Politecnico di Torino

Thesis of Masters

Department of Engineering Management & Production (DIGEP)
Graduation Session March/April-2022

Predictive Project Management Inculcates with Lean Manufacturing

Submitted to:

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Abstract

Organizations/industries want to gain a competitive advantage by applying profitable solutions and controls on overhead costs. Usually, organizations/industries projects face a challenge when they want to improve their output characteristics in terms of services or products as well as they want to decrease their time and cost while increasing customer satisfaction levels. Without a suitable strategy, addressing this challenge would be difficult. For this reason, the optimal practice to handle such situations is to cater to management solutions.

Studies suggest that lean six sigma (LSS) has a positive and effective outcome for these kinds of solutions, where Lean is about waste elimination and six sigma controls variability reduction in processes. The literature shows that LSS is supported by DMAIC (Define-Measure-Analyze-Improve-Control) framework which helps to highlight the main issues in the project management life cycle. However, some experts indicate that the DMIAC principle has some problems (e.g. lack of guidelines, sustainability of results, no involvement of other lean tools).

So, in order to resolve this problem SDMMAICS (Select-Define-Measure-Map-Analyze-Improve-Control-Sustain) framework is conceptualized and empirically tested. ‘SDMMAICS’ helps in project selection, project value mapping, and project sustainability. If any consideration is left and recognized later, then the SDMMAICS framework compels us to address that as well.

To cater to this challenge, we propose frontloading in the ‘SDMMAICS framework’ which then becomes ‘SDMMAICS - Frontloading’ (Select-Define-Frontloading-Measure-Map-Analyze-Improve-Control-Sustain) framework. Implementation of frontloading in SDMMAICS helps to cater to the uncertainty in the project as it gives all kinds of data considerations before the actual implementation/development of a project. Moreover, frontloading provides more concrete results and strengthens this framework. Additionally, this research can be used for future guidelines and practical implications. As it has potential for faultless/error-free process execution.

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1. Literature Review

1.1 Project Management

One author highlight that PM (project management) has no standard definition. Nevertheless, as a result of the research progress, some authors suggest that this practice plays an important role in the development of projects [1]. Some authors emphasize the project manager’s role, project management concepts, and frame of reference, along with recommended practices as a critical part of project management [2] [3].

Companies that adopt standardized project management methodologies and practices may see considerable success with their initiatives [1]. Consequently, they stated that project management focuses on addressing the needs of stakeholders while taking into account cost, time, and performance variables [2]. External and internal stakeholders, the performance of the industry, rivals, technological breakthroughs, legislation and policies, economic variables, and the project organizational structure were all mentioned as factors that influence project management [4]. Finally, the goal of the project management approach is to improve project deliverables and use them as a guide to stay competitive while satisfying project goals [4] [3]. It is critical that project managers have the ability to motivate project stakeholders and team members to achieve client needs through high-quality, cost-effective outputs [5].

1.2 Project Management in Contrast with Lean Six Sigma

An author said that the majority of project management books of knowledge (PMBOK) & lean six sigma (LSS) approaches have a lot in common. Both aim to manage timelines, create a strong plan, costs, perform regular reviews, identify & communicate with key stakeholders, and resources [6] [7]. The LSS technique is more than a project management initiative, a process improvement program, or a mash-up of previous ideas [6]. LSS is a methodology and a strategy for continuous improvement that integrates cultural and statistical techniques [8]. The LSS is a supplementary tool to current project management initiatives and norms, but it is also distinct [9].

Some project management approaches failed because they were unable to assess the methodology's effectiveness or identify the value added by process changes, not because they didn't add value [10]. The results of process performance can be used by project managers to gauge the success of six sigma deployment. They can then analyze the sources of variation, enhance them, and reach or surpass the desired performance levels [11]. Understanding the approach's parameters, its application, and desired results are critical to the success of LSS implementation [8].

LSS has a well-defined project charter that outlines the project scope, financial goals, expected benefits, and stages [9]. It's also based on solid economic data and calculated savings [9]. LSS is a solid continuous improvement method that integrates statistical techniques like Total Quality Management (TQM), which focuses on techniques for long-term management, and Statistical Process Control (SPC), which assesses and controlled quality by data analysis [10]. Lean and Six Sigma complementary strategies for improving business processes and outcomes [12]. This was accomplished by combining their methodologies and concepts and using DMAIC (define, measure, analyze, improve, control) cycle as the combined continuous improvement framework [13] [14].

1.3 Challenges of DMAIC Framework

The author stated that the long-term outcomes are a crucial element of project management that is not addressed adequately in DMAIC [15]. When a professional is too keen to move on to the next project before establishing the long-term viability of the proposed changes for the previous project, the project suffers [16]. Sustaining a project is a difficult undertaking for many businesses [17]. The original DMAIC framework did not allow for the use of any other lean tools. As a result, incorporating the Lean tool will improve the DMAIC approach's capability [18] [19]. An author emphasized that the DMAIC of Six Sigma focuses on difficulties involving facts and measurable variables and motivates project leaders to accomplish them; instead, it should emphasize ambiguous and subjective human problems [20]. Another author uses the AHP technique, to construct a model for analyzing lean projects. Rather than directing the project to completion, the model focuses on selecting the lean project [21]. Another author built a lean product development model. However, the model's creation is wholly based on the literature's results, and it was not vetted for implementation by topic specialists [22]. Another author established a multilayer model for lean product development system design in a similar study. The methodology was designed for a product development environment and was not adaptable to other projects by the managers [23]. Another author also develop a model for the banking industry, a six-sigma methodology was designed to improve 'customer satisfaction. The model's key flaws were that it was service-centric and couldn't be utilized in a production context [24].

2. Introduction

2.1 Background

2.1.1 Lean and Strategy of Eliminating Waste

- Womack and Jones in **figure-1** suggested a five-step conceptual process to aid managers through a lean transformation in 1996 [25]. The five principles are,

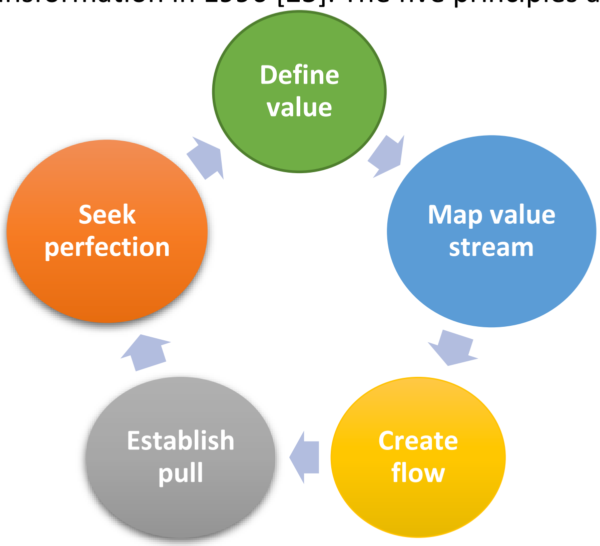


Figure 1: Five-step process for guiding the implementation of the lean technique [25].

- Regarding product category, define significance from the perspective of the final consumer.
- Analyze all phases in the supply chain for each product category and omit those that do not add value.
- Assemble the value-creating activities in a precise order so that the product flows toward the buyer.
- Enable the customers to extract value from the forward operation when the flow is introduced.

- As unnecessary stages are deleted, value streams are found, value is defined, and push & pull are added, repeat the process until it reaches flawless, at which point flawless value is created with no loss.
- Lean is a 'Principle Approach' whereas Project management is 'Not a Principle Approach'.

2.1.2 Overview of Lean Manufacturing: (Continuous Waste Elimination)

- Waste: Anything that raises the price of a product without increasing its worth.
- Value-adding activities: Basically, Transformation of material into the particular product that the client demanded.
- Non-Value adding activities: Transforming the material into a product that the client wouldn't be needed.
- Categories of waste are; MUDA – Waste, MURA – Unevenness (Fluctuation or Variation), MURI – Overburden.
- Lean Manufacturing is surrounded with the term "Downtime". In the term "Downtime" every letter indicates a certain type of waste.
- D= Defects, O= Overproduction, W= Waiting, N= Non-utilized Potential, T= Transport, I= Inventory, M= Motion, E= Extra-Processing (Over Processing).
- Among all wastes, Over-Production is the mother of all waste. As its hides other waste such as Waiting, Movement, and Transportation.
- By applying for lean tools and methodologies firm benefits from Shorter production lead times, Inventory levels reduction, Lower production costs, Labor productivity improvement, Increased output, Defects, and wastage elimination, Cycle time improvement, Improved utilization of equipment, spaces, and Improved flexibility.

2.1.2.1 Wastes

The eight wastes that we encounter in any procedure can be divided into the following categories.

Transportation (moving products that are not required to perform the processing). Inventory (all components, work-in-progress, and unprocessed completed goods) Motion (people or machinery moving or walking more than necessary to complete the processing). Waiting (for the next phase of production, production interruptions due to shifting changes). Overproduction (production more than demand) is a term used to describe when production exceeds demand. Excessive Processing (resulting from poor tool or product design creating activity), non-utilized processing, and faults (the effort required in checking for and repairing defects).

2.1.2.1.1 Defects

Poor performance raises expenses by squandering materials and increasing workers' wages. Quality improvement techniques are extensively used in lean production, which aims to ensure that every action adds value. This process is interrupted by faults, leading to the loss of labor and materials. With the advent of six sigma techniques, minimizing waste and removing faults has advanced significantly. Several practitioners refer to the pairing of Lean Six Sigma because six sigma tools enhance the lean paradigm.

2.1.2.1.2 Overproduction

Generally defined, overproduction occurs when an item is produced before it is necessary. Overproduction is expensive for a manufacturing facility because it disrupts the movement of supplies and lowers productivity and quality. Because every item is created just as it is needed, the Toyota Production System is also known as "Just in Time" (JIT). Creating more than is required. Waste is defined as any resource being used needlessly, and manufacturing something when it is not required is a regular waste in the manufacturing industry. This can happen as a result of ineffective planning and control, or as a result of incentive schemes that encourage overproduction.

2.1.2.1.3 Waiting

The waste of waiting happens whenever items are neither flowing nor being produced. In traditional batch-and-queue production, a product will often spend more than 99 percent of its life waiting to be processed. Much of a product's lead time is spent sitting for the next activity to finish; this is typically due to lack of proper material flow, long production units, and large distances between workstations. In an ideal world, every asset would be put to good use 100 percent of the time. Any time a resource remains idle, capability and productivity is lost, and the lead time to the client grows.

2.1.2.1.4 Non-Utilized potential

The father of TPS, Taiichi Ohno, defined the 7 wastes of lean manufacturing in the theory of total production system (TPS). A group of practitioners introduced the 8th waste as "non-utilized potential" which is a concept specific to manufacturing management, unlike its others 7 peers which are core manufacturing centric [26].

The non-utilized potential refers to the underutilization of staff who is directly or indirectly involved with any value-adding process of an organization. From depicting the unnecessary task performance to staying ideal, this could take various forms. It could even relate to under or non-utilizing the employees' abilities such as their crucial thinking [27]. Moreover, it could also include the employees' loss of interest in potential as a result of offering poor incentives. In addition, asking for tasks delivery that doesn't match the qualification could also be declared as non-utilized potential.

2.1.2.1.5 Transport

Resource flow that does not improve the customer's experience with the product. Within the lean community, the concepts of waste and value differ. Some people regard all transportation costs as a waste. Others view transportation to be value-added since a product becomes more useful to a client after it is delivered. Irrespective of one's perspective on transportation, lean aims to reduce transportation expenses.

2.1.2.1.6 Inventory

Excess supply and wait result in a lot of work in progress (WIP). Excessive stock tends to conceal issues on the plant floor, which must be discovered and handled in an attempt to optimize operating performance. Excess inventory lengthens lead times, takes up valuable space, delays problem detection, and obstructs communication. Lean aims to achieve the intended value, such as quick lead times, while eliminating waste, such as large inventory levels.

2.1.2.1.7 Motion

This wastage is generated by aesthetics and can be visible when leaning, stretching, strolling, raising, or extending. These are also health concerns, which are becoming more of a problem for businesses in today's legal environment. With the help of maintenance staff, excessive motion positions should be evaluated and remodeled for betterment.

2.1.2.1.8 Extra-Processing (Over Processing)

Any effort that adds no value to products or services is termed excessive processing. Excessive processing often happens when a single processing operation can be merged with other processes or removed entirely. Packaging operations, for instance, contribute no value to a product.

2.1.3 House of Lean Tools

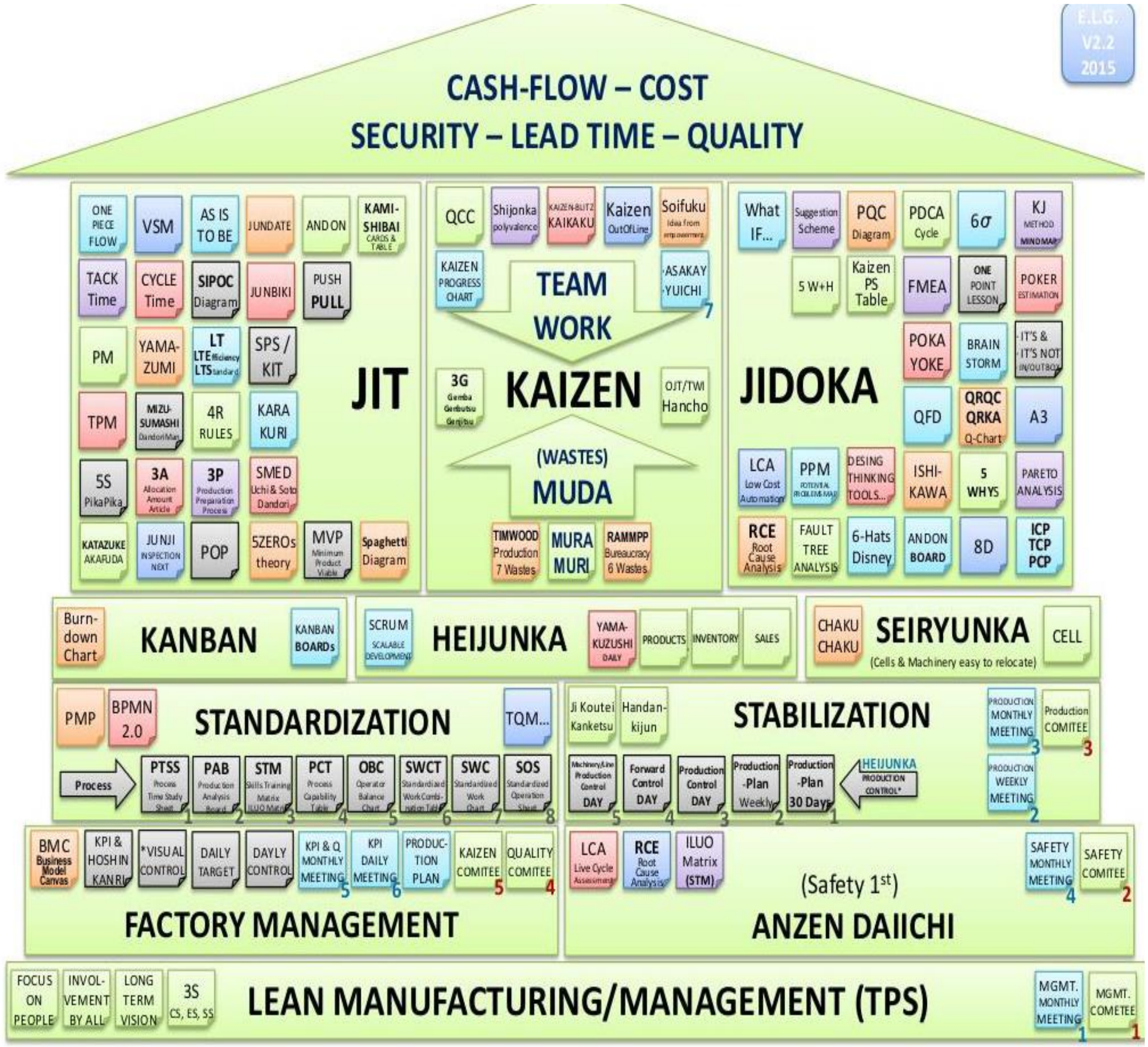


Figure 2: House of Lean [28]

2.1.4 Some Important Tools and Methodologies of Lean Manufacturing

- **Andon:** This tool is used for Error Indication.
- **Poka-Yoke:** Poke-a-Yoke is a method of quality control that ensures that a process is error-free. Poke-a-purpose Yoke's is to eliminate the possibility of a flaw. Error-Proofing is a crucial part of lean since faults are a major source of waste.

- **Gemba:** A Gemba walk, sometimes known as a Waste Walk, is a lean waste identification approach. Typically, the tour will be led by a group of people, allowing learners to develop from one another. Hundreds of possibilities can be rapidly uncovered during a thorough garbage walk. The rubbish tour can focus on a certain region, a specific form of waste, or something else the participants notice (Basically, Crime Scene).
- **SMED (single minutes exchange of dies):** It's used for changeover time. (Traditional Changeover Vs Pitstop mentality). SMED (single-minute exchange of die) is a way of finishing an ongoing process in less time. It has an impact on machinery that is set up to switch from one job to the other in just under 10 minutes, indicated as a single digit.
- **Bottleneck Analysis:** Analysis of bottlenecks examines a procedure to find the stage in the process where the factor of capacity falls short of desired capacity. The constraint is the name for this procedure. The next step is to figure out how to get rid of the constraint.
- **Takt Time:** Takt Time is a measurement of the greatest amount of time that can be spent meeting customer demand. It's calculated by dividing the available production time by the pace of consumer demand. For example, if your anticipated capacity is 932 minutes per day and your demand is 1000 units per day, the Takt time is 932 minutes/1000 units, which equals.93 minutes. This means that every.86 minutes, a completed unit must exit your manufacturing process. Employees can correctly pace tasks and notice when there is a problem in brewing inside a work cell thanks to Takt Time monitoring pace activities and recognizing when a problem is developing within a work cell i.e., Takt time= (Available time / Customer required).
- **Time Study:** A thorough examination of the various operations inside a process is called a Time Study. To determine production rates and product costs, time studies are employed. Time studies can also be applied to lean manufacturing to discover unnecessary processes and movements that can be removed. Value Stream Maps frequently use data from time studies to pace operations and determine when an issue is emerging within a work cell.
- **Value Stream Mapping (VSM):** Value Stream Mapping is a technique for recording a collection of procedures associated with a single stream of value, including each activity

and step from beginning to end. Processing time, waiting period, and material movement are all highlighted in Value Stream Maps. In lean manufacturing, the maps are particularly useful to reduce lead - time and remove redundant process steps.

- **A3 Report:** An A3 Study is a one-sheet exposition of an issue that includes all necessary background information, root causes, proposed solutions, and planning processes. The A3 paper size, which is typically 11′′ x 17′′, inspired the name. The A3 Report could be a highly effective root cause analysis tool because everything is presented on one piece of paper. Many lean experts feel that limiting issue-solving on a single sheet of paper helps you think much more clearly and structurally.
- **Lead Time:** It's used to identify, the amount of time that passes from the start of a process until it concludes.
- **Kaizen:** Kaizen is a Japanese term that implies "continuous improvement." These methods are backed by management and necessitate staff effort. Kaizen Events are targeted exercises in which a group tries to find and implement a significant process improvement. The events have a limited capacity and are meant to bring about considerable change and progress in a short amount of time.
- **Milk Run:** The milk run is a designed and optimized route of delivery to reduce trip time. It can be used to schedule supplies by delivery services or to organize material handling traffic within a plant.
- **Spaghetti Diagram:** The real movement of material or personnel in an operation is monitored using a spaghetti diagram. The finalized diagrams were compared to a dish of spaghetti because they frequently illustrate resources crossing each other.
- **JIT (Just in Time):** JIT stands for just-in-time production, which implies creating only what is required at the time it is required, and in the quantity required. It reduces lead-time, reduces inventory, removes defects, and accomplishes all of this at a low cost.
- **Jidoka:** Toyota Production Systems introduced the Jidoka concept. It gives the employees confidence, and they have the authority to stop the line. "Automation with a human mentality" is how it's described. It is made up of the three principles listed below,

    - Don't manufacture flaws
    - Don't pass flaws on to others
    - Don't accept flaws
    - Automation with the human touch. Rather than implementing production functions, automation implements some supervision functions. By doing 4 –steps: Detect the abnormality, stop, fixed or correct the immediate condition, Investigate the root cause and install the countermeasures.

- **Kanban (visual system/signboard):** In Japanese, Kanban refers to a tag that is affixed to a specific number of products or parts in a line of products and directs the delivery of a precise amount. The Kanban card travels the length of the line, back to its initial location after the part or procedure is completed. It's used in a pull system. i.e., N=[(unit daily demand × lead time × Safety factor) / lot size].
- **Heijunka (leveling):** Heijunka divides the burden across all staff equally. It focuses on maintaining stable output levels. It maintains line balance by distributing the load evenly and creating an inventory reserve**.** It's a Method for eliminating unevenness in a manufacturing process and limiting the risk of overburdening.
- **Seiryunka (cellular Manufacturing):** One effective way to lower the cost of production.
- **Standardization:** The actions of an assignment and the arrangement in which they must be performed are documented.
- **Stabilization:** Tendency of something to keep its current state.
- **Factory Management:** It's like, Business Model Canvas, Visual control, Daily targets, Daily Control, Production Plan, etc.
- **Anzen Daiichi:** It means Safety first with the help of LCA (life cycle assessments), RCA (root cause analysis), Safety monthly meetings, safety committee.

- **Arrow Diagram:** Finding waste in the flow of goods. There are 4 types of flows: Processing, Inspection, Transportation, and Storage.

- **Operation Analysis Table:** It is an analytical tool that helps us bring the waste inherent in worker operations to the surface. (Basically, finding waste in people).

- **Process Oriented Management (POM):** It concentrates on the method for reaching the desired outcome. To produce better results, the processes are improved and complex.

- **Visual management:** Visual management is a tool for both employees and supervisors to visualize information. Both the current state and the desired outcome are visually represented, making it simple to understand.

- **Work Standards:** Work standards describe the most efficient method of performing a task. It is made up of a set of policies, regulations, instructions, and processes that have been developed by management. Takt time, work sequence, and standard work-in-progress are a standardized job that consists of three components.
  The following are the essential phases when it comes to adopting work standards;
    - Determining issues in the existing process.
    - Create a process map.
    - Improve the procedure.
    - Put the process into action.
    - Keep the process going.

- **The PDCA/SDCA Cycle:** The PDCA (Plan-Do-Check-Act) cycle is a never-ending improvement cycle that requires each team to Plan (set an improvement target through an action plan), Do (execute the plan), Verify (measured and reviewed effects), and Act (set targets for further progress or standardize new procedures). Because all processes are incredibly unpredictable, they must be stabilized utilizing the SDCA cycle (Standardize-do-check-act).
- **Statistical Process Control (SPC):** Statistical Process Control (SPC) is the use of statistical approaches to manage a process and remove irregularities caused by a variety of factors.

- **5S:** A Method of establishing a clean and organized workplace that exposes waste and makes immediately noticeable anomalies. These are sort, set an order, shine, standardize, sustain. It can be done with the help of red tags, a cleanliness checklist, a cleaned-up checklist, floor marking standards, workplace common visuals, Andon, 5S Audit form. “The 5S program will not give you money, It will stop wasting money”.
- **Production Flow Analysis:** It’s a method for identifying part families & associated machine groupings.

2.1.5 Benefits of Lean Manufacturing

2.1.5.1 Improved Quality

In a lean setting, much of the effort is committed to improving quality. When quality concerns develop, problem-solving strategies are employed to determine the source of the issue. Then, to reinforce the system to prevent a recurrence, mistake proofing is implemented. As a result, your product's quality will improve.

2.1.5.2 Improved Visual Management

Management by vision is another advantage of lean production. The plant will be set up such that you may use a visual inspection to evaluate a complete region if everything is done correctly. Any deviations will pop out and be easy to spot as a problem.

2.1.5.3 Increased Efficiency

Line balancing ensures that everyone involved in the process is functioning at their best. Standardized work ensures that they accomplish the work correctly and in the same manner each time. This results in enhanced efficiency and consistency.

2.1.5.4 Manpower Reductions

One of the main advantages of lean is that you can get more done with fewer workers. The potential to perform the job with minimal people is a quite realistic possibility with standardized work and enhanced efficiencies. This does not imply that you must place these individuals on the unemployment line. These individuals could be used to undertake more kaizen activities, training to improve skill levels, or system maintenance once it's in place, according to the lean philosophy.

2.1.5.5 Easier to Manage

People know what they have to accomplish and when they have to do it because of the project specifications and standardized tasks. This makes it much easier to maintain a space. And issues will continue to arise. They will, however, be far easier to cope with in a cohesive team when peer support is willing to assist in issue solutions.

2.1.5.6 Total Company Involvement

Lean is designed to incorporate the entire organization. It is not designed to be implemented in just one location. It's a management philosophy it should pervade your entire organization. This contributes to the idea that everyone in the business is a member of the team.

2.1.5.7 Problem Elimination

Lean manufacturing forces you to take on a problem head-on and research it until it is resolved. To ensure that a problem gets the attention it deserves to be fixed, root cause analysis and cross-functional teams are used.

2.1.5.8 Reduced Space

Space will be produced as part of the waste reduction procedure. Vertically in your racking and horizontally across your ground, decreasing completed and raw inventory saves space.

2.1.5.9 Safer Work Environment

When items are all out of order, visual management and 5S can aid. The workspace becomes significantly more ordered when unneeded aspects are removed from the activity. And a safe work environment is well-organized.

2.1.6 Lean Six Sigma (LSS)

The lean six sigma methodology, which is a blend of Toyota's lean manufacturing [29] [30] and Motorola's six sigma [31] methodologies, concentrates on implementing continuous improvement by analyzing components including speed, waste, efficiency, and effectiveness in order to accommodate customer needs. Lean six sigma as in **figure-3**, according to ASQ, is a data-driven improvement methodology that emphasizes defect prevention over defect discovery. It enhances customer satisfaction and bottom-line results by lowering variance, waste, and cycle time through the application of statistical process control and flow, resulting in a competitive advantage. It applies whenever there is inconsistency as well as waste [32].

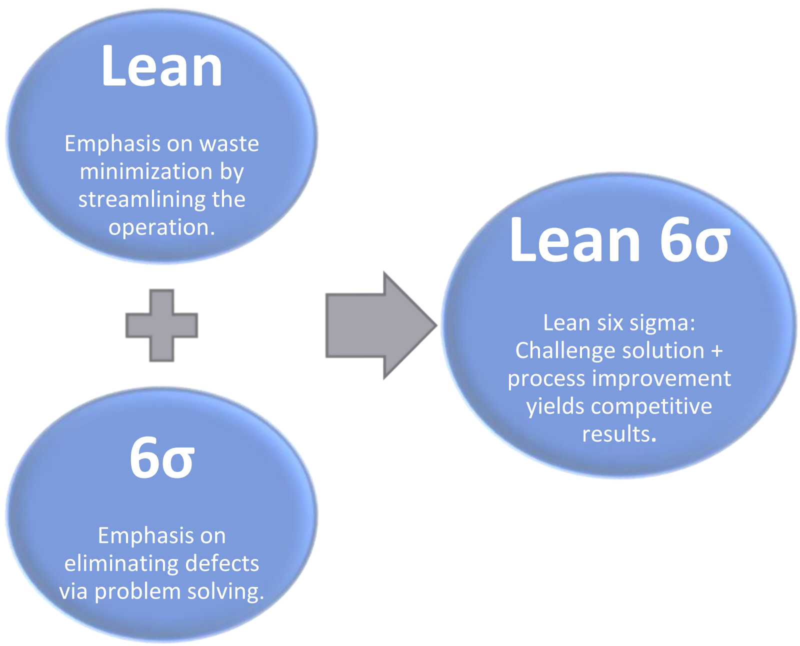


Figure 3: What is Lean Six Sigma [32]*?*

Lean six sigma (LSS) is an improved model for project management [33]. Usually, organizations/industries projects face a challenge when they want to improve their output characteristics in terms of services or products, as well as decreasing their time and cost, while increasing client loyalty. Most of the literature shows that LSS has a positive and effective outcome for these kinds of solutions. Most of the literature shows that LSS supported by the DMAIC framework helps to highlight the main issues and causes in the project management life cycle [34].

Regardless of the fact that LSS in **figure-4**, is a blended technique for improved productivity that integrates lean and six sigma, the DMAIC methodology has not yet been updated to reflect this combination [35].

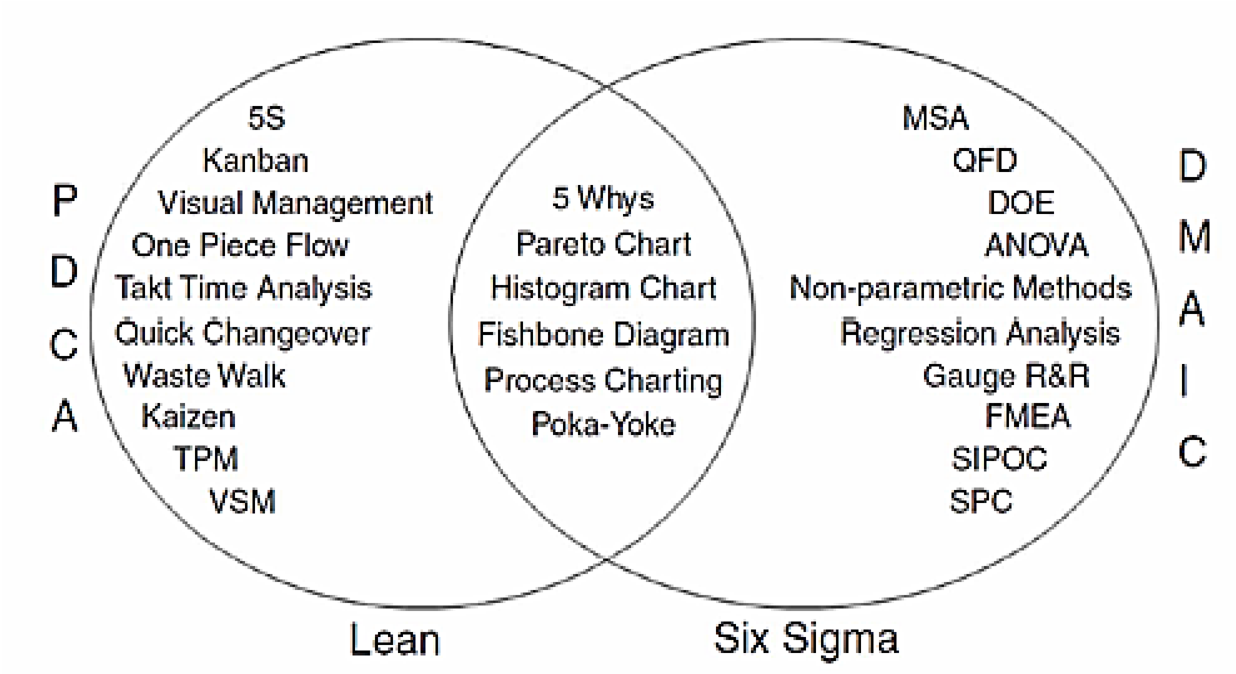


Figure 4: Lean and Six Sigma methodologies [86]

2.2 Incompatibility of DMAIC Framework in LSS

However there is ample evidence that DMAIC contributes to considerable performance improvements in organizations, there is still potential for improvement [36]. Unfortunately, DMAIC was used in the same way as the six-sigma technique, leaving numerous gaps unexplained. Some of them include project selection criteria, process mapping, and assuring the process's long-term viability, among others [37]. The lack of explicit rules in DMAIC that determine when, where, and how to apply the contextual and conceptual features of LSS is among the principal factors why several industries fail to implement LSS projects effectively and efficiently [38] [39]. The LSS methodology focuses on continuous improvement and stresses establishing long-term process improvement viability, which is not described in the DMAIC methodology [40]. An author highlight that project suffers as a result of project teams hurrying to meet deadlines and thus lacking to ensure sustainability [41]. Similarly, various researchers mentioned there were no obvious criteria for LSS projects in their initial phases of project management [42] [43] [12] [44]. According to some authors, the integration of lean and six sigma results in a wide range of tools, which are difficult to comprehend and use [45] [46] [47]. Moreover, several authors have argued that addressing sustainability challenges in project management requires a comprehensive LSS model. As a result, the goal of this research is to bridge the inadequacies in the LSS approach and create a customized framework for this application [48] [49] [50].

2.3 Bridging DMAIC with SDMMAICS Framework

The ability to integrate the organizational objectives to the deliverable causes continuous improvement projects to fail, as a result, a tailored six-sigma framework can be used to cater to this challenge. Also, the improper selection is one of the most significant reasons for project failure. Whenever these projects do not correlate with the organization's objectives, this becomes increasingly evident [51] [52]. The limitations of DMAIC were enlarged extensively, and a new framework SDMMAICS has been developed. As per SDMMAICS, it helps bridge the gap left by the DMAIC framework, increasing its efficiency in LSS initiatives [53]. The lack of continuous integration projects has indeed been attributed to a lack of project understanding and an inability to integrate the continuous integration endeavor into the organizational objectives. As a result, a tailored LSS model should be able to address these challenges [54]. The SDMMAICS model aids in the efficient deployment of LSS initiatives. It is indeed adaptive enough to meet the organization's objectives as well as provide long-term measures of improvement. The SDMMAICS framework's select phase provides appropriate project selection by incorporating a project's restraining and driving forces. The map phase strengthens LSS by incorporating lean and six-sigma closer together. However, after months, the sustain phase makes sure that the control phase continues to maintain and does not divert from the project objectives. The sustain phase elevates the control phase committed to advancing assure stability of the process after the project has been completed by analyzing the methods to enhance process performance.

3. Overview

3.1 Brief Overview

This analysis incorporates the findings of several scholars and suggests novel approaches to issues and challenges. The SDMMAICS framework is designed to fill voids in the LSS DMAIC (i.e., lack of guidelines, sustainability of results, no involvement of other lean tools).

Indeed, the scholars endorse the model's implication in the context of project management. Develops a realistic project management evaluation technique for LSS scenarios taking a design-science-investigation strategy, approving a beneficial expansion to show for both imaginary and reasonable applications. In contrast to the studied data sources, the model's main goal is to enable efficient LSS project management, and it is customizable enough to cater to a variety of objectives. Such objectives could be determined by various LSS implementation in organizations, stakeholder management throughout LSS activities, improve retention, and so on.

There are eight phases of LSS project management in the SDMMAICS framework: (a) Selection (b) Define (c) Measure (d) Map (e) Analyze (f) Improve (g) Control & (h) Sustain. Following that, many functions throughout these stages are subdivided into sub-activities that should be performed throughout LSS projects.

3.2 Front-Loading Overview

The term 'Frontloading' is also called 'stage-gate'. Frontloading refers to moving the entire contract's value to the initiation of the project. Construction projects frequently move a large portion of project costs towards the initiation of the project, instead of uniformly sharing overhead and profits throughout the entire plan. It also refers to a technique under which the development process is divided into different stages, and each has its own set of activities and outcomes [55]. The go/kill financial decision points are selected by gates that anticipate each level. Manufacturing companies are extensively using this technique to introduce new product initiatives to market. Product development is given a comprehensive view by stage-gate. These gates enable the organization's ability to think about the big concerns surrounding a project as it progresses: Are we executing the project right, or are we executing the right project? These gates also filter out projects that aren't satisfactory and also give a pathway to focus in the advancement pipeline [56].

As per [57], Large projects complexities frequently lead to the early setback by misjudging the amount of unpredictability and variability associated with the project and being unable to accommodate improvement efforts and techniques to changing scenarios. Project management in complicated tasks consequently entails early focus and observation by project management on the project's uncertainty and complexity throughout its life cycle. Frontloading notice and response on such challenges improve the ability to take advantage of opportunities provided by 'unknown unknowns. The urgency of addressing these challenges is stressed to manage uncertainties in complicated, one-of-a-kind projects which are based on unknown situations [58].

Another author stated that representatives of the recipient and source sides can get a more precise view of the information, authenticity, and level of members' competence by interaction, observation, targeted conversation, and practice during the early/initial phase of a transfer [59]. Front-loading adaption for tacit information sharing supports the development of deep understanding required for early detection of possible challenges in the transmission of tacit knowledge, casually odd awareness, thereby increasing the chances and lowering costs of minimizing or reducing such challenges [60].

3.2.1 Frontloading a gateway to success

The Frontloading phase usually involves three 'gateways' once advancing with the execution of a project and start-up. Each gate involves the completion, presentation, and confirmation of specified tasks to pass thru [61].

3.3 Motivation & Methods of 'SDMMAICS - Frontloading' Framework

The inadequacies of a DMAIC framework, and also the potential pitfalls of other available LSS frameworks, were addressed in the literature review, indicating the need for a new way to conduct LSS projects. The researchers hope to create a modern framework and evaluate its applicability for LSS project management, seeing this as a unique opportunity and was able to address the gaps that were observed. Using the knowledge of both professionals and researchers in information gathering provided an opportunity to establish a model that can be used in a real situation [62] [63]. As an outcome of the findings, the study established a modern conceptual framework called ‘SDMMAICS’ (select, define, measure, map, analyze, improve, control, and sustain). The existing LSS tools were described at each phase of the ‘SDMMAICS’ framework to ensure that LSS practitioners (project managers) are properly utilized. After that, a comprehensive implementation plan for the proposed conceptual framework was established.

According to some findings from the case studies, they found SDMMAICS was successful. The SDMMAICS selection phase encourages proper project selection by a force field analysis, which is key in understanding the employee’s perspective of the project’s driving and restraining forces. In addition, the map phase included tools such as VSM (value stream map), takt time complement lean tools with six sigma to strengthen LSS more. Furthermore, the sustain phase assures that the project is under control, and the control charts are accurate would not differ from the project aim after a few months. Also, this phase broadens the project’s monitoring phase after the control phase and the creation of tools that can help manage and stabilize the process. Although SDMMAICS follows a series of phases in a systematic manner, it can be customized to accommodate the needs of the organization. As a result of these findings, it is apparent that SDMMAICS is much more helpful to LSS projects than DMAIC.

LSS tools namely force-field analysis, Pareto analysis, Ishikawa diagram, project charter, process capability, control charts, gage R&R (ANOVA), SIPOC (suppliers, inputs, process, outputs, and customers), and takt time analysis, are incorporated into the following case study SDMMAICS. As indicated earlier, frontloading is infused in this framework making it distinctive in terms of literature and real implementation.

3.4 Functionalities of ‘SDMMAICS’ Framework

Functionalities of the SDMMAICS framework are as follows,

3.4.1 Select

This phase of the project seeks to make the best appropriate LSS project selection related to business objectives. [64] states that there has been no single standard for determining whether LSS projects are appropriate, however, not all organizational projects can be solved with LSS [65]. Improper resource planning can waste resources and lead to misleading observations among workers about LSS implementation overall. At this stage, a project selection framework is preferred as a tool for accurately prioritizing project prospects depending on a specified criterion, including available resources, acceptability/suppression to estimated adjustments, process risk, organization requirements, or structure wellbeing as characterized by key performance indicators. This phase should also include a realistic overview of organizational needs and their compatibility with the project selection choices. Another crucial step is to evaluate the ROI or possible returns that the project will bring is a task that must be performed during the 'selection' phase [66]. It's instrumental to attract project sponsors with concrete comparisons to past financial LSS project ROI/profit gains.

3.4.2 Define

In this phase, the professional would have access to some historical data (baseline) that could be used to support the business challenge. Furthermore, descriptive data analysis is used to identify process challenges. As a result, the project manager can establish a problem description that indicates "how big the problem" that needs to be faced by the project, and also some description of intensity, business impact, and process requirements [67]. A clearly defined target description must be established that addresses the project's performance metrics from the given situation. Then, the project manager is obliged to develop a project charter that describes the problem description, aim, and a project manager with roles and functions. Generally, black belts are in charge of making and presenting the project charter to senior leadership, intending to obtain support to formally commence the LSS project. SIPOC (suppliers, inputs, process, outputs, customers) is a typical LSS tool that could assist the project manager to establish an aerial view of the end-to-end activity with stated limits to understand the scope during the define phase.

3.4.3 Measure

In this phase, the project manager prepares a data collecting roadmap to confirm the business challenges through process-specific data. In addition, when contrasted to its baseline data provided in the project charter, the data recorded is more comprehensive over the process output. Before actually implementing the data gathering process, it is recommended that the accuracy and precision of the data gathering system be verified. Standard LSS tools such as measurement system analysis, gauge R&R may be useful for this. These are objective ways for evaluating the correctness of a data measurement system in order to minimize the elements that contribute to deviations caused by the measurement gauge [68]. The project manager is then supposed to use the data obtained to determine the process capability (the current state of a process on the sigma scale).

3.4.4 Map

According to the researchers, [69] are involved in this phase of a project. According to whom, the essential element for betterment is 'process' stated is a continuous collection of events combining products and assistance to satisfy consumer problems [70]. Strengthening processes for suppliers and producers (either employees, managers, or entrepreneurs) needed to figure out is how to design-related economic activities, especially between organizations, to satisfy consumers' wants instead of wasting the time, resources, and effort [71] [72].

The purpose of incorporating the 'Map' phase to LSS project management is to facilitate the Lean process aspects in LSS [73]. At this phase, lean tools such as process mapping, value stream mapping (VSM), flowcharting, and others are prescribed. These tools not just facilitate the understanding of the process from start to finish, but also provide a clear picture of the organization's value chain. With some of those process metrics like lead time, takt time, and others, it also facilitates in contrasting the value-added versus non-value-added tasks in the process. Limitations of data-oriented specialized abilities are considered to be a barrier to project implementation in the typical LSS DMAIC methodology [74] [75]. Although not all employees in companies are familiar with intensive data analysis tools, the introduction of the 'Map' phase nullifies such an assumption by giving process-oriented tools to realize risks using observational tools. Moreover, this phase of a project facilitates the recognition and clarification of numerous types of waste generated within and across activities.

3.4.5 Analyze

The professional would be capable to list challenges or specific problems inside the process after developing, validating, and analyzing through process maps in the previous phase. Nevertheless, evaluating the problem from a process point of view solely does not provide a comprehensive picture of the issues. So because the 'Map' phase provides data regarding process metrics, these metrics get more relevant and usable thru data analysis. The researchers, on the other hand, do not advise LSS project managers to rely solely on data analysis.

The fact is, LSS data tools aren't easier to comprehend for all types of employees. As a result, the 'Analyze' phase should always be examined from a data as well as a process aspect, enabling for the effective application of area professionals' cumulative experience in the relevant organizational processes. Additional process analyses, such as value analysis are advised at this phase, in addition to traditional analysis tools such as to cause & effect diagram [76].

3.4.6 Improve

The 'Improve' phase allows the identification of solutions by focusing on the stated sources of the problem that the project aims to solve. Because it requires both rational and unconventional understanding, the entire project staff persons at all levels of the organization must be inclined to perform a vital role throughout this phase. Further comprehensive thinking tools, such as the benchmarking and Pugh matrix are a few finest approaches that are suggested [77]. Thereafter, the choices are chosen depending on factors such as cost, deployment time, practicality, and resource availability.

Experimentation is another useful technique for visualizing the outcomes of recommended process improvements, as a result, seeking the support of top management (stakeholders) for moving forward with improvements becomes smoother (specifically where cost is involved). Before a full-scale distribution of changes, pilot projects are commonly done. For many circumstances, a project manager could use a list of process improvements, but if they are bound to choose among several possibilities, tools such as the weighted criteria matrix, pugh matrix, and others may be useful [78]. The professional could build a better overview of the project termed as 'To-be' map having viable solutions in consideration to minimize rework cycles, waste, and waiting periods. Experiments based on simulations, to-be process maps, and cost-benefit analysis of solutions are just a few scientific stakeholder management methods used to secure project sponsors' approval to move forward with the improvement plan.

3.4.7 Control

This phase entails ongoing evaluation of the outcomes due to the implementation of improvements in line with the project improvement project. Control charts and visual dashboards may be useful in this case. Controlling the process allows you to see the true value of the improvements and estimate obstacles. This could perhaps come through employees who were habituated to old practices and are reluctant to the recent modifications that have been made [78]. Over the timeframe of post-monitoring a process (usually 4-6 weeks), the project manager needs to statistically verify the process metric results by comparing before and after improvements to demonstrate the project's value contribution to upper management. Change management, developing and implementing an appropriate communication plan, and emphasizing the importance of transformation through data and results are some of the approaches project managers are advised to utilize at this phase [79]. Through the completion of this phase, the project manager had effectively standardized and documented the processes, created training programs, sops, databases, and set up a framework for continuous process monitoring.

3.4.8 Sustain

The researchers noted that several lean, six sigma, and lean six sigma programs struggle from the lack of performance sustainability, based on the material collected as part of this study. Even though the process data show substantial improvement during the control phase, straying from the project objective after several months would be a norm. As a result, if somehow the improvements were not sustainable, the project isn't a success [80]. This phase stretches the project's post-control phase which leads to increased monitoring and the development of a tool that helps control and stabilize the process. Mistake-proofing, an escalation matrix, and continuous process control are part of the organizational culture are examples of control systems. Control charts are highly recommended by researchers for monitoring the process at this point. Control charts, on the other hand, are only measures of process control, but they would not control the operation. At this phase, transferring the responsibility of the modified process to the process managers from the project manager is necessary, such that outcomes are held by individual people even when the business case is moved from the project phase to the operating condition.

At this phase, displaying process status dashboards using metric dashboards or implementing andon and jidoka tools could be helpful. Despite the fact that LSS projects are declared finished at the completion of the control phase, it is advised that they must be officially closed only upon 2-3 months of sustain phase review.

As an outcome, the sustain phase explained how the prior phase information can be implemented, transferred, and spread across the organization to produce long-term gains. The aim of incorporating this phase was just to assure that the achievements and experience gained by LSS programs are sustained throughout time.

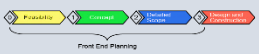
3.5 Activities Table in each phase of ‘SDFMMAICS’ Model

Selection

- Commitee responsible for project selection
- Situational analysis
- Stakeholder evaluation
- Risk evaluation and feasibility study

Define

- Evaluate the potential benefit of a project
- Establish clear objectives
- Formulate a strategy
- Supervising squad representatives



Front-loading

- Business Analysis
- Selection of Alternative
- Preliminary design and execution plan

Measure

- Method for collecting the data
- Gathering information
- Measure deviation

Map

- Evaluate the core problem
- Observing the overall process
- Estimate what is ongoing right now
- Highlighted and omitted waste and inefficiency occur

Analysis

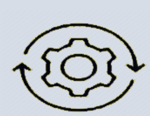
- Analyze all of the details (Previous data may indicate loopholes)
- Sketch the cause & effect relationship
- Evaluate defects, process inefficiencies, and quality flaws

Improve

- Based on the analysis phase, seek for a new concept
- Apply tools and approaches to put it into practice
- Choose the available options
- 5S, pull system, SMED, TPM

Control

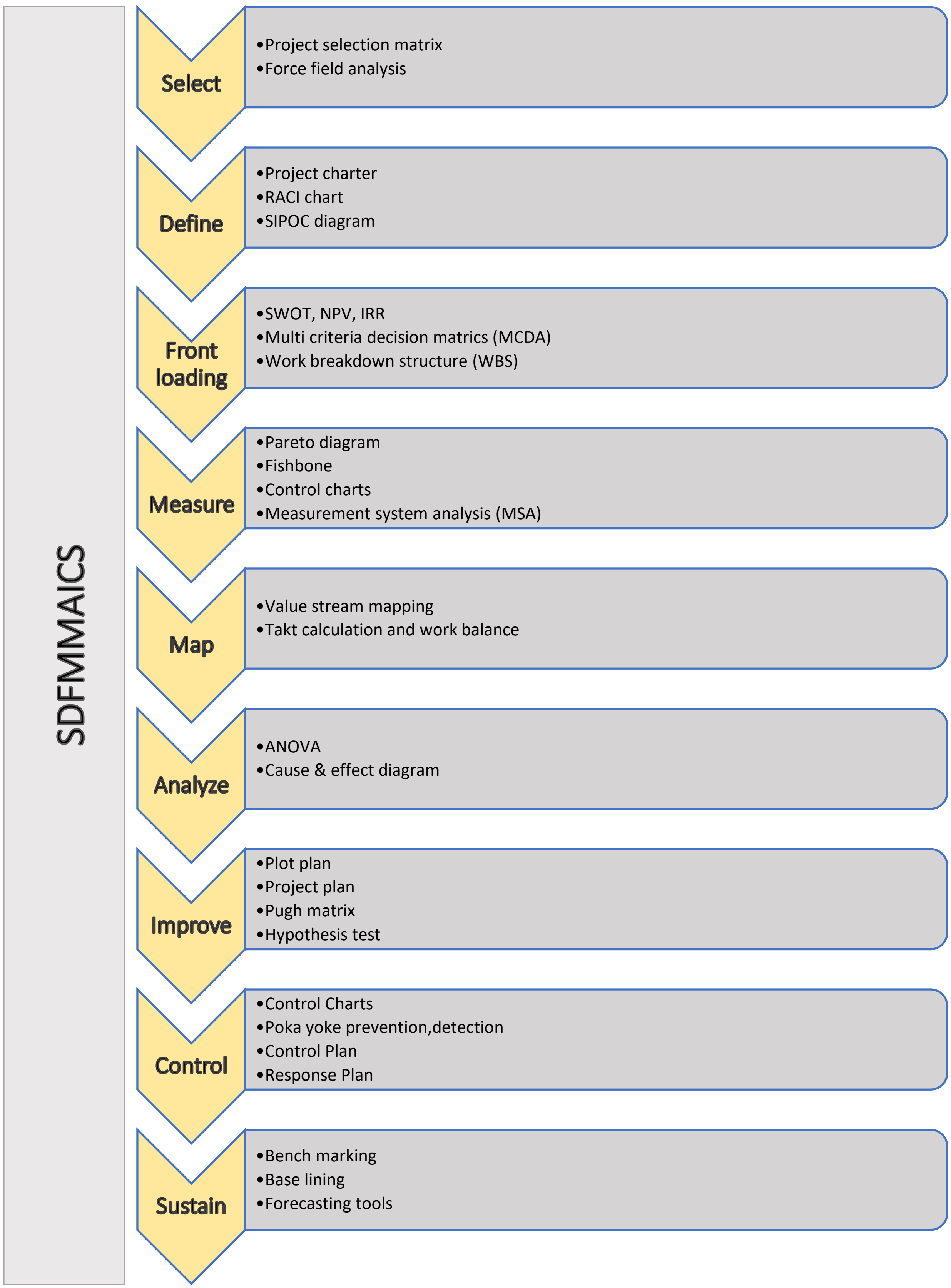
- Streamline the procedure
- Make formal documentation of the operation
- Explain it comprehensively and provide training
- Strategy for a successful deployment



Sustain

- Analyze the results on a regular basis at predetermined periods
- Continue the project's progress untill a successor version emerges
- Prepare the necessary data
- Submit the document to the top management

3.6 LSS Tools Table in each phase of 'SDFMMAICS' Model



4. Methodology

4.1 Front-Loading Methodology

Frontloading (FL) is segmented into three stages (FL 1 to 3), each with its own decision-making 'gate'. **Figure-5** illustrates a schematic diagram of a process. Approximately 75% of potential projects inside an organization's portfolio don't always pass from the FL-1 to FL-2 gate, and approximately 25% of programs don't proceed from FL-2 to FL-3, and just 1% of initiatives are accepted for successful execution at the FL-3 gate. This would be due to the lack of business attraction, the incapability to identify a feasible technological solution, or the reality is that not every alternative option was evaluated.

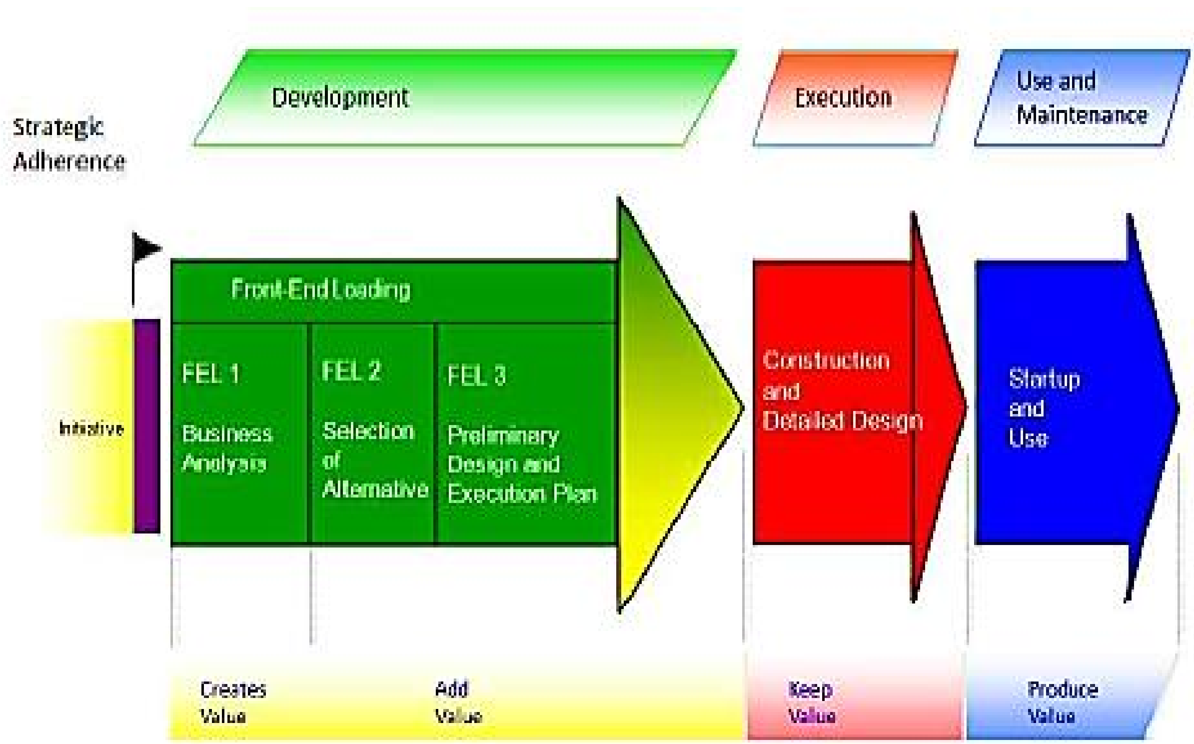


Figure 5: Schematic representation of front-loading methodology [81].

Through a brief overview, the beginning stage (FL-1) entails defining a project's scope and objectives, as well as an approximate assessment of investment amounts, with such a cost range of -25% to +40%. In this step, a business evaluation process is carried out by calculating critical business economic indicators, such as IRR (internal rate of return), IPV (investment present value), discounted payback, NPV (net present value), etc. This phase ensures that the project development requirements are under the organization's portfolio management policies and objectives.

The FL-2 step includes an evaluation of technological and purposeful alternatives related to development, concluding through the selection of either of these alternatives and the essential definitions (project briefing) of such facilities. This stage estimates a range of -15% to +25% fluctuation in project expenses. It also carried out the selection of VIPs (value improving practices) for use in the project's basic technical development.

The technical solution chosen in FL-2 is refined in the last phase of a pre-planning stage (FL-3). More VIPs are now being chosen to be evaluated in the fundamental design development. The techniques are used to give a range of -10% to +10% fluctuation in project costs, as well as integrate the organization's main indicators of profitability [81].

4.2 'SDMMAICS' Framework in Front-Loading Methodology - (A Case for Project Design)

This section addresses the suggested approach for capital project design from a conceptual perspective. The theoretical connection between the frontloading and SDMMAICS stages serves as the guideline, project definition and lean design are critically valuable over the first two phases. It's indeed essential to recommend lean thinking concepts that can be incorporated in FEL methodology based on an analysis of two methodologies. The below **figure-6** shows the steps in schematic form.

Figure 6: Steps were taken to create a model proposition [81].

The SDMMAICS is a project management methodology that emphasizes the early stages of project definition while adopting lean and six sigma principles. This approach emphasizes the incorporation of project strategy, design definitions, and sustainable supply while taking into account all aspects of a project from conception to completion. Initial stages of project planning and design are valued in both conceptual frameworks, with a special focus dedicated to the creation of project goals that are aligned with stakeholders' demands and values.

The FL-1 stage brings value to the project design, just like the project definition stage in the SDMMAICS framework. The important aim of the FL-1 stage, as previously stated, is to identify the goals and plans of the operation in conjunction with an estimated cost and the computation of the organization's key operational factors. The project definition part of the SDMMAICS framework is responsible for defining the goals, means, and limitations, as well as focusing on the project budget to fulfill the prerequisites of the customers.

The FL-2 stage is similar to the 'lean design' stage as in the SDMMAICS framework, where value is provided by choosing a substitute for fundamental engineering and design development. SDMMAICS frameworks, on the other hand, are added and improved over time through target costing and set-based design. Basic design approaches are given in FL-2 and would be expanded 'downstream' as in the following project definition phase.

The third stage (FL-3) correlates to the SDMMAICS framework of 'lean design' and 'lean supply', with the creation of basic engineering.

Lean and six sigma concepts could be used to the front-loading flow of activity once a theoretical similarity of Frontloading stages with SDMMAICS has been established. A few key points are briefly discussed below.

The formation of a functional team is the first factor to be considered. The frontloading methodology also addresses the formation of heterogeneous and versatile workgroups, as well as agents all across the project lifecycle. However, through creating a lean and six sigma mentality in which stakeholders get a comprehensive understanding of the project, SDMMAICS can initiate the concept of forming new contractual connections amongst the agents. The matrix structures and the formulation of a project-focused organizational structure, which prioritizes the image of a project manager with complete authority, are generally preferred to this approach.

The following phase, with such a specified team, had to integrate the project's early ideas with the needs, means, and limitations, using functionalities outlined by the SDMMAICS, such as understanding the project's needs and requirements, as well as project criteria and design [81].

4.3 Discussion and Limitations

The entire study focus was to strengthen the LSS model for LSS projects. Stressed the importance of information intake procedures through an LSS project. In addition, LSS initiatives must be able to exchange details on the project's processes [82]. [83] found that to get better results, LSS projects must incorporate lean tools with the six-sigma toolkit. As per stakeholders SDMMAICS framework prioritized both data-oriented and process-oriented methods, also made executive sponsorship easier for top management to consider, and interest levels remained high throughout the LSS projects. Projects managers should have an end-to-end vision and grasp of activity from all aspects, rather than focusing solely on improving project metrics. An author stated that high project ambiguity frequently leads to an early failure by overlooking the scope of complexity and uncertainty associated with the project and struggling to accommodate management actions and strategies to the uncertain environment, as a result, project management in complicated systems entails upfront focus and assessment by project management on the project's ambiguity over its entire lifecycle [84]. Further with Frontloading, the LSS team offers a systematic analysis with details needed. Moreover, Frontloading attention and consideration on such challenges enhance the capability to take advantage of opportunities addressed by unknown unknowns. That need for addressing these challenges is stressed for managing uncertainty in complicated, one-of-a-kind projects caused by unexpected situations [58]. Several development projects can benefit from frontloading, even highly unclear and uncertain projects may gain the maximum benefits, also the no-linear form of frontloading is not a drawback but may be more effective if market and customer demands are predictable and stable. The SDMMAICS framework was identified as an outcome of the study organization's past DMAIC initiatives' incompetency. The SDMMAICS is the effective outcome for addressing the DMAIC's weaknesses. The lack of information to quantify the financial improvements obtained through the SDMMAICS-Frontloading model limits the scope of the thesis.

5. Conclusion

The main goal of this thesis is to present a modified framework, which specifically focuses on eliminating uncertainties which further leads to saving costs and time. Moreover, it focuses on improving the overall project management phases.

The three key frameworks including the framework which is the main focus of this thesis are listed below:

- **DMAIC**
- **SDMMAICS**
- **SDMMAICS - Frontloading Framework**

DMAIC aims towards improving an existing process by dividing the whole process into five divisions from define to control. It is also known as a data-driven strategy, as key analytics are performed using the process data. Moreover, the reason being SDMMAICS introduced as DMAIC does not comprehensively address the factors such as appropriate project selection, assuring the long-term processes sustainability, and cost-saving. In addition, SDMMAICS including the framework of frontloading was introduced in this thesis which mainly focuses on gathering all the required and necessary information of carrying the efficient project management at the very early stages, which could provide potential time and cost-saving benefits.

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