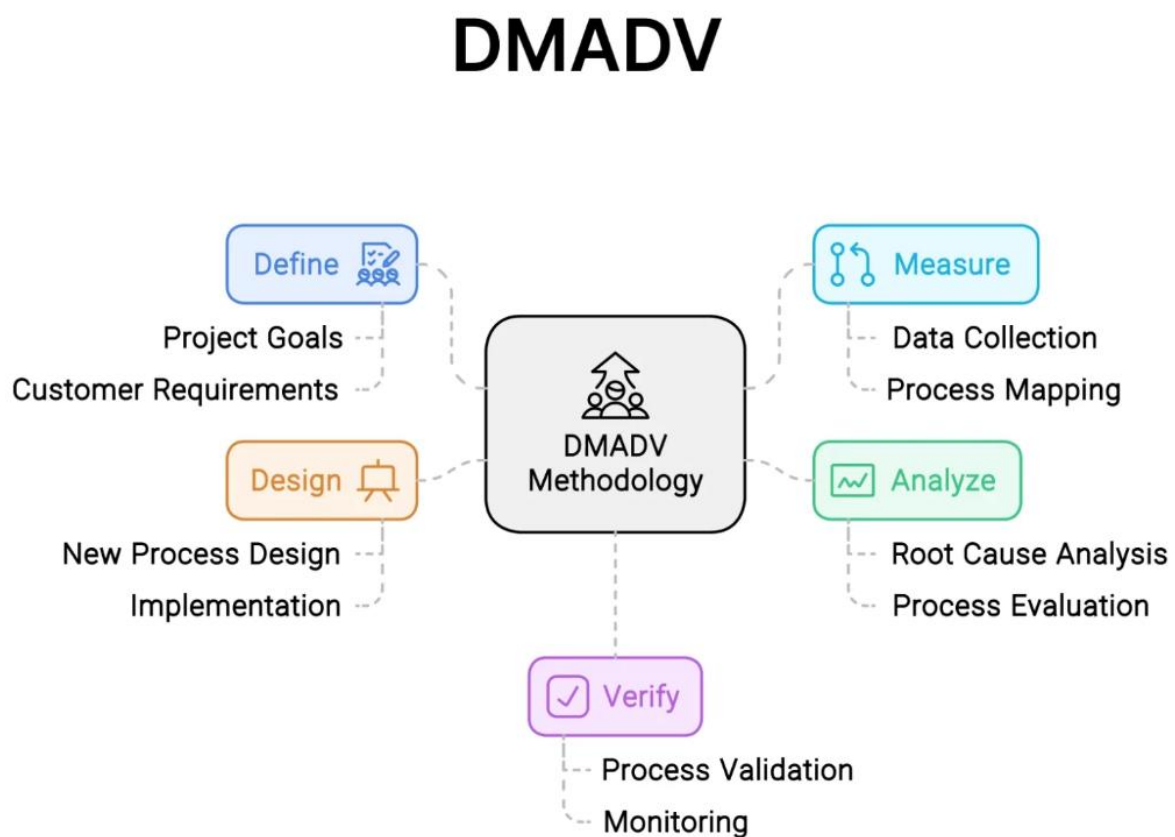


Figure 13 – DMADV Methodology (Peterka, 2024)

The graphic in figure 4 represents the DMADV process, another key Six Sigma principle. The DMADV process incorporates three of the five steps that make up the DMAIC philosophy. However, the final two steps differ, this is due to the DMADV principal being applicable to new product or product redesign.

An explanation of the DMADV phases in Six Sigma:

1. **Define** - Identify the project goals and customer requirements (both internal and external). Clearly define the purpose, scope, and timeline of the design project.
2. **Measure** - Gather data on customer needs and critical quality attributes. Measure key process characteristics and define performance metrics that the new design must meet.
3. **Analyse** - Analyse the data to develop design alternatives. Evaluate potential options against customer requirements and identify the best approach using tools like Failure Modes and Effects Analysis (FMEA).
4. **Design** - Develop detailed designs of selected solution, including systems, processes or products. Ensure the design aligns with Six Sigma principles and meets all identified requirements.
5. **Verify** - Test the design under real-world conditions to ensure it functions as intended. Validate results with stakeholders, refine as needed and implement full deployment.

(Peterka, 2024)

4 Lean and Six Sigma comparison

A high-level comparison of the continuous improvement techniques would be that lean can be applied purely with common sense at the forethought of any lean process. The 'Kaizen' low hanging fruit analogy engrained within this methodology is very apt. Low cost, simple, but effective improvements that can be deployed by someone without necessary relevant technical expertise of a particular manufacturing process.

On the contrary, six sigma requires data and information to enable advancement of a production process. The principles of six sigma are to reduce defects and variations within a system and to achieve this, analysis of the relevant data sets is critical. The retrieval of data and analysis of such information will induce significant resources and suitable expertise in a particular process.

The graphic shown in figure 14 further emphasises the comparable analysis.

Key Differences Between Lean and Six Sigma		
FOCUS: Lean is about flow and efficiency, primarily by eliminating waste and increasing customer value.	APPROACH: Lean emphasizes cultural and behavioral change to create a mindset of continuous improvement.	TOOLS: Lean tools are often more visual and intuitive, designed for quick implementation and cultural impact.
Six Sigma is about quality and consistency, reducing defects and variation.	Six Sigma uses statistical analysis and relies heavily on data for problem-solving.	Six Sigma tools are more technical, involving statistical methods and often requiring specialized training (e.g., <i>Green Belt</i> , <i>Black Belt</i>).

Figure 14 - Six Sigma vs Lean (Manous, 2024)

5 Conclusion

Lean and Six Sigma are powerful methodologies for driving continuous improvement and operational excellence. Lean focuses on eliminating waste and improving flow, while Six Sigma targets reducing variation and defects through data-driven decision-making. Both methods offer unique strengths and can be applied independently or in combination, depending on organisational needs. The analysis shows that Lean is often more accessible and faster to implement, while Six Sigma provides deeper statistical control. At Dragon LNG, adopting a tailored approach using the most appropriate methodology can deliver measurable benefits, improving efficiency, reducing costs and enhancing overall business performance and competitiveness.

A sensible approach to applying continuous improvement methods to any business, would be to consider the application of Lean methodologies in the first instance. Implementation of calculated Lean principles has the potential to achieve meaningful gains for relatively low investment. For more technical and automated industry-based enhancements, Six Sigma is a methodology that can provide the tools to produce sizeable returns on investment, however the initial investment is generally seen as far greater than that of application of Lean principles.

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