

Establishing A Systematic Outline for Operational Excellence Model and Proposing a Comprehensive Model

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Omkar Rajendra Ghosalkar
August 2022

Copyright © 2022 by Omkar Rajendra Ghosalkar.
All rights reserved.

ABSTRACT

Manufacturing organizations adopt operational excellence strategies to meet performance targets. While Lean Manufacturing (LM) is widely used in OPEX and is supported by many industries case studies but faces two major challenges. First, there is an absence of a standard framework to implement LM. Second, the framework does not explicitly address employee engagement and quality of life in the continuous improvement process. This has led to low reported levels of sustainability of LM. People-Centric Operational Excellence (PCOM) has been presented as a response to challenges in LM. PCOM comprises four modules: problem definition, design of metrics, design of reliability-based solutions, and alignment of solutions with employee quality of life. However, PCOM is not supported by an implementation template and case studies for the framework are not well documented in the literature. This paper compares PCOM with LM using literature-driven criteria, develops an implementation-ready template for PCOM, and documents case studies in PCOM for the manufacturing sector. Moreover, this paper presents the conceptual basis for a new model, Comprehensive PCOM or CPCOM, that combines the strengths of LM and PCOM and provides an initial roadmap for its implementation.

TABLE OF CONTENTS

1	CHAPTER ONE INTRODUCTION	1
1.1	Motivation.....	1
1.2	Background.....	1
1.3	Problem statement.....	3
1.4	Approach.....	3
1.5	Outline of thesis	5
2	CHAPTER TWO LITERATURE REVIEW	7
2.1	Lean Approaches	8
2.2	Approaches explaining the cases of lean implementation	10
2.3	Studies conducted on comparison between lean and other approaches	14
2.4	Research Gaps	16
3	CHAPTER THREE METHODOLOGY.....	17
3.1	Overview	17
3.2	Introduction to People-Centric Operational Excellence Model (PCOM)	17
3.3	Template for the People-Centric Operational Model	19
3.3.1	Process followed for Building the template for PCOM	19
3.3.2	People-Centric Operational Excellence Model's relationship to Critical Problem Solving	19
3.3.3	Template for Defining the Problem	23
3.3.4	Template for Aligning Effects to Organizational Effects	27
3.3.5	Template for Reliability-Based Solution	30
3.3.6	Template for Aligning Employee Self Interest with Solution.....	31
3.4	Developing Survey Questions for Building Cases.....	33
3.4.1	Process followed to build the Survey Question and Conducting Survey ..	33
3.4.2	Connect the Survey Question to the Template	35
3.5	Developing Criteria for Evaluating Lean Manufacturing and People-Centric Operational Excellence Model	38
3.5.1	Building the Criteria	38
	What is the problem faced by the company?	40
3.5.2	Linking the Criteria with Template.....	42
3.5.3	Conceptual Comparison between Lean Manufacturing and the Sawhney Model	43
3.6	Proposing the Comprehensive People-Centric Operational Excellence Model	44
3.6.1	Opportunities for CPCOM	44
3.6.2	Framework for Comprehensive People-Centric Operational Excellence Model (CPCOM).....	48
3.6.2.1	Define	48
3.6.3	Management Guidelines for Comprehensive People Centric Operational Excellence Model.....	61
4	CHAPTER FOUR RESULTS	72
4.1	Introduction	72

4.2	Presenting the output of the Survey	72
4.3	Case Studies.....	83
4.3.1	Case study 1.....	83
4.3.2	Case Study 2	94
5	CHAPTER FIVE CONCLUSION AND RECOMENDATIONS	104
5.1	Summary.....	104
5.2	Limitations.....	104
5.3	Future Work	105
	LIST OF REFERENCES	106
	VITA	110

LIST OF TABLES

Table 1: Framework mentions about people considerations.	11
Table 2: PCOM prioritization based on process classification{Sawhney, 2020 #315}... ..	20
Table 3: Survey Question Based on PCOM template	40
Table 4: Linking Question with template.....	41
Table 5: Criterion Definitions	46
Table 6: Linking criteria with template	49
Table 7 Conceptual Comparison between Lean manufacturing and PCOM	50
Table 8: Missing elements in PCOM and LM	53
Table 9: Comparison of methodologies followed by lean manufacturing, PCOM and CPCPCOM.....	54
Table 10: Improvement steps and the reliability improvement achieve after implementation.....	63
Table 11: PCOM application result[61].....	92
Table 12: Comparison between LM, PCOM AND CPCOM for XYZ company	97
Table 13: NVA/VA for Part Family 1[63]	100
Table 14: NVA/VA for Part Family 2[63]	101
Table 15 Reliability of the Forging Process[63]	102
Table 16: Reliability of turning process[63].....	102
Table 17: Improvement after implementing policies[63]	102
Table 18: LM, PCOM and CPCOM comparison for ABC company	103

LIST OF FIGURES

Figure 1: Approach for thesis	6
Figure 2: PCOM Categorization	21
Figure 3: PCOM relation with critical problem solving	22
Figure 4: Define for CPCOM	56
Figure 5: Solve for CPCOM.....	62
Figure 6: Sustain for CPCOM.....	64
Figure 7: Application guideline for Define of CPCOM.....	69
Figure 8: Application Guideline for Solve OF CPCOM	70
Figure 9: Application guideline for Sustain of CPCOM	71
Figure 10: Application of Module 1 in various sectors	79
Figure 11: Application of Module 2 in various sectors	80
Figure 12: Application of Module 3 in various sectors	81
Figure 13: Application of Module 4 in various sectors	82
Figure 14: XYZ Critical Path [61]	85
Figure 15: Bottleneck identified for XYZ company[61].....	86
Figure 16: Calculation of Bottleneck stations for XYZ company[61].....	87
Figure 17: ZBM formulation for XYZ company[61]	91
Figure 18: ZBM implementation changes at workstation at various workstation	93
Figure 19: Sensitivity analysis for XYZ company	93

1 CHAPTER ONE INTRODUCTION

1.1 Motivation

Manufacturing companies continually face the challenge of meeting production requirements. There are many operational excellence philosophies that can be used as guidelines in this effort, such as total quality management (TQM), lean manufacturing (LM), six sigma, and excellence models. Lean manufacturing is a popular philosophy used by many organizations that have experienced various benefits, including higher profits and market expansion [1]. Because LM is relatively uncomplicated, companies can manufacture products in medium-to-large quantities in a medium-to-large scope of variety that allows them to meet the needs of a wide range of customers. The primary notion of LM is to minimize waste in a production system by solving material and information flow issues, thus making it more efficient and competitive. Overproduction, surplus inventory, long wait periods, over-processing, transportation, motion, and flaws result in the wastes that LM eliminates [2-4].

Despite being a popular philosophy, LM implementation in many organizations has had poor outcomes: it has a very low success rate [2], and only 20% of the organization can sustain lean implementation [1]. At least 50% of corporate improvement plans following LM fail long-term, with up to 70% failing to achieve the required benefits [2]. Studies [3] have found that none of the available LM frameworks or models provides a step-by-step guide or method for implementing lean manufacturing, so the projects fail because organizations lack knowledge about implementing lean manufacturing and face resistance from the employees [4-7]. One study [3] described the lean manufacturing implementation failures due to inappropriate tool selection, dependence on a single tool to address all problems, a lack of understanding, and a poor decision-making environment. Another [7] maintained that the lack of education in LM manufacturing and processes ultimately results in an inability to implement lean manufacturing successfully. Yet another study [8] explained that the failure to enforce LM resulted from a lack of commitment to the process among top management, poor communication, and insufficient training. Since lean manufacturing is often perceived as creating extra work and gives the impression that it results in job loss, it is necessary to seek a methodology that considers employee engagement, motivation, and quality of life as part of the improvement process.

1.2 Background

There is a lack of consistency in frameworks that provide steps for implementing lean manufacturing. The LM framework has established a model that combines concepts of lean and green manufacturing and quality models [9]; a range of assessment criteria was established to connect and integrate lean and green ideas and technologies. The framework encourages the integration of lean tools. It includes the people in the improvement process by assessing the organization but does not provide the steps

necessary to implement both philosophies. The framework talks integration of lean tools and including the people in the improvement process by assessing the organization, but the framework does not give any steps to implement both philosophies. On the other hand, another model [10] aims to effectively teach lean concepts and promote long-term transformation in organizations with little prior exposure to those ideas by presenting LM implementation as a series of four phases. However, while it mentions the need to assess the organization following the implementation, it does not mention the importance of people in the framework and focuses solely on tool implementation. The model in [11] uses RFID deployment and value stream mapping (VSM) for lean implementation and technology-organization-environment (TOE) architecture; this data was used to create an implementation framework with 21 steps and four phases. The framework is focused on implementing lean manufacturing tools in the plant and does not consider employee motivation or engagement. In the example that uses a one-machine scenario, [12] a framework for choosing among multiple lean-based improvement strategies is developed and implemented in an aeronautics company by focusing on implementing lean tools but not considering the importance of people in the process. The framework focuses on implementing lean tools and does not mention the importance of people in the improvement process. The framework in [13] gathers a collection of interconnected and internally consistent lean techniques and, although it mentions people safety and employee motivation, it does not have standardized steps for lean implementation. As these examples demonstrate, LM implementation has a variety of approaches, but no consistence. Thus, there is a need for a step-by-step standard framework that will help implement techniques in any organization. Also, since most established LM models do not consider the human element as a part of the improvement process, it is essential to design a framework that is considers both people and techniques as a part of the improvement process.

Lean manufacturing has a diverse field of application in the manufacturing field, and one application is found in a case study of a camshaft factory [13] seeking to improve work in progress (WIP), lead time, and cycle time. Another case study was about LM implementation in an automobile part manufacturing company [14]; the study used value stream mapping (VSM) to identify waste and proposed lean tools for mitigating that waste. The facility layout for lean implementation in cellular manufacturing [15] can be either a line layout or a cell configuration; it categorizes parts into part families, and machine cells produce specific parts within the cells. It categorizes parts into part families, and machine cells produce specific parts within the cells. Lean implementation in the textile industry [16] optimizes the processes by using VSM, 5S, Kanban, kaizen, poka-yoke, and visual controls. The manufacturing industry identified the current state to find non-value-added activities by charting the VSM using lean methods such as 5S, VSM, and line balancing [17]. The lean implementation demonstrates that lean production control principles can be applied successfully: following implementation, flow times were reduced, and on-time delivery performance improved. The observation in this section demonstrates a diverse application of lean manufacturing in various organizations.

Lean manufacturing has been conceptually compared to different operational excellence techniques. For instance, one study [17] compared lean manufacturing and six sigma and reported experiencing the benefits of both the methods and the synergy of both methods. Another [18] identifies the similarities and differences between lean, six sigma and total quality management (TQM). The comparison in [19] was done using a literature study and interviewing experts. The research compares lean and JIT and six sigma and TQM and points out issues with each method; it also provides a study of critical success factors (CSF) to implement this method by reviewing and comparing the six sigma and TQM. Another comparison study [20] checked the differences and similarities between lean manufacturing, six sigma, and TQM, identifying the competitive priorities that lead to the best performance due to the policies implemented in the decision areas of the model adopted. Clearly, the research shows that the conceptual comparison of LM with other OPEX techniques is a useful method for detecting the successes and weaknesses of implementation.

The People-Centric Operational Excellence Model (PCOM) [21] presented in this study proposes establishing and maintaining policies that carefully balance improvement in both productivity and employee quality of life. The PCOM has four modules, and the model emphasizes including the people in the improvement process and paying attention to their perceptions before implementing policies based on the model. The proposed framework brings fundamental changes based on reliability, which is supported by four main goals: (a) reduce resource and effort levels by strategically defining the problem; (b) align efforts with system growth and competitiveness; (c) improve capacity through reliability and flow; (d) improve employee quality of life.

1.3 Problem statement

The problem statement is:

1. There is a lack of cohesion in frameworks that provide steps for the organization's implementation.
2. Most of the framework is focused on implementing tools in the organization, but very few consider people as a part of improvement operation.

1.4 Approach

Introduction to the People-Centric Operational Model

The introduction of the People-Centric Operational Model in the methodology addresses the framework problem statement regarding people as part of the improvement process[21]. The model is proposed in four modules, i.e., "Module 1: Defining the problem," "Module 2: Aligning the effects to organizational effect," "Module 3: Reliability-Based Solutions," and "Module 4: Aligning Employee Self Interest with Solution"[21]. Each module is important for improving organizations and proposes to focus on improving

employee quality of life. Module 1 defines the problem in the organization from a systems perspective and identifies the root cause of the problem. Module 2 examines the metrics based on identified problems and aligns them with the organizational requirements; the model proposes including reliability-based leading metrics and people-based lagging metrics to measure the organization's success. Module 3 addresses the organization's reliability based on People, Equipment, Materials and Information (PMEI) [21] by proposing a one-piece flow. Module 4 considers people-based factors such as employee motivation, engagement, and culture, by proposing these elements should be integrated with policy development, and if the model finds that employee factors are not incorporated, the policy should be made employee-friendly.

Template for the People-Centric Operational Excellence Model

The template for PCOM addresses the problem statement component of frameworks missing operational excellence steps. The model is categorized into numerous concepts, components, and steps to build the templates. The template is divided into four parts based on the modules of PCOM. Part 1 of the PCOM template is called the Template for Defining the Problem, Part 2 is the Template for Aligning Effect with the Organizational Outcomes, Part 3 is the Template for Reliability-Based Solution, and Part 4 is Template for Aligning Employee Self Interest with Solutions. The templates will be used to develop a survey for presenting the cases of PCOM applications in various sectors.

Developing and Conducting the Survey to build Cases

The PCOM has been implemented in various sectors, but it has not been documented. The diverse application of lean manufacturing in various sectors provides an opportunity to present the case for the PCOM model. The survey was created to collect information from PCOM practitioners about their experience in implementing the model in various sectors. The survey questions are based on the template for the PCOM. This section in the methodology chapter covers the construction of the survey questions and explains how the survey was conducted with the participants. Finally, the PCOM model implementation of each project is demonstrated in the results chapter.

Performing the Conceptual Comparison between lean manufacturing and PCOM

Lean Manufacturing is compared with different operational excellence philosophies based on the criteria referred to in previous research, which provides an opportunity for the current study to compare LM with PCOM and create criteria found in the literature. The comparison helps to identify the strong points in both methodologies and, as a result, the fundamental differences and shortcomings were identified from this conceptual comparison.

Proposing a Comprehensive People-Centric Operational Excellence Model

Based on the results gained from the conceptual comparison between LM and PCOM, the Comprehensive People-Centric Operational Model is proposed in this section. The proposed conceptual model integrates the key elements of both methods and is based on the principle of critical problem solving, presented in three parts “Define,” “Solve,” and “Sustain.” Figure 1 shows the approach followed by this thesis.

1.5 Outline of thesis

The thesis is divided into five chapters. Chapter One introduces the concept of lean manufacturing, and the current challenges manufacturing companies face while implementing LM. Chapter Two describes a systematic literature review on lean manufacturing. Chapter Three: Methodology describes the process of closing research gaps and proposes a comprehensive model that integrates LM and PCOM. Chapter Four validates the steps proposed in the previous chapter and presents the survey outcomes. Furthermore, how the PCOM was implemented in the organization. It utilizes the criteria used to compare PCOM and LM to show how LM, PCOM and CPCOM will fundamentally differ when implemented in the organization.

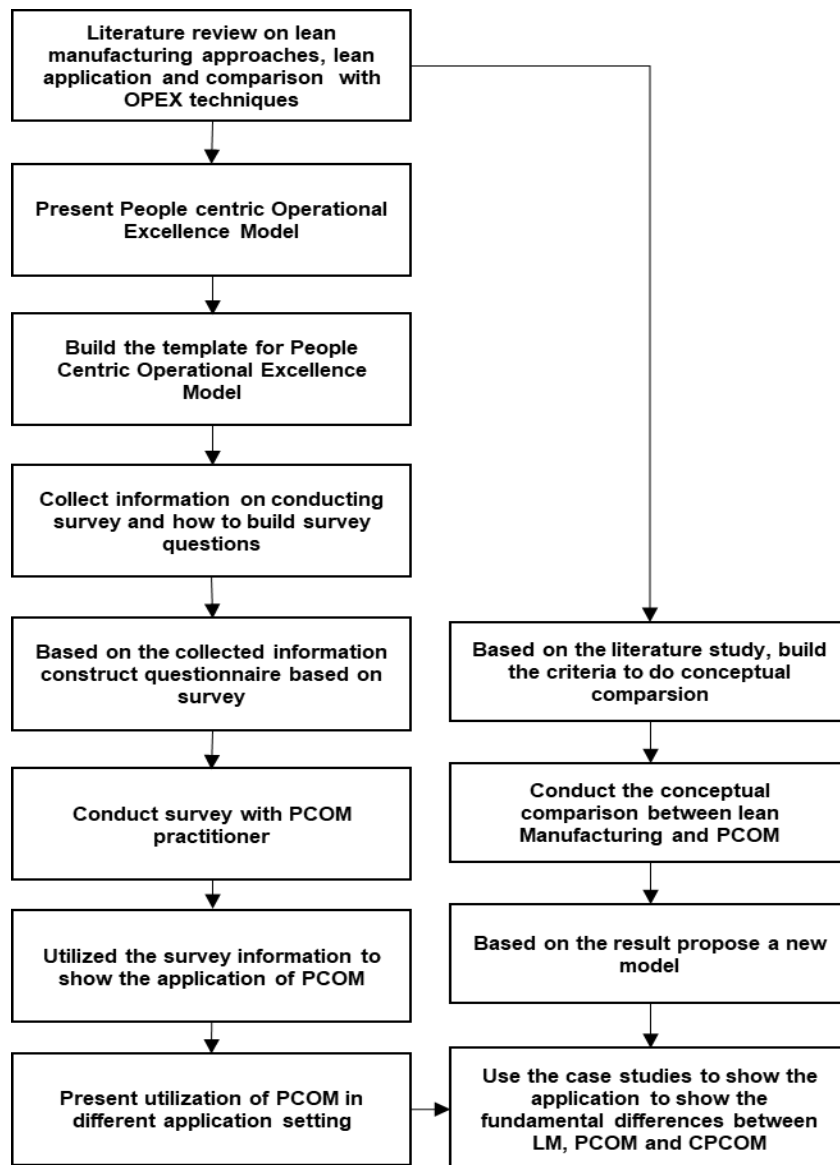


Figure 1: Approach for thesis

2 CHAPTER TWO LITERATURE REVIEW

The literature review for this thesis is presented in three parts: (a) studying the lean manufacturing framework, (b) understanding the lean manufacturing application in a manufacturing setting, and (c) examining how lean manufacturing compares with other operational excellence techniques.

The investigation of frameworks will explain how various researchers have perceived lean manufacturing in previous studies. The database used for identifying LM frameworks was compiled using Google Scholar, including Emerald, Elsevier, Springer, Science-Direct, and Taylor and Francis. Searches used the following keywords: "lean framework," "lean roadmaps," "lean models," "lean framework implementation," and "lean manufacturing implementation." The study sought to include the lean manufacturing frameworks and excluded those that integrate LM with six sigma. The following additional keywords were used to filter results to more specifically targeted studies: "systematic lean implementation" and "lean implementation step by step approach template." The LM framework search focused on finding those that focus on implementing the complete lean manufacturing philosophy and not those that focus on implementing specific lean manufacturing tools. In the last filter, only those frameworks cited at least five times were chosen for this literature review. After utilizing these filters, 13 frameworks have been chosen for the literature study.

The second section of the literature review aims to grasp the application of lean manufacturing in manufacturing settings to understand the changes that occur when lean manufacturing is implemented in an organization and the motivation for implementing LM. The same Google Scholar database (Emerald, Elsevier, Springer, Science-Direct, and Taylor and Francis) were used to identify lean manufacturing frameworks with the keywords "lean implementation cases," "lean implementation examples," and "case studies of lean manufacturing." The results were filtered to locate those that included the application of LM in the organizations; studies papers excluded from the search were those that demonstrated the drivers and enablers of LM. The case studies chosen for this section were published from 2000 to 2020, and eight are presented in this section of the literature review.

The third section of the literature review chapter compares lean manufacturing and other operational excellence techniques and includes studies with established criteria for conducting theoretical comparisons of LM and other OPEX techniques. The database used for identifying lean manufacturing frameworks was also compiled using Google Scholar (Emerald, Elsevier, Springer, Science-Direct, and Taylor and Francis). First, by reviewing the published literature to understand the application drivers and critical success factors for implementing lean manufacturing. The studies included in the third literature review section were published from 2000 to 2020. Next, the search of the material to locate work done in comparing lean manufacturing and other OPEX

techniques conceptually using criteria used the additional search terms “success factors to implement lean,” “lean comparison with six sigma,” “lean,” and “comparison with operational excellence techniques.” In the end, seven studies that developed criteria for comparing lean manufacturing and other operational excellence techniques based on the selection criteria were included in the third section.

2.1 Lean Approaches

This section focuses on studying the lean manufacturing frameworks, roadmaps, and models to determine whether there is a standard framework for lean manufacturing implementation. One framework that has been proposed [22] has five parts: value proposition, value stream, flow, pull, and perfection. The framework focuses on identifying waste, choosing lean tools, selecting relevant performance indicators, and achieving significant improvement; it also emphasizes the inclusion of employees’ perspectives by training them prior to the lean implementation process. This training will teach team members about lean manufacturing and assign them responsibilities; however, it does not specify how to create these teams. Furthermore, the framework does not mention measuring people's views on policy implementation, such as engagement and motivation. Another proposed framework [23] comprises four phases: conceptual, design and implementation, implementation and evaluation, and complete lean implementation: each phase provides the lean implementation steps for the organization. The framework mentions training the employees to generate awareness about lean policies and recommends integrating them by creating awareness by forming an internal team and hiring lean experts to train employees on lean manufacturing. The framework also mentions assessing the organization before and after lean implementation but does not mention assessing people-based factors like employee engagement, motivation, and culture. The framework [24] proposes implementing lean in three phases: unfreezing, transition, and freezing. The unfreezing phase proposes the motivation for implementing lean manufacturing, the transition phase talks about how to implement lean policies, and the freezing phase describes sustaining the lean policies. This framework does mention assessing employee engagement but does not mention on how to achieve that engagement. Yet another framework [25] divides the concept into three parts: pre-implementation, implementation, and post-implementation; each has a set of instructions for implementation. The framework explains how to seek employee commitment before implementing lean manufacturing and instructs users to form lean teams to provide information about lean policies. The framework also recommends using scorecards to assess the KPIs identified for the organization; it does not specifically mention measuring employee-based factors. The lean implementation framework in [11] has four phases conceptual phases: recognizing the need to implement lean, identifying the problem, training in how to implement lean tools, and planning future steps. This framework suggests training employees in lean management and forming a team, focusing on process improvement and not on assessing employee-based factors.

Another framework [26] provides the steps for implementing lean manufacturing in an organization by going from a study of the current state study to identify the problem to developing policies to mitigate it. This framework mentions the importance of communication for implementing lean manufacturing and suggests using scorecards to check the organization's productivity. The model in [27] proposes four phases of lean implementation: existing lean, output, and impact; it does not mention the employee perspective regarding implementing lean manufacturing. One other framework [28] has established five bundles to establish lean manufacturing. The framework is presented as a flowchart to check whether each required task is completed before moving to the next part. This framework includes workplace and ergonomic safety, but it does not measure employee motivation, engagement, and culture. The lean roadmap proposed in [29] has proposed six implementation phases: initial investigation, preparation, focus on a specific project, focus on a specific plot, expanding the whole system, and perfection. The framework application focuses on mitigating one problem at a time, emphasizing conducting pilot projects, and then expanding to the whole organization. The framework recommends checking that the organization has lean knowledge and whether management is committed to implementing lean; however, it does not provide any method to check these factors. The framework also recommends checking the changes after the lean manufacturing policies are implemented but does not mention checking people-based factors such as employee motivation, engagement, and commitment. The lean implementation framework presented in [30] has nine steps, each with tasks that supplement lean implementation: awareness, lean assessment, conceptual design, LPS implementation master planning, organizational changes for implementation, LPS implementation detailed planning, pilot, rollout, and daily operations/continuous improvement. This framework does not have steps to check for employee motivation, engagement, and culture. The framework in [31] proposes to combine lean and 6R (reduce, reuse, recycle, recover, redesign and remanufacture) to achieve sustainable lean practice. This framework has four phases: preparation, current assessment phase, analysis and elimination phase, and action: each phase has implementation steps presented in a flowchart to guide the user. This framework focuses on implementing lean policies and does not discuss checking people-related factors before or after each phase. The last framework presented here [32] provides seven steps for implementing lean manufacturing in a flowchart from problem identification to solution verification. The framework focuses on implementing lean tools and does not include people-related factors.

The study of all these models concludes that lean manufacturing frameworks differ depending on the author's perception of lean manufacturing, leading to identifying the essential gap: lean manufacturing does not have any standardized implementation framework. In addition, most frameworks presented here focus on implementing lean tools and do not consider employee perspectives on implementing those policies. Table 1 shows the study conducted on different frameworks.

2.2 Approaches explaining the cases of lean implementation

This section of the literature review presents a review of lean manufacturing case studies in manufacturing settings. Lean manufacturing was used in firms primarily focused on civil, mining, and industrial engineering projects [33]. The company's products were divided into two categories: drawings and documentation. The major finding was a significant quantity of work in progress between the drawing and document production stages, suggesting that the time spent designing was only a minor portion of the total time spent manufacturing the products. Documents and drawings sat in inventories, waiting to be worked on most of the time. An application resulted in a 31% increase in value-adding activities, a 44% reduction in product unit mistakes, a 58% reduction in process waiting times, and an expansion of cycle time utilization. The case study did not focus on measuring employee-based factors before and after implementing lean manufacturing.

EFGTL is part of the MNO Group, which employs roughly 500 people who make precision machine and automobile components [34]. Transmission gears and shafts, engine gears, and pump gears are all manufactured by EFGT, which also produces propeller shaft components and assemblies, manifold housing, oil coolers, and covers for engines and transmissions for Original Equipment Manufacturers (OEMs). The company had low productivity, meeting the demand, and streamlining the process. The 5s helped to organize the workplace, and autonomous maintenance from TPM has helped improve the breakdown. Installation of standard containers and trolleys improved material availability and productivity, and a new layout designed reduced transportation time and motion. The lean manufacturing implementation focused on process improvement, not checking employee-based factors, forming teams, or employee training.

PQR organization specializes in the production of plastic bags and sheets to store explosives. It employs 25 people and operates on a combined inventory and shop floor space of 11000 square feet [35]. To make explosive-carrying bags of the specified gauge, the company performs five processes on raw material to manufacture the product: mixing, extrusion, printing, sealing, quality check, and packaging and shipping. The total lead time of the manufacturing process was 6.04 days, and the current total processing time is 46 minutes.

Table 1: Framework mentions about people considerations.

Framework	Employee's training	Employee engagement	Establish communication	Workplace Safety and Ergonomic risk	Check for employee commitment, change of management and assigning responsibilities before implementing LM	Deploy scorecards to check post LM implementation
23	X				X	
24	X					
25	X	X	X			
26						
12	X					
27					X	X
28					X	
29				X		
30					X	
31					X	
32						
33						

During sealing and printing activities, the cumulative idle time of workers and machines accounts for 25% of shift time. The mixing process produces 200 kg in 10 minutes, whereas the extrusion process produces 50 kg for one cycle. Due to the large disparities in cycle periods, there is discontinuous flow throughout the plant. Also, the extrusion machine does not operate at maximum capacity due to the lack of a helper. Lean implementation is needed to mitigate the problem of idleness and the resulting discontinuous flow. Two operators are assigned to extrusion and packaging due to the termination of the mixing process. The extrusion machine is currently operating at maximum output capacity, resulting in a cycle time of only 10 minutes. Unwanted inventory between the extrusion and mixing processes was removed because of the supermarket system's adoption. The overall lead time has been shortened to 6 days. The processing time has been slashed to just 26 minutes. The non-value-added time went from 55% to 9.54%, and value-added time improvement from 15% to 89.85%. The lean implementation was based on process improvement and not on employee-based factors.

Company A specializes in the research and development, manufacture, marketing, sales and service of low and medium voltage switchgear products [22]. The time required to finish the entire assembly process was tracked using the time study method. The entire operation was broken down into 302 motions, which took the operator around 62 minutes to complete. The team also discovered that the operator spent 34.46 minutes on non-value-adding (NVA) duties and only 27.15 minutes on value-adding tasks. Adjusting components, walking to hold parts, acquiring tools, getting parts, unpacking and disassembly, inspection, handling parts and tools, cleaning, and rework were all identified as NVA activities. Most of the waste (about 49%) came from walking, holding, and manipulating the parts and tools, according to these NVA times. The operator's distance travelled (251 meters), lack of proper tools, and poor product quality were the three main causes of significant waste. The organization focused on balancing workloads, workplace redesign, and installing trolleys at each workstation, which improved the NVA/VA ratio by 42%, and efficiency by 22%. The post-implementation of lean manufacturing is compared based on process efficiency and effectiveness but not on people-based factors.

Another use of lean manufacturing techniques is found in a textile company in southern India, a major player in the textile sector, and primarily deals with the manufacture of clothes [32]. The company has three sections those are: dyeing, weaving, and processing. The most significant characteristic in analyzing the current condition is the takt time which refers to the output rate required to meet a customer's deadline. The monthly demand is 900,000 m, which translates to daily demand of 26,670m. The organization runs on a 12-hour shift (1430 minutes). Working hours divided by demand will determine the value of takt time (i.e., $0.054 \text{ min/meter} = 3.28 \text{ s/meter}$). While current production is 550,000 meters, the processing time for one meter of fabric is 5.20 seconds. The running time is 1.65 times longer than the takt time, resulting in a 320,000 m deficit at the end of the month. The next step is to determine where time is lost; human error, system flaws, poor components, and inappropriate procedures contribute to problems. According to the data obtained, the factory's biggest concerns are excessive cycle times

(CT), a lack of uniformity, and employees' lack of job knowledge. The value stream mapping [32] helped identify the problem of high CT due to process breakdowns, high waiting times, high processing times, and setup times. Implementing tools 5s, kaizen, Poka-Yoke, quality circles, and Kanban system established continuous flow, standardized work, more throughput, and better inventory control. The lean manufacturing implementation used here is based on process improvement.

Business, economy, and crew seats are the three types of Aero seat products [36]. At the beginning of the flow, the long-cycle time is frequently seen at WS1. The low-quality rate was to blame for the incomplete or defective construction, which required reworking the assembled seat. Before WS7(workstation 7), the workspace was overburdened by a high WIP. Because of the lengthy preparation of the materials and tools, considerable setup durations occurred before shifting to a different seat reference (at WS1). In WS7, there were long wait times because the assigned resource became a bottleneck, preventing the flow from moving forward. These initial findings and the subsequent explanation of the deployed lean technologies form the foundation for improving product flow. A similar lean implementation [36] uses the VSM to identify the waste in the organization due to high cycle times, incomplete/defective parts, high WIP, and high set-up times. The implementation of cellular manufacturing achieves one-piece flow in the manufacturing. The production balancing achieved stable production and balanced cycle time. Standardized work and Poka-Yoke helped to reduce reworks. Single-minute exchange of die (SMED) was implemented to reduce setup time from 675s to 410s. The lean implementation case includes training employees about lean manufacturing, but it does not include assessing employee-based factors.

The lean implemented in another example [37] was used through process mapping to identify the 60% spent on travelling and waiting times. The value mapping showed that in 10 of the producing weeks, only 25% was value-adding. The Kanban and visual management systems have affected a 50% reduction in overall cycle time, a 25% increase in customer orders, and a 30%reduction in inventory. The value stream mapping and observation in another case [34] identified the problem of high CT due to process breakdowns, high waiting times, high processing times, and setup times. Implementing tools 5s, kaizen, Poka-Yoke, quality circles, and Kanban system established continuous flow, standardized work, improved throughput, and inventory control. The review of lean manufacturing case studies found diverse lean manufacturing applications in various manufacturing industries, meaning an absence of standardized implementation and selection of lean manufacturing techniques, which provides an opportunity to build a case for an operational excellence model. It also shows that lean manufacturing is often seen only as a toolbox when the practitioner focuses on implementing lean tools and not on people's perspectives about implementing lean manufacturing.

2.3 Studies conducted on comparison between lean and other approaches

This literature search comprised finding the papers and articles that have made theoretical and conceptual comparisons between lean manufacturing and other operational excellence approaches. The importance of this section is to observe the criteria used by the authors in those comparisons.

A theoretical comparison between lean and six sigma [38] identified the strengths and weaknesses of lean and six sigma using 18 comparison criteria. The criteria are “origin,” “applicability structure,” “focus, assumptions,” “primary effect,” “secondary effects,” “deficiencies,” “ease of implementation,” “managerial-level,” “effect on variability,” “major contributions,” “aspect of the process,” “lot sizes,” “production planning and control,” and “quality control.” The “focus” criterion explains how each method improves the organization; therefore, the focus is on improving the flow in lean manufacturing. In lean manufacturing, the target is to increase productivity. The primary and secondary effects cover the initial and subsequent changes. Reduction of the flow time and increase in process changes are primary changes; uniform process outputs, inventory reduction, and improved quality are secondary effects. Major contributions are pull-flow, takt time, production levelling, the single flow of parts, and the value stream mapping.

Another conceptual comparison [39] of lean manufacturing, six sigma, and the theory of constraint (TOC) was conducted using the factors of application deadlines, focus, assumptions, primary effect, the second effect, and criticism. A further comparison [40] of total quality management (TQM) and lean manufacturing examined the concepts of TQM and lean manufacturing found in the literature and then compared methods based on the criteria: “focus,” “learning and continuous improvement,” “process management techniques,” “fundamental concept,” “participation, methodological tools,” “primary effect,” “secondary effects,” “change introduced,” “implementation time,” and “critics.” The criterion “approach” is about the focus of implementing the methodology. In lean manufacturing, the approach is understanding customer value and waste elimination. The “fundamental concept” criterion for lean manufacturing is constantly improving the value created for customer's concept towards customers and suppliers by allowing them to pull value through a streamlined value stream. The “primary effect” of lean is reduced lead time, while the “secondary effects” are reduced inventory, increased productivity, and customer satisfaction. The comparison is conducted based on the improvement observed when both methods are implemented in the organization.

One study [41] observed an approach that followed lean implementation in different organizations. The comparison was based on the lean tools used and the expected results; the changes occurred, and the reaction to adopting lean policies was noted. The lean implementation process monitored the lean culture, improvement teams were formed, and lean coordinators were considered during implementation. Another study [42] compared lean manufacturing, six sigma, and the theory of constraint (TOC) by

examining the available literature on these methods. The comparison was conducted using 28 comparative criteria, ranging from “source,” “assumptions,” and “ease of implementation” to “requirements” for implementation. The comparison study also covers comparative criteria “focus” (explains the purpose of implementation of lean manufacturing, TOC and six sigma), “strategic objectives” (goals that help a company define an overall vision, set goals, and measurable steps to attain the desired conclusion), “primary effects” (the initial changes that occur when implemented in any organization), “side effects” (long term effects observed when implemented in the organization). The “side effects” (immediate effect after lean is implemented) of implementing lean manufacturing are uniform process outputs, reduced inventory, and improved quality and productivity. “Major highlights” (the major tools that each method has provided) cover pull, takt time, one-piece flow, and value stream mapping. “Application structure” is the application of each method), and “leadership style” is the type of leadership required for implementing lean. The “capacity planning” criterion refers to lean manufacturing’s focus on finite capacity planning. The “data requirements” for lean manufacturing are the amount and accuracy of data that is critical for traditional production methods. The distribution of knowledge about lean means the previous cases of lean manufacturing implementation in the reduction of waste. Comparison is about the dominant culture aspect and type of leadership required when the methods are implemented in the organization.

This paper explores the possibility of implementing lean manufacturing and six sigma in the pharmaceutical industry by identifying the differences and similarities of both methods [43]. The criteria the authors have proposed are “objective” (the motive of implementing the methods) and “improvement” (the changes observed is continuous and simultaneous when lean manufacturing is implemented in the organization). Another study [18] compares the difference between lean and six sigma by studying the literature to highlight the similarities and differences of each method. The criteria developed were “theory,” “process view,” “primary effect,” and secondary effects.” The “primary effect” is observed when lean is implemented to improve customer satisfaction, and the secondary effect is improving customer satisfaction and operational performance.

Lean Manufacturing has been compared with different OPEX techniques using the criteria collected from the literature in the field. This provides an opportunity to compare lean manufacturing with an operational excellence model in which every method of comparison is seen from the process improvement perspective.

2.4 Research Gaps

1. There are numerous frameworks to implement lean in the organization, but it does not have steps to implement it and people's consideration to be a part of the improvement process is absent.
2. There are many cases of lean manufacturing implementation, and this provides an opportunity to build case studies for an operational excellence model.
3. Lean manufacturing is being compared with different operational excellence philosophies using the criteria. Thus, providing the opportunity to compare lean manufacturing with an operational excellence technique.
4. Lean manufacturing is often used as a toolbox and not seen as a philosophy leading to failing to address people's needs. Thus, there is a requirement for a framework that considers both the people and process as part of the improvement process.

3 CHAPTER THREE METHODOLOGY

3.1 Overview

This chapter provides the methodology to address the research gaps in the literature. First, in introducing the People-Centric Operational Excellence Model (PCOM), the PCOM considers people as a part of the improvement process and mitigates the absence of frameworks that consider people as a part of improvement. Second, this chapter provides the People-Centric Operational Excellence Model (PCOM) template. It mitigates a gap in the literature by providing operational excellence steps that are absent from the frameworks. The PCOM model has been implemented in various application sectors, and none of the case studies has been reported in the literature. According to the literature, lean manufacturing has case studies of its application in various industries. Based on this opportunity, the methodology chapter will take the first step in documenting the cases of application of PCOM in multiple sectors. The information was collected by surveying the PCOM practitioners. The questions for the survey were based on the template created for the PCOM. Lean manufacturing is compared with other operational excellence techniques with the help of the criteria derived from the literature. This has provided an opportunity to compare PCOM with lean manufacturing. Based on the criteria, the conceptual comparison is presented between lean manufacturing and PCOM. The results of the conceptual comparison identified the strengths and weaknesses of both methods. Based on the effective aspects of both approaches, a new model has been proposed, one that provides scope for implementing the new model in different sectors.

3.2 Introduction to People-Centric Operational Excellence Model (PCOM)

PCOM proposes a framework to guide and sustain implementation policies while improving quality of life. The People-Centric Operational Excellence Model is divided into four major modules: (I) Defining the Problem, (ii) aligning effect for desired organizational outcomes, (iii) Reliability-Based Solution (iv) Aligning Employee Self Interest with Policies[21].

Modules 1- Defining the Problem

Module 1 of the PCOM sees organizations from a system perspective and focuses on identifying the organization's constraints to identify the problem. Next, it determines the constraint value stream within the constraint limiting system growth. In conjunction with the theory of constraint (TOC) philosophy, this analysis identifies the value stream and product family that most constrains system growth. The value stream is depicted as a precedence-based activity network diagram. The critical path in the value stream is the path that takes the most time to complete and is the best one to complete the process. Therefore, the model proposes identifying the critical path limiting the system's progress.

Then, the PCOM model proposes categorizing the process as stochastic, deterministic, or conditional. The categorization of the process will identify the nature of the system, and based on the categorization, prioritize the factors to be mitigated first. The deterministic, stochastic, and conditional processes have disruption, variational, and flow factors that must be mitigated according to the process categorization (Table 2). Therefore, based on the deterministic process, the disruption-based factors will be mitigated first, then the variation causing factors, and then flow-based factors. Similarly, in the stochastic process, the variation causing factors are mitigated first, then disruption-based factors and flow-based factors. The flow-based factors are mitigated first in the conditional process, then the variation-based and disruption-based factors. Thus, the model proposes identifying the constraint and the root cause of the problem[21].

Module 2- Aligning Effect for Organizational Needs

Module 2 of the PCOM identifies the performance indicators based on the identified problems. Module 2 of the PCOM proposes a systematic way of identifying the metrics and people-based metrics to identify the organization's progress. The PCOM proposes identifying the indicators based on reliability and employee-based factors such as employee motivation, engagement, stress, and culture. The process is identifying the leading indicators based on the categorization of the process; then classifying the leading indicators according to People, Material, Equipment, and Information (PMEI). The organization's cycle times and throughput are improved by improving the leading indicators. The lagging indicators are identified based on the requirements of the organization. The requirement could be in terms of capability, capacity, and improving people's quality of life[21].

Module 3- Reliability-Based Solution

Module 3 of the PCOM proposes to improve the organization by enhancing the reliability based on PMEI. The reliability mitigates the disruption, variation, and flow-based factors identified in Module 2 of the PCOM. The model focuses on improving the organization's reliability to establish a one-piece flow. Improving the reliability of a deterministic process will mitigate disruption-causing factors; improving the reliability of a stochastic process will mitigate variation-causing factors while reducing flow-based factors. The PCOM also suggests developing a solution that focuses on improving employee well-being[21].

Module 4- Aligning Employee Self Interest with the Solutions

Module 4 of the PCOM proposes improving the employees' quality of life by focusing on the people. The model recommends checking the people-based factors such as employee motivation, engagement, and culture based on the introduced policies. This is achieved by ascertaining whether employees are getting fair compensation, whether they have work-related stress, checking if the policies affect their engagement and if the

policies affect the workplace culture. If these factors are affected by the policies, the model proposes improving the policies that ease the effects on employee-based factors[21].

3.3 Template for the People-Centric Operational Model

3.3.1 Process followed for Building the template for PCOM

This methodology proposes the People-Centric Operational Excellence Model template to address the lack of frameworks in the literature that provide operational excellence steps. The goal is to gain knowledge about the model found in PCOM-based research papers [52, 53] and reports on industry projects. The aim of reviewing these documents was to understand the objectives, concepts and tools included in the model. Information on PCOM principles and outtakes on how the PCOM helps to achieve operational excellence was gathered through discussions with PCOM experts. The People-Centric Operational Excellence model has adopted and proposed numerous concepts. These concepts (O) are broken down into a series of logical components (C), each of which is made up of steps (S) that are direct actions to implement PCOM (Figure 2).

The People-Centric Operational Excellence Model has incorporated standard tools from different OPEX techniques. The standard techniques are those that are widely used in a variety of organizations and forms and have predefined steps, which are documented in the literature

The standard techniques are adopted from lean manufacturing, theory of constraints (TOC), and operational excellence techniques. It is necessary to know how to write the concepts, components, and steps for the PCOM model. These steps are the key to implementing the PCOM. The instructions below are followed to write the steps for the outline [44]:

1. Writing that is clear, concise, and easy to understand.
2. A complete understanding of the process, including all technical details.
3. The ability to put yourself in the reader's place; the person is trying to use your instructions.
4. The ability to imagine the process in-depth and write down what you see.

3.3.2 People-Centric Operational Excellence Model's relationship to Critical Problem Solving

"The ability to analyze facts, generate and organize ideas, defend opinions, make comparisons, draw inferences, evaluate arguments, and solve problems is referred to as critical thinking [45]." The authors in [46] have defined critical thinking characteristics as asking questions, defining a problem, examining evidence, analyzing assumptions and biases, avoiding emotional reasoning, avoiding oversimplification, and considering other interpretations.

Table 2: PCOM prioritization based on process classification[21]

Process	Disruption	Variation	Flow
Deterministic	1	2	3
Stochastic	2	1	3
Conditional	3	2	1/4

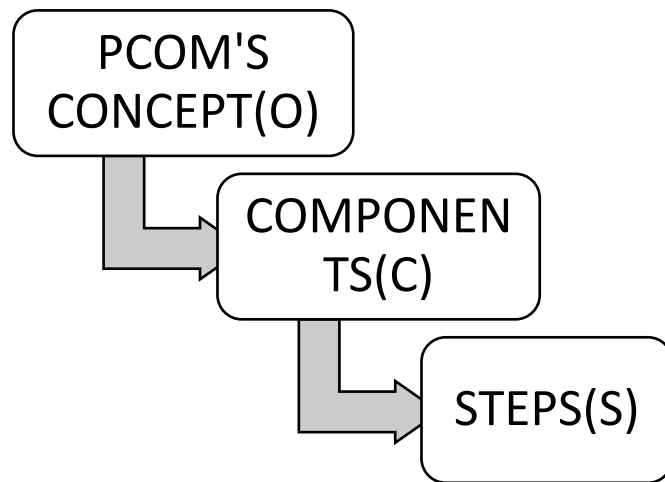


Figure 2: PCOM Categorization

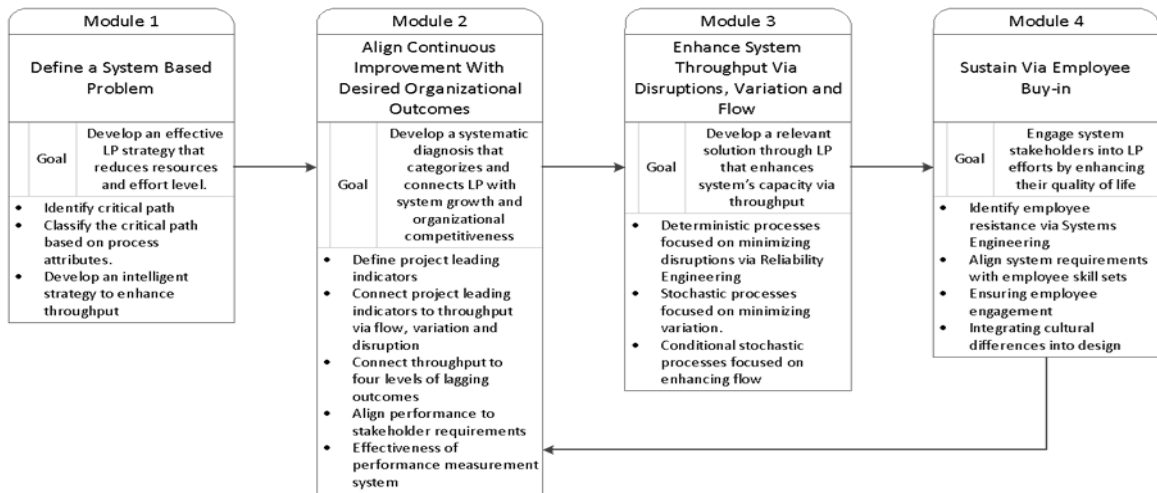


Figure 3: PCOM relation with critical problem solving[21]

Critical problem solving proposes to solve the problem, and the PCOM proposes solving the problem by improving the system's reliability based on people, equipment, material, and information (PMEI). Module 3 of the PCOM proposes mitigating the problem based on improving the system's reliability, so the Template for Reliability-Based Solution proposes steps for Module 3 of the PCOM. Module 4 of the PCOM investigates the long-term sustainability of the developed policies and suggests that organizations to focus on improving people's quality of life by focusing on employee engagement, motivation, and meeting their needs. This is how the PCOM views critical problem solving, and the section that follows will go over the modules in detail and the template created for each. Figure 3 shows the relationship between PCOM and critical problem-solving.

3.3.3 Template for Defining the Problem

3.3.3.1 Importance of Defining the Problem

According to the PCOM, determining the root cause of a problem aids the organization in determining the appropriate improvement policy. This enables the organization to devote adequate time and resources to the improvement policy, thereby improving the company's overall performance. Module 1 of the PCOM, "Template for Defining the Problem," focuses on identifying the problem.

Module 1 of the PCOM model is divided into six parts. The first part, "Define the Constrained Business Function," focuses on determining which business function restricts the system's growth. This section adopts TOC (Theory of Constraint) concepts, viewing the entire organization as a system. Then it determines the system's function and identifies the goals. Elements of the system architecture plan, organize, manage, and control system resources like equipment, materials, people, information products, processes, and departments. The model identifies the organization's constraint once the function and goals have been identified [47]. The second part is "Define the Constrained Value Stream" identifies the constraint value stream that limits the system's growth within the constraint business function. The model instructs users to determine the product family and value stream in the organization that is causing the constraint [48].

In the third part, "Define the Critical Path," two fundamental principles are used to determine the critical path of the value stream. First, employing network analysis determines the critical path of the constraint value stream. Second, the critical path is represented using the value stream mapping concept (VSM); the value stream is depicted as a precedence-based activity network diagram. The critical path in the value stream is the path that takes the most time to complete. As a result, the model proposes identifying the critical path that limits most system growth [48]. The fourth part, "Define the Bottleneck," aims to find the bottleneck process from the critical path. The PCOM emphasizes the identification of multiple bottlenecks, referred to as floating bottlenecks, which are those that change location over time due to disruption, variation, and flow in the manufacturing environment. The concept of floating bottlenecks emerges when the

period for bottleneck analysis is reduced. To determine the floating bottlenecks, the production mix, production sequence, and process times are required for the production sequence to be processed on the critical path. The PCOM template is built using the concept of critical problem-solving. Identifying the problem is the first step in critical problem-solving, and the PCOM identifies a problem by identifying constraints and determining the root cause. Then, it proposes identifying the nature of the process and prioritizing the factors that must be mitigated based on its nature (Table 2). Module 1 of the PCOM focuses on defining the problem by identifying constraint bottlenecks and prioritizing bottlenecks to be resolved. The “Template for Problem Solving” is based on module 1 of the PCOM, and it provides steps to implement module 1 in the organization.

Examining evidence and analyzing assumptions is part of critical problem-solving, and the PCOM investigates the evidence and analyzes the assumptions by identifying metrics based on the identified problem and organizational requirements. In the fifth part, “Categorize the Critical Path,” the critical path improvement strategy is chosen based on whether the critical path is a deterministic, stochastic, or conditional process. This classification is based on three critical path attributes: certainty in the process steps, the level of process time variation, and the likelihood of disruptions.

The deterministic process has a high level of certainty in the sequence of process steps and a low level of variation in processing time. Flow in this category is built into the process and the equipment.

The stochastic process has a high level of uncertainty in the sequence of process steps and a moderate to a high level of variation in processing time. The steps of the process are well-known and repeatable.

The conditional process has a low to moderate level of certainty in the sequence of process steps and a high level of variability in processing time. Conditional process flow is determined by the route and process times associated with the product/service[48].

The practitioner must identify the factors and generate an improvement plan based on the process classification. If the process is deterministic, the goal is to keep the disruption to a minimum. Similarly, the stochastic and conditional processes aim to reduce variation while improving process flow. Even though the strategies are interdependent, each strategy is considered independent in identifying the key drivers for throughput enhancement [48].

In the sixth part, “Identify the Performance Metrics,” the indicators are based on the categorization of the critical path of the key-value stream. A deterministic critical path aims to improve product reliability and thus availability by minimizing bottleneck disruptions. Three major types of disruption are considered in this regard: disruptions caused by maintenance, setups, and quality concerns. The goal of stochastic critical paths is to improve reliability by lowering variation. Personnel-based, material-based, equipment-based, and information-based variations are the sources of variation. Finally,

there are conditional critical paths to consider. The goal, in this case, is to avoid ripple effects caused by variation or disruption. The ripple effect can be explained as one failure causing it to stall all the other processes in the system [48].

The module proposes non-system-based methods, such as TOC, VSM, and six sigma, to define the problem of implementing the traditional lean concept [48]. The template can identify floating bottlenecks in the production line under study by utilizing process categorization and system-based solution strategies. The template is going to help from people perspective by proposing a systematic way to establish the problem, identify the root cause of the problem, and prioritize the problem must be mitigated first.

3.3.3.2 Outline for the template for Defining the Problem

Concepts and components in the first module included in the outline

The module one concepts are as follows:

- O1 Physically Locating the Constraint.
- O2 Categorize the Critical Path.
- O3 Develop the Strategy.

List of all the components

- C1 Identify the Organizational Function that is Constraining the Growth of the Organization.
- C2 Generating the Constrained Value Stream Map.
- C3 Generate the Critical Path Diagram of the Constrained Value Stream Map.
- C4 Classify the Critical Path.
- C5 Prioritize the Factors According to the Classification.

Steps for the first module in the Template

Module 1 Template-Template for Problem Solving

O1 Physically Locating the Problem.

C1 Identify Organizational Function that is Constraining the Growth of the Organization

- S1 Locate the constraint, which is limiting in the organization.
- S2 Interview the hierarchy to information of the constraint.
- S3 List all the processes which are involved in the system.
- S4 List all the dependencies between the process.
- S5 Estimate the time required to complete each process in the system.

C2 Generating the Constrained Value Stream Map

S6 Identify the product mix and processes.

S7 Collect process data i.e., cycle times, inventory data, Actual work time versus unused/wait time, Unnecessary movement (of items, material, and workers), scrap rate, etc.

S8 Add data and generate times lines of the map which represent process time, inventory, and total lead time.

C3 Generate the Critical Path Diagram of the Constrained Value Stream Map

S9 Draw the network diagram of the constraint value stream map.

S10 Estimate the activity duration of every process.

S11 Identify the processes which have the highest cycle time or queue timing.

S12 Identify the highest cycle time or queue timing station as the bottleneck station and the second-highest cycle time station as the floating bottleneck.

O2 Categorize the Critical Path of the Constrained Value Stream Map

C4 Classify the Critical Path

S13 Deterministic process- predefined process, no product mix involved, fixed daily demand.

S14 Stochastic process- order requirement and the product mix are varied, processes involved in the production of product varies according to the time required to complete the process varies as per the product mix.

S15 Conditional process- the process depends on the product mix.

O3 Develop the Strategy

C5 Prioritize the Factors According to the Classification

S16 Deterministic process- the priority is to fix disruption, variation, and flow, respectively. The example could be equipment, unavailability, breakdowns, maintenance, quality issues.

S17 Stochastic process- the priority is fixing variation, disruption, and flow. The example of metrics could be product mix, no standard operating procedure

S18 Conditional process- the priority is to fix flow, variation, and disruption respectively. The metrics could be based on the type of work that arises and the requirements. The metrics will be based on job shop work environment or emergency room.

3.3.4 Template for Aligning Effects to Organizational Effects

3.3.4.1 Importance of Organizational Effects

The second module of the PCOM is concerned with identifying appropriate indicators for the organization [49]. This module proposes determining which leading indicators can be used to measure the desired outcomes of the system (lagging indicators). In establishing lagging and leading indicators, this module addresses the balance between a system designed to optimize operational parameters (the perfect operational system) and a system that focuses its operation on the people involved (the perfect people system). The template for module 2 is "Template for Aligning Effects to Organizational Effects."

Module 2's main goal is to identify performance metrics based on the identified problem. The first step is to identify the leading indicators based on the factors identified in module 1. Leading indicators assess change; they address development and are easier to manipulate but much more difficult to quantify. It is considered that the PCOM proposes identifying leading indicators based on reliability. The PCOM divides reliability into four components: people, materials, equipment, and information (PMEI). The reliability of PMEI is critical in establishing and maintaining methodology in the company. A reliable system aids in achieving desired production outcomes, and it depends on four factors: PMEI [47]. The identified leading indicators are classified as disruption-causing factors, variation-causing factors, and flow-based factors. The disruption-causing factors, variation-causing factors, and flow-based factors are then further classified as PMEI. As a result, if the factors identified in Module 1 are due to disruption, leading indicators in Module 2 will be based on disruption-causing factors. The cause of the disruption is then classified into PMEI based on the factors that caused it. For instance, if the disruption results from people, the identified leading indicators will then be based on people. Similarly, equipment, materials, and information are used. The same procedure will be used to identify variation-based and flow-based factors.

According to the model, throughput analysis is critical in determining the system's leading indicators. It is understood that a higher throughput allows organizations to increase their capacity to achieve the specified lagging outcomes (organizational outcomes). Throughput is improved by managing the process cycle time. Little's Law adopts the throughput and process cycle time theory. The system's effectiveness plays a vital role in achieving the desired cycle time, and effectiveness depends on reliability and flow. Therefore, the leading indicators will improve the reliability and flow of the process[21].

The leading indicators are chosen to improve the cycle time and throughput of the process.

The second part of module 2 is identifying the lagging indicators for the organization; lagging indicators are used to monitor a project's progress, which implies that they are a direct product of the company's activities. Lagging indicators are simple to calculate but challenging to boost or influence. The PCOM has four levels of lagging indicators that emphasize organizational needs, such as capacity and capability, while focusing on people's quality of life. The first level reflects the company's increased ability to meet the production requirement. At level two, the optimized capacity improves the system's financial performance (i.e., profitability). At level three, the company's improved financial condition enables it to expand in the market. Finally, at level four, growth must positively affect the system's environment (i.e., credibility, people's quality of life). Key leading indicators must perfectly complement and endorse these lagging outcomes.

The template addresses the balance between a system designed to optimize operational parameters (the perfect operational system) and a system that focuses its operation on the people involved in the construction of lagging and leading indicators (the perfect people system). The template for Aligning Effects to Organizational Effects will help people by providing a systematic way to identify the metrics linked to the problem identified. The proposed metrics also propose to have reliability metrics in the leading metrics and consider people-related metrics in the lagging indicators as an output of the project. This will help the practitioner build a people-centric solution to meet the objective.

3.3.4.2 Outline for Template for Aligning Effects to Organizational Needs

Concepts in module two concepts are as follows

O4 Identify the Performance Metrics.

The components in the concept

C6 The Leading Indicators Based on the Bottleneck Station.

C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators).

Steps for each concept and its components in the second module in the outline

Module 2 Template or linking effects with the Organizational Need

O4 Identify the Performance Metrics

C6 The Leading Indicators Based on the Bottleneck Station

S19 Identify and classify the disruptions causing factors into the following category:

Equipment-equipment unavailability, breakdowns, maintenance, meantime in failures, mean time between failures, setup time, quality defects

Material- Material unavailability, material quality issues.

Information- Unavailability of Schedule

People- Absenteeism

S20 Identify and classify the variation causing factors in the bottleneck process

Material- interarrival times of material

Equipment- difference in process time due to product mix

People- difference in process time due to task based on product mix

Information- scheduling of the process

S21 Identify the conditional process factors into the following category.

S22 Prioritizing these specific factors as the leading indicators as per the classification of process and emphasizing on decreases cycle time and increasing throughput

C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators)

S23 Choose Lagging Indicator based on level 1: operations limitations

1. Capacity
2. Capability

S24 Choose Lagging Indicator based on level 2: operation performance

1. Reduce cost
2. On-time delivery
3. Stress reduction

S25 Choose Lagging Indicator based on level 3: competitive status

Increase in market share

S26 Choose Lagging Indicator based on Level 4: reputation

1. Improved reputation in the market
2. Improved in quality of life

3.3.5 Template for Reliability-Based Solution

3.3.5.1 Importance of Reliability-Based Solution

Module 3 proposes to build an improvement plan by improving the reliability of the process [49]. Developing a strategic plan of improvement starts by calculating the system's reliability. Reliability is calculated according to PMEI (people, material, equipment, and information). Developing a strategic plan of improvement starts by calculating the system's reliability calculated according to PMEI). Developing a solution demands a clear understanding of performance metrics (leading indicators) to enhance based on the process attributes (i.e., deterministic, or stochastic or flow). First, in developing the solution, the failure modes are identified based on PMEI. Second, the failure data is analyzed to identify the lowest reliability based on PMEI. Stabilizing follows according to the identified process attributes. The process categorized as deterministic is enhanced by minimizing its disruptions, such as machine breakdowns, disruptions are reduced, the cycle time of the process is reduced as well, and the result provides a solution in which equipment is available during the specified time, on the other hand, processes that were categorized as stochastic are stabilized by minimizing their variation that propagates in subsequent processes. Similarly, for the processes categorized as conditional, the proposed solution is enhancing the flow in the process[21]. The template for “Reliability-Based Solution” provides the steps to identify the reliability of the process. Module 3 proposes to build solutions that include people-related factors such as employee motivation, engagement, and culture.

3.3.5.2 Outline for Reliability-Based Solution

The module three concepts are as follows

O5 Calculating the Reliability of the Process.

O6 Propose the Strategy.

The components in the concepts

C8 Identify the Failure Modes.

C9 Identify the Lowest Reliability.

Steps for each concept and its components in the third module in the outline

Module 3 Template for Reliability-Based Solutions

O5 Calculating the Reliability of the Process

C8 Identify the Failure Modes

S27 Collect Failure data based on

Material reliability- material failure, quality, and unavailability.

Equipment reliability-equipment failures and unavailability.

People reliability-people errors and unavailability.

Information reliability- information flow and unavailability.

C9 Identify the Lowest Reliability

S28 Identify the Distribution followed by the data and calculate the reliability based on the failure data identified in S27.

O6 Propose the Strategy

S29 Build the strategies to improve factors to improve the lowest reliability.

3.3.6 Template for Aligning Employee Self Interest with Solution

3.3.6.1 Importance of the Aligning Employee Self Interest with Solution

According to Module 4, the key to developing a sustainable practice is balancing the ideal operating and people systems. While implementing policies, the model suggests considering organizational culture, national culture, people's engagement, motivation, and stress. The model proposes five levels to assess people's motivation, engagement, and culture; the first two levels are assigned to assess employee motivation by determining whether the employee has job security, is receiving compensation, has social security, and the workplace is safe[21]. Employee engagement is assessed at levels three and four by determining whether the employee has workload stress and believes they are valued in the organization, respectively[21]. The fifth level involves deciding whether the work culture and national culture have been impacted, which can be used to determine whether the employee believes they can advance professionally within the organization[21]. The model does not include definitive steps to assess culture, stress, and engagement, and more work is needed to include definitive steps to assess behavioral factors in the model. The following studies have focused on the PCOM emphasis on these people-behavioral factors.

Methods of aligning organizational culture, national culture, people's engagement, motivation, and stress while implementing the policies with solutions are determined by the impact of national culture in the organizations and how culture can be integrated into the organizational system's design to achieve operational excellence [55]. The employees' ergonomic risks have been evaluated and the jobs reassigned to reduce the ergonomic risk factors such as force, posture, and repetition [56]. A model to minimize the unequal workload distribution has also been developed [57]. The model determines

whether there is a relationship between subjective fatigue and employee work engagement [58]. The result showed that, although there is a connection between subjective fatigue and employee engagement, there is no unidirectional causality between the two. The goal of the template in developing a sustainable practice is to strike a balance between the ideal operational system and the ideal people system. The template includes a checklist for gathering feedback on whether the policies developed are appropriate for both the organization and the people.

3.3.6.2 Outline for the Aligning Employee Self Interest with Solutions

The module four concepts are as follows

O7 Employee Motivation.

O8 Employee Engagement.

O9 Company and National Culture.

The component of each concept

C10 Check for Employee Motivation at Different Levels.

C11 Check for Employee Engagement at Different Levels.

C12 Check for Company and National Culture at Different Levels.

Steps for each concept and its components in the fourth module in the outline

Module 4 Template for Aligning Employee Self Interest with Solution

O7 Employee Motivation

C10 Check for Employee Motivation at Different Levels

S30 Determining these factors at different levels

Level 1

Does the employee have fair compensation?

Does the employee have job security?

Level 2

Does the employee have physical safety in the plant?

Does the employee have professional safety?

Does the employee have social safety?

O8 Employee Engagement

C11 Check for Employee Engagement at Different Levels

S31 Determining these factors at different levels

Level 3

Does the employee experience balance of work-related stress and productivity?

Level 4

Does the employee find a sense of belonging and purpose in the organization?

O9 Company and National Culture

C12 Check for Company and National Culture at Different Levels

S32 Determining these factors at different levels

Level 5

Can the employee grow and lead?

3.4 Developing Survey Questions for Building Cases

3.4.1 Process followed to build the Survey Question and Conducting Survey

The PCOM is used in various industries, but no cases have been documented in the literature. According to the literature, lean manufacturing has numerous case studies of its application, which allows for developing cases for PCOM applications in various sectors. The survey will aid in developing PCOM case studies and carried out in collaboration with PCOM experts.

The first step is to determine the type of survey to be conducted from among the types of surveys [50, 51]. The One-to-One Interview survey type was chosen because it provides an opportunity to collect information directly from the participants and provide insight regarding the projects [51, 52]. The next step was to choose the type of questions suitable for the questionnaire. Open-ended questions encourage respondents to answer in free format, allowing them to communicate their full awareness, feelings, and understanding because the answer is not restricted to a collection of choices [53]. Open-ended questions were chosen for this questionnaire because the participants could freely share their opinions and experiences. It also allows participants to include as much context as possible while still allowing the researcher to ask probing questions as a follow-up [53]. While developing the questionnaire, these instructions were followed [54]:

1. Use of simple, familiar words.
2. Use of simple syntax.
3. Words with unclear meanings should be avoided.
4. Ask about one thing at a time.
5. Ask about one thing at a time.

The questions based on module 1 were created to understand the process followed to identify the problem and the tools used to determine the problem in the organization. The information extracted from these questions includes the types of processes involved in the organization and information on the company's problem. The questions in the second, third and fourth modules are procedural and based on the problem that was identified. The questions in the second module will provide information on the leading and lagging indicators identified based on the problem identified. Third module questions will provide information on the techniques used to mitigate the problem. The fourth module will provide information on the human behavioral factors considered and improved on when the policy is implemented. Thus, one can see more concentration of questions in the first module than in the rest.

The survey questionnaire has gone through six iterations. The survey questions have undergone several changes, including improved grammar, language, and the addition of questions required for data collection. The surveyed participants had extensive knowledge of implementing PCOM. The participant's responses were documented for the detailed study of the application of PCOM. The feedback received in the interview was marked as "positive" if the participant understood the questions and "negative" if they did not understand them. The negative feedback question is modified in the next version of the questionnaire. This approach was followed until all the questions were understandable to the participants, and they did not have any follow up question regarding it.

In-person interviews were conducted with PCOM practitioners to collect information from the participants on the projects that have implemented the PCOM. First, a detailed list of all projects that have used the PCOM was compiled. Then, all the people who worked on these projects were incorporated into the list. Following this sequence, an in-person interview was conducted sequentially for one project at a time and one member at a time. This sequence followed instructions for conducting this kind of interview [53].

1. Select a location that is free of distractions.
2. Describe the interview's intent.
3. Start by explaining the format of the interview.
4. Give an estimation of how long an interview normally lasts.
5. If they want to contact you later, tell them how to do so.

6. Before the interview begins, ask them if they have any questions regarding the interview.

Seven projects are presented using the survey results that have extensively applied the PCOM. The survey was conducted with PCOM experts, and a total of 10 PCOM experts were surveyed.

3.4.2 Connect the Survey Question to the Template

The template for module 1 of the PCOM is called "Template for Defining the Problem." It has three concepts: "O1 Physically Locating the Problem," "O2 Categorize the Critical Path of the Constrained Value Stream Map," and "O3 Develop the Strategy." In the concept "O1 Physically Locating the Problem," there are three components: "C1 Identify Organizational Function that Is Constraining the Growth of the Organization," "C2 Generating the Constrained Value Stream Map," and "C3 Generate the Critical Path Diagram of The Constrained Value Stream Map." The component "C1 Identify Organizational Function that Is Constraining the Organization's Growth" intends to identify the problem in the company, i.e., understanding the issues that are causing the organization not to meet its objectives. The questions are based on these components are "Q1 What is the problem faced by the company?" "Q2 How did the team identify the problem?" and "Q3 What is the study performed by the team based on the constraint identified?" The component "C2 Generating the Constrained Value Stream Map" intends to understand the waste identified using the value stream map. The questions based on this component are "Q4 What is the data required for charting the VSM?" and "Q5 What are the waste identified through charting the map?" Component "C3 Generate the Critical Path Diagram of the Constrained Value Stream Map," intends to understand the system's critical path and identify the organization's bottlenecks. The critical path is the most efficient way to complete the process and can aid in identifying the process with the longest cycle time. The bottleneck process is the one with the longest cycle time. The questions based on the component "C3 Generate the critical path diagram of the constrained value stream map" is "Q6 What is the Critical Path for the project?" and "Q7 What was the bottleneck of the system?"

In the concept "O2 Categorize the Critical Path of the Constrained Value Stream Map," there is one component, i.e., "C4 Classify the Critical path." The component intends to understand the nature of the process because it will help prioritize which factors have to be mitigated first. The question for this component is "Q8 What was the classification of the process?" In the concept of "O3 Develop the Strategy," there is a component "C5 Prioritize the Factors According to the Classification." The component intends to understand the initial prioritization of factors identified by the team that will be mitigated first and to understand how the action plan was formulated for mitigating the bottleneck and the reference material and guidance received from the PCOM to formulate the plan of execution. The questions based on this concept are "Q9 What was a strategy

developed to mitigate the bottleneck based on classification” and “Q10 What was the guidance provided to the organization by the team for implementing the strategy?”

Module 2 of the PCOM is based on identifying the performance metrics for the organization. The template for module 2 is “Aligning Effects to Organizational Effect (3.3.4).” There is one concept in the template, “O4 Identify the Performance Metrics,” with two components: “C6 The Leading Indicators Based on the Bottleneck Station” and “C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators).” Component “C6 The Leading Indicators Based on the Bottleneck Station,” intends to understand the leading indicator identified for the organization. The leading indicators will be used to observe the organization’s progress. Therefore, the question for the component is, “Q11 What are the leading indicators identified for the project?” The component “C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators)” intends to understand the organization’s requirements after the implemented policies. The questions for the component are “Q12 What are the lagging indicators identified for the project?” and “Q13 What are the people metrics considered to track the progress?” These questions help to understand the organizational needs; in addition, the people-related questions help to understand the different people-related metrics identified for the project.

Module 3 of the PCOM is based on proposing solutions to improve the organization’s reliability. The template for Module 3 is “Template for Reliability-Based Solution (3.3.5).” In the Module 3 template, the two concepts are “O5 Calculating the Reliability of The Process” and “O6 Propose the Strategy.” In the concept “O5 Calculating the Reliability of the Process” are components “C8 Identify the Failure Modes” and “C9 Identify the Lowest Reliability,” which intend to understand the reliability calculated for data acquired by the team and determine the lowest reliability by the team. The question formulated for these components is “Q14 What is the lowest reliability identified based on PMEI?” There is no component in the concept “O6 Propose the Strategy,” which intends to understand the strategy developed by the team to improve the lowest reliability identified by the team. The question for this concept is “Q15 What was the process followed to solve the problem?”

Module 4 of the PCOM proposes checking people factors such as people motivation, people engagement, and people culture when the policies are implemented. Its template is called “Template for Aligning Employee Self Interest with Solution (3.3.6).” It has three concepts: “O7 Employee Motivation,” “O8 Employee Engagement,” and “O9 Company and National Culture.” The questions for module 4 are more subjective because the model does not provide concrete steps to check these factors. Therefore, the questions are based on subjective outtakes from PCOM practitioners about whether they think they helped improve people’s motivation, engagement, and culture based on the policies they proposed for the organization. The concept “O7 Employee Motivation” has a component

“C10 Check for Employee Motivation at Different Levels,” which intends to understand whether the team thinks motivation improved when the policy was introduced. The question for this component is “Q16 Do you think the policy helped improve the motivation in the project?” The concept “O8 Employee Engagement,” has the component “C11 Check for Employee Engagement at Different Levels.” The component intends to understand whether the team thinks employee engagement improved when the policy was introduced. The question for this is “Q17 Do you think the policy helped to improve the engagement in the project?” In the concept “O9 Company and National Culture,” has a component of “C12 Check for Company and National Culture at Different Levels.” The question for the component is “Q18 Do you think the policy helped to maintain the culture in the project?” With this question, the team seeks to understand whether the company and national culture were affected when the policy was introduced.

There are a total of 18 questions in the questionnaire: ten questions for Module 1, three questions for Module 2, two questions for Module 3, and three questions for Module 4.

Table 3). These questions are also connected with the template shown in Table 4.

3.5 Developing Criteria for Evaluating Lean Manufacturing and People-Centric Operational Excellence Model

3.5.1 Building the Criteria

The comparison criteria were inspired by studying the literature in section 2.3 of the literature review chapter. Section 2.3 of the literature review chapter examines how lean manufacturing has been compared to other excellence models based on the criteria. The criteria helped to make a conceptual comparison of lean manufacturing and PCOM.

The comparison criteria were divided into "Paradigm," "Resources," and "Process." For this comparison study, "Paradigm" is defined as the motivation for implementing the new methodology in the organization and the changes that will result from its implementation. The definition of "Resources" is the material, workforce, and knowledge about implementing the method required to implement the methodology in the organization. The methodology used by the methodology to mitigate the challenges posed by the organization is defined as "Process."

The "Paradigm" has four criteria naming "Cr1 motivation," "Cr2 strategic objective," "Cr3 operational objective," and "Cr4 focus." The criterion "Cr1 motivation" was developed to observe why the methodology is implemented in the organization. This criterion "Cr1 motivation" is not mentioned in the literature study done for generating the criteria, but it is derived from the criterion named "theory" and "target" in the literature to compare lean manufacturing and six sigma [43]. The criterion of "theory" explains the purpose of implementing the methodology, and "target" explains the benefits that will be achieved when the methodologies are implemented in the organization. The criterion "Cr2 strategic objective" is defined as long-term organizational goals that help transform a mission statement into more concrete plans and policies. This criterion was used to observe the long-term goal of the methodology when implemented in any organization. This criterion has been compared to the theory of constraint (TOC), lean manufacturing, and six sigma [47]. The "operational objective" criterion is defined as the methodology's plan to execute weekly or monthly objectives. The criterion "Cr3 operational objective" was developed to observe the short-term goals of the methodology when implemented in the organization. The criterion "Cr3 operational objective" is not mentioned in the literature study done for generating the criteria, but it is derived from the criterion named "secondary effect." This criterion "secondary effect" has been employed in the literature to compare lean manufacturing and six sigma in [43] and "side effect" for comparing lean manufacturing, TOC and six sigma in [47]. The "Focus" is a defined process of accomplishing the broader goal(motivation) by eliminating difficulties and establishing a practice to achieve the desired goals. The criterion "Cr4 focus" is developed to understand the target of the methodology when it is implemented in the organization. This criterion is employed in

literature to compare lean and six sigma in [43], Also, in [44, 47] to compare the theory of constraint (TOC), lean manufacturing and six sigma.

The "resources" has three criteria: "Cr5 leadership," "Cr6 data requirement," and "Cr7 team requirements." The goal of these criteria is to understand the material needed to implement the methodology in the organization. The criterion "Cr5 leadership" observes the type of guidance skills that are expected. This criterion has been employed to compare TOC, lean manufacturing, and six sigma in [47]. The criterion "Cr6 data requirement" is developed to understand the typical information required when the methodology is implemented in the organization. The criterion has been employed to compare TOC, lean manufacturing, and six sigma in [47]. The criterion "team requirement" is to understand the requirement work team to implement the methodology in the organization. The criterion "Cr7 team requirements" is employed to compare TQM and lean manufacturing as "participation" in [45]. The criterion "improvement team" is used in [46] to observe the lean implementation in various organizations.

The "Process" has five criteria "Cr8 problem identification," "Cr9 KPI System," "Cr10 leading indicators," "Cr11 lagging indicators," "Cr12 continuous improvement," "Cr13 sustainability." The criterion "Cr8 problem identification" is developed to understand the methodology utilized to identify the bottleneck in the organization.

Table 3: Survey Question Based on PCOM template

Module 1	Questions
Q1	What is the problem faced by the company?
Q2	How did the team identify the problem?
Q3	What is the study performed by the team based on the constrain identified?
Q4	What is the data required for charting the VSM?
Q5	What is the waste identified through charting the value stream map?
Q6	What is the Critical Path for the project?
Q7	What was the bottleneck of the system?
Q8	What was the classification of the process?
Q9	What was strategy developed to mitigate the bottleneck based on classification
Q10	What was guidance provided to the organization by the team for implementing the strategy?
Module 2	Question
Q11	What are the leading indicators identified for the project?
Q12	What are the lagging indicators identified for the project?
Q13	What are the people metrics considered to track the progress?
Module 3	Question
Q14	What was lowest reliability calculated based on PMEI?
Q15	What was the process followed to solve the problem?
Module 4	Question
Q16	Do you think the policy helped to improve the motivation in the project?
Q17	Do you think the policy helped to improve the engagement in the project?
Q18	Do you think the policy helped to maintain the culture in the project?

Table 4: Linking Question with template

PCOM Template			
Module	Concept	Component	Question
Module 1	O1	C1.	Q1 Q2 Q3
		C2	Q4 Q5
		C3	Q6 Q7
	O2	C4	Q8
	O3	C5	Q9 Q10
Module 2	O4	C6	Q11
		C7	Q12 Q13
Module 3	O5	C8	Q14
		C9	
	O6		Q15
Module 4	O7	C10	Q16
	O8	C11	Q17
	O9	C12	Q18

This criterion “Cr8 problem identification” is not mentioned in the literature study done for generating the criteria, but it is derived from the criterion named “application structure” and “application guidelines” in [44, 47], respectively. In both papers, the comparison is conducted between lean, six sigma and TOC. Both the criterion explains the structures and how the problem is identified in the methodologies. The criterion “Cr9 KPI system” is to understand the process used by the methodologies to identify the performance indicators when applied in the organization. The criterion “key performance indicators systems (KPI system)” is derived from module 2 of the PCOM. This criterion has been employed to compare TOC, lean manufacturing and six sigma [47]. The literature studied for developing the criteria has used the criterion “indicators for performance measurement” for comparing the KPI system, but none of the papers has tapered the comparison based on leading and lagging indicators. The criterion “Cr12 continuous improvement” is adopted to understand the changes that will be observed when the methodology in the organization. The criterion has been employed as “primary effect” and “secondary effect” that has compared lean manufacturing and six sigma in [43, 45]. The “primary effect” and “secondary effects” shows the short term and long-term changes that occur when methodologies are implemented. The criterion is “Cr13 sustainability,” which is to observe how both the methodologies' outtakes to keep the policies in place once they are implemented. The PCOM's fourth module is intended to determine whether policies influence people's motivation, engagement, and culture. Examining whether policies improve people's quality of life. A total of 13 criteria were developed from the literature will be used to make a conceptual comparison between lean manufacturing and PCOM. shows the definition for every criterion. Table 5 presents the definition of the criteria.

3.5.2 Linking the Criteria with Template

The PCOM module template proposed various concepts to achieve operational excellence in the organization. Each module's template includes a clear objective of what needs to be done and explains the goal of using these concepts and components. The criteria have a connection to the template to provide the connection with the concepts and component of the PCOM template. The proposed criteria will help to make a conceptual comparison between lean manufacturing and PCOM. Table 6 presents the linking of criteria with the template. This is linked to module one because the component helps identify the organization's problem and helps identify goals when it is being applied in the organization.

The concepts of “Cr2 strategy objective” and “Cr3 operational objective” are based on the concept of “O3 Develop the Strategy.” The connection is made because the concept of PCOM is based on identifying the factors of disruption, variation, and flow, and based on the categorization, long-term and short-term goals can be identified. The criterion “Cr4 Focus” is linked to the component of “C1 Identify Organizational Function that is Limiting the Organization's Growth” in the concept of “O1 Physically Locating the Problem” of module 1 of the PCOM. This criterion addresses the methodologies' primary goal of

mitigating the constraint. The “Cr5 leadership” is based is linked to the component “C5 Prioritize the Factors According to The Classification” and the concept “O3 Develop the Strategy” justification for the linking with the concept is because this is where the team and the leader decide factors that must be mitigated first based on the process categorization. The criterion “Cr6 data requirement” is linked to the concept of “O2 Categorize the Critical path” and component “C4 Classify the Critical Path.” When this concept when applied in the organization, it requires this information about the organization to develop a plan for improvement. The criterion “Cr7 team requirement” is linked to the component “C1 Identify the Constraint” and concept of “O1 Physically Locating the Problem.” The justification for linking the criteria is because the team that will be identified will be based on the constraint identified.

The criterion “Cr8 problem identification” is linked to the entire concepts and component in module 1. As module 1 proposes the problem identification process for the PCOM. The criterion “KPI system” is linked to components “C6 The Leading Indicators Based on the Bottleneck Station” and “C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators),” which comes under the concept “O4 Identify the Performance Indicators” of module 2. The reason for the linkage is the criterion observes how the performance indicators are identified in PCOM. The criterion “leading indicators” and “lagging indicators are linked “C6 The Leading Indicators Based on The Bottleneck Station” and “C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators).”

The criterion “continuous improvement” is linked to the component “C8 Identify the Failure Modes,” “C9 Identify the Lowest Reliability,” and “O6 Propose the Strategy.” The component instructs to identify the lowest reliability based on PMEI and develop a plan to mitigate it. Based on the classification of the process, the other bottlenecks are mitigated to achieve one-piece flow. Thus, proposing a continuous effort to enhance the organization’s reliability and establish one piece. The criterion “Cr13 sustainability” is linked to the concept of “O6 Propose the Strategy” in module 3 of PCOM. The concepts that are connected to the criterion are “O7 Employee Motivation,” “O8 Employee Engagement,” and “O9 Company and National Culture.” Module four proposes to check whether the policy affects people’s motivation, engagement, and culture. The criterion is linked to module 4's concepts because it proposes to enhance the policies if any of the factors are affected. The concepts that connected to the “O7) Employee Motivation,” “O8 Employee Engagement,” and “O9 Company and National Culture.” A total of 13 criterion were developed from the template and used to build survey questions. Table 6 shows the connection between the criteria and the template.

3.5.3 Conceptual Comparison between Lean Manufacturing and the Sawhney Model

The conceptual comparison was categorized into three parts: Paradigm, Resources, and Process (Table 7). This comparison will provide information on the difference in perspective between lean manufacturing and PCOM and how each method attempts to

solve the problem while focusing on policy sustainability. The first section, “Paradigm,” provides information on how the methodologies will be used in the organization and contains information on the goals of each methodology, the approach each methodology will take to achieve the goals and the short- and long-term changes that will be observed when each methodology is implemented in the organization. The second section, “Resources,” provides information on each methodology's leadership and workforce requirements and the types of information on which each methodology relies to identify and mitigate problems. The information will establish a link between the comparison study's focus and the information requirements that will aid the methodologies in the comparison study's process of solving the problem in the organization.

The third section, “Process,” provides information on the actions taken by each methodology to address problems in the organization. As a result, this section's information covers the problem identification process, the performance metrics that will be identified when each method is used to identify problems, and the changes that will be observed when each method is used to implement and sustain policies. As a result, this section's information covers the problem identification process, the performance metrics that will be identified when each method is used to identify problems, and the changes that will be observed when each method is used to implement and sustain policies. Table 7 present the comparison between PCOM and lean manufacturing based on criteria.

3.6 Proposing the Comprehensive People-Centric Operational Excellence Model

3.6.1 Opportunities for CPCOM

Based on the conceptual comparison done in section 3.5.3, this section will highlight the shortcomings of both the methods in problem identification, key performance indicators system, problem-solving approach, and sustainability perspective. Table 7 summarizes the conceptual comparison; it shows the missing elements in both methods and the adopted elements proposed in the Comprehensive People-Centric Operational Excellence Model (CPCOM).

Problem Identification Process

Lean manufacturing has established a method for identifying the problem; however, the problem identification process in lean manufacturing does not always assist in determining the root cause. Lean manufacturing frameworks recommend forming a team to implement lean manufacturing, which is a step forward in implementing lean policies. It intends to train employees in lean manufacturing, and team members are aware of the tools and techniques used in the organization. The PCOM does not discuss team formation because it is assumed that the workers are skilled. The PCOM proposes identifying the constraint and then narrowing it by identifying the root cause of the problem, and its proposed classification aids in understanding the nature of the process,

allowing for the prioritization of factors that can be mitigated first. This will assist in prioritizing the issues that need to be addressed first.

Key Performance Indicators system

The KPI system in lean manufacturing lacks consensus about identifying metrics, and the PCOM has proposed steps for identifying performance metrics through linking the identified problem, the metrics for tracking the progress, and the metrics for addressing organizational needs. Furthermore, the PCOM proposes that people-related factors be included in organizational needs so that the improvement plan includes human-centric metrics as part of the improvement process.

Problem Solving Approach

Lean manufacturing has plenty of tools and techniques for process improvement scenarios. On the other hand, although the PCOM does not provide any tools to improve the system and must rely on lean manufacturing for building the improvement plans, it does propose improving the process's reliability perspective.

Sustainability

The PCOM proposes to examine sustainability but does not provide concrete steps to analyze these factors. Lean manufacturing has tools like Gemba Walks and Kaizen events that can be used to test these factors, but most lean implementation projects do not see these tools as being useful for establishing communication, explaining the benefits of implementing lean manufacturing and providing motivation for implementation. Instead, it is always used as a tool to analyze the organization's equipment and materials. As a result, lean manufacturing is frequently regarded as a tool rather than a philosophy.

Table 5: Criterion Definitions

Sr no	Criterion	Definitions
Cr 1	Motivation	The organization's desire or willingness to implement the PCOM.
Cr 2	Strategic objective	Strategic objectives are long-term organizational goals that help transform a mission statement into more concrete plans and policies.
Cr 3	Operational objective	The operational objective is the project's benchmarks that execute broader strategic objectives regularly, weekly, or monthly.
Cr 4	Focus	The process of accomplishing the broader goal(motivation) by eliminating difficulties and establishing a practice to achieve the desired goals.
Cr 5	Leadership	Leadership is a social influence mechanism that maximizes the contributions of others in the pursuit of a common purpose [59].
Cr 6	Team Requirement	teams and groups: (a) are made up of two or more people, (b) exist to execute organizationally related activities, (c) have one or more shared objectives, (d) communicate socially, (e) have job interdependencies (i.e., workflow, goals, and outcomes), and (f) maintain and handle boundaries [60]
Cr 7	Data requirement	The information is needed to identify the problem in the organization. The information collected from the problem identifying tools.
Cr 8	Problem identification	The problem identification is to identify the causes of delay in the organization by using tools and techniques.
Cr 9	Key performance indicators system (KPIs)	A measurable indicator of a company's, employee's, or individual's progress in achieving performance goals.

Table 5 continued

Cr 10	Leading indicators	Leading indicators assess change. They address development and are easier to manipulate but much more difficult to quantify. It is considered difficult because it requires the implementation of processes and tools to calculate them accurately.
Cr 11	Lagging indicators	Lagging indicators are used to monitor the progress of a project. This implies that they are a direct product or performance of the company's activities. Lagging indicators are simple to calculate but challenging to boost or influence.
Cr12	Continuous improvement	Continuous improvement is a method, not a single act. Therefore, it's a continuous task that must be completed over time. The quality improvement cycle should include everybody in the company. [61]
Cr 13	Sustainability	Sustainable manufacturing is characterized as the production of manufactured goods that have low negative environmental impacts, conserve energy and natural resources, are healthy for workers, communities, and customers, and are financially sound [62].

3.6.2 Framework for Comprehensive People-Centric Operational Excellence Model (CPCOM)

The proposed Comprehensive People-Centric Operational Excellence Model (CPCOM) incorporates tools and techniques from lean manufacturing and concepts from PCOM. The conceptual model is based on the problem-critical problem-solving principle. Thus, this model is divided into three sections: Define, Solve, and Sustain. The Define stage of the CPCOM represents the problem identification stage. It proposes a new problem identification procedure by combining the waste identification and team formation concepts from lean manufacturing with the system thinking perspective of the PCOM. The proposed problem identification process will be a systematic approach to identifying system and function constraints, assembling a team, determining the root cause of the constraint, determining the nature of the process, and ranking the mitigation factors based on the nature of the process. Solve represents the problem mitigation approach based on the identified problem, proposing seven improvement scenarios that suggest lean tools for each scenario and the improved reliability when implemented. Sustainability in the CPCOM proposes merging the lean tools of Gemba Walk and Kaizen events to check people-based factors such as motivation, engagement, and culture. Table 9 presents the approaches of all three methodologies and shows the key elements borrowed from both the methods for the Comprehensive People-Centric Operational Excellence Model (CPCOM).

3.6.2.1 Define

The proposed steps for “Define” part in the Comprehensive People-Centric Operational Excellence Model. Figure 4 depicts steps for the “Define” part for the CPCOM model

- Identify the system constraints.
- Identify the function constraints.
- Identify the processes that must be improved by assembling the work team.
- Identify the cycle times, throughput, and inventories data.
- Chart the current state value stream maps to identify the waste
- Identify the critical path of the key-value stream map.
- Classify the critical path of the key-value stream map.
- Prioritize the action according to the classification.
- Identify the key leading indicators.
- Identify the key lagging indicators.
- Present the action plan on A3

Table 6: Linking criteria with template

[illegible]

Table 7 Conceptual Comparison between Lean manufacturing and PCOM

	Criterion	Concept of Lean	Concept of PCOM
Paradigm	Motivation	Enhance operational competitiveness	Enhance and sustain operational competitiveness
	Strategic objective	The strategic objective is to reduce the cost, balance flow, and establish a practice.	Developing a culture that promotes and sustain capacity and capability
	Operational Objective	Improving the efficiency of the organization to increase the outputs and reduce resource utilization	Improving the reliability for stable production and focusing on improving employee well being
	Focus	Operational roadmap: elimination of waste	Critical problem solving: Align productivity and employee well being
Resources	Leadership	An effort to champion in implementing lean, focus on workplace development	Proposes to be the mediator of implementing the people-centric operational excellence model and serves as a servant leader
	Data Requirement	1. Inventory data 2. Nonvalue added to added time 3. Cycle times 4. Lot size data 5. Throughput	1. Failure data 2. Inventory data 3. Nonvalue added times to added time 4. Cycle time 5. Lot size data 6. Throughput 7. People data
	Resources availability	The cases of implementation, the countries they are implemented, the way they are implemented.	Case studies represent the implementation of PCOM.
	Team requirement	An essential part of implementing lean	The model proposes to have a skilled workforce to implement the people-centric operational excellence model
Process	Problem identification	1. Product family 2. Current state VSM 3. Future State VSM 4. Present the improvement plan on A3	1. System-level constraint 2. Function level constraint 3. Critical path identification 4. Critical path categorization 5. Key leading indicators

Table 7 Continued

	KPI system	The method to identify the performance indicators	The process to identify the leading and lagging indicators
	Lagging indicator	1. Competitiveness 2. Profitability 3. Revenue 4. Cost	1. Four levels of lagging indicators
	Continuous paradigm	Continuous improvement is through kaizen events and standardized work.	Continuous improvement through reliability
	Continuous improvement platform	1. Define problem. 2. Design Workplace. 3. Multifunctional team. 4. Standardize Work. 5. Design Flexibility.	1. System based problem definition. 2. Ensure organizational outcomes. 3. A reliable system reduces lead times via variation, disruption, and flow
	Sustainability	Continuous improvement	aligning organizational value to employee well-being
		The employee's motivation is the commitment, Enthusiasm for implementing lean manufacturing.	The employee's motivation is commitment, Enthusiasm for implementing the PCOM.
		Employee engagement refers to the level of mental and emotional attachment employees have to their jobs, teams, and company. ("The Impact of Effective Leadership on Employee Engagement")	Understanding the many demands of employees is the key to achieving employee engagement. At the same time, these requirements must consider stress reduction, skill development and alignment, and the ability to adapt to other cultures.
		The value such as culture, work culture, employee respect is considered in the improvement process	The employee alignment aligns the employee's value with the company's value to achieve the company's common goal.

Identify the system constraints

Identifying the system constraint is identifying the problems in the organization. This step is associated with the concept of “O1 Physically Locating the Constraint” in PCOM module one. This step provides a clear objective to the organization as it helps to locate the problem and focus on mitigating that problem and aims to identify the overall problem faced by the company.

Identifying the function constraint

Identifying the function is identifying the factors that are the causes of the problem identified in the previous step, identify organizational function that is constraining the growth of the organization. This step is associated with the PCOM Module 1 component “C1 Identify Organizational Function that is Constraining the Organization's Growth.”

Identify the processes that must be improved by assembling the work team

Based on the previous step, “Identifying the Function Constraint,” the team is formed with the members working in the departments or workstations where the constraints are in the organization. This step is associated with team formation in lean manufacturing. One study in [25] suggested that team formation is associated with employee training in lean manufacturing. Lean manufacturing and PCOM training will also facilitate a smooth implementation of lean manufacturing policies. In CPCOM, the team is formed based on the identified constraint and then training the team in lean manufacturing and PCOM concepts.

Identify the cycle times, throughput, and inventories data

This step is associated with lean manufacturing regarding collecting the organization's information that includes all the cycle times of the processes, the production rates, and the lot size data. As the critical data is available, it will be much easier to implement tools to identify the causes of problems in the system.

Chart the current state value stream maps to identify the waste

This step outlines how to chart the value stream map of the organization that will identify waste in the organization and will help present the system's current state and illustrate the waste in the system. This step is associated with lean manufacturing and is a standard tool to identify the waste problems of the organization. In the CPCOM, the value stream map will identify the numerous value stream map in the organization, illustrate critical information, and identify the waste in the organization.

Table 8: Missing elements in PCOM and LM

CRITERION	Motivation	Strategic Objective	Operational Objective	Focus	Leadership	Data Requirement	Problem Identification	KPI System	Leading Indicators	Lagging Indicators	Human Factors	Continuous Improvement	Sustainability
Lean Manufacturing	LM	LM	LM	LM	LM	LM			LM	LM		LM	LM
People-Centric Operational Model	PCOM	PCOM	PCOM	PCOM			PCOM	PCOM	PCOM	PCOM	PCOM		PCOM
CPCOM	LM+PCOM	LM+PCOM	LM+PCOM	LM+PCOM	LM	LM	PCOM	PCOM	LM+PCOM	LM+PCOM	PCOM	LM	LM+PCOM

Table 9: Comparison of methodologies followed by lean manufacturing, PCOM and CPCPCOM

	Lean Manufacturing	People-Centric Operational Excellence Model	Comprehensive People-Centric Operational Excellence Model
Problem Identification	Form a team Chart the VSM Identify the Waste Plan to eliminate the Waste	Identify the System and Function Constraint Chart the VSM Chart the Critical Path Classification the Critical Path	Identify the System and Function Constraint Form a team based on identified constraint Chart the VSM Chart the Critical Path Classification of the Critical Path Identify the leading indicators Identify the lagging indicators Present on A3
KPI System	Absence of a standard KPI system, but the metrics are based on identified waste	There is a systematic approach to identify the leading and lagging indicators	There is a systematic approach to identify the leading and lagging indicators based on PCOM
Solving the Problem	The policies implementation will be based on waste identified. There are plethora of tools for every waste identified in lean manufacturing	The process improvement process will be based on improving the system reliability based on PMEI. Adopts tools from lean manufacturing	The improvement process will be based on seven improvement scenarios, these will be adopting to lean tools according to the requirement and these improvements will also focus to improve the reliability of the system

Table 8 Continued

Sustainability	The sustainability-based standardizing the policies by training and utilizing tools such as Kaizen Gemba Walks, SOPs and 5s	The sustainability is improving the system's overall reliability by mitigating all disruption, variation, and flow in the system. In addition to that the model proposes to check the people's employee motivation, engagement and culture is affected when new policies are implemented	The sustainability will be integrating the Gemba walks to identify the concerns from the people about the policies in terms of motivation, engagement and cultures. The integration of the Kiazen events will provides training, establish communication and continous improvement effort to improve the estbalished policies
----------------	---	--	---

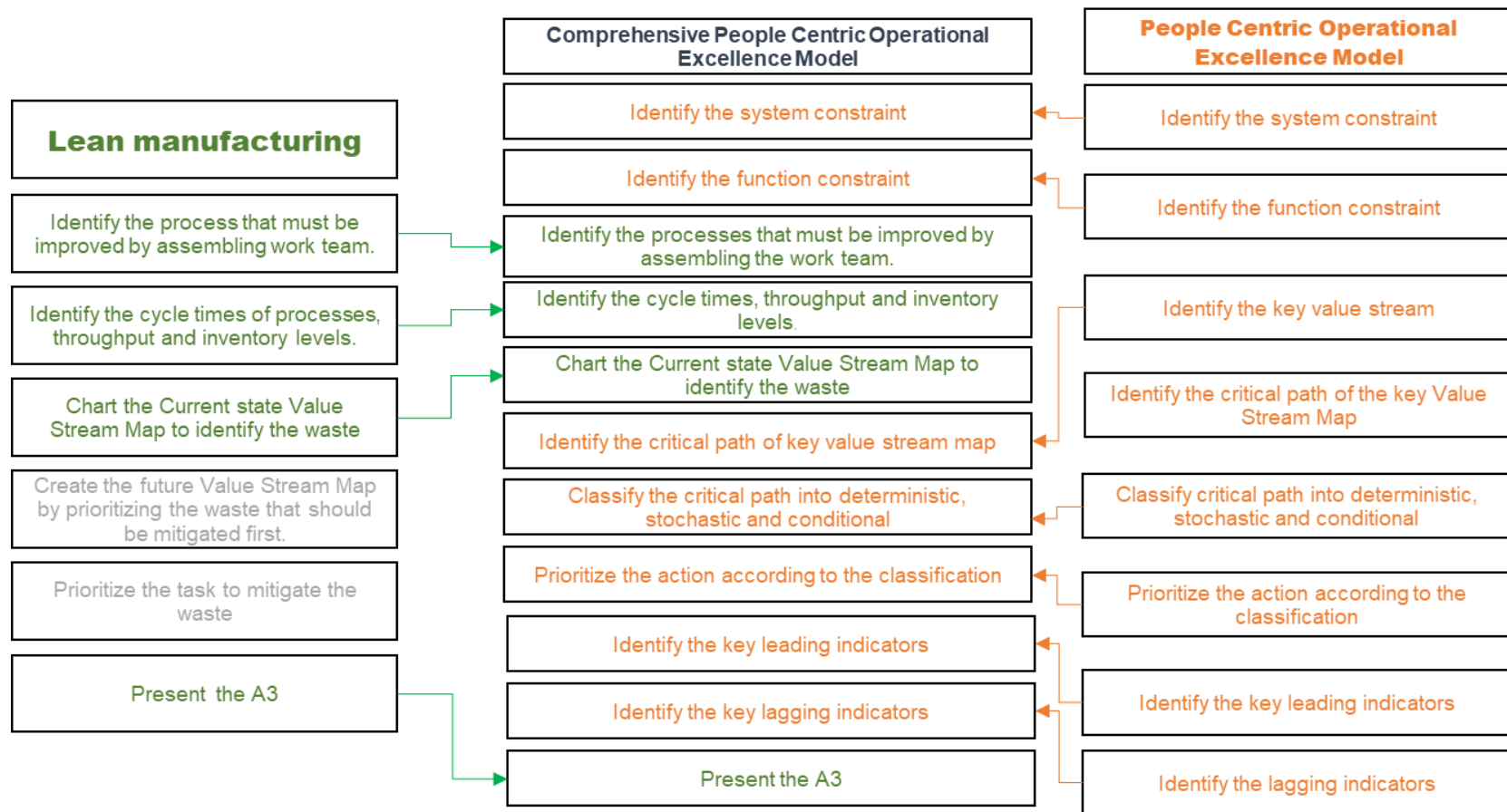


Figure 4: Define for CPCOM

Identify the critical path of the key-value stream map

This step is associated with the module 1 component “C3 Generate the critical path diagram of the constrained value stream map” by helping to identify the main path of production and bottlenecks in the key-value stream maps. This step of identifying the critical path assists in identifying bottlenecks and the best path to complete the process.

Classify the critical path of the key-value stream map

This step is associated with the concept “O2 Categorize the Critical Path of the Constrained Value Stream Map” in PCOM module 1 and helps to identify the nature of the system. The organization will identify the disruption, variation, and flow-causing factors based on the nature of the process. Therefore, the team can focus on mitigating the disruption, variation, and flow and come up with metrics to track the organization’s progress.

Identify the leading indicators

This step is associated with the component of “C6 The Leading Indicators Based on the Bottleneck Station” in the concept “O4 Identify the Performance Metrics Of PCOM” module 2. The step proposes identifying reliability metrics to improve the cycle time and throughput. As this step is adopted from PCOM, it proposes to track the metrics based on the reliability of people, material, equipment, and information, which track the system's reliability according to PMEI.

Identify the lagging indicators

This step is associated with the Module 2 concept of “C7 Focus on Improving the Leading Indicators to Achieve the Following Operational Goals (Lagging Indicators),” focusing on the team’s desired outcomes. These metrics propose a combination of metrics regarding organizational outcomes and building employee-friendly solutions.

Present the action plan using A3

This step is associated with lean manufacturing by laying the plan using the A3. It is adopted in the CPCOM to help the team present the constraint, root cause of the constraint, and the metrics and action plan proposed to mitigate the constraints. A step-by-step method for identifying constraints and metrics needed to track progress in the organization is established.

A step-by-step method for identifying constraints and metrics needed to track progress in the organization is established. The objective achieved is in the problem identification methodology from a system perspective to identify the root causes of the problem.

3.6.2.2 Solve

The CPCOM proposes an improvement plan in seven ways. The steps in the “Solve” section are intended to improve the organization’s reliability. Implementing the suggested lean tools and techniques depends on the organization’s requirements. The

proposed improvement scenarios improve the reliability of people, equipment, material, and information. Each proposed improvement scenario aims to improve at least one aspect of the organization's reliability. Figure 5 shows the representation of the “Solve” of the Comprehensive People-Centric Operational Excellence Model (CPCOM). Table 10 shows the possible reliability that could be improved in when the scenarios are implemented.

The following are the steps proposed for the “solve” part of the Comprehensive People-Centric Operational Excellence Model.

- Develop the work area
- Standardize work
- Stabilize the process
- Create agility
- Design Cell
- Production smoothing
- Focus on improving the flow

Develop the work area

The goal of developing the work area is based on reorganizing and redesigning the organization to reduce waste and is based on lean manufacturing; the tools used for these operations are 5s, Poka Yoke, and visual controls. This step could be used for the first part of the organization's improvement process by establishing a practice and creating workstations that are structured, clean, efficient, and effective. As a result, the improvement that occurs after this step is implemented will assist the organization in visualizing the process and establishing the practice in the organization. Thus, the organization can track its progress and develop plans to improve it further. When this step is implemented in the organization, the reliability of people, materials, and information will improve.

Standardize the workplace-

The goal of workplace standardization is to create a method that includes fixed instructions that must be followed to reduce waste and lead time in the organization and is related to lean manufacturing and standard operating procedures: Standard Operating Procedure, Mistake Proofing (Poka Yoke), and 5s are standardization techniques. This step could be used to improve the organization by providing a consistent way of working and saving people's time, thereby improving the system's efficiency, and shortening the lead time. As a result, when this step is implemented in the organization, the reliability of people, materials, and information will improve.

Stabilize the process

The PCOM improvement process begins with enhancing the process's reliability, which means improving in terms of people, materials, equipment, and information. This helps to improve process reliability but also helps to stabilize the process by ensuring the availability of required resources, ensuring smooth production and meeting customer requirements. The detailed instruction of the PCOM improvement process is presented in module 3, “Template for Reliability-Based Solutions.” The comprehensive model will

be utilized to improve the organization's process reliability according to the organization's requirement.

Create production agility

Production agility is the ability to produce different batches of products while reducing inventory size to reduce equipment wear and tear. This step is related to lean manufacturing; total productive maintenance (TPM) and single minute die exchange (SMED) are two tools used to achieve production agility. As a result of this step, it is possible to target smaller lot sizes, which allows for more frequent product changes due to faster changeovers and improves the life cycle of the equipment to meet customer demands. Equipment and information reliability will be improved because of the step's implementation.

Create cellular manufacturing environments

The workstations and equipment are organized to allow materials and components to flow smoothly through the manufacturing process with minimal transportation and delay. This step is associated with lean manufacturing and the technique used for cellular manufacturing. This establishes a new manufacturing practice to meet daily requirements, focus on meeting customer demands, and make processes more efficient, therefore improving equipment, material, and information reliability.

Production smoothing

Production smoothing is a technique for reducing Muda by minimizing Mura (waste). The concept is to produce intermediate commodities at a constant rate so that subsequent processing can also be done consistently. This step is associated with lean manufacturing, and Heijunka is a technique used for production smoothing. Material, equipment, and information reliability improve after implementing the technique. These levels of dependability are increased because the techniques allow for the flexibility to produce the required amount while focusing on a variety of products.

Focus on improving the flow

The goal is to have a constant stream of products that results in more consistent delivery and added value for customers, teams, and stakeholders. This step is related to lean manufacturing, and the techniques used to improve the flow are push, pull, and one-piece flow strategies. The overall improvement strategy will be to create new scheduling for manufacturing parts based on customer specifications. This step is based on lean manufacturing, and the reliability that will be improved is in the areas of people, materials, equipment, and information. Because the methodology aims to completely plan a new manufacturing schedule, it will change every aspect of the manufacturing process, so every part of PMEI will be involved in the improvement plan. As a result, efforts will be made to improve the dependability of all four components (PMEI)

Solve in the CPCOM achieves the following:

Combines the lean tools according to the objectives of implementation in the organizations

Focuses on improving the process according to the PMEI perspective when the lean tools are combined with reliability

3.6.2.3 Sustain

The steps implemented for the “Sustain” part of the Comprehensive People-Centric Model are:

- Deploy Gemba walks.
- Check the performance metrics based on people factors are considered.
- Deploy kaizen events and scorecards in the organization.
- Ensure employee motivation, engagement, and cultural alignment.

Figure 6 shows the representation of the “Sustain” of the Comprehensive People-Centric Operational Excellence Model.

Deploy Gemba walks

Lean manufacturing achieves sustainability by implementing different tools and techniques. The Gemba walk's goal is to identify opportunities to reduce wasteful activities and discover new ways to increase productivity. Gemba walk is a practice in which leaders are brought to the shop floor to observe processes as they take place. The tool ensures communication between the employees and addresses the problems that are identified in the manufacturing processes.

Check the performance metrics based on people factors are considered

This step is associated with module 4, “Template for Aligning Employee Self Interest with Solution.” The PCOM proposes considering employee motivation, engagement, and values while developing the policies. Therefore, the model includes people-related factors while identifying the performance metrics so that the practitioner will also focus on improving those factors. People-related factors include national culture, ergonomic workload, and workload stress, which can be considered in gauging the impact of national culture in the organization and how culture can be integrated into the organizational system design to achieve operational excellence [55]. The employee ergonomic risks have been evaluated, and the jobs reassigned to reduce the ergonomic risk factors such as force, posture, and repetition [56]. A model to minimize the unequal workload distribution has also been developed [57]. The model determines whether there is a relationship between subjective fatigue and employee work engagement [58]. The result shows that, although there is a connection between subjective fatigue and employee engagement, there is no unidirectional causality between the two. Thus, the developed policies focus on improving the process and improving the people-related metrics. As a result, the CPCOM proposes adapting this step of assessing people-related factors to focus on employee development. The goal is to collect people's opinions on the organization's policy and then ensure that the proposed policy does not increase ergonomic workload, stress, or impact the organization's culture. Thus, the use of Gemba walks identifies process constraints and checks the employee concerns about policies and techniques.

Deploy kaizen events and scorecards in the organization

This step is associated with lean manufacturing, and the kaizen events and scorecards form a continuous improvement effort to sustain policies by mitigating one problem at a time. Lean manufacturing is considered as a toolbox instead of thinking of it as a philosophy; therefore, in lean manufacturing implementation, people factors are not taken into consideration, which is also a reason that lean projects fail. The integration of kaizen events and scorecards in the CPCOM will establish a continuous improvement practice and check the people factors by proposing to train employees in the lean culture and adapt to the theory proposed by PCOM. In addition, it proposes motivating people by establishing communication between workers and management in the organization. It focuses on training, communication, and process improvement practices by implementing kaizen events.

Ensure employee motivation, engagement, and cultural alignment.

The incorporation of lean techniques will serve as a tool to determine whether these factors are considered. The kaizen events and scorecards will be implemented for training and communicating with the employees to satisfy customers, discuss policies, establish communication, and serve as a motivational workshop because all the benefits of implementing the methodologies will be explained to the team. As a result, the new method incorporates both people and process improvement perspectives. Furthermore, the organization will monitor the overall system's dependability by ensuring that the policies implemented are maintained as new practices.

3.6.3 Management Guidelines for Comprehensive People Centric Operational Excellence Model

Define

Identify the System Constraint

The system constraint step identifies where the problem is located by interviewing people and visiting the organization. This helps the practitioner become familiar with the problems in the organization and its work.

Identify the function constraints

The function constraint step identifies the specific workstations, departments, and functions hindering the organization's progress.

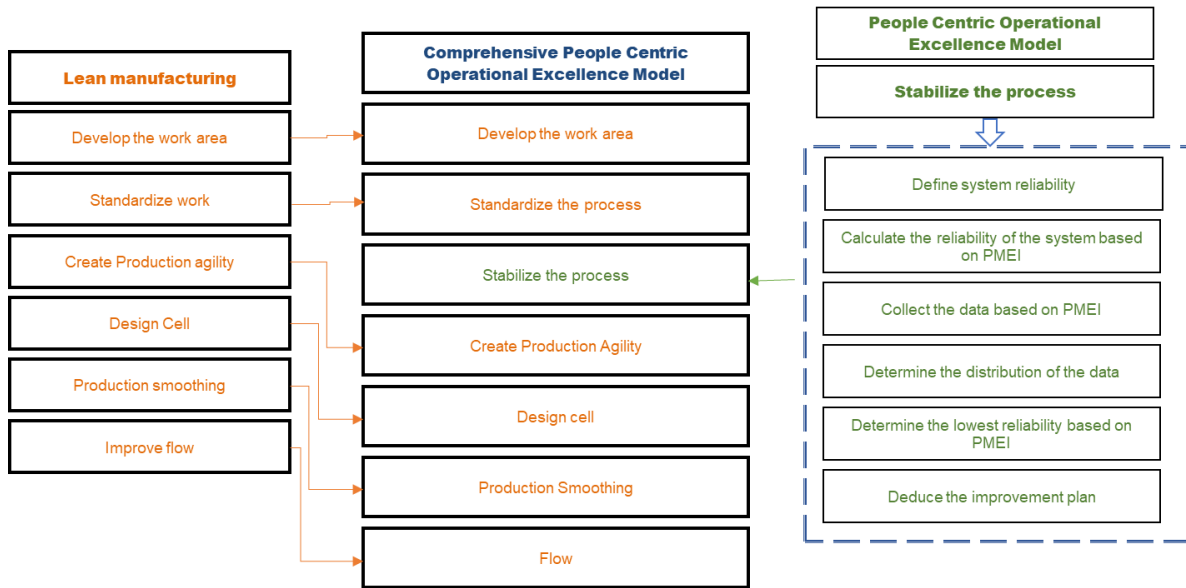


Figure 5: Solve for CPCOM

Table 10: Improvement steps and the reliability improvement achieve after implementation.

Steps proposed in the model	People's reliability	Material reliability	Equipment reliability	Information reliability
Develop the work area	X	X		X
Standardized work	X	X		X
Stabilize the process	X	X	X	X
Create agility		X	X	
Design of cell		X	X	
Production smoothing		X	X	X
Focus on improving the flow	X	X	X	X

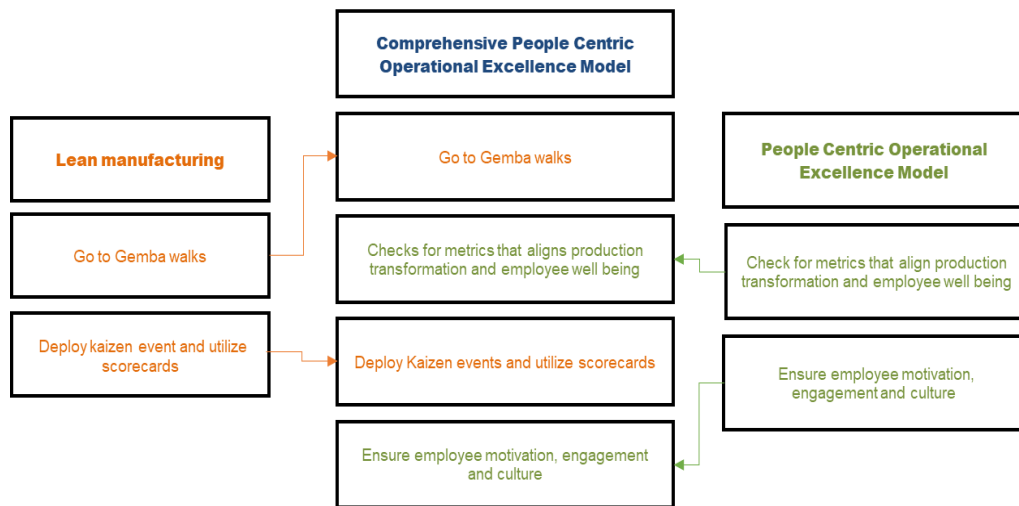


Figure 6: Sustain for CPCOM

Form the team based on the identified constraint

The team will be formed based on the functional constraints that have been identified and the people who are working in the identified constraints and will provide training on LM and PCOM policies.

Collect the information such as cycle times, product mix, throughput, and inventory levels

Once the team is formed, it will collect the significant data about the organization such as cycle times, throughput, delay times, and inventory.

Chart the Value Stream Map

Based on the collected information, the practitioner can chart the Value Stream Map to identify the location of the constraint in the organization.

Identify the critical path in the Value Stream Map

The constraint might be involved in different value streams, so the organization's critical path will help identify the best path to complete the process and identify the bottlenecks in the system.

Classify the Critical Path

The classification of the critical path identifies the nature of the process, which will help identify the factors and prioritize the factors to be mitigated first. The classification is based on deterministic, stochastic and flow.

Develop the strategy

Based on the nature identified, the strategy is to prioritize the factors so stochastic process variation-based factors will be mitigated first, the deterministic process disruption-causing factors will be mitigated first. Similarly, for the conditional process, flow-based factors are to be mitigated first.

Identify the leading indicators

Leading indicators will be identified based on the nature of the process. Therefore, the indicators that will be based on disruption-causing indicators, variation-causing indicators, and flow-based indicators. These indicators are further categorized into people, material, equipment, and information, which will be addressed to improve the cycle times and throughput of the organization.

Identify and classify the disruptions-causing factors into the following categories:

- Equipment: equipment unavailability, breakdowns, maintenance, meantime in failures, meantime between failures, setup time, quality defects
- Material: material unavailability, quality issues

- Information: unavailability of schedule

People – Absenteeism

Or

Identify and classify the variation causing factors in the bottleneck process:

- Material: interarrival times of material
- Equipment: difference in process time due to product mix
- People: difference in process time due to task based on product mix
- Information: scheduling of the process

Or

Identify the conditional process factors based on PMEI

Identify the lagging indicators

Lagging indicators will be identified based on the requirements of the organization based on the following levels:

Level 1: operations limitations

- Capacity
- Capability

Level 2: operation performance

- Reduce cost
- On-time delivery
- Stress reduction

Level 3: competitive status

- Increase in market share

Level 4: reputation

- Improved reputation in the market
- Improved in quality of life.

Present the plan on A3

The complete problem identification process will be presented on the A3, including the metrics and plan of action (Figure 7).

Solve

Based on the problem identified and the requirement, the practitioner can choose which work scenarios should be implemented.

Develop Work Area

According to the leading indicators identified in the Define section, the step for developing the work area will be used to improve the work area is based on reorganizing and redesigning the organization to reduce waste (Figure 8). The tools that facilitate this include 5S, Poka Yoke, and visual controls.

Work Standardization

According to the leading indicators identified in the Define section, workplace standardization creates a method that includes fixed instructions that must be followed to reduce waste and lead time in the organization. The tools that facilitate this include SOP, Poka Yoke, and 5s.

Stabilize the Process

According to the leading indicators identified in the Define section, stabilizing the process begins with enhancing the process's reliability based on the requirement that the lean tools can be chosen to improve the reliability of the process.

Design Cell

According to the leading indicators identified in the Define section, the workstations and equipment are organized to allow materials and components to flow smoothly through the manufacturing process with minimal transportation and delay. The tools that facilitate this include cellular manufacturing.

Focus on Improving Flow

According to the leading indicators identified in the “define,” the workstation is to have a constant stream of products that results in more consistent delivery and added value for customers, teams, and stakeholders. The tools that facilitate this include this is to focus on building a push, pull and one-piece flow system.

Production Smoothing

The workstations and equipment are organized to allow materials and components to flow smoothly through the manufacturing process with minimal transportation and delay. The tools that facilitate this include Heijunka.

Sustain

Deploy the Gemba Walks

Gemba walks will be deployed to identify constraints after the organization implements the policy.

Check for employee motivation, engagement, and culture

The Gemba walks it will be used to observe whether employee engagement, motivation, or culture are violated when the new policies are implemented.

Deploy Kaizen Events

Deploy kaizen events to establish practice regarding the implementation of the PCOM and LM.

Ensure employee motivation, engagement, and culture

Deploying kaizen events also ensures that people-based factors are considered by establishing communication to explain the importance of implementing the PCOM and LM training on lean and PCOM. Figure 9 shows the implementation guide of sustain of CPCOM

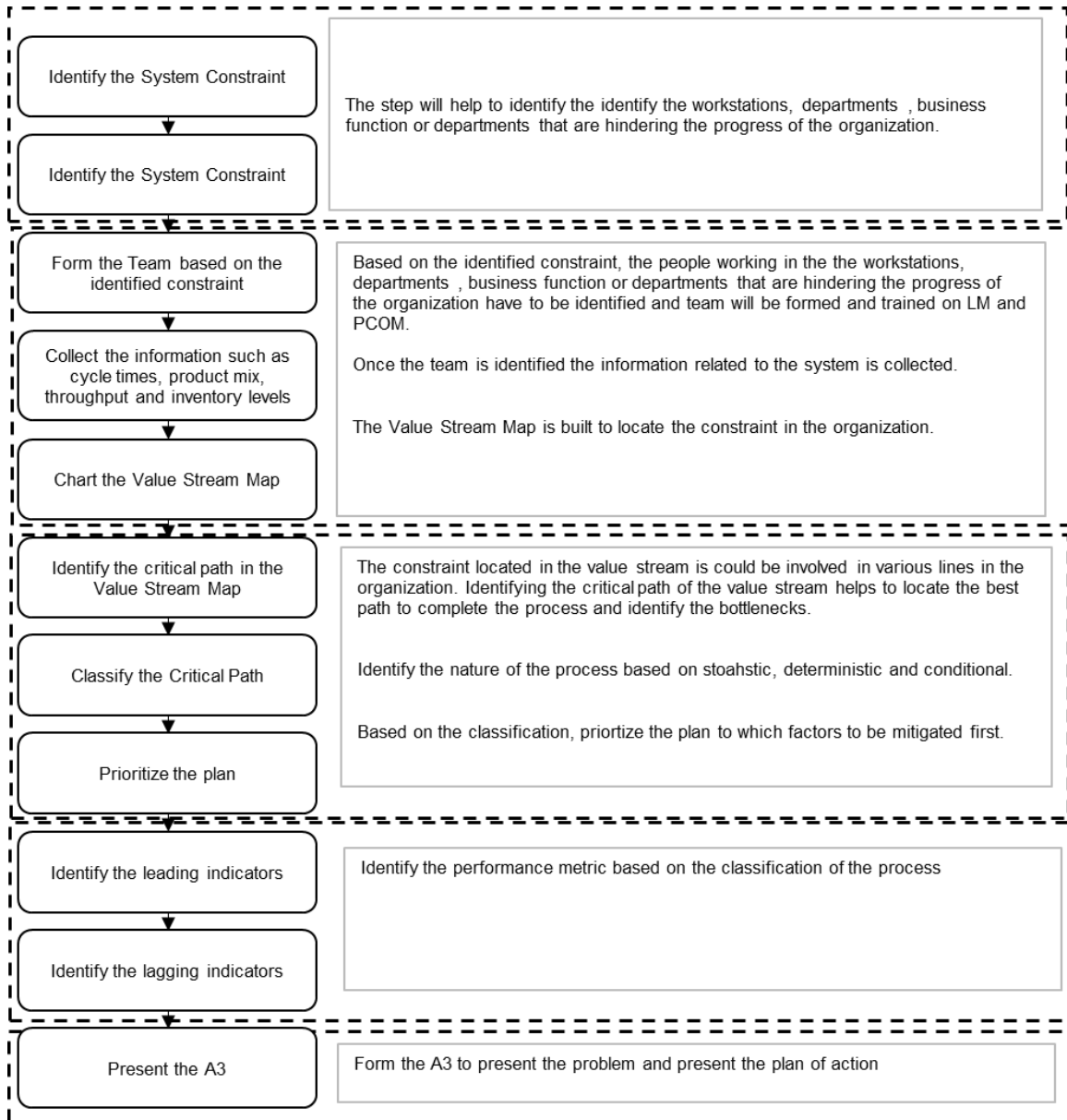


Figure 7: Application guideline for Define of CPCOM

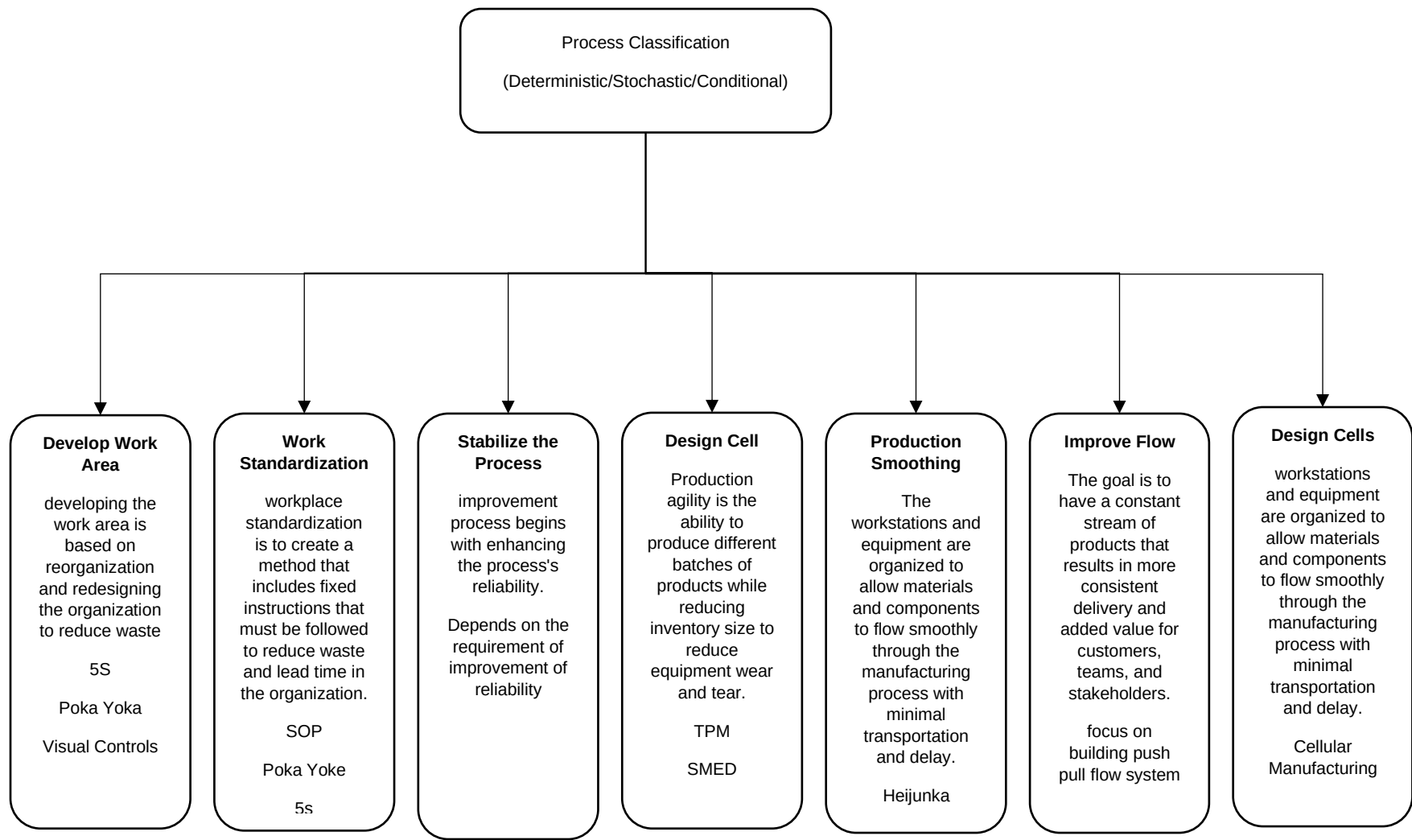


Figure 8: Application Guideline for Solve OF CPCOM

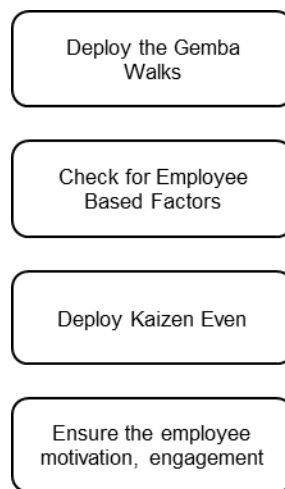


Figure 9: Application guideline for Sustain of CPCOM

4 CHAPTER FOUR RESULTS

4.1 Introduction

The steps highlighted in the methodology are validated by the results described in this chapter. First, the survey results reported here will help build the base in case studies, demonstrating how the template was used to solve the problem proposed by an organization. Second, the chapter uses the criteria derived from the conceptual comparison of lean manufacturing and PCOM to compare PCOM to lean manufacturing and CPCOM in case studies to discover how all three methodologies perform.

The case studies used to compare three methods in the comparison study were chosen based on each project's application sector. The PCOM is applied to two government agencies, two supply chain agencies, one healthcare project, and two manufacturing firms. The literature review for the current study is based on lean manufacturing in manufacturing settings. As a result, the two case studies were chosen to compare as they are based in the manufacturing industry. The case studies are presented in the following format: a) by company background, b) in terms of the PCOM application in the organization, and c) showing how CPCOM will be implemented in the organization d) by comparing lean manufacturing, PCOM, and CPCOM according to the criteria.

4.2 Presenting the output of the Survey

The format presenting the survey starts by explaining the motivation for implementing PCOM in the organization, which includes explaining the organization's background, problem, and requirements. Next, it explains how the PCOM was implemented in the organization: as survey questions are based on the template of PCOM, the output of the survey shows the application of the template. Based on the survey conducted in the section. "Developing Survey Question for Building Case Studies (3.4)." Figure 10, Figure 11, Figure 12 and Figure 13 show the application of PCOM modules in various sectors. Figure 10 demonstrates the application of the PCOM Module 1. The table shown in Figure 10 shows the hierarchy format of the template developed for Module 1. Columns A to D shows the template's hierarchy, which includes the module number, concept (O), component (C), and steps (S). The projects where the PCOM was used in columns E to L. The steps used in the project are labelled "Done" and are highlighted in green, and the steps that were not performed are identified as "Not Done" and highlighted in red. The same format was utilized to show the application of Module 2 of PCOM in projects shown in Figure 11. Figure 12 shows the application of Module 3 in the projects, and Figure 13 shows the application of Module 4. The observation done is the application of the PCOM model steps depends on the organization's requirement.

House Manufacturing company

The motivation for implementing PCOM

The house manufacturing company specializes in building custom houses to customer specifications. The company's challenge was a backlog of demand on the number of orders. Due to an unbalanced workload, the workers had to wait, which increased the cycle time of each station. Due to a lack of materials at the workstation, the company was also having difficulty retaining employees.

PCOM implementation in House Manufacturing company

The module 1 application began by identifying problems during a visit to the organization, identifying the processes, building the critical path of the process, and categorizing the critical path in the model's process. Module 2 was put into action by identifying metrics; the team decided to improve material unavailability and workload balance. Different policies were implemented to enhance the reliability of people and materials, and the organization's throughput improved. This aspect of policy development is linked to PCOM module 3. The team provided a subjective evaluation of module 4 implementation, implying that the policy implemented by the team must have improved people's quality of life. The team provided a subjective evaluation of the module 4 implementation, finding that the policy implemented by the team must have improved people's quality of life. The employees' ergonomic risks were evaluated, and jobs were reassigned to reduce the ergonomic risk factors such as force, posture, and repetition [56]. The model determines whether there is a relationship between subjective fatigue and employee work engagement [58].

Supply chain project 1

The motivation for Implementing PCOM

The organization provides pre-packaged food to various customers across the United States. The problem was that the food product spoiled before it expired, so customers received spoiled food. Several bulges were discovered in the boxes used to pack the food by the company; as a result, the food packages tore, and the food was crushed, resulting in food degradation. The organization was also having transportation difficulties due to the bulging in the boxes, which was also causing problems in the supply chain. The organization wished to mitigate the packaging issue, reduce the degradation of food packets due to damaged packages caused by improper packing, and minimize supply chain disruptions.

PCOM implementation in Supply Chain project 1

PCOM practitioners have been provided with clear objectives because the problem was identified for them by the organization. The practitioners implemented steps “S1” and “S2” to identify and understand the constraints through interviews with company administrators. Due to the project's sensitivity, the team was not provided with the details of the value stream and supply chain; therefore, the steps for value stream mapping and identifying the critical path were not applied. The problem in the supply chain was due to the disruption caused due to faulty packaging, and thus the process was categorized as deterministic.

Module 2 of the PCOM began by identifying leading and lagging indicators. The leading indicators were “quality rejects products” and “number of bulged boxes,” According to organizational requirements, the lagging indicators identified were improving “operational capabilities” and focusing on “on-time delivery.”

The module 3 application identifies the lowest reliability based on PMEI and proposes mitigation measures for the lowest reliability. The faulty packing procedure resulted in low people reliability, and material reliability was low due to degradation and faulty packing. The solution developed to mitigate the risk of people and materials failure is to optimize the packaging process of the boxes [59] and supplement it by proposing the SOP for packing the food packets. The new optimized method of packaging the packets improved the material's reliability, and the SOP assisted in enhancing people's reliability. Module 4 was not implemented because practitioners did not prioritize the people factor; the team provided a subjective evaluation of the fourth module, but they were assured that the policy had improved people's quality of life.

Supply chain project 2

The motivation for Implementing PCOM

The organization supplied perishable food product to various customers in the USA, and the problem was that the food product was spoiled during the transportation. The organization stated the goal was to improve the supply chain by improving the shelf life of the products.

PCOM implementation in Supply Chain project 1

The problem had already been assigned to PCOM practitioners, and steps “S1”, “S2”, “S3”, “S4”, and “S5” to identify the constraint. Due to the project's sensitivity, the team was not provided with the details of the value stream and supply chain; therefore, the steps for value stream mapping and identifying the critical path were not applied. The problem in the supply chain was due to the disruption caused due to faulty packaging, and thus the process was categorized as deterministic.

Module 2 of the PCOM began by identifying leading and lagging indicators. The leading indicators were “quality rejects products” and “number of bulged boxes,” According to organizational requirements, the lagging indicators identified were improving “operational capabilities” and focusing on “on-time delivery.”

The module 3 application identifies the lowest reliability based on PMEI and proposes mitigation measures for the lowest reliability. The faulty packing procedure resulted in low people reliability, and material reliability was low due to degradation and faulty packing. The solution developed to mitigate the risk of people and materials failure is to optimize the packaging process of the boxes [60]. And supplement it by proposing the SOP for packing the food packets. The new optimized method of packaging the packets improved the material's reliability, and the SOP assisted in enhancing people's reliability. Module 4 was not implemented because practitioners did not prioritize the people factor; the team provided a subjective evaluation of the fourth module, but they were assured that the policy had improved people's quality of life.

Government project 1

The motivation for Implementing PCOM

This company is a major energy provider in the US. Inconsistencies were discovered in the inventory management processes across the enterprise, resulting in increased inventory value and inefficiencies in the organization's supply chain. Inventory management, related metrics, and business unit decisions were all challenges; the organization's inventory management and classification procedures were inconsistent. As a result, the cost of holding the inventory increased, as did capacity utilization.

PCOM implementation in Government project 1

The practitioner implemented steps “S1” and “S2” from the module 1 template to identify the constraint. To track inventory levels, the organization shared ERP data. Regarding a centralized inventory, there was no requirement to identify the critical path, VSM, or categorization of the process claimed by the practitioner. As a result, because the organization provided detailed information to the team, module 1 was not implemented in the project.

Module 2 identifies the leading and the lagging indicators based on the problem identified and organizational requirements. In this instance, the leading indicators identified by the practitioner were “monthly usage of stocks,” “stocks labels,” “holding cost of stocks” “annual cost of stock,” “transportation cost,” and “inventory levels of stocks.” The lagging indicators identified “operational capacity” and “cost reduction.”

Module 3 identifies and proposes mitigation measures for the lowest reliability based on PMEI. Still, because the organization did not have the proper techniques to track every

inventory level, information was the lowest reliability identified. The data was proposed by segregating and clustering based on the data provided by the organization. A machine learning model was proposed to centralize the inventory based on the data analysis results. The practitioner did not prioritize the fourth module because the team stated that the organization did not require it.

Healthcare project 1

The motivation for Implementing PCOM

The healthcare organization is the recognized health care provider providing various medical services in the metropolitan area. Based on its multifunctionality, it has many incoming patients, and the organization is having difficulty managing the patient. The healthcare organization proposed the problem that they need better management of the inflow and assignment of the patients to their requirements.

PCOM implementation in healthcare project 1

The practitioner applied Module 1 to identify the constraint in the organization, applying steps “S1”, “S2”, “S3”, “S4”, and “S5” from Module 1 template. The constraint identified was the variations in assigning patients to their required departments. The cause of the variation was a lack of staff and non-standardized work assigned to the staff to meet patient needs. This resulted in a longer wait time for patients and an imbalanced workload for staff. The team simulated the value stream map of incoming patients, transfer to the appropriate department, and discharge process. The constrained critical path was high for one department because there was maximum utilization of staff assigned to get each patient into that department resulting in a long wait time for the patient to get to the department. The process was classified as stochastic due to the high variability in assigning the worker to the patient.

Module 2 identifies the leading and the lagging indicators based on the problem identified and organizational requirements, and in this project, the leading indicators identified for the organization were “queue time,” “resource utilization,” and “time in system.” The lagging indicators were “operational capability” and “on-time delivery.”

Based on PMEI, module 3 identified and proposed mitigation measures for the lowest reliability, which was determined due to people assigned unequal work. The improvement strategy consisted of optimizing staff schedules each week based on the equal distribution of work to mitigate worker understaffing and overstaffing. The optimized workload distribution helped to reduce the variation. The project team provided a subjective assessment of module 4, indicating that the policy recommended to the organization will help them achieve work-life balance and improve their quality of life.

Government project 2

The motivation for Implementing PCOM

The government agency in this project has provided energy services to several counties in a metropolitan area. Its focus is on providing services through “efficiency, innovation, and communication” while maintaining the “safety and well-being” of both customers and employees and recognizing employees’ “commitment and hard work.” The organizational problem was an operational obstacle in their call center, which is a division of their customer experience unit. This call center is frequently the first point of contact with new customers and the preferred point of contact for customers who require assistance with their utility services.

PCOM implementation in Government project 2

Module 1 was applied by the practitioners to identify the constraint in the organization, so steps “S1”, “S2”, “S3”, “S4”, and “S5” from the Module 1 template. The constraint identified among the organization’s customer service representatives (CSRs) were the agents answering the incoming calls. The service level observed for the highest volume of incoming calls offered (2500) with the highest functional CSRs (35) ranges from 30% to 40%. The workload of CSRs affects responsiveness, which directly affects service level. As a result, any improvements are contingent on an optimized assignment of CSRs to the types of calls. The PCOM practitioner described the focus as understanding the calls’ database and the customer’s time to wait. Thus, the practitioners did need to identify the critical path, VSM, or the type of process classification.

Module 2 was not implemented for tracking the process because the practitioners reported that they did not focus on building the KPIs as they concentrated on improving call processing times.

Module 3 identifies and proposes mitigation measures for the lowest reliability based on PMEI, and in this case, the lowest reliability identified was due to people because of high waiting times. The study conducted by PCOM practitioners conducted data analysis on call-log data to identify periods when the number of calls was highest and the peak times of the wait calls. The solution suggested is based on the analysis. Module 4 was not implemented as the practitioners were not focused on people factors. The project team provided a subjective evaluation of the fourth module, indicating that the policy recommended to the organization will assist them in achieving a work-life balance and improving workload distribution.

Automobile manufacturing company

The motivation for Implementing PCOM

This automobile manufacturing company is a leading global supplier of commercial vehicle and industrial drivetrain, mobility, braking, aftermarket, and electric powertrain solutions. The company's mission is to provide innovative products that provide superior performance, efficiency, and reliability. The company could not meet the demand due to lengthy cycle times resulting from the constant breakdown of equipment and material unavailability at workstations.

PCOM implementation in Government project 2

Module 1 was implemented by identifying the constraint in the organization, which was that the equipment was frequently breaking down. Due to constant breakdown, the company experienced workstation starvation due to a lack of material to process. The practitioners identified the value stream maps to discover the shared resources and equipment for the two product families. The critical path charted for the manufacturing line included shared equipment and identified the bottlenecks in the manufacturing line - the forging station was the main bottleneck, and the turning station was the secondary bottleneck. The forging station is the first bottleneck because of the constant breakdown of the equipment, leading to disruption; the turning station then experienced material unavailability at the workstation, thus starving the workstation. The process had constant cycle times and fixed demand, but there was variation in the arrival times of material at the workstation, leading to different timing for processing the same parts. The process was classified as a combination of deterministic and stochastic

Module 2 identifies the leading and the lagging indicators based on the identified problem and organizational requirements. The leading indicators identified for the breakdowns are “unplanned maintenance” and “material interarrival times.” The lagging indicators are throughput, on-time delivery, and competitiveness in market share.

Module 3 identifies and proposes mitigation measures for the lowest reliability based on PMEI, and the lowest reliability in the company was due to equipment and material inadequacies. Equipment reliability was improved by introducing the preventive maintenance policy in the organization. Material reliability was improved by implementing the supermarket at the turning station to feed the workstation and constantly mitigate the bottleneck. Module 4 was not implemented as the practitioners were not focused on people factors. The project team provided a subjective evaluation of the fourth module, indicating that the policy recommended to the organization will assist them in achieving work-life balance and improving workload distribution.

PCOM Template				Projects						
Module	Concept	Component	Steps	House Manufacturing Company	Supply Chain Project 1	Supply Chain Project 2	Government Project 1	Government Project 2	Healthcare Project 1	Auto Manufacturing Plant
Module 1	O1.Physically locating the problem	C1) Identify organizational function that is constraining the growth of the organization								
			S1	Done	Done	Done	Done	Done	Done	Done
			S2	Done	Done	Done	Done	Done	Done	Done
			S3	Done	Not Done	Done	Not Done	Done	Done	Done
			S4	Done	Not Done	Done	Not Done	Done	Done	Done
			S5	Done	Not Done	Done	Not Done	Done	Done	Done
		C2) Generating the constrained value stream map								
			S6	Not Done	Not Done	Not Done	Not Done	Not Done	Done	Done
			S7	Not Done	Not Done	Not Done	Not Done	Not Done	Done	Done
			S8	Not Done	Not Done	Not Done	Not Done	Not Done	Done	Done
		C3) Generate the critical path diagram of the constrained value stream map								
			S9	Not Done	Not Done	Not Done	Not Done	Not Done	Done	Done
			S10	Done	Not Done	Not Done	Not Done	Not Done	Done	Done
			S11	Done	Not Done	Not Done	Not Done	Not Done	Done	Done
			S12	Done	Not Done	Not Done	Not Done	Not Done	Done	Done
	O2.Categorize the Critical path	C4) Classify the Critical path identified based on these definitions.								
			S13		Not Done	Not Done	Not Done			Done
			S14	Done	Not Done		Not Done	Done	Done	Done
	O3.Develop the Strategy	C5) Prioritize the factors according to the classification								
			S16		Not Done	Done	Not Done			Done
			S17	Done	Not Done	Done	Not Done	Done	Done	Done
			S18		Not Done		Not Done			

Figure 10: Application of Module 1 in various sectors

PCOM Template				Projects						
Module	Concept	Component	Steps	House Manufacturing company	Supply chain project 1	Supply chain project 2	Government project 1	Government project 2	Healthcare Project 1	Auto Manufacturing Plant
Module 2	04. Identify the Performance Metrics	C6) The leading indicators based on the bottleneck station								
			S19		Done	Done	Done	Not Done	Done	Done
			S20	Done		Done			Done	Done
			S21							
			S22	Done	Done			Not Done	Done	Done
		C7) Focus on improving the leading indicators to achieve the following operational goals (lagging indicators)								
			S23	Done	Done	Done	Done		Done	Done
			S24	Done	Done	Done	Done	Not Done	Done	Done
			S25					Not Done		Done
			S26							

Figure 11: Application of Module 2 in various sectors

PCOM Template				Projects						
Module	Concept	Component	Steps	House Manufacturing company	Supply chain project 1	Supply chain project 2	Government project 1	Government project 2	Healthcare Project 1	Auto Manufacturing Plant
Module 3	05.Calculate the Reliability	C8) Identify the Failure Modes C9) Identify the lowest Reliability								
			S27)	Done	Done	Done	Done	Not Done	Done	Done
			S28)	Done	Done	Done	Done	Not Done	Done	Done
			S29)	Done	Done	Done	Done	Not Done	Done	Done
	O6) Propose the Strategy									

Figure 12: Application of Module 3 in various sectors

PCOM Template				Projects							
Module	Concept	Component	Steps	House Manufacturing company	Supply chain project 1	Supply chain project 2	Government project 1	Healthcare Project 1	Healthcare Project 2	Government project 2	Auto Manufacturing Plant
Module 4	07.Employee Motivation	C10.Check for Employee motivation at different levels									
			S30	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done
	08.Employee Engagement	C11.Check the Employee Engagement at different levels									
			S31	Done	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done
	09.Company and National Culture	C12.Check the Company and National Culture at different levels									
			S32	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done	Not Done

Figure 13: Application of Module 4 in various sectors.

4.3 Case Studies

4.3.1 Case study 1

4.3.1.1 Company background

XYZ is a major manufacturer of a wide range of mobile homes, but it could not meet demand. The procedure consists of multiple workstations linked by homes that rotate from one station to the next every 60 minutes. As a result, any interruption at any station affects the entire production line, and frequent line outages contribute to the inability to meet demand. The inconsistency of material delivery to the line is a major cause of line stoppage. As a result, workers had to travel to the warehouse to retrieve the material and then return to their stations, lengthening the cycle time. Therefore, employee workload increased, and the company's employee retention rate was low. The company's goal is to increase throughput to reduce the backlog[61].

4.3.1.2 People-Centric Operational Excellence Model Application in XYZ Company Module 1 implementation

The PCOM implementation in XYZ began by identifying the constraint in the organization. As constraint identified is due to backlog and low workforce retention. Identifying the constraint in the organization is based on the concept of "C1 Identify Organizational Function That Is Constraining the Organization's Growth" from the template. The steps are: "S1," "S2," "S3," "S4," and "S5."

The team then identified XYZ's critical path. Because the house manufacturing line has only one manufacturing line, the manufacturing line is the critical path of the process. The critical path is related to the template concept "C3 Generate the Critical Path Diagram" of the constrained value stream map. To chart the critical path, the project used steps "S10," "S11," and "S12" to Identify the highest cycle time or queue timing station as the bottleneck station and the second-highest cycle time station as the floating bottleneck.

The causes of the constraint were constant disruption due to material unavailability at the workstations, which resulted in line stoppage until the worker returned with the material from the workstation. This resulted in a longer cycle time for producing one unit of house. Because the manufacturing line produces a variety of home products, the work procedures assigned to each worker were unique. To complete the task, the worker had to complete both the work assigned to him and the unassigned workload at the workstation due to worker unavailability. This unassigned work caused variations in time for producing the same unit. The unbalanced workload increased workload stress due to transportation time and completing unassigned work. According to the study on causes, most of the cycle time was increased due to process variation (Figure 14 and Figure 15).

Categorization of the critical path led to classifying the process as stochastic. The concept “O2 Categorize the critical path of the constrained value stream map” was used to categorize the critical path in the project; step S14, stochastic Process-Order requirement and the product mix are varied, processes involved in the production of product varies, was used to identify the nature of the process. Stations 1, 5, and 7 were identified as the bottlenecks. The concept “O3 Develop the Strategy” was used to identify the factor to be mitigated. Step “S17,” stochastic process- the priority is fixing variation, disruption, and flow. The example of “metrics could be product mix, no standard operating procedure” used to help to identify “workload unbalance,” “material unavailability,” and “employee stress” are the specific areas that the team will plan to mitigate. The workstation study shows the difference in takt times at every workstation and proposed reducing the takt time (Figure 16).

Module 2 Implementation

The module 2 application in XYZ is to identify the metrics based on the process categorization and identified bottlenecks. The process categorization is stochastic; therefore, the metrics will be based on reducing the variation. The problem was due to material unavailability and unbalanced workloads. The leading indicators identified for the XYZ company was to reduce transportation and delay times; the lagging indicators identified for the project is throughput employee stress. The concept is “O4 Identify The Performance Metrics,” and the steps are “S20” was used to identify and classify the variation causing factors in the bottleneck process material (interarrival times of material and equipment, the difference in process time due to product mix), and people (the difference in process time due to task based on product mix), and information (scheduling of the process for identifying the leading indicators); “S23” was used to choose lagging indicator based on Level 1 operations limitations (capacity and capability); and “S24” to choose lagging indicator based on Level 2: operation performance (reduce cost, on-time delivery, and stress reduction) to identify the lagging indicators.

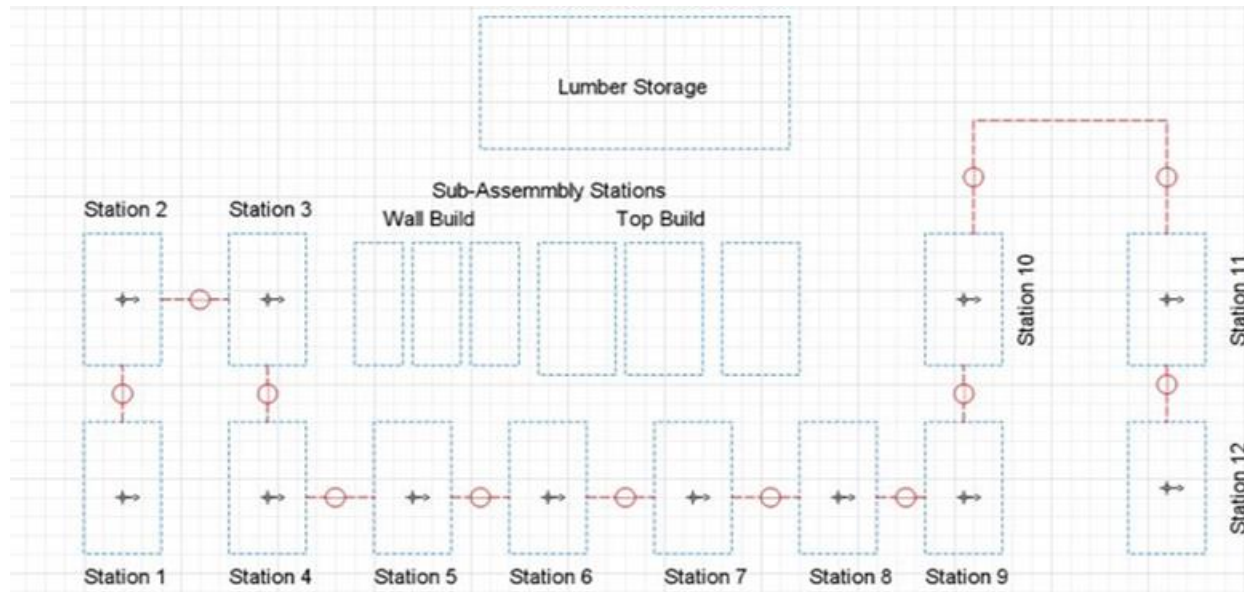


Figure 14: XYZ Critical Path [61]

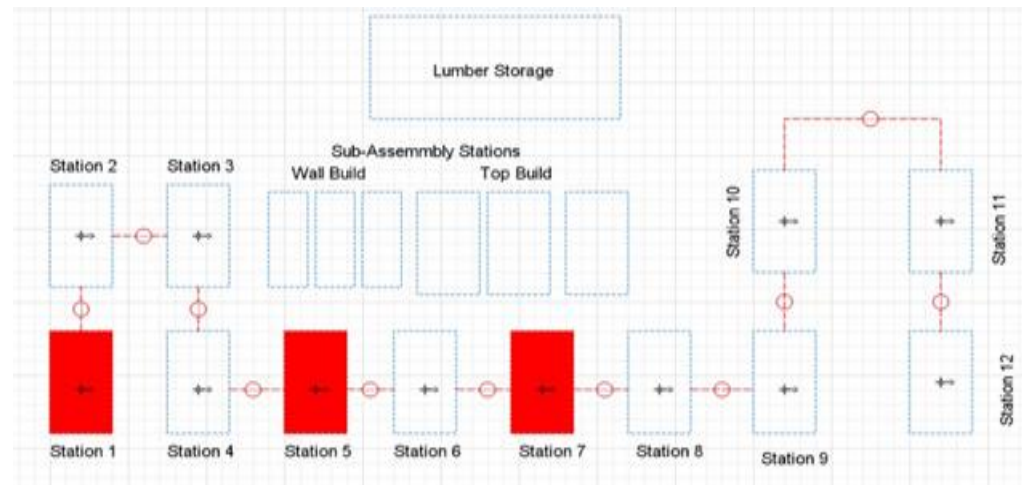


Figure 15: Bottleneck identified for XYZ company[61]

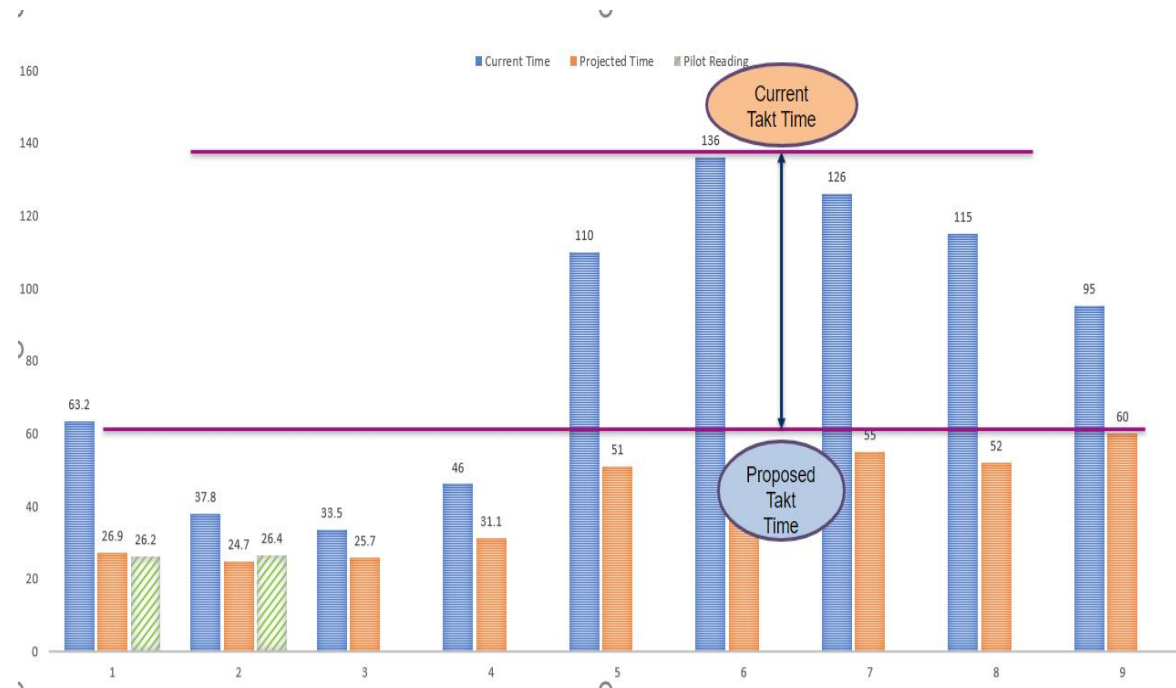


Figure 16: Calculation of Bottleneck stations for XYZ company[61]

Module 3 Implementation

Module 3 implementation is focused on developing a reliable solution. The identified metrics were to reduce transportation and delay time caused by an unbalanced workload. Based on the identified issue, material and people reliability will be improved. According to the identified constraint, the failures at the bottleneck stations were caused by people due to an unbalanced workload and material due to a lack of materials at the workstations. The failures were discovered using job task analysis to identify NVA and VA. The steps “S27” was use to collect failure data based on material reliability (material failure, quality and unavailability, equipment reliability as equipment failures and unavailability), People reliability (people errors and unavailability) and Information reliability (information flow and unavailability), and “S28” to identify the distribution followed by the data and calculate the reliability based on the failure data identified in “S30” was used to propose a solution to reduce the variation in the process is achieved by observing employees’ non-value-added (NVA) and value-added activities (VA) using the job task analysis.

The solutions are based on the component “O6 Propose the Strategy,” which has step “S29” was used to build the strategies to improve factors to improve the lowest reliability” from the template. The solution proposed to mitigate the problem is by introducing Zone-Based Manufacturing(ZBM) at the workstations [57]. The ZBM employs the employee scheduling and physical placement method. "Scheduling" and "placement" collaborate to ensure ZBM's success. "Scheduling" ensures that the time factor of CT reduction is addressed, whereas "placement" specifies where employees should be present to complete tasks. It specifies the location and the number of employees needed for the task. Figure 17 depicts an example of ZBM formulation. A short explanation of implementing ZBM is dividing the workstation into equal parts and assigning fixed tasks to the workers, as well as sequencing the tasks in the order that they must be completed first. Variation is reduced due to the worker being assigned a fixed workload. The pilot study saw a reduction in cycle times in the pilot studies. Figure 17 and Figure 18 shows the reduction of cycle time after the application of ZBM. Briefly, implementing ZBM means dividing the workstation into equal parts and assigning fixed tasks to the workers, as well as sequencing the tasks in the order that they must be completed; variation is reduced because of worker being assigned a fixed workload. The pilot study found that cycle times were reduced in bottleneck stations (Table 11) cycle times were reduced after the application of ZBM.

To reduce worker transportation time, a framework for designing a dependable material feeding system using supermarket warehouses that complements the zone base manufacturing technique achieved a standardized flow of materials within the facility. “To determine key decisions, such as the location and number of supermarkets, safety

inventory, and the flow of materials within the facility, a mathematical model with an optimization approach is applicable [62].” When the methodology was implemented, the NVA to VA ratio improved. The sensitivity analysis showed on the simulation showed the possible results:

- Best case (production of just 48 ft. houses): The result shows that the CT is 38 mins and throughput is 11.8 floors/day.
- Worst case (production of just 72 ft. houses): The result shows that the CT is 46 mins and throughput is 9.8 floors/day.
- Product mix (production of different models): The average CT is 42 mins and throughput is 10.5 floors/day. The result based on the sensitivity analysis (Figure 19).

Module 4: Sustain Via Employee Buy-in

Module 4 was partially implemented in the project, that is, the work conducted in order to improve people’s quality of life by evaluating ergonomic risks and reassigning jobs to reduce ergonomic risk factors such as force, posture, and repetition [56]. Minimizing the ergonomic workload risk is based on “S30” for determining these factors at different levels: level 1, Does the employee have fair compensation? Does the employee have job security? and level 2? Does the employee have physical safety in the plant? Does the employee have professional safety? Does the employee have social safety? This step was undertaken by checking employee motivation about job security (Level1) and checking employee physical and professional safety (Level 2). The model determines whether there is a relationship between subjective fatigue and employee work engagement [58]. The result showed that, although there is a connection between subjective fatigue and employee engagement, there is no unidirectional causality between the two. The goal of the template in developing a sustainable practice is to strike a balance between the ideal operating system and the ideal people system. The template includes a checklist for gathering feedback on whether the policies developed are appropriate for both the organization and the people. The second proposed solution is based on the “S31” for determining these factors at different levels: level 3, Does the employee experience balance of work-related stress and productivity? and level 4, Does the employee find a sense of belonging and purpose in the organization? of the component “C11 Check for Employee Engagement at different levels.” The proposed model is specifically based on checking whether policies cause workload stress and affect employee engagement.

Implementation of Comprehensive People-Centric Operational Model

The proposed model, the Comprehensive People-Centric Operational Excellence Model (CPCOM) outlined in Chapter 3, section 3.6. is based on integrating LM and PCOM. The CPCOM is divided into three parts Define, Control and Sustain. When implemented in XYZ, the “Define” of the CPCOM identifies system and function constraints in XYZ. The system constraint will be identified by conducting site visits and interviewing the organization’s people. The constraint identified is workstations with high cycle times because workers would have to work overtime due to high cycle times, the organization could not meet the daily demands, and the organization had a low worker retention rate. Based on the constraints identified, a work team will be formed. The team will be based on the workers, engineers, and managers involved at the workstation with high cycle times.

Then, the constraint value stream will be identified, and because XYZ had only one manufacturing line, there will be only one constrained value stream map. The value stream map will help to identify waste in the organization, which will be workstations with a high waiting time and idleness due to material unavailability. Next, the critical path of the constrained value stream map will be identified; the critical path is utilized to identify the bottleneck stations. In the case of XYZ, stations 1,5 and 7 will be identified as the bottleneck of the station due to their high cycle time.

Further examination of the workstations reveals that idleness is due to material unavailability at the workstation, and the work assigned to each worker is not standard. Because the cycle times for completing the same task differ, the process type is identified as stochastic. The process classification will be used to identify the leading and lagging indicators; XYZ’s leading indicators were reduced transportation and delay times, and the project’s lagging indicator was throughput employee stress. The lagging indicators will be overcoming operational capability and capacity, reducing stress, and focusing on on-time delivery. The “Solve” of the CPCOM will be based on utilizing the seven scenarios proposed in the CPCOM. The workstations had high variation due to workload imbalance and material unavailability due to workstations. The possible scenarios that will be utilized to overcome imbalance workloads included proposing SOPs for every worker and line balancing by assigning the fixed workload to the workers.

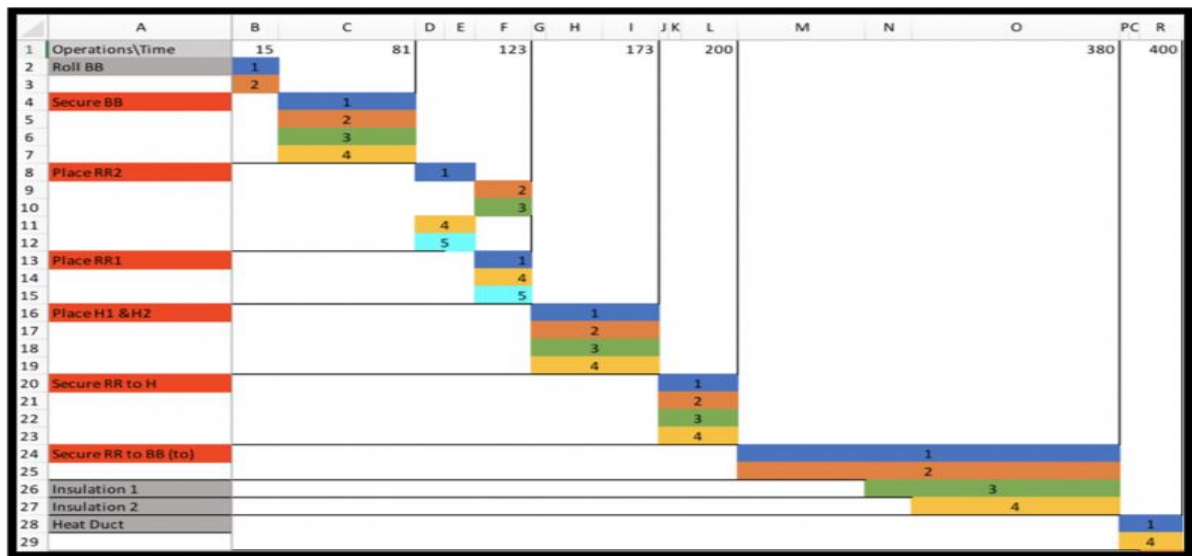


Figure 17: ZBM formulation for XYZ company[61]

Table 11: PCOM application result[61]

Stations	Current CT (mins)	ZBM CT (mins)
Station 1	60	26.5
Station 2	60	24.76
Station 3	60	25.7
Station 4	60	31.16
Station 5	120	51
Station 6	120	47.66
Station 7	120	55
Station 8	120	50
Station 9	120	50
Station 10	120	50

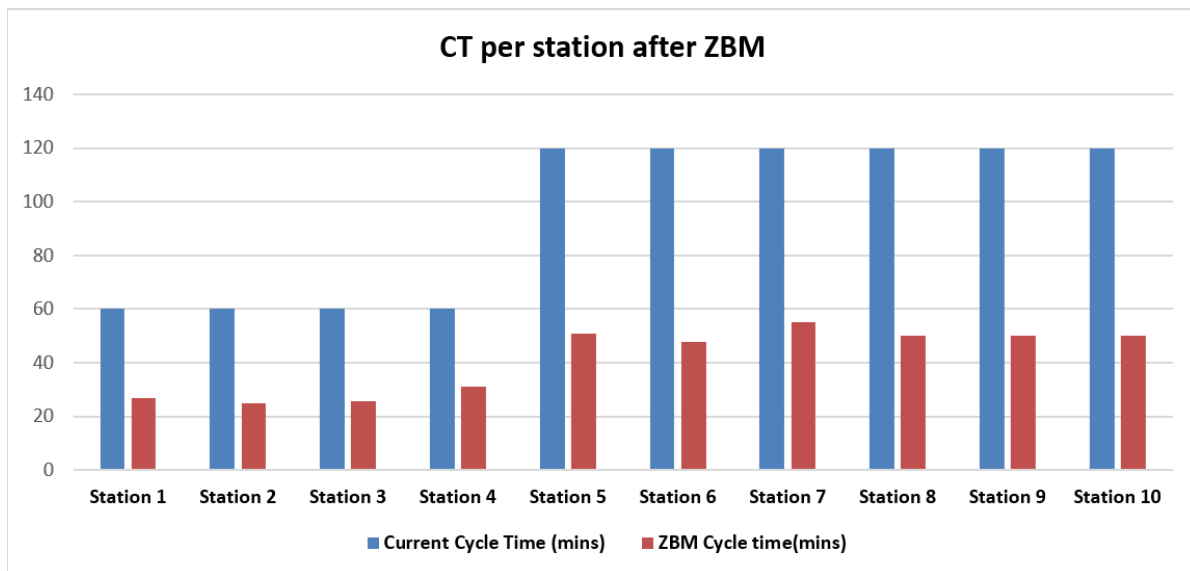


Figure 18: ZBM implementation changes at workstation at various workstation

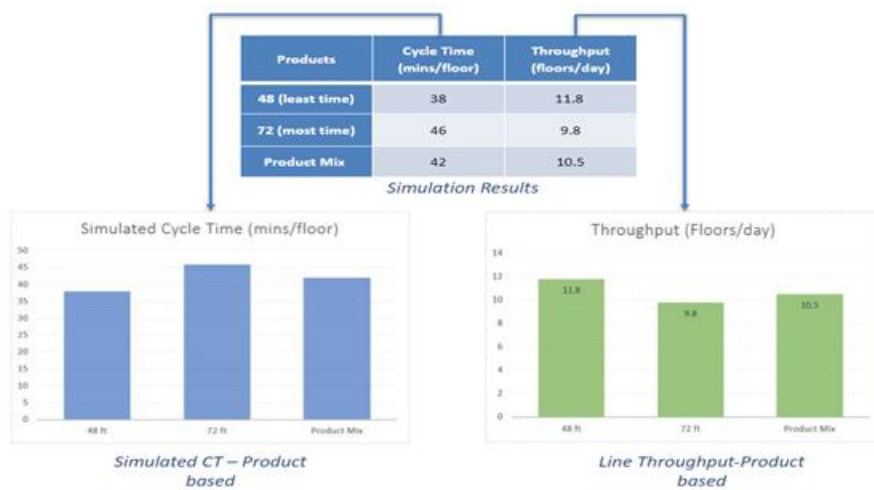


Figure 19: Sensitivity analysis for XYZ company

The improvement in reliability proposed is using work standardization regarding people so that assigning the work will lead to standardization and a reduction of unbalanced workloads. Material unavailability will be mitigated by using supermarkets at the workstations, which was achieved by designing cell scenarios and providing the supermarkets where the material was unavailable at workstations, thereby improving material reliability so material will be available at the workstation and reduce transportation times.

The “Sustain” of the CPCOM will implement the Gemba walk and scorecards, which will identify progress and problems when policies are implemented. The Gemba walk will provide feedback on the policy when implemented in the organization and establish whether people’s motivation, engagement, or culture were affected when the policy was implemented. After that, kaizen events will be deployed to provide training in lean manufacturing and PCOM and establish communication between workers and management. The training will be utilized to build a people-centric environment where employees understand their role and the improvements that will be achieved when these policies are implemented.

4.3.1.3 Comparison between Lean Manufacturing (LM), PCOM and CPCOM

Section 4.3.1.2 shows the application of the PCOM and the result achieved after the application of PCOM in XYZ Company. The criteria used to make a conceptual comparison between lean manufacturing and PCOM (3.5.3) was used to compare how lean manufacturing, PCOM, and CPCOM would approach the problem in XYZ (Table 12). There are differences in requirements, approach, and how tools might be used in the organization is shown, as well as similarities in all the tools used to mitigate the problem and solutions to sustain it.

4.3.2 Case Study 2

4.3.2.1 Company background

ABC is a leading global provider of commercial vehicle and industrial drivetrain, mobility, brake, aftermarket, and electric powertrain solutions. The manufacturing plant uses processes that require a long cycle time to produce a specific part. To meet daily requirements, equipment was overutilized, which was the primary cause of line stoppages. Overutilization resulted in equipment failure and process starvation. As a result, the overall manufacturing cycle time increased, and the machines sat idle for an extended period. Processes along the manufacturing line were hampered due to a lack of materials and, as a result, the company’s throughput requirements were not met, and a significant backlog of work existed. Parts had to be sent outside the plant for processing as part of the manufacturing process so that incoming and outgoing processing times of semi-finished products had to be considered. Due to variations in arrival times, manufacturing cycle times increased significantly. The company aimed to improve cycle

times, prioritize daily requirements, reduce employee workload, increase organizational capacity, and prioritize customer requirements. On-time delivery, inventory levels, and overtime were all major challenges for the company.

4.3.2.2 PCOM APPLICATION Module 1 Application

The PCOM application in ABC company starts by identifying the constraints. Steps “S1,” “S2,” “S3,” “S4” and “S5” from the “Template for Defining the Problem (3.3.3).” Step “S6” was used to identify the product mix and processes; “S7” to collect process data, i.e., cycle times, inventory data, actual work time versus unused/wait time, unnecessary movement (items, material, and workers), and scrap rate; and “S8” was used to add data and generate times lines of the map which represent process time, inventory, and total lead time from component “C2 Generating The Constrained Value Stream Map.” The value stream mapping process assisted in identifying which processes along the manufacturing line were hampered by a lack of materials. As a result, the company's throughput requirements were not met, and there was a significant work backlog. Parts had to be sent outside the plant for processing as part of the manufacturing process

It was necessary to consider incoming and outgoing processing times of semi-finished products, finding that manufacturing cycle times increased significantly due to variations in arrival times. The company's goals were to improve cycle times, prioritize daily requirements, reduce employee workload, increase organizational capacity, and prioritize customer requirements. Utilizing the “S9” to draw the network diagram of the constraint value stream map; S10, Estimate the activity duration of every process; “S11” to identify the processes which have the highest cycle time or queue timing; and “S12” to identify the highest cycle time or queue timing station as the bottleneck station and the second-highest cycle time station as the floating bottleneck identified the critical path for both the part families based on the component “C3 Generate The Critical Path Diagram Of The Constrained Value Stream Map.” The critical path helped identify the process's bottlenecks: the forging station as the primary and the turning station as the secondary bottlenecks. The critical path also helped to show the combined workstation for producing part family 1 and part family 2.

Further study on bottlenecks was conducted for both part families by identifying non-value-added activities (NVA) and value-added processes (VA). The NVA in manufacturing the part families is very high, resulting in the production line being unable to meet the production demand (

Table 13 and Table 14). Next, “S13,” deterministic process (predefined process, no product mix involved, fixed daily demand) and “S14” stochastic process (order requirement and the product mix are varied, processes involved in the production of product varies) were applied from the component “C4 Classify the Critical path,” was adopted to understand the nature of the process of the production line. The process had constant cycle times and fix demand, but there were variations in the arrival times of material at the workstation, leading to different times needed to process the same parts. The process was classified as a both deterministic and stochastic.

Module 2 Implementation

Module 2 identifies the metrics based on the process classification and problem identified. The steps used to identify the metrics are adopted from the “S16” deterministic process in which the priority is to fix disruption, variation, and flow, respectively. It could be equipment, unavailability, breakdowns, maintenance, or quality issues causing the disruption. Step “S17” was used to know the variation due to stochastic process is where the priority is to fix variation, disruption, and flow respectively by addressing product mix and a lack of standard operating procedure for variation causing factors based on the problem identified. The leading indicators identified are the disruptions (deterministic process) characterized by breakdowns and unplanned maintenance according to the disruptions or material interarrival time (a stochastic process).

Step “S24,” Choose lagging indicator is based on level 2: operation performance (reduce cost, on-time delivery, stress reduction, and “S25” to choose lagging indicator is based on level 3: competitive status¹ (increase in market share) and S22, prioritizing these specific factors as the leading indicators per the classification of process and emphasizing decreases cycle time. Increasing throughput to identify the lagging indicators for the organization.

Module 3 Implementation

Module 3 proposes reliability based on the problem identified by implementing the “Template for Reliability-Based Solution (3.3.5).” “S27” was used to collect failure data based on material reliability (material failure, quality, and unavailability, equipment reliability (equipment failures and unavailability), people reliability (people errors and unavailability) and information reliability (information flow and unavailability), and “S28” to identify the distribution followed by the data and calculate the reliability based on the failure data identified in S27 and S29 are used to build the strategies to improve factors to improve the lowest reliability to helped to identify the lowest reliability and devise an improvement plan. The reliability calculation showed that the bottleneck's reliability tree was generated, highlighting the leading causes of process disruptions. The equipment failures caused at the forging station were due to changeovers, tools, and die changes, which consumed a total of 416.1 hours (Table 14 and Table 15).

Table 12: Comparison between LM, PCOM AND CPCOM for XYZ company

Classification	Criterion	Lean Manufacturing	PCOM	CPCOM
Paradigm	Motivation	Establish a Manufacturing Role Model for Corporate	Build a systematic approach to improve to achieve productivity transformation and employee retention	Building a practice to enhance the operational capability and improve
	Strategic Objective	A lean blueprint for bringing the process improvement to the XYZ manufacturing plant	To reestablish the throughput levels, while building a flexible workforce	Design adaptive manufacturing line that provides an opportunity for growth to incorporate new challenges
	Operational Objective	The goal of the organization is to build 10.5 floors/day from 7.5 floors per day	Improving the reliability of the organization for stable production of 10.5 floors per day from 7.5 floors per day.	Enhancing the process by systematic reduction of waste in the organization to achieve the objective of producing 10.5 floors a day
	Focus	Waste Elimination at the bottleneck causes due to material unavailability and unbalanced workload station and expanding the lean application throughout the manufacturing line	Identify the causes of variation, disruption and flow at the bottleneck stations and focus on improving reliability based on people and material	Reduction of variation, disruption and flow and focus on improving reliability based on people and material
Resource Requirement	Leadership	The one who facilitates the lean implementation and provides training about the policies that will be implemented to mitigate the unbalanced workload and material unavailability	A servant leader who facilitates communication between workers and management and driver profile of implementing lean, six sigma and reliability concepts	Facilitates the application of PCOM and lean manufacturing principles in the organization
	Team Requirement	A team will be formed from every department and provided lean manufacturing training	The XYZ company participation is excepted in the application of PCOM.	Provides training on lean manufacturing and PCOM principles
	Data Requirement	Downtime Data, inventory data, production data, process data	Failure data, Downtime data, Failure Modes, System data, people travel data	Failure data, Downtime data, Failure Modes, System data, inventory data, production data and process data, people travel data
Process	Problem Identification	1) Team Formation 2) VSM formation 3)Waste identified: Workers travelled from workstations 1,5 and 7 to get the materials and complete the work leading to an increase in transportation time and idleness at the workstation and unbalanced workload due to varied completion time for the same product mix. 3) Present A3 to mitigate waste due to idleness and transportation time and balancing workloads at bottleneck station 1, 5 and 7.	1) System Constraint: product mix, product volume, backlog, and workforce retention 2) Critical path and bottleneck identification •Unbalanced workload causing variation at stations 1,5,7 •Delay time due to material unavailability at stations 1,5,7 •Workload Stress and low retention 3) Process Categorization •Stochastic- Based on the variation of work completion for the same units	1) System Constraint: product mix, product volume, backlog, and workforce retention 2) VSM Charting 3)Waste Identification(transportation and idleness) 4) Critical path and bottleneck identification •Unbalanced workload causing variation at station 1,5,7 •Delay time due to material unavailability at stations 1,5,7 •Workload Stress and low retention 5) Process Categorization •Stochastic- Based on the variation of work completion for same units
	KPI System	Absent	Identifying the leading and lagging indicators	Identifying the leading and lagging indicators
	Leading Indicators	reducing cycle time based on identified waste Reduction in Transportation time Reduction in idleness due to uneven work	Reduce variation due to unbalanced at stations 1,5,7 Delay time due to transportation at stations 1,5,7	Reduce variation due to unbalanced workload Delay time due to transportation
	Lagging Indicators	Cost, throughput, organizational capability	Throughput Employee stress Ergonomic risk	Throughput Employee stress Ergonomic risk, Cost
	Continuous Improvement	Line Balancing to reduce the idleness Provision of Material Supermarket at workstation	Zone-Based Manufacturing Mathematical Model for feeding material based on ZBM	Improvement based on proposed seven scenarios
	Sustainability	SOP- Work aining standardization Gemba Walk- Identify the problems after policy implementation Kaizen Events- training the employee on lean policies and communication	Ergonomic Workload Balancing Measuring stress, fatigue, and people travel data	Through Gemba walks identify the problem and check for people related factors and deploy Kiazen events for training, communication and promoting people related factors

Preventive maintenance is the solution to the bottleneck station. The proposed solution to mitigate the problem at the forging cell was to build preventive maintenance to minimize equipment failures at the stations. The policies were tested in a simulation, and the results showed that cutting in half failure caused by unscheduled maintenance increases throughput by 400 parts per week (Table 17). In other words, increasing the frequency of preventive maintenance increases throughput directly (Table 17). The turning workstation (TASK 6), i.e., the turning process where the root cause of the bottleneck was due to part unavailability to process, was the source of the bottleneck, which was due to a lack of materials at the workstation; the turning station has the lowest reliability at 83% (Table 16). The provision of supermarket provides more throughput (Table 17).

.To mitigate the problem, it was suggested that a supermarket be built to feed the starving station, and the simulation revealed that the change increased throughput by 1400 units per week. Overtime problems and employee stress levels were reduced due to the increased production rate in the same time frame, i.e., per shift (Table 17).

Module 4 was not implemented as the practitioner was not focused on people factors. The project team provided a subjective evaluation of the fourth module, indicating that the policy recommended to the organization will assist them in achieving work-life balance and improving their workload balance.

Implementation of Comprehensive People-Centric Operational Model in ABC company

The proposed model, the Comprehensive People-Centric Operational Excellence Model (CPCOM) (3.6), is based on integrating LM and PCOM. The CPCOM is divided into three parts Define, Control, and Sustain. When implemented in ABC, the Define of CPCOM is by identifying the ABC's system and function constraints. The constraints will be identified based on plant visits and interviewing the people in the organization focusing on workstations that constantly break down and why the organization cannot meet customer demand. The constrained value stream map will identify the waste due to idleness and overprocessing as well as the organization's shared resources and equipment. The VSM will also help to determine waste in the organization; the waste identified was due to delay time resulting from material breakdown, and material unavailability at the workstation was causing variation in the process. The critical path will identify the best path to complete the process and identify bottlenecks. The critical path proposed includes shared resources and equipment. The bottleneck identified from the further analysis of the identified workstation led to the understanding that the forging station was the bottleneck of the station due to high cycle times, and the turning station was the second bottleneck. The cause of the forging station bottleneck was constant breakdowns, and the problem at the turning station was due to material unavailability. Based on the process has a fixed output and fixed cycle times. Also, the variation in material arrival times was causing

variation in the process. Therefore, the process was identified as both deterministic and stochastic. The leading indicators identified are the disruptions (deterministic process) such as breakdowns due to unplanned maintenance according to the disruptions (a stochastic process) in material interarrival time. The lagging indicators were on-time delivery, capacity, and improved market share. The Solve component of the CPCOM is accomplished by implementing seven work scenarios. The work scenario that will mitigate the problem is deploying “create agility, “implementing TPM to reduce the wear and tear of the equipment. The allocation of supermarkets at the turning station will reduce the variation in the process.

The reliability improved will be based on material and equipment. The Sustain portion of the CPCOM is deploying Gemba walk to identify problems where the policies are a cause of concern, which is achieved by deploying scorecards to assess whether employee motivation, engagement, or culture have been affected. Kaizen events would be deployed to provide training in PCOM and lean manufacturing.

4.3.2.3 Comparing Between Lean Manufacturing, PCOM and CPCOM

Section 4.3.1.2 shows the application of the PCOM and the result that are achieved after the application of PCOM in the XYZ company. Using the criteria used to do conceptual comparison between lean manufacturing and PCOM in 3.5.3 is used to the comparing the lean manufacturing, PCOM and CPCOM approaches when applied in the with the problem proposed in ABC company. Table 18 shows the comparison between lean manufacturing, PCOM and CPCOM. The Table 18 shows the difference in the principle when applied in the same problem posed in the problem. The difference in requirements, approach and how tools might be used in the organization is shown.

Table 13: NVA/VA for Part Family 1[63]

Sr. No .	Tasks for Part family 1	Duration (hours)	V/NV Activity
1.	Task 1	64.08	NV
2.	Task 2(Forging) station	1.22	V
3.	Task 3	48.00	NV
4.	Task 4	0.47	V
5.	Task 5	48.00	NV
6.	Task 6(Turning Process)	0.24	V
7.	Task 7	12.00	NV
8.	Task 8	24.00	V
9.	Task 9	36.00	NV
10.	Task 10	8.00	V
11.	Task 11	24.00	NV
12.	Task 12	0.18	V
13.	Task 13	30.00	NV
14.	Task 14	0.16	V
15.	Task 15	6.00	NV
16.	Task 16	0.02	V
17.	Task 17	18.00	NV
	V – Value – Added Activities NV – Non – Value Added Activities	Total VA time (hours)	34.28
		Total NVA time (hours)	286.08

Table 14: NVA/VA for Part Family 2[63]

Sr. No.	Tasks for Part family 2	Duration (hours)	V/NV Activity
1.	Task 1	64.08	NV
2.	Task 2(Forging station)	1.22	V
3.	Task 3	48.00	NV
4.	Task 4	0.47	V
5.	Task 5	48.00	NV
6.	Task 6 (Turning station)	2.25	V
7.	Task 7	12.00	NV
8.	Task 8	0.01	V
9.	Task 9	36.00	NV
10.	Task 10	16.00	V
11.	Task 11	24.00	NV
12.	Task 12	0.18	V
13.	Task 13	30.00	NV
14.	Task 14	0.16	V
15.	Task 15	6.00	NV
16.	Task 16	0.02	V
17.	Task 17	18.00	NV
	V – Value Added Activities NV – Non – Value Added Activities	Total VA time (hours)	20.30
		Total NVA time (hours)	286.08

Table 15 Reliability of the Forging Process[63]

Workstation Forging Station	Reliability	Total
Material	92%	67%
Equipment	80%	
People	99%	
Scheduling	92%	

Table 16: Reliability of turning process[63]

Workstation Turning Station	Reliability	Total
Material	83%	70%
Equipment	91%	
People	98%	
Scheduling	95%	

Table 17: Improvement after implementing policies[63]

Description	Current State	First bottleneck Resolved	Introduction of Supermarket
Throughput per week			
Part Family 1	2800	3000	3200
Part Family 2	3600	3800	4200
Total Production	6400	6800	7400

Table 18: LM, PCOM and CPCOM comparison for ABC company

Classification	Criterion	Lean Manufacturing	PCOM	CPCOM
Process	Problem Identification	1) Team Formation 2) VSM formation for the part family 1 and part family 2 3)Waste identified overprocessing at the forging process leading to the constant breakdown of equipment, idleness of turning workstation due to part unavailability at workstations 3) Present the plan on A3 to mitigate to mitigate the waste	1) System Constraint: Part family 1 and Part family product mix, equipment breakdowns at the forging process, equipment idleness at turning process due to due to unavailability of the material to process 2) Critical path and bottleneck identification- identifying the shared resources workstation i.e. forging , turning stations to cleaning station to identify the bottlenecks • Delay time due to material unavailability and equipment breakdowns • Worker Overtime 3) Process Categorization • Deterministic- Based on the constant equipment breakdowns thus not be able to meet the production demand Stochastic- Absence of material at the workstations to process	1) System Constraint Part family 1 and Party family 2, equipment breakdowns, equipment idleness 2) Team Formation 3) VSM charting 4)Waste Identification(transportation and idleness) • Delay time due to material unavailability and equipment breakdown 5) Process Categorization • Deterministic- Based on the constant equipment breakdowns thus not be able to meet the production demand and Stochastic for the absence of material at the workstation
	KPI System	ABSENT	Identify the leading and lagging indicators	Identify the leading and lagging indicators
	Leading Indicators	Reducing the cycle time due to equipment breakdown, Improve the interval times	breakdowns, unplanned maintenance, material interarrival time	breakdowns, unplanned maintenance, material interarrival time
	Lagging Indicators	Throughput, Organizational Capacity, Production Cost, On-time Delivery	Throughput, on-time delivery, competitiveness in market share	Throughput, on-time delivery, competitiveness in market share
	Continous Improvement	Deploying TPM Policies to reduce the equipment breakdown, Provide Supermarket where material is unavailable , 5S For standardization of process	Reliability Calculation leads to identification that equipment and material reliability is lowest between PMEI, Adopting TPM policies for improving equipment reliability and minimize the breakdowns. Adopt the Supermarket for providing material for tackling interarrival times and improving material reliability	Based on the proposed seven improvement scenarios to improve reliability and focus on standardization.
	Sustainability	5S for work standarization, Gemba Walks identifying the problem after implementing the policies and Kaizen events for training about the policies and expanding the lean practice throughout the plant	Conducting the pilot studies and training the employees for maintaining policies. Focusing on mitigating other constraints and establishing a practice of constant communication in order explain the benefits of implementing PCOM	Conduct Gemba Walks to analyze the equipment and materials and conduct study on people's view on the new policies and conduct Kaizen to implement training and creating motivation, engagment in the training session. Use fitbit to analyze the reduction of steps after implementation of policies, develop scorecards to identify the productivity.

5 CHAPTER FIVE CONCLUSION AND RECOMENDATIONS

5.1 Summary

Manufacturing organizations face numerous challenges in meeting their production demands, improving their processes, and competing in the market. To assist the organizations in meeting these challenges, they adopt operational excellence philosophies. Among these philosophies are lean manufacturing, six sigma, and business excellence models such as the European Foundation for Quality Management (EFQM) Excellence Model or The Malcolm Baldrige National Quality Award and, of these lean manufacturing is the most popular. According to the previous research examined for the current study, there is a lack of consensus on a standard framework for implementing lean manufacturing in an organization. Therefore, this study has established a template for PCOM that contains information on the steps taken to create the PCOM template. The template assisted in creating the criteria that provides the necessary information for generating survey questions, which were used to collect information about the application of PCOM in various sectors. In addition, the application of the PCOM model in various sectors collected information from the survey that was conducted in the CASRE research group. The CASRE research group had experience in implementing PCOM in the industry, therefore it was considered appropriate for conducting the survey.

Finally, the criteria aided in the comparison of PCOM and lean manufacturing. The comparison focuses on the differences in thinking used by both methods in two case studies, highlighting the differences in thinking styles, requirements of resources, the approach to solving the problem, and the approach to sustainability. The outcomes of the comparison study aided in proposing a Comprehensive People-Centric Operational Excellence Model that explores the possibilities of adopting the best practice of both methodologies. The proposed model is divided into Define, Solve, and Sustain. Define refers to isolating the problems in the organization by adopting the step for identifying the constraint from PCOM and the waste from the VSM of lean manufacturing. The Solve of the model provides seven improvement scenarios for improving the reliability of the process. Sustain is about adopting lean manufacturing techniques and proposing to integrate the principles from the “template for aligning the employee value with solutions” by establishing whether employee motivation, engagement, and culture are considered when the new policies are introduced in the organization.

5.2 Limitations

CPCOM is a newly proposed model is a conceptual model. Being a conceptual model, it does not have numerous case studies of application in the organizations.

5.3 Future Work

There is scope for future work is the opportunity of the implementation of CPCOM in various organizations and to provide case studies of CPCOM implementation in various organizations.

In Module 4 there is opportunity for integrating excellence models such as The European Foundation for Quality Management Excellence Model (EFQM) or Malcolm Baldrige National Quality Award Model (MBNQA) as they have established criteria to assess an organization in terms of process, workforce, leadership, and customers. Therefore, this would help the PCOM establish a detailed framework to assess the effect of policies that are implemented in the organization.

LIST OF REFERENCES

1. Yuik, C.J. and P. Puvanasvaran, *Development of Lean Manufacturing Implementation Framework in Machinery and Equipment SMEs*.
2. Chaple, A.P., et al., *Modeling the lean barriers for successful lean implementation: TISM approach*. International Journal of Lean six sigma, 2018.
3. Bhamu, J. and K.S. Sangwan, *Lean manufacturing: literature review and research issues*. International Journal of Operations & Production Management, 2014.
4. Liker, J. and M. Rother, *Why lean programs fail*. Lean enterprise institute, 2011. **2011**: p. 45-79.
5. Pay, R., *Everybody's jumping on the lean bandwagon, but many are being taken for a ride*. Industry Week, 2008. **5**: p. 21-23.
6. McLean, R.S., J. Antony, and J.J. Dahlgaard, *Failure of Continuous Improvement initiatives in manufacturing environments: a systematic review of the evidence*. Total Quality Management & Business Excellence, 2017. **28**(3-4): p. 219-237.
7. Bakås, O., T. Govaert, and H. Van Landeghem. *Challenges and success factors for implementation of lean manufacturing in European SMES*. in *13th International conference on the modern information technology in the innovation processes of the industrial enterprise (MITIP 2011)*. 2011. Tapir Academic Press.
8. Hernandez-Matias, J.C., et al., *Lean manufacturing and operational performance: Interrelationships between human-related lean practices*. Journal of Manufacturing Technology Management, 2019.
9. Duarte, S. and V. Cruz-Machado. *Lean and green: a business model framework*. in *Proceedings of the Sixth International Conference on Management Science and Engineering Management*. 2013. Springer.
10. Chong, M.Y., J.F. Chin, and W.P. Loh, *LEAN INCIPIENCE SPIRAL MODEL FOR SMALL AND MEDIUM ENTERPRISES*. International Journal of Industrial Engineering, 2013. **20**.
11. Rafique, M.Z., et al., *A systematic review of lean implementation approaches: A proposed technology combined lean implementation framework*. Total Quality Management & Business Excellence, 2019. **30**(3-4): p. 386-421.
12. Godinho Filho, M. and C.F. Barco, *A framework for choosing among different lean-based improvement programs*. The International Journal of Advanced Manufacturing Technology, 2015. **81**(1): p. 183-197.
13. Jadhav, J.R., S. Mantha, and S.B. Rane, *Development of framework for sustainable Lean implementation: an ISM approach*. Journal of Industrial Engineering International, 2014. **10**(3): p. 1-27.
14. Ben Fredj-Ben Alaya, L., *VSM a powerful diagnostic and planning tool for a successful Lean implementation: a Tunisian case study of an auto parts manufacturing firm*. Production Planning & Control, 2016. **27**(7-8): p. 563-578.
15. Pattanaik, L. and B. Sharma, *Implementing lean manufacturing with cellular layout: a case study*. The International Journal of Advanced Manufacturing Technology, 2009. **42**(7): p. 772-779.

16. Saleeshya, P., P. Raghuram, and N. Vamsi, *Lean manufacturing practices in textile industries—a case study*. Int. J. Collaborative Enterprise, 2012. **3**(1).
17. Bendell, T., *A review and comparison of six sigma and the lean organisations*. The TQM magazine, 2006.
18. Andersson, R., H. Eriksson, and H. Torstensson, *Similarities and differences between TQM, six sigma and lean*. The TQM magazine, 2006.
19. Näslund, D., *Lean, six sigma and lean sigma: fads or real process improvement methods?* Business process management journal, 2008.
20. Patyal, V.S. and K. Maddulety, *Interrelationship between total quality management and six sigma: A review*. Global Business Review, 2015. **16**(6): p. 1025-1060.
21. Sawhney, R., et al., *A conceptual people-centric framework for sustainable operational excellence*. 2020.
22. Arif-Uz-Zaman, A.K.K., *A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations*.
23. Mostafa, S., J. Dumrak, and H. Soltan, *A framework for lean manufacturing implementation*. Production & Manufacturing Research, 2013. **1**(1): p. 44-64.
24. Asnan, R., N. Nordin, and S.N. Othman, *Managing change on lean implementation in service sector*. Procedia-Social and Behavioral Sciences, 2015. **211**: p. 313-319.
25. Belhadi, A. and F.E. Touriki, *A framework for effective implementation of lean production in small and medium-sized enterprises*. Journal of Industrial Engineering and Management, 2016. **9**(3): p. 786-810.
26. Allway, M. and S. Corbett, *Shifting to lean service: Stealing a page from manufacturers' playbooks*. Journal of organizational excellence, 2002. **21**(2): p. 45-54.
27. Goshime, Y., D. Kitaw, and K. Jilcha, *Lean manufacturing as a vehicle for improving productivity and customer satisfaction*. International Journal of Lean six sigma, 2019.
28. Barbosa, G. and J. Carvalho, *A proper framework for design of aircraft production system based on lean manufacturing principles focusing to automated processes*. The International Journal of Advanced Manufacturing Technology, 2014. **72**(9): p. 1257-1273.
29. Anvari, A., et al., *A proposed dynamic model for a lean roadmap*. African Journal of Business Management, 2011. **5**(16): p. 6727-6737.
30. Dombrowski, U., T. Zahn, and T. Mielke. *Roadmap for the implementation of Lean Production Systems*. in *Proceedings of the 5th Americas International Conference on Production Research*, Bogota. 2010.
31. Maqbool, Y., et al., *An implementation framework to attain 6R-based sustainable lean implementation—a case study*. Ieee Access, 2019. **7**: p. 117561-117579.
32. Prasad, M.M., et al., *A framework for lean manufacturing implementation in Indian textile industry*. Materials today: proceedings, 2020. **33**: p. 2986-2995.
33. Freire, J. and L.F. Alarcón, *Achieving lean design process: Improvement methodology*. Journal of Construction Engineering and management, 2002. **128**(3): p. 248-256.

34. Anand, G. and R. Kodali, *Development of a framework for lean manufacturing systems*. International Journal of Services and Operations Management, 2009. **5**(5): p. 687-716.
35. Kumar, S., A.K. Dhingra, and B. Singh, *Process improvement through Lean-Kaizen using value stream map: a case study in India*. The International Journal of Advanced Manufacturing Technology, 2018. **96**(5-8): p. 2687-2698.
36. Amrani, A. and Y. Ducq, *Lean practices implementation in aerospace based on sector characteristics: methodology and case study*. Production Planning & Control, 2020. **31**(16): p. 1313-1335.
37. Melton, T., *The benefits of lean manufacturing: what lean thinking has to offer the process industries*. Chemical engineering research and design, 2005. **83**(6): p. 662-673.
38. Pacheco, D., et al., *18 comparative aspects between lean and six sigma: complementarity and implications*. International Journal of Lean six sigma, 2015.
39. Nave, D., *How to compare six sigma, lean and the theory of constraints*. Quality progress, 2002. **35**(3): p. 73-80.
40. Anvari, A., Y. Ismail, and S.M.H. Hojjati, *A study on total quality management and lean manufacturing: through lean thinking approach*. World applied sciences journal, 2011. **12**(9): p. 1585-1596.
41. Brännmark, M., et al., *Researching Lean: Methodological implications of loose definitions*. Quality innovation prosperity, 2012. **16**(2): p. 35-48.
42. de Jesus Pacheco, D.A., *TOC, lean and six sigma: The missing link to increase productivity?* African Journal of Business Management, 2015. **9**(12): p. 513-520.
43. Pavlović, K. and V. Božanić, *Lean and six sigma Concepts–Application in Pharmaceutical Industry*. Center for Quality, 2010: p. 259-268.
44. BC CAMPUS, S.L., *Writing Instructions*. 2019.
45. Huitt, W., *Critical thinking: An overview*. Educational psychology interactive, 1998. **3**(6): p. 34-50.
46. Wade, C., *Using writing to develop and assess critical thinking*. Teaching of psychology, 1995. **22**(1): p. 24-28.
47. Sawhney, D.R., *Systems-based reliability characterization: Key steps for problem definition in organizational environments*, in *Journal of Operations Management*. 2021.
48. Rapinder Sawhney, G.Z., Fabiano Sene, Ebrahim Sharifnia, *System-Based Methodology for Accurate Problem Definition*. 2021.
49. Sawhney, R., et al., *A Conceptual People-Centric Framework for Sustainable Operational Excellence*, in *Open Journal of Business and Management*. 2020. p. 1034-1058.
50. Rossi, P.H., J.D. Wright, and A.B. Anderson, *Handbook of survey research*. 2013: Academic Press.
51. *Types of Survey with Examples*. QuestionPro.
52. Pribyl, J.R., *Using surveys and questionnaires*. 1994, ACS Publications.
53. Turner III, D.W., *Qualitative interview design: A practical guide for novice investigators*. The qualitative report, 2010. **15**(3): p. 754.

54. Krosnick, J.A. and S. Presser, *Question and Questionnaire Design*. 2010.
55. Macias de Anda, E., *Empirical Research to Integrate National Culture in the Design of Lean Systems*. 2018.
56. Sharma, K.K., *Ergonomic Workload Balancing*. 2020.
57. Bajpai, A.R., *Zone-based Manufacturing*. 2020.
58. Balasubramanian, P.G., *Examining the empirical relationship between subjective fatigue and employee work engagement in a heavy workload manufacturing environment*. May 2021.
59. Akram, R., *A Flexible Packing Optimization Approach to Improve Product Quality and Worker Training*. 2019.
60. Padghan, S.R., *UHT Milk: Supply Chain Based Shelf Life Assessment and Risk Mitigation*. 2021.
61. Sawhney, R., Bajpai, A., Pandav, V., Sharma, K., Zuccolotto, G.B., *Case Study on House Manufacturing Company*. 2019. p. 10.
62. Pandav, V.S., *Mathematical Model to Design a Reliable Flow of Materials using Supermarkets*. 2020.
63. Dr Rupy Sawhney, K.V., Omkar Ghosalkar, *Report on Auto manufacturing plant and application of PCOM*. 2020. p. 26.

VITA

Omkar Rajendra Ghosalkar was born in Thane, a city in the state of Maharashtra, India to Rajendra and Sangeeta Ghosalkar. He completed his B.E. in Mechanical Engineering from the University of Mumbai, Mumbai, India. In 2018, he joined the graduate program in Industrial & System Engineering Department of the University of Tennessee, Knoxville. Currently he is working as a Graduate Research Assistant under the guidance of Dr. Rupy Sawhney in Industrial & Systems Engineering Department. Omkar will graduate with a MS in Industrial Engineering in Aug 2022. He is passionate about sports like soccer, volleyball, and cricket.