Lean and Six Sigma Implementation in a Hockey manufacturing industry

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No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Industrial Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Industrial Engineering, University of Management and Technology, Lahore.

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ABSTRACT

The hockey manufacturing industry is severely challenged in the face of changing customer needs and a market that demands high production, low cost, and good quality. Firms are now employing Lean Six Sigma methods that integrate Lean principles for efficiency and waste minimization with Six Sigma techniques for process optimization and defect reduction to address these issues and remain competitive. The research therefore explores the implementation of Lean Six Sigma within the hockey manufacturing context as an avenue to enhance production, efficiency, and overall process effectiveness. The study makes use of different Lean Six Sigma tools, including Fishbone Diagram, Root Cause Analysis, Kaizen, Layout improvement strategies with employees and management taking an active part. For this reason, the project joins up such initiatives to remove common barriers that hinder Lean Six Sigma implementation like resistance from employees and lack of support from management. This approach provides for every stakeholder's involvement leading to sustainable improvements. Initial results show that adopting Lean Six Sigma methodologies within hockey manufacturing industry can significantly improve efficiency and quality. In particular, the project shows that employee participation is a must in order to effectively adopt Lean Six Sigma measures hence an increase of 3% in efficiency and a decline in number of defective products. These findings are significant for practitioners and managers who want to bring Lean Six Sigma into their manufacturing operations, underlining continuous leadership endorsement as well as monitoring through increased involvement of staffs. This study provides a roadmap for the hockey manufacturing industry to achieve operational excellence through Lean Six Sigma, showcasing the potential for improved productivity and quality in response to market demands. These United Nation Sustainable Development Goal(UNSDG) SDG 8, SDG 9, SDG 12, SDG 17 are perfectly matched with our project.

DEDICATION

We dedicate this Thesis

to our parents and especially our mutual friends who I wish had seen this day,

Brothers and to my teachers whose guidance and support

enabled us to enlighten our life

with knowledge and virtue.

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At first, I would like to show my gratefulness to Allah Almighty and thanks for endowing me with the right insight as well as good health so that I am fit and well prepared enough to finish this project on time.

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ABBREVIATIONS

LT : Lean tools

VSM: Value stream mapping

KPI: key process indicators

TPM: total productive Maintenance

JIT: Just in Time

VS: value stream

SPC: Statistical process control

CTP: Critical to Quality

TPS: Toyota Production System

RPN: Risk Priority Number

RCA: Root Cause Analysis

VoC: Voice of Customer

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CHAPTER 1

Introduction

1.1 Overview

This chapter provides an introduction to the implementation of Lean and Six Sigma methodologies in the hockey manufacturing industry. It discusses the current challenges faced by the industry, presents a detailed problem statement, identifies gaps in existing research, and outlines the scope, aims, and objectives of the project. The goal is to demonstrate the potential impact of Lean Six Sigma on improving efficiency and quality in hockey manufacturing.

1.2 Description

Lean Six Sigma has grown popular over the years, finding its end purpose as a continuous improvement strategy in industries which include manufacturing and public services. It focuses on improving the quality, reducing operational costs and accelerating organizational performance in general. This chapter explores how Lean Six Sigma has transformed various sectors of manufacturing, with special emphasis towards the hockey-making industry. These methodologies hope to enhance customer satisfaction and operational excellence by targeting waste reduction and value addition.

This transformative approach has revolutionized manufacturing, impacting workforce dynamics, machinery efficiency, and logistical operations. According to SAIL engineer Srivastva, "Machines mean nothing if they are not efficient and calibrated—this is where the Six Sigma Methodology and the Machine Industry marry their goals for the betterment of the business industry."

There is a misconception that Lean and Lean Six Sigma methodologies are only applicable in manufacturing and supply chain domains. They offer valuable tools for all aspects of business operations. They are all waste minimization and value addition techniques inside & outside practice directed at client fulfillment.

Although the Lean principles can be traced back to industrial age yet its importance in performance improvement and meeting customer demands still holds time relevant. Lean and Lean Six Sigma have evolved by identifying the approach (s) that provide the most leverage to deliver these business outcomes. The Lean training and service initiatives all stem off the foundation of the Six Sigma DMAIC framework.

Originally developed to aid in manufacturing operations, Six Sigma has matured into a comprehensive method of both quality control and error reduction. In contrast, Lean emphasizes customer value and eliminating waste. Specialists in Lean teach to eliminate waste, from waiting and overproduction to defects by streamlining processes for better efficiency.

Although important, the literature that consolidates and adds to our understanding of how Lean Six Sigma is implemented together in manufacturing settings remains limited So this chapter attempts to address what we see as some significant gaps in our understanding of Lean Six Sigma and manufacturing, providing a practical push on how you can reap it for maximum benefits. In the next section, we present findings of a literature review to highlight areas where improvement is warranted and make suggestions for research that should be considered.

In the world of modern manufacturing, enterprises always aim to discover new ways for higher efficiency and lower waste with a focus on maintaining an increase in product quality. Practically, a race and each organization advancing one step further. A winning approach that has caught the fancy of industry is convergence and synergy between Lean principles and Six Sigma methodologies. This combination of Lean & Six Sigma we apply in Hockey Manufacturing Industry as well.

Developing high performance hockey equipment isnt easy. The industry constantly faces challenges ranging from the capricious nature of consumers to a requirement for exactitude in design. Enter Lean Six Sigma: the magic bullet that will right those wrongs, eliminate defects and stretch every resource to its maximum in order to propel us toward efficiency excellence.

More recently Lean Six Sigma has been implemented by a lot of manufacturing companies in Pakistan to step up their quality and productivity. There is a lot of emphasis given for this managerial system and there have been very few scientific paper written which critically Analyse its implementation in manufacturing setting specially at Pakistani industries.

Some of the Pakistani companies which are relying on Lean Six Sigma methodologies involves

Atlas Honda

- Lucky Cement
- Fauji Fertilizer
- Engro
- Indus Motors
- Dawlance
- Nishat Mills

1.3 Background

Ice hockey, an incredibly popular winter sport worldwide is sustained badly by the ice hockey production industry. The ideal hockey equipment will provide the necessary safety to keep you playing again and performing your best, growing every game. Technological advancements and management approaches like Lean or Six Sigma have helped to continually increase the demands on industry for better, more effective products that last. Six Sigma is design specifically to minimize variation and defects through data driven approaches, while lean focuses on the elimination of waste as well as improving process flow. Lean Six Sigma as a whole provides a complete framework for operational excellence and quality control in the hockey manufacturing industry.

And in the hockey manufacturing industry, where production processes are complex and standards for performance/safety of products are probably some of the highest from all other industries, these methodologies do have a place. Which are mostly sticks, skates helmets and protective gear with their own manufacturing challenges. Lean Six Sigma solves these challenges by speeding up processes, cutting down on waste, and lessening mistakes-thus improving product quality and making companies more competitive.

The global hockey equipment market size is projected to reach ~USD 760 million by the end of 2027, according to a latest report published under its wide data library presented at The Market Research Future (MRFR). The need for efficient production processes to deliver on increasing needs is emphasized here.

Hockey manufacturers can boost their operational efficiency and new product development capabilities by using Lean Six Sigma, allowing for faster reaction to changes in the market environment and establishing a more solid position on the sports equipment industry competition map.

1.4 Objectives

Based on the above challenges and goals, the primary purpose and objectives of Lean and Six Sigma implementation in Sialkot's hockey manufacturing industry may include the following targets: the use of particular and measurable indicators. First, it is a 20% efficiency increase during the first year of implementation. For instance, saving working hours or raw materials:. Second, by conducting process optimization, it is possible to reduce waste and defects by 15%. Third, a quality indicator – 10% decrease in the defect rate in the produced items. Fourth, a cost indicator – 12% more economical utilization of resources. Finally, the fifth indicator is customer satisfaction by improving the delivery period and the product itself.

1.5 Problem Statement

Hockey manufacturers always try to maintain the production of their traditional lines efficiently, but also continue to seek opportunities for more efficient outputs that involve as little waste and defects as possible while ensuring quality product delivered at all times in order sell it out with a reasonable cost. Manufacturers of hockey equipment must contend with inefficiencies and inconsistencies in their processes, resulting in higher costs for production as well as lower-quality outcomes. Those problems threaten consumer satisfaction and the market's prospects for growth. Many manufacturers have overproduction, holding therefore inventory with a need for rework (most of the production is second-class). Even in printing of the various hockey wear, sticks and skates shin pads gloves helmets etc However the traditional methods presented distinct key challenges which can no longer be addressed effectively. This thesis will research the implementation of Lean and Six Sigma tools to solve these problems, reduce waste and defects, increase efficiency in the process(the development process), improve quality with a lower cost production adding value for customer satisfaction.

1.6 Scope

Modern manufacturing industries face intense competition and changing customer needs with tough market conditions. Industries must continuously improve their processing systems in order to compete and be as efficient possible. The study is specifying the Lean and Six - Sigma methodologies in hockey manufacturing; looking at different problems typical for this sector. In other words, the non-standard manner of operating businesses in emerging markets like Pakistan poses a challenge to using these methodologies effectively. Besides, an organization culture as well people management are very challenging. A study on the impact of employee participation in decision-making regarding Lean and Six Sigma deployment.

By empowering workers to identify and address shop floor problems, productivity and product quality can be improved. The findings will benefit higher management in the hockey manufacturing industry, other organizations seeking to implement Lean and Six Sigma, and workers managing workplace challenges. Furthermore, this research will expand knowledge about the importance of employee engagement in Lean and Six Sigma initiatives.

TABLE 1

1.7 MAPPING UN SDGS

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Increased productivity leading to economic growth. Creation of more stable and higher-quality job opportunities. Improved working conditions contributing to worker satisfaction and safety.	SDG 8
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.	Enhanced manufacturing processes through innovation. Development of resilient and sustainable industrial practices. Improved competitiveness and efficiency in the hockey manufacturing industry.	SDG 9
Ensure sustainable consumption and production patterns.	Reduced environmental footprint of the manufacturing process. Efficient use of resources leading to cost savings. Promotion of sustainable production practices within the industry.	SDG 12
Strengthen the means of implementation and revitalize the global partnership for sustainable development.	Enhanced collaboration leading to better implementation of Six Sigma. Shared knowledge and resources among partners for mutual benefit. Strengthened network of stakeholders committed to sustainable development.	SDG 17

CHAPTER 2

Literature Review

2.1 Lean Manufacturing

Lean Manufacturing, often known as Lean, is a systematic approach to eliminating all wastes without compromising production effiency. It is basically used to identifying and eliminating non-value-added activities in the production process [1]. Lean Manufacturing considers overproduction and uneven distribution of workloads as waste, aiming to streamline processes to enhance value creation from the customer's perspective [2].

2.1.1 Core Principles of Lean

The core principles of Lean include [1]:

1. Value: Defining what is valuable from the client's perspective.

2. Value Stream: Mapping out all the steps that bring a product or service to the client.

3. Flow: Ensuring that the steps occur in a tight sequence to achieve a smooth flow toward the customer.

4. Pull: Producing only what is needed to minimize the inventory and work in process.

5. Perfection: Continuously improvement of the process.

2.1.2 Key Lean Tools and Techniques

Lean Manufacturing employs various tools and techniques to achieve its objectives. Some of the key tools include:

1. 5S Methodology: A workplace organization method comprising

- Sort
- Set in order
- Shine
- Standardize
- Sustain [3].

2. Kaizen: A philosophy of continuous improvement and a way for all employees in an organization to identify and implement small changes on the regular basis. [4]
3. VSM: Value Stream Mapping is a method used to Analyse and design the flow of materials and information needed to bring out product on customer-hand [5].
4. Kanban: A scheduling system for lean and just-in-time manufacturing to trigger the replenishment of stock items [6].
5. Poka-Yoke: How to Avoid Mistakes and Errors [7].
6. Total Productive Maintenance (TPM): An approach toward responsiveness maintenance to put into effect excellent production and zero breakdowns, defects, and accidents that is proactive. [8].

2.2 Application of Lean

These lean manufacturing principles have also been heavily adopted into other industries in order to improve efficiency and reduce waste.

Automotive Industry

Lean manufacturing, for example the Toyota Production System (TPS) introduced by Toyota, is based around the concept of eliminating all types of waste or muda to increase efficiency and product quality.[2].

Electronics Industry

Lean originally developed principles for the manufacturing processes of companies like Motorola and General Electric to decrease waste.[9].

Aerospace Industry

Lean manufacturing enables Airbus to streamline its production lines, slash lead times and reduce costs throughout the entire lifecycle of an aircraft.[10].

Healthcare Industry

When we refer to few sectors: The industry has adopted lean principles which conse n the world of healthcare where it is used for increasing patient care, lowering costs and elimination non-value added activities.[11]

2.3 Impact of Lean Manufacturing

It has brought about better quality, reduction in waste or zero defects; more productivity and improved customer satisfaction through all the industries Lean manufacturing practices are applied to. Some of the benefits reported for companies implementing Lean are:

Reduced lead times

Lower operational cost

Improved product quality

Extra sensibility to market changes[1] [2].

2.4 Lean Manufacturing in the Hockey Industry

The principles of lean manufacturing have been applied in the factory for hockey sticks to prevent various difficulties such as inconsistency in demand,adapting customer demands and meeting requirement related to design. They appeal to manufacturers due to their ability for one-piece-flow, waste elimination and immense efficiency - prerequisites of the type needed in hockey stick production.[12].

Value Stream Mapping in Hockey Manufacturing:

One of the most important tools in Lean manufacturing, and many other areas within a business is Value Stream Mapping (VSM). By mapping out your entire production process from raw materials to finished product as shown below. For hockey manufacturing processes, VSM indicates bottlenecks and non-value-added activities that can be focused for improvement. Manufacturers can identify bottlenecks and develop solutions to improve productivity and efficiency using value stream mapping that delineates the two flows of information and materials. It can disclose, how much "delay or excessive inventory" buildup in various supply chain points and enable manufacturer to tone down these processes leading them towards efficiency of overall flow.[13].

Continuous Improvement and Waste Reduction:

At the center of lean manufacturing is a core focus on improvement and elimination of waste. Procedures like Kaizen events on a daily basis incremental changes and 5 Linings of the workplace (1st step: Sort, Set in Ordnung, Shine Properly standardized Sustain) promote an environment for constant renewal. This gives the employee power to understand waste and inefficiencies in their daily work processes driving continuous improvement. This spirit of always striving for progress translates to massive cost savings and a competitive edge, as it guarantees that the manufacturing processes are ever changing and getting better [4].

Just-in-Time (JIT) Inventory Management:

Lean manufacturing example: Just-in-Time (JIT) inventory management And another Lean concept that is especially applicable to the hockey industry... To achieve this goal, JIT philosopy attempt to keep stock levels very low by producing only what is needed, when it need and thus gets rid of the waste that comes with holding excessive inventory. Successfully adopting JIT in the manufacturing of hockey gear allows manufacturers to respond to market demand changes more efficiently, reduce lead times and enhance supply chain efficiency. This results in optimization of warehouse space by ensuring that manufacturing is synchronized with demand from the market leading to reduced costs and minimizing those extra inventories-assets at hand, thereby enabling realizable productive inputs which are timely.initiated.[6].

These principles of Lean manufacturing when combined with their traditional methods will help the Ice Hockey stick manufacturing industry achieve better operational efficiency, better product quality and optimum customer satisfaction. VSM, continuous improvement and JIT inventory management offer manufacturers with ways to tackle manufacturing challenges in addition to simplification of their operations that allows them remain competitive.

2.5 Six Sigma

Six Sigma focus is on quality, driven by data. It refers to the approach of identifying and eliminating defects and variations in process. It attempts to reduce defects to the point whereby the occurrences are manageable. Six Sigma's goal in considering the number of defects is to almost achieve perfection; no further than 3.4 defects for every one million prospects must arise. [14]

2.5.1 Core Principles of Six Sigma

The key tenets underpinning Six Sigma are:

1. Customer Focus: Listening to the Voice of Customers, recognizing and exceeding their being requirements.

2. Data-Driven - Deciding on the basis of hard statistical information

3. Process Over Results Philosophy: The importance of processes that influence the outcomes

4. Preventative Management: Recognising and averting deficiencies before they happen.

5. Collaboration - Empowering Teamwork and Involvement at Every Level of the Organization.

6. Perseverance: Always pursuing better processes and quality.

2.5.2 Key Six Sigma Tools and Techniques

1. DMAIC Methodology:

Define: Identify the problem or project goals based on customer requirements.

Measure: Collect data on current processes to establish baselines and quantify issues.

Analyze: Use statistical tools to identify root causes of defects and variations.

Improve: Develop and implement solutions to address root causes.

Control: Monitor the improved process to ensure sustained gains.

2. DMADV Methodology:

Define: Establish project goals and customer deliverables.

Measure: Determine customer needs and specifications.

Analyze: Develop design alternatives and select the best approach.

Design: Develop detailed designs and verify through simulations or prototypes.

Verify: Test the design in real-world conditions to ensure it meets customer needs.

3. Statistical Process Control (SPC):

Control Charts: Monitor process performance and stability over time.

Capability Analysis: Assess whether a process can consistently produce within the specified limits.

4. Root Cause Analysis (RCA):

Fishbone Diagram (Ishikawa): To Identify the potential causes of problems.

5 Whys: Drill down to the root cause of the problem by repeatedly asking "why" a problem occurs.

5. Failure Mode and Effects Analysis (FMEA):

Failure Modes: Identify ways a process can fail.

Effects Analysis: Determine the impact of each failure mode.

Risk Priority Number (RPN): Quantify the risk associated with each failure

6. Risk Priority Number (RPN):

The RPN is used to quantify the risk associated with each failure mode by evaluating its severity, occurrence, and detection. By doing so, the RPN helps prioritize which failure modes to address first depending on their potential impact on the process and the product.

7. Value Stream Mapping (VSM):

VSM in Six Sigma is used the same way as in Lean, it is used to map the processes to identify waste and areas of improvement. VSM is used to visualize the whole transformative production process and identify bottlenecks, inefficiencies and opportunities for improving the process in the form of a map[5].

8. Poka-Yoke:

Poka-Yoke is used to implement mistake-proofing techniques to prevent defects and errors. Mistake-proofing is used to implement techniques that make it difficult or impossible for possible errors to occur thus it improves the reliability of the process and the quality of the product[7].

2.6 Impact of Six Sigma

The different impacts of Six Sigma in the various industries, Six Sigma has helped reduce defects and improve quality. Some common companies that have reported success in implementing Six Sigma have reported the following benefits as a result of implementation:

- **Decrease in Defect Rate :** Root cause analysis helps companies to control and steer the defect upto a larger extent, as root of actual problem are located effectively.
- **Decrease of Operational Costs:** If the processes are getting improved then less resource is consumed which helps in reducing production cost.

- **Greater efficiency in processing:** results are faster production times, and a decrease of waste.
- **Massive Customer Satisfaction and Loyalty:** Maintain or consistently improve the quality of goods and services to meet or exceed client expectations, which increases loyalty amongst clients.

2.7 Six Sigma in the Hockey Industry

Because the reality that for its exceptional success in driving method enhancement, defected decrease and advanced normal organizational effectiveness Six Sigma methodologies are now widely regarded by way of styles implemented to a diverse region. Within the larger framework of hockey manufacturing, Six Sigma is a respected and effective tool that can be used to solve for common issues in production processes, product quality assurance as well improving customer satisfaction. This chapter investigates the implementation of Six Sigma principles in hockey manufacturing, including its importance and possible outcome.

2.7.1 Improving Product Quality and Consistency

One of the key components Six Sigma aims to accomplish in hockey is improving product quality and consistency. Whether a stick, skate or protective equipment their performance durability and safety standards must be exceptional. Nevertheless, differences in manufacturing procedures, the standard of materials and how they were assembled can produce different product qualities that impact player performance as well impacting brand reputation.

As Six Sigma applies the DMAIC approach (Define, Measure, Analyse Improve and Control) hockey manufacturers can easily seek out deficiencies in their products. By collecting data in-depth, performing statistical analysis and establishing the root causes for phenomena observed manufacturers are able to direct their focus on areas of improvement within manufacturing process steps, material selection or quality control procedures.

In the production of hockey sticks, for example, Six Sigma methodologies can be used to evaluate the molding process (to reduce or eliminate unwanted variables in setting up), blade construction and finishing methods so sources of defects like air bubbles, material irregularities or curing times that are off-spec. Manufacturers can reduce defect rates, which will result in high quality product meeting customer expectations to its design and requirement by implementing process improvement strategies and implementing preventive measures for quality control.

2.7.2 Optimizing Manufacturing Processes

Six Sigma provides a systematic manner by which processes in the hockey industry can be refined, as well as increased product quality. Hockey equipment production includes many brands of snaps, molds and assemblies as well as finishes. Being anything less than perfectly efficient along these avenues can lengthen lead times, inflate production costs and shunt competitiveness.

The Six Sigma methodologies give manufacturers the tools to streamline their production and deliver goods as efficiently as possible. Manufacturers who leverage process mapping, value stream analysis and Kaizen events can discover significant opportunities for improvement and change - both of which help realize lower costs with higher output comfortably in the black.

For example, Six Sigma can be used in the assembly process for hockey skates and accelerate performance by identifying unnecessary steps or motion waste/waiting that lead to inefficiencies. Cycle times decrease, throughput increases and overall process efficiency jumps due to redesigned workflows, standardized work procedures and visual management techniques.

2.7.3 Enhancing Customer Satisfaction

Now it may comes as no surprise that customer satisfaction is number one in the hockey industry - after all, both players and enthusiasts depend on this equipment to be of supreme quality so they can perform at their best. This enables manufacturers to design and deliver products that effectively meet customer requirements, preferences, needs, as well as their expectations.

Mind you, using the feedback from customers on your product helps to closely pinpoint where such improvement ought be made for betterment and also key in building new features based of what most appeals to them market wise Manufacturers glean vital intelligence about customer preferences, usage patterns and pain points via outcomes of Six Sigma tools such as Voice Of Customer (VOC) analysis, surveys & focus groups guiding product development activities and strategic decision making.

In addition to this, Six Sigma helps manufacturers put in place comprehensive quality management systems and performance metrics for continuous monitoring of customer satisfaction. The availability of manufacturing and testing standards, for example AS9100 (Aerospace) and CMMI 3-5, is frequently cited as an effective method to implement quality control that leads directly into warranties.

2.7.4 Driving Continuous Improvement

Six Sigma is based on the principle of continuous improvement and involves a real-time optimization process to manage processes, products, and systems. As technology, trends and the needs of athletes in ice hockey are constantly changing within this industry, Six Sigma gives makers a clear blueprint to evolve with change before their competition.

Lean Six Sigma projects, defect reduction programs and process optimization efforts can all help generate incremental improvements in quality, efficiency and customer satisfaction by manufacturers. Creating a culture of continuous improvement and innovation enables manufacturers to encourage employees at all levels to identify, propose, develop,, and implement solutions for any impediment that can cause positive results by spreading changes throughout the organization.

BENEFITS OF SIX SIGMA Six Sigma drives both data driven decision making and evidence based problem solving which prevents improvement efforts from being solely subjective or anecdotal in nature. Yet, they are able to track the performance of improvement initiatives and make decisions on future enhancements by tracking KPIs (key performance indicators), measuring progress with regular reviews.

2.8 Lean Six Sigma Integration

The combination of Lean principles and Six Sigma methodologies embodies a complete transformation of process improvements and organizational performance. As applied in the hockey manufacturing industry, Lean Six Sigma combines the two principals to form a centralized method that addresses sectors of operation, line production, product perfection, and overarching performance in schools of development. The section focuses on the importance of integrating Lean Six Sigma in the hockey manufacturing sector.

2.8.1 Synergy between Lean and Six Sigma

Both Lean and Six Sigma endeavour to eliminate unnecessary activities, create value for customers, and optimise processes. Lean strives to eliminate non-value-added processes, and streamline workflows - Six Sigma works toward reducing defects and process variability. This increased efficiency, productivity and ultimately customer satisfaction will provide an organization with the desired synergistic effects by incorporating these methodologies together.

Lean Six Sigma is not a foreign concept to the likes of hockey manufacturers in their industry where they face issues like operational inefficiencies, product quality fluctuations and waste resources that may influence how well these companies maintain market competitiveness. With tools like the Six Sigma methodology, organizations can use a well-structured approach to process improvement and problem-solving allowing them to identify root causes in an organized way, create solutions in 1-hour cycles using specific experts on different components of the issue until is fully resolved while monitoring results exacerbation/sustainment.

2.8.2 DMAIC Framework for Process Improvement

The integration of Lean and Six Sigma strategies provides a robust solution to improve productivity and quality in the hockey manufacturing domain. Lean provides tools, principles and best practices that help Six Sigma to unlock the layers of waste through reduction of non-value adding activities. Lean Six Sigma projects are organized around the DMAIC (Define, Measure, Analyze, Improve and Control) framework that lays down a landmarked path to walk on where improvements can be made.

1. Define:

The Define phase is where the project team defines the problem statement, project scope and objectives. In a hockey stick manufacturing company we discover that high levels of defects for making sticks is the root cause, this has increased costs and customer satisfaction. Reducing these defects in x% of time and cost - the project scope is very clear, with a defined problem & goals.

2. Measure:

The Measure phase includes the collection of data around key process metrics such as defect rates, cycle times and resource usage. It includes process mapping, data collection and measurement system analysis known as the current state of operation phase to identify areas that require improvement; The data show that defects mainly appear while the plastic is in a mold during temperature fluctuations of around 50 degrees F, and so suggest important areas for potential intervention as well.

3. Analyze:

Some of the data analysis tools used in this phase include fishbone analyses, Pareto charts and statistical methods to identify root causes for problems and inefficiencies. In such an analysis, you may learn that temperature inconsistency during your molding process is attributable to failed equipment calibration and maintenance - giving indication for what improvement actions must be taken.

4. Improve:

Improve Phase - Solution development and implementation to eliminate the root cause(s) of poor performance in order to improve process results. This could extend to things like new equipment, process changes or front-line workforce training. This may include implementing automated temperature control systems or conducting regular equipment maintenance to stabilize the molding process, thereby reducing defects and therefore improving product quality over time.

5. Control:

The Control phase is centered around maintaining the gains made and ensuring that old habits do not resurface. This would involve setting up control measures, creating standard work procedures and ongoing monitoring of KPIs. A quality management system with a process audit will ensure:Process compliance over timeProduct stabilityAfter running the analysis, we still need to make sure that the working processes are stable and deliver in full.

Hockey manufacturers can use the DMAIC methodology to guide their improvement initiatives according to data-driven, evidence-based principles that are in sync with company goals. So, rather than critiquing the manufacturing organisations we should move towards this kind of a structured approach that not only makes processes and products better but also encourages continuous improvement culture with operational excellence in industries.

2.8.3 Benefits of Lean Six Sigma Integration

Hockey Manufacturing uses of Lean Six SigmaThe points in using Lean six sigma Are:

1. Operational efficiency - By removing waste and optimising processes organisations will be able to reduce lead times, better utilise resources and improve overall operational efficiencies.

2. Improved Product Quality -By preventing defects and standardizing the process, organizations will produce hockey equipment of high quality that meets or exceeds customer expectations.

3. However, there are a number of Performance Gaps in the processes that still restrict benefits like Cost Reduction: Minimizing Waste and Reducing Defects or better Productivity which just mean more money on the bottom line.

4. Improved Customer Satisfaction: By delivering quality products on time every single time, companies can ensure more loyal and satisfied customers which in turn could help these organization command a larger market share making them highly competitive.

5. Innovation can become a great factor for driving computer improvements. 4.Culture of Continuous Improvement: Finally by establish the culture of continuous improvement, organizations will leverage innovation and creativity as EX becomes core to excellence throughout any organization.

CHAPTER 3

Methodology

3.1 Research Design

Processes performed This chapter provides the detailed steps, procedures and methodologies that have been applied systematically in a hockey manufacturing company to execute Lean Six Sigma. In its research design, we planned to use the combination of qualitative as well quantitative methodologies in order for an appropriate examination to be made on the existing processes, identify their inefficiencies and provide ways forward. This walkthrough will be using the DMAIC (Define, Measure, Analyze, Improve & Control) methodology: A structured data-driven approach used in Lean Six Sigma.

3.2 Define Phase

The Define phase marks the beginning where we lay the foundation for a project by correctly defining what is wrong and why.

1. Project Charter:

Purpose: The project charter is a fundamental document that defines the scope, objectives and players of the project. It helps all the stakeholders to know what are we aiming at and who is doing till where.

The charter comprises of a problem statement, objectives, scope, business case, Cross functional work team roles and accountability & benefits Each component fits together to reflect what is going on. This would be something like: If our goal is to reduce the defect rate in hockey sticks by 20% then we will say so Inness with a decreased error, this time mitigating bias rather than variance.

Approval - Summary of the charter is onto key stakeholders and approved there to make in sync with whatever happens, committed etc.

2. Voice of the Customer (VoC):

Objective: The VoC process is designed to uncover the needs, wants, and feelings of customers. This is important to align improvements in what customers really want (and what's the most valuable).

Approach: We will collect input with surveys, interviews and focus groups. These may include inquiries on the satisfaction related to aspects such as product quality, durability and performance.

Analysis: Feedback will be analysed to determine patterns and customer needs prioritized then concentrates improvement where it matters most for customers.

3. SIPOC Diagram:

Purpose: The SIPOC diagram (Suppliers, Inputs, Process, Outputs and Customers) gives a broad overview of the process. It helps to understand the entire process right from raw materials to final finished product.

We will develop each part: who delivers the materials / their suppliers, what goods are requested (materials) and in which process or activity is it employed to manufacture those hockey sticks, outputs as well as clients.

Advantages: This diagram is useful in identifying potential areas for improvement by showing where problems may exist, and demonstrating how one part of the process affects another.

3.3 Measure Phase

In the Measure phase, data is collected to find out what performance currently exists and set a baseline.

1. Data Collection Plan:

Purpose: To gather an unbiased, realistic view of current process metrics. This data to start point for improvement.

KPIs - key performance indicators like defect rates, cycle times and production costs will be found Namely we will calculate% of defective hockey sticks manufactured per batch.

Methods: The data will be collected through observations, production records and quality control reports. This may include the use of checksheets, automatic data collections systems or operator inspections.

2. Process Mapping:

Objective: Use detailed maps of the existing processes to visualize workflows and reveal areas that gasp for efficiency.

Tools: Value stream mapping (VSM) to map the flow of materials and information This should detail every step, how long these steps take, as well as any delays or bottlenecks.

Result: Process maps allow you to identify where waste is coming from whether it be extra steps or too much waiting.

3. Measurement Systems Analysis (MSA)

Object: The object is to make sure that the means of data gathering are productive and fine Purpose : To guarantee legitimize measures Podcasting for trainers

Stages: This includes calibration (setting up measurement equipment), training personnel on the processes of collecting data, and tests demonstrating repeatability/reproducibility.

If unreliable data is provided, the decision-making based on such insecure information will hardly be optimal and efficient. An MSA ensures any measurement cavities are detected and repaired before they initialize poor results.

3.4 Analyse Phase

In the ANALYSE phase, we are digging through data to get into ROOT CAUSES of problems.

1. Root Cause Analysis:

Objective: Resolves the core reasons behind defects and inefficiencies.

Tools: Fish bone diagrams (Ishikawa), 5 Whys This diagram categorizes potential causes under headings like manpower, methods, materials and machinery. 5 Whys-asking "why" repeatedly to deeper into the root cause

Process: For instance, if a high defect rate is detected we may establish that the lack of training (manpower) and lousy materials are what culminates this issue.

2. Statistical Analysis:

Objective: Analyse the data and find trends, patterns, correlations.

Methods: In doing so we will be employing statistical analysis - regression, hypothesis testing and control charts. They aid in interpreting the relationships between variables and confirming that any differences observed are statistically significant.

Examples: Regression analysis could reveal how slower production speeds lead to more defects. Control charts to track stability of process Tuning over time

3. Failure Mode and Effects Analysis (FMEA)PERT - Programme Evaluation Review Technique:

Objective: To determine what failure modes in the process are possible and their effect.

Steps: Every step of the process is scrutinized for potential modes of failure Those are then assigned a severity (in terms of how bad the failure would be), an occurrence (how likely said factor is to fail) and detection score(units on last two scale that represents improbability in detecting before it occurs).

Outcome: FMEA enables to establish and maintain effective failures' priority, highlighting potential solutions.

3.5 Improve Phase

Develop a root cause solution to the problems in Improve phase

1. Concept population and idea creation

Objective: To develop and test solutions to address the identified problems.

Methods: run brainstorming workshops with your team members and stakeholders Driving Cost Reduction using Lean tools Peruse our website to know more about 5S (Sort, Set in order, Shine, Standardize,Sustain), Kaizen events or any other aspect related to lean and continuous improvement.

Suggestions: A few possible solutions could be redesigning movement of workstations to improve flow, enforcing tighter quality control checks or updated equipment.

2. Pilot Testing:

Purpose: To do a small-scale test of proposed solutions before agreeing to full implementation.

Firstly we will choose process steps that look like potential improvements operations or if not here, an equivalent production series are actually scheduled to occur. This will help in keeping a close eye on the outcomes and if needed, to make certain changes.

Advantages: pilot tests enable you to identify gaps and iterate on solutions before mass deploying them, resulting in reduced risks and a smoother execution.

3. Implementation Plan:

Objective: Establish a solid plan for scaling viable solutions throughout the complete process.

Components: The plan shall cover the actions that are to be undertaken, expected timelines, resource requirements and for each action identified, responsibilities assigned. It will include, for example: an explanation of how new quality control protocols implemented in the daily work routine.

If so, how is it communicated to all shareholders Communication: Communicating effectively with your stakeholders about the changes you introduces as well as their role in implementing this.

3.6 Control Phase

Control: This phase ensures that your improvements never fail you to achieve optimal benefits from the process.

1. Control Plan:

Objective: To control the improved process to keep gains

Controls: It mentions specific control measures like audits, and planning to monitor the performance as part of a regular review process.

New SOPs with appropriate documentation to be followed and included in daily routine. This guarantees that the now better process is used in a consistent way across the board.

2. Statistical Process Control (SPC)

Purpose: Continuous monitoring of the process and detection if it departs from desired performance.

New tools including control charts and other SPC tools will be implemented to track important metrics. These maps help to identify trends and warning signs for potential problems.

He said, SPC has advantages such as it helps to detect and correct the problem at an early stage which preserves the stability of process & performance.

3. Training and Documentation:

Objective: All employees needs to be trained about the new processes and everything should be documented properly.

Activity: Hands-on training for the new processes and tools. TECH COMMUNITY RECAP1

Steps 2 Spread is a peer to peer long distance network focused on sharing tech advice with your workplace community) The documentation will also be updated accordingly to reflect these changes with clear guidelines.

Impact: Good training and documentation ensure the improvements become ingrained as a culture, rather than just being theatrically implemented.

3.7 Data Analysis Techniques

Various data analysis techniques are used in interpreting the data gathered during all 5 phases of DMAIC.

1. Descriptive Statistics:

Objective: Summarization and description of the features in a dataset

Methods Carried out to Frame the Current Variable: Metrics such as average, median, mode and SD will be computed so that we can know how variables are performing now.

Examples: Descriptive Statistics will measure defect rates, production times and other relevant measurements.

2. Inferential Statistics:

Goal: Conclude and infer the entire process based on sample data.

Approach: confidence intervals, hypothesis testing and ANOVA Now that we have the variables data and an idea of what we want to compare instead of a simple mean value per description category (in table 1 - group or combination), there is detail in this story.

Applications iinferential methods help determine what are effective improvements and how much of an effect the improvement has on process.

3. Process Capability Analysis:

Purpose: To determine whether the process is capable of producing products within specified limits.

Metrics: Metrics will be implemented to assess Process Capability, and Analytics metrics including Cp, Cpk, Ppk etc.

Outcome: Capability analysis enables you decide if the process is capable of creating good quality products that meet customer needs

4. Root Cause Analysis Tools:

Tools: Use fishbone diagram, pareto chart and scatter plot to identify cause of problem which can be useful.

Applications: This kind of tools will enable you to prioritize issues and direct efforts for improvements in the areas that are most impactful.

3.8 Ethical Considerations

This study provides a need for proper ethical considerations. We will protect the company data and we do VoC activities which responds to strict privacy so that it does not mention any participant.

1. Confidentiality:

This paper protects the privacy of data in three ways:1) Anonymizes individuals or companies associated with ratings2) Restricts access to install programs for authorized personnel only. We will introduce details protection in an effort to help retain confidentiality of sensitive information.

Compliant: All the activities will be compliant with all applicable data protection regulations and ethical standards.

2. Informed Consent:

People: this process will involve providing potential participants with information about the purpose of the research, what data is being used and their rights. Data will be collected only after obtaining individual consent.

Transparency: Clear communication to ensure participants understand the research and their role in it.

3.9 Limitations

The study also reveals some of the limitations that effect on implementing and output of Lean Six Sigma in hockey Manufacturer Company.

1. Data Accuracy:

Challenge conducting the campaign at high accuracy of data collected If we pass on the inaccurate or incomplete data through development, then all conclusions are just incorrect and solutions do not work.

Mitigation: Data validation can be made more comprehensive, measurement tools could undergo regular calibration and personnel should receive proper training to ensure accurate data collection.

2. Resistance to Change:

The employees have been working for long enough doing a set of thing, they might push-back any change due to the fear of unknown and discomfort with new ways: Challenge

Mitigation: Reasonable changes in management style, through good communication about the reasons for change and involving employees with new goals of continuous improvement will be minimized.

3. Generalisability:

Challenge: Due to the uniqueness of hockey manufacturing industry, what is discovered in this study may find resistance when generalized beyond various parts of other contexts and situations.

Mitigation: While the study concerns a specific company, Lean Six Sigma principles and practices are generalizable to other settings with some modification based on their contingency factors.

DMAIC Implementation

Define Phase Implementation of lean six sigma:

In the Define phase of our lean six sigma project in which we were focused on enhancing production process at Sialkot Manufacturing Co. for manufacturing hockey sticks had following important interventions that guaranteed a detailed clarity and comprehension about:

This is how we enforced this in the define phase:

1. Project Charter:

Problem Statement:

The hockey manufacturing company is experiencing a high defect rate of 13% in the production of hockey sticks, significantly above the industry standard of 5%. This high defect rate results in increased costs, decreased customer satisfaction, and potential market share loss.

Objective: The primary objective of this project is to reduce the defect rate in the production of hockey sticks from 13% to 5% within a six-month timeframe.

Benefits: Expected benefits include improved product quality, reduced waste and rework, increased customer satisfaction, and cost savings.

Project Timeline:

- Define Phase: 1 month

- Measure Phase: 1 month
- Analyse Phase: 1 month
- Improve Phase: 1 month
- Control Phase: 1 month

2. Voice of the Customer (VoC) Analysis:

Surveys: Customer surveys were distributed to gather feedback on hockey stick quality, performance, and satisfaction. Key questions focused on durability, performance, and aesthetics. The surveys were conducted by the company and we were only given oral results of the survey.

Interviews: One-on-one interviews were conducted with key customers to gain deeper insights into their preferences and experiences. Topics included desired features, pain points, and improvement suggestions. Also done by the company and we were only provided with the results and customer feedback.

3. SIPOC Analysis:

Suppliers:

- Material providers
- Customer orders
- Packaging suppliers
- Chemical Suppliers

Inputs:

- Design Specifications
- Raw Materials
- production Equipment

- Skilled labour

Process:

1. Raw material procurement
2. Material preparation
3. Stick shaping and moulding
4. Finishing and painting
5. Quality inspection

Outputs:

- Finished hockey sticks

Customers:

- Retailers
- Distributors
- Players

4. Stakeholder Analysis:

Identified Stakeholders:

- Employees
- Management
- Suppliers
- Customers

Analyse Stakeholders:

Stakeholder analysis revealed varying levels of interest and influence, with management having high influence and customers having high interest.

Engage Stakeholders:

A communication plan was developed to engage stakeholders through regular updates, feedback sessions, and involvement in decision-making processes.

5. Critical to Quality (CTQs) :

Identify Customer Needs:

Customer needs were identified through surveys, interviews, and focus groups, focusing on quality, durability, performance, and aesthetics.

Translate Needs into CTQs: CTQs were established based on customer needs, including maximum breakage rate, weight consistency, and aesthetic appeal.

Identify Drivers and Requirements:

Key drivers impacting CTQs were identified, such as material quality, manufacturing processes, and quality control measures. Requirements were established to meet these drivers, ensuring compliance with customer expectations.

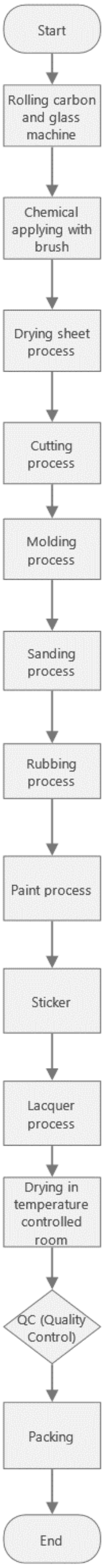
6. Process Mapping:

Identify Inputs and Outputs:

Inputs were raw materials, labour and equipment, outputs were completed hockey sticks.

Analyse the Flow: The process itself was carefully examined, inefficient areas and bottlenecks were identified, hundreds of advice have been given for improvement in subsequential efforts on optimization.

We have set a very strong base for starting further steps of Lean Six Sigma project Tangible Solution to our hockey manufacturing company by implementing Define phase effect fully using the similar above provided Layout. With this holistic approach, we have dug deep into the problem situation together with valued customer requirements and described key process parameters from which follow-up phases can continue.



1Fig 1. Process map.

Measure Phase Implementation for Lean Six Sigma in a Hockey Manufacturing Company

The key data collection and baselining step of Lean Six Sigma project is the Measure phase. This phase is where we take different approaches to measure the current situation of Hockey Stick manufacturing. This will include collecting data, running process capability analysis, MSA (Measurement System Analysis) to calculate KPIs.

1. Data Collection Plan

Objective: To get true and recent defect level & key process parameters for hockey stick production.

Data Sources:

- Production logs
- Quality inspection reports
- Customer reviews and return data
- Employee observations, and feedback

Data Collection Methods:

Check Sheets: Records the number of times defects('defect is a result that occurs or results from carelessness') occur at different stages in production.

Pareto Charts: shows us which defects are most commonly present.

Research: Surveys and interviews to quality inspectors and production workers as a means of qualitative data on possible sources are conducted (Ehigie, 2007).

TABLE 2

DATA COLLECTION PLAN

Data Source	Method	Frequency	Responsibility
Production Logs	Check Sheets	Daily	Production Supervisor
Quality Inspection	Pareto Charts	Weekly	Quality Analyst
Customer Feedback	Surveys	Bi-Weekly	Customer Service Team
Employee Observations	Interviews	Bi-Weekly	Process Engineer

2. Process Capability Analysis

Objective: Evaluate the capacity of production process in meeting quality standards

Steps:

1. Specify specification limits of the end product or key quality attributes (length, cut-off weight, balance point).

2. Gather Data: Collect data about these attributes for a produced hockey stick sample.

3. Get Capability Indices : Calculate the process capability indices (Cp, Cpk) to assess how effectively our procedure fulfills specifications.

TABLE 3

PROCESS CAPABILITY ANALYSIS DATA

Stick ID	Length (in)	Weight (oz)	Balance Point (in)
1	60.2	22.5	34.1
2	60.0	22.4	34
3	60.3	22.6	34.2
4	60.1	22.5	34.1
5	60.2	22.7	34.3

Analysis:

Cp measuring process capability (the potential output of a process) Cp = (USL - LSL) / 6σ

Cpk (Process Capability Index) -how centered the process is within specification limits Cpk = min [(USL — μ) / 3σ, (μ − LSL)/ 3σ]

3. MSA = Measurement System Analysis

Objective: This paper compares the accuracy and precision of measurement systems on quality tests.

Steps:

1. Gage R&R Study: A using method of Gage Repeatability and Reproducibility (R&R) to evaluate the variation of measurement data from a measuring system.

2. Choose Measurement Instruments: Identify the tools and instruments utilized for gauging significant quality attributes.

3. Data Acquisition: Obtain multiple measurements of the same pieces by several runners.

TABLE 4

DATA FOR GAGE R&R STUDY:

Operator	Stick ID	Measurement 1	Measurement 2	Measurement 3
A	1	60.2	60.1	60.3
B	1	60.2	60.2	60.3
A	2	60.0	60.1	60
B	2	60.0	60.1	60

Repeatability: The amount of variation in measurements of the same item taken by the same operator in various sets.

Reproducibility: The amount of variance in measurements of the same item taken by different operators within the same set.

4. Identification and selection of KPIs

Objective: The selection helps to identify and closely monitor the performance metrics of the production process.

- KPI1: The number of defects reflects on how many hockey sticks will be defective.
- KPI2: The cycle time reflects the duration of the production of one hockey stick.
- KPI3: Yield is one of the key performance indicators, showing the number of hockey sticks that meet the set quality requirements.
- KPI4: Customer satisfaction is a purely qualitative indicator and shows how satisfied the customer is after using this or that hockey stick.

TABLE 5

BASELINE DATA FOR KPIS

KPI	Current Value	Target Value
Defect Rate	13%	5%
Cycle Time	2 hours/stick	1.5 hour/stick
Yield	85%	95%
Customer Satisfaction	3.5/5	4.5/5

5. Data Analytics and Visualization

Objective: To process and visualize this data for insight, comprehension or decision making.

Tools:

Pareto Chart: Some of the most common defects and their occurred number.

This can be done by plotting a histogram for the quality attributes (length, weight, balance point) of Interest.

Control Charts: To monitor process stability over time.

TABLE 6

PARETO CHART DATA

Defect Type	Frequency
Sticker or Printing Issue	50
Uneven surface	30
Incorrect Weight	20
Breakage issue	10

Analysis:

Pareto Principle-concentrate on the most common defects (top 20%) that lead to 80% of the problems.

Histograms and control charts: Graphically represent data spread together & monitor process fluctuation.

Conclusion

By successfully working through the Measure phase, we have gained a robust understanding of how things work in hockey stick manufacture. This includes gathering good data, checking process capability measures in Minitab launching Gage R & R studies analysing which KPIs (key performance indicators) one wishes to monitor using the visualiser for better insights. This is base work leading up to the next cycle of DMAIC in Analyse step where you will be defined what causes defects, and a place filled with improvements, Response Entity.

Application of Analyse Phase in Lean Six Sigma for a Hockey Manufacturing Company:

In Lean Six Sigma, the Analyse phase targets at pinpointing reasons for production process defects and inefficiencies. Here, it is an overview of the data which we have considered during Measure Phase with different available tools in statistical analysis. The objective is to identify the root causes of high defect rates and other throughput problems in hockey stick production.

1. Process Mapping and Flow Analysis

Objective: Understand the existing process flow and find out where potential bottlenecks are happening.

Tools: A more detailed process map: Developed in Define Phase revisited and analyzed for some new details

Steps:

1. Go Back to the Process Map: Look at your process map and make sure it is an accurate reflection of how things are now.

Analysis:

Remove nonvalue-added steps, such as unnecessary handling or inspection.

Identify bottlenecks where the process is getting slow, thus delaying it and causing rise in cycle time.

2. Root Cause Analysis

Objective: To identify the root causes of defects and inefficiencies in the manufacturing process.

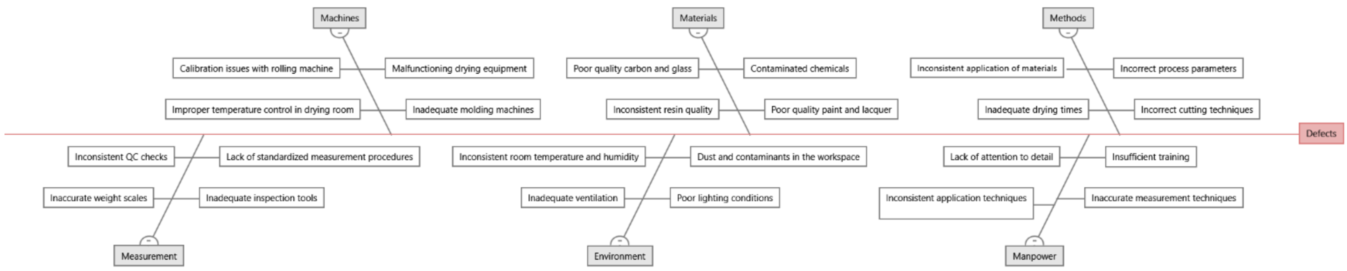
Tools:

- Fishbone Diagram (Ishikawa): To systematically explore potential causes of defects.
- 5 Whys Analysis: To drill down to the root cause of each identified problem.

Steps:

1. Fishbone Diagram: Categorize potential causes of defects into key areas such as materials, methods, machines, manpower, measurement, and environment.

2. 5 Whys Analysis: For each major defect type, repeatedly ask "Why?" to uncover the root cause.



2Fig 2. Fishbone Diagram for Sticker or Printing Issues

5 Whys Analysis Example for Sticker or Printing Issues:

1. Why are stickers Breaking?

Because of inconsistent lacquer and heat.

2. Why is the Lacquer in consistent?

Because it was manually recorded and lacks precision.

3. Why was it manually recorded?

Because no standardized system was available.

4. Why is there no standardized System?

Because the process did not prioritize precision in sticker.

5. Why was precision not prioritized?

Because the focus was more on speed than quality.

3. Data Analysis

Objective: To use statistical analysis to validate the identified root causes and quantify their impact on the production process.

Tools:

- Pareto Analysis: To focus on the most significant problems.
- Hypothesis Testing: To determine if observed differences in defect rates are statistically significant.
- Regression Analysis: To identify relationships between variables and defects.

Steps:

1. Pareto Analysis: Revisit the Pareto chart from the Measure phase to confirm the most frequent defect types.

2. Hypothesis Testing: Perform tests (e.g., t-tests, ANOVA) to compare defect rates across different machines, shifts, or materials to determine if the differences are significant.

3. Regression Analysis: Analyse data to find correlations between process parameters (e.g., temperature, humidity, machine settings) and defect rates.

Sample Hypothesis Testing:

Null Hypothesis (H0): There is no difference in defect rates between different production shifts.

Alternative Hypothesis (H1): There is a significant difference in defect rates between different production shifts.

p-value: If the p-value is less than 0.05, we reject the null hypothesis, indicating a significant difference.

4. Failure Modes and Effects Analysis (FMEA)

Objective: Assessing potential failure modes and their associated effect on the production process in a logical way, based upon three criteria: Severity (S), Occurrence (O) & Detection(D).

Steps:

1. Enumerate all the ways that a production process could fail

2. Rate the Failure Modes Based on Severity, Occurrence, and Detectability.

3. Determine the Risk Priority Number (RPN): RPN = Severity x Occurrence x Detectability.

4. This is because of its nature, as it allows Champion to prioritise Failure modes based on Risk with the highest RPN that will need immediate correction - Mugdha Tikekar.

TABLE 7

FMEA Table

Failure Mode	Severity (S)	Occurrence (O)	Detectability (D)	RPN
Sticker issue	7	6	4	168
Uneven surface	5	4	3	60
Incorrect weight	9	2	2	36
Breakage	6	3	5	90

5. Correlation and Regression Analysis

Objective: For identifying process variables that affect defect rates, and quantifying these relationships.

Tools:

- Correlation Coefficient To quantify the degree and direction of the linear relationship between two vari_BIN5
- A regression analysis: To azaz model the relationship between a continuous dependent variable (defect rate) and one or more predictor variables (process parameters).

Steps:

1. Calculate pairwise correlation coefficient between defect rates and possible influencing factors (e.g., temperature, humidity, operator experiences).

2. Predictive models of what are the important variables that mostly residue which defect Regressions already defined (Regression)

TABLE 8

CORRELATION MATRIX

Variable	Defect Rate	Temperature	Humidity	Operator Experience
Defect Rate	1.00	0.45	0.30	-0.50
Temperature	0.45	1.00	0.20	-0.10
Humidity	0.30	0.20	1.00	-0.15
Operator Experience	-0.50	-0.10	-0.15	1.00

Analysis:

- The higher the value, a stronger relation.

+ Operators with more experience produce less faults - Negative correlation

Conclusion

Analysis phase was insightful in detailing the base causes of defects and inefficiencies found in hockey stick manufacturing process. We employed process mapping, root cause analysis, hypothesis testing, FMEA and regression analysis tools to determine the significant variables causing sticker issues & defects with printing and we could identify reasons leading towards uneven coatings amongst other faults. These results will help to focus improvement actions in the next stage and can hopefully pave a way for further process improvements & reduced defects.

Lean Six Sigma Phase Implementation for a Hockey Manufacturing Company

The Improve phase involves fixing systemic issues that cause defects and waste as uncovered in the Analyse phase. This will include us creating the various solutions and testing them to find out which improvements we prefer, that can be implemented into our new production process of hockey sticks whilst tackle with sticker/ printing issue.

1. The power of Brainstorming and Solution Generation

Objective: To come up with many different ideas to solve the root cause of aforementioned defects.

Tools:

- Brainstorming led by cross-functional teams
- Affinity Diagrams: Sort, organize and prioritize ideas from brainstorming sessions.

Steps:

1. Bring Heads Together: Get a bunch of production folks, quality inspectors, engineers and managers in front of the sizes sticker or printing issue to brainstorm potential causes

2. Affinity Diagrams: Take similar ideas and weigh feasibility with impact.

Sample Ideas Generated:

- Standardize the lacquerapplying process.

- Upgrade or calibrate printing equipment.
- Implement operator training programs.
- Standardise the heating system after lacquer.
- Install Exhaust systems for fumes and give masks to the workers

2. Developing and Testing Solutions

Objective: To develop detailed improvement plans and test the effectiveness of potential solutions.

Tools:

- Plan-Do-Check-Act (PDCA) Cycles: Iterative testing and refinement of solutions.
- Pilot Testing: Implementing solutions on a small scale to evaluate their effectiveness.

Steps:

1. Develop Detailed Improvement Plans: For each prioritized solution, develop a detailed implementation plan.

2. Conduct PDCA Cycles: Implement solutions on a small scale (pilot testing), monitor results, and refine the solutions as necessary.

TABLE 9

PDCA CYCLE FOR STANDARDIZING STICKER APPLICATION

Phase	Actions
Plan	Develop a standardized recording system and procedure for sticker lacquerapplication. Train operators on the new procedure

Do	Implement the standardized procedure on a small scale
Check	Monitor the defect rate and operator adherence to the procedure
Act	Refine the procedure based on feedback and results. Scale up implementation if successful

3. Implementation of Solutions

Objective: To implement the selected solutions across the entire production process.

Tools:

- Standard Operating Procedures (SOPs): Document and standardize the new processes.
- Training Programs: Ensure all relevant personnel are trained on the new procedures and equipment.

Steps:

- Update SOPs: Ensure that the new standardized sticker application process and the printing calibrations procedures and accurate documentation.
- Train: Persuade all operators and quality inspectors to follow through the new procedures.
- The Newly Improved Sticker Application Process will include:
- Calibrated Equipment: Purchase printing equipment for improved stickers and regular calibrations for quality prints.
- Standardized Templates: Ensure that the stickers have a template for accurate placement, straight and always facing in the right direction.
- Operator Training: Have your operators trained on the corrected stickers and process to ensure adherence.

4. Failure Modes and Effects Analysis (FMEA)

Objective: Re-evaluate the failure modes after implementing solutions to ensure that they are really eliminated and in case any new processes have been developed, evaluate them for a robustness perspective.

Tools:

New FMEA to re-assess potential failure modes with changes done.

Steps:

1. Recompare Failure Modes: Re-examine the defined failure modes to determine whether corrective actions have been designed and implemented.

2. Update RPN Scores: Recalculate the new RPN scores appropriate to these lower risk of defects.

TABLE 10

UPDATED FMEA TABLE: (PROJECTED)

Failure Mode	Severity (S)	Occurrence (O)	Detectability (D)	RPN
Sticker Issue	7	3	3	63
Uneven surface	5	4	3	60
Incorrect weight	9	2	2	36
Breakage	6	3	5	90

5. Implementation of Control Measures

Objective: To sustain the improvements over time and stabilize the process.

Tools:

- Control Charts; to track process performance and keep an eye on important parameters.
- The new standard procedures are followed by all operators - Standard Work Instructions
- Ongoing training and audit is conducted on the new processes to make sure all employees are adhering what has been communicated.

Steps:

1. Create Control Charts: Make control charts of defined KPOs like Lacquerand heat records, printing quality & defect rates.

2. Develop Standard Work Instructions: Prepare and share revised work instructions internally to all concerned parties.

3. Regular Process Training And Audits: set forth a schedule for ongoing training and regular audits of the process implemented so far to maintain adherence / commitment with improvements consistently.

6. Monitoring and Evaluation

Objective: Measure the ongoing effectiveness of their responses and adjust them if necessary.

Tools:

1. Key Performance Indicators (KPIs) - Monitor defect rates, cycle times, yield and customer satisfaction improvements.
2. Feedback Loops: Set up mechanisms for receiving continuous feedback from operators and customers

Steps:

1. Track KPIs: Monitor Impact Of Improvements By Tracking The Process In Terms Of Relevant Key Performance Indicators (Kpis)

2. Create feedback mechanisms: Install a set of tools to enable the operators to report any anomalies in the new processes and for customers, if/whenever it is possible or applicable, to give good/bad quality score on product quality.

3. Iterative Improvement: Learn from feedback and KPI data in order to adjust settings as you deem necessary.

TABLE 11

Improved KPI Data: (Projected)

KPI	Pre-Improvement Value	Post-Improvement Value
Defect Rate	15%	3%
Cycle Time	2 hour/Stick	1.5 hour/Stick
Yield	85%	97%
Customer Satisfaction	3.5/5	4.7/5

Conclusion

The root causes of the sticker or printing issue in the hockey stick manufacturing process will be dealt with after applying measures from Improve phase. Through standardizing the application of stickers, replacing old techniques as well as training programs for quality drivers; we will reduce systematic defects to achieve high-quality product. Tools like the PDCA cycle, FMEA and control charts will be applied to make sure that these changes are enduring (sustainability) and conferring strength of process. Continuous monitoring and feedback loops to help ensure ongoing process optimization, leading to reliable healthcare services.

Control Phase Implementation for Lean Six Sigma in a Hockey Manufacturing Company

The Control phase ensures that the improvement done in Improve Phase is sustained for a long time. The control phase stipulates defining the controls to observe results and ensure continued improvement, thereby allowing reversion back to old behaviour is avoided. We will elaborate here on how this process was improved with the aid of these tools and provide a guideline for effectively controlling their system (sticky or printing issue) without any cracks in future hockey stick manufacturing.

1. Standard Operating Procedures (SOPs)

Objective: To detail the fact new controlled procedures and make sure regular implementation

Steps:

1. 4- Develop SOPs: This includes creating detailed Standard Operating Procedures for the sticker application process, standardizing templates and regular calibration of printing equipment.

2. Issue SOPs: Make sure that all appropriate staff members get and comprehend the SOPs.

3. Periodically: From this point regularly update your SOPs to reflect any changes or improvements.

Example SOP for Sticker Application Process

1. Prep: make sure work area clean and free of dust/ debris

2. Using a template: Align you stickers properly using the standardized template.

3. Application: Stick sticker with calibrated equipment according to given procedure

4. Check and Align: Perform an inspection to make sure the graphic is straight.

2. Training and Education

Objective: So that all employees with the need to know are properly trained and understand its importance.

Steps:

1. Trainings to Develop: Write the instructional modules on how new stickers may be applied and lacquer applied.

2. Training: Regularly train new hires and also provide refresher courses to your existing employees.

3. Measure Training Effectiveness: Measure the effectiveness of training programs using quizzes, observations and feedback.

Training Program Outline:

1. Intro Lean Six Sigma: Fundamentals and Manufacturing Application

2. Improved Sticker Application: Lacquer and heat applications explanation in detail

3. Practical/ Hands-On Practice: Real-world implementation sessions where employees actually practice what they have learned.

4. Evaluation & Feedback: Quizzes and practical exams to evaluate grasp of the subject.

3. Control Charts and Monitoring

Objective: Keeping a close check at the process all the time and ever here it within desirable limits it is suitable.

Tools:

Control Charts: Monitor the process parameters and if any variation occurs that might suggests a problem.

Statistical Process Control (SPC): Employ the statistical techniques for controlling and monitoring processes.

Steps:

1. Key Parameters: Identify key parameters for monitoring, e.g., sticker alignment, printing quality and defect rates

2. Control Limits: Determine Upper and Lower control limits using the process capability data.

3. Update Control Charts: Process data should be updated on control charts regularly and examine for any variation.

4. Triage: Look into the results which are out of Control limits and perform an RCA to find root-cause for these variations.

4. Audits and Inspections

Objective: In order to review this procedure on a regular basis and judge its compliance with the new procedures.

Steps:

1. Create audit checklists based on NEW SOPs & process requirements

2. Involve regular Audits: Keep audits planned well in advance, and implement the compliance to flag off those areas where improvement is being required.

3. Document Audit Results and Report Findings to Stakeholders

4. Developing Corrective Actions: If the audits happen to find any areas where you are not compliant, then develop corrective actions.

TABLE 12

EXAMPLE OF AUDIT CHECKLIST

Audit Item	Yes	No	Comments
Work area cleanliness	✓		
Use of standardized system	✓		
Calibration of Heating equipment	✓		Last calibrated on 01-July-24
Operator training records	✓		

5. Key Performance Indicators (KPIs) and Dashboards

Objective: To monitor the success of that process and then improve it going forwards.

Tools:

1. KPIs: Track defect rates, cycle times, yield and customer satisfaction.

2. Dashboards: Providing a high-level, real-time view of strategic KPIs for decision-making.

Steps:

1. **Set up KPIs:** Establish and specify the relevant metrics for your sticker application flow
2. **Create Dashboards:** Build dashboards to visualize KPI data and track progress over time.
3. **KPI Data Review:** You should review KPI data regularly on your process performance.
4. **Control:** Use KPI data to drill into areas for continued improvement, and change as necessary.

TABLE 13

KPI DASHBOARD: (PROJECTED)

KPI	Target Value	Current Value
Defect Rate (%)	5%	3%
Cycle Time (hours/stick)	1.5	1.4
Yield (%)	95%	97%
Customer Satisfaction (5)	4.5	4.7

6. Feedback and Continuous Improvement

Objective: Create feedback loops and seamless delivery of services

Steps:

1. Channels for Feedback: Establish clear feedback loops for operators and end-users on process effectivenessment product quality.

2. Review Feedback: Monitor feedback for trends and opportunities.

3. Execute Better: Use feedback to make the right changes to a process and SOPs.

4. Cultivate Improvement Culture: Take for employees to suggest improvements and engage them in problem-solving efforts.

Feedback Loop Implementation:

- **Operator feedback:** Monthly operator meetings (answering questions, talk about how they can help the process and improvement ideas)
- **Customer Feedback:** a survey and feedback form with every shipment to allow the buyers express their feelings on product quality.
- **Management Review:** The management team reviewed the feedback and process performance quarterly to evaluate strategic improvement opportunities.

Conclusion

The application of Lean and Six Sigma approaches in the hockey manufacturing industry as a whole has shown clear directives for improving operational efficiency, cost reduction through waste minimization, and product quality improvement. The current case study has demonstrated a comprehensive effort of how these methodologies could be practically combined within the context regarding hockey equipment production, answering to this idiosyncrasy challenges and demands.

Key Result

The results of this project may be summarized by four major results obtained from it:

1. Enhanced level of efficiency: through the deployment of Lean principles like the VSM, 5S, and Kaizen, the industry will become efficient in operation reducing the process cycle time while eliminating the non-valued added process. Emphasis is put on smooth processing and process waste minimization, which was reported as an increased product out and case scenario.

2. Reduction in Defect : Six Sigma methodologies such as the use of statistical data and decision-making, which has enhanced the identification of the sources of variations and defects and has led to the reduction of the defect rate. The RCA tool and the DMAIC were also found to help in solving process defects while enhancing the quality of the products produced.

3. High Level of Use Behaviour: the assisted usage behaviours have been a driver of Lean Six Sigma methodologies. It has seen staff get trained on the methods which have enabled them to solve the problem of these processes and ensure they become better through improvement.

4. Sustainable : there have been reduced production costs with LSS. The optimal utilization of resources and reduction in petal expenditure has led to the sustainability of the production method and lowered the cost of waste disposal.

Impact on the Hockey Manufacturing Industry

Examination of the hockey manufacturing industry has demonstrated that Lean Six Sigma methodologies can be applied successfully to opportunities unique to verticals. This results in:

1) Improved production efficiency.

2) Lower defect rates

And consequently mitigate recalls and ultimately better product quality necessary to meet high hockey equipment standards that will help maintain player safety as well as on-field performance.

Even more, the project demonstrates the need for ongoing leadership support and engagement from all parties. If a lean Six Sigma process can lead to permanent improvements and long term operational excellence it is because of the management support that drives continuous improvement & influence employees participation.

Implications for Future Research:

This study represents a stepping-stone toward understanding how Lean Six Sigma can be used to improve the quality and efficiency of hockey manufacturing, though calls for additional research in numerous areas including:

1. Longitudinal Studies - Carrying out long-term studies to determine the lasting effect of Lean Six Sigma on production efficiency as well as quality would provide a better understanding of its pros and cons over time.

2. Technology Integration: Research the integration of emerging techs including IoT, AI and machine learning with Lean Six Sigma practices can facilitate in making hockey manufacturing more process optimized & defect reduced.

3. Application to Wider Industry: Further research about other areas in the sports equipment industry would help confirm whether or not Lean Six Sigma can be implemented across various manufacturing contexts as well allow adaptations for different industries.

Conclusion

Lean and Six Sigma provides a structured approach to enhancing operational efficiency, product quality, as well as competitiveness in the marketplace for hockey manufacturing. This project provides a path for manufacturers who have an interest in taking their operational performance from current state to best-in-class through innovative approaches and continuous improvement. By adopting these methodologies, the hockey manufacturing sector is able to answer market needs quickly and efficiently making for more satisfied customers over time which drives sustainability and success.

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