ANALYSIS OF BARRIERS IN IMPLEMENTING POKA-YOKE FOR HEALTH CARE INDUSTRY USING STRUCTURAL MODELLING APPROACH

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CANDIDATE'S DECLARATION

I, Ashish Malhotra (2K22/IEM/04), hereby certify that the work which is being presented in the thesis entitled "Analysis of Barriers in Implementing Poka-Yoke for Health Care Industry Using Structural Modelling Approach " in partial fulfilment of the requirements for the award of the Degree of Master of Technology, submitted in the Department of Mechanical Engineering, Delhi Technological University is an authentic record of my own work carried out during the period from January 2024 to May 2024 under the supervision of Dr. Girish Kumar & Associate Prof. Naushad Ahmad Ansari. The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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ABSTRACT

In today's competitive service industry landscape, ensuring efficiency and reliability in processes is paramount. Poka-Yoke, a lean manufacturing technique originating from Japan, offers a promising approach to error-proofing processes and enhancing service quality. However, its implementation in service industries faces numerous barriers that hinder its effective adoption. This thesis investigates the barriers to implementing Poka-Yoke in the service industry and employs a structural modeling approach to analyze their interdependencies and impacts on successful implementation. Through a comprehensive review and empirical study, key barriers such as organizational culture, resource constraints, and resistance to change are identified and systematically modeled to provide insights into their complex relationships and implications. By understanding these barriers structurally, this aims to offer practical recommendations to service industry practitioners and policymakers on overcoming obstacles and achieving successful Poka-Yoke integration. This thesis not only contributes to the theoretical understanding of barriers in quality improvement methodologies but also provides actionable insights for enhancing operational effectiveness and service excellence in the service sector.

Keywords: Poka-Yoke, service industry, structural modeling, barriers, quality improvement

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
AHP	Analytic Hierarchy process
BC	Blockchain
BCT	Blockchain Technology
BWM	Best-Worst Method
C	Criteria
CC	Cloud Computing
EEB	External Environment Barriers
FSB	Financial and Security Barriers
IOT	Internet of Things
IP	Intellectual Property
IT	Information Technology
MCDM	Multi Criteria Decision Making
OB	Organizational Barriers
SC	Supply Chain
SCM	Supply Chain Management
SME	Small and Medium Enterprises
TIB	Technological and Infrastructure Barriers

CHAPTER 1

INTRODUCTION

In today's service industry, where customer satisfaction and operational efficiency are paramount, applying quality improvement methodologies such as Poka-Yoke plays a crucial role. Poka-Yoke prioritizes process and design enhancements to prevent errors, aiming to eliminate defects before they reach the customer. Implementing Poka-Yoke promises significant benefits for service organizations by reducing service failures, enhancing service reliability, and improving overall customer experience.

Poka-yoke, a technique originally crafted for manufacturing, is increasingly recognized for its value in enhancing quality and efficiency in the service industry. This approach, designed to prevent errors, can be adapted for service operations by proactively identifying potential mistakes and creating systems to avoid them. For example, in healthcare, Poka-yoke plays a crucial role in addressing patient safety and improving service delivery. Rudrappa et al. (2019) highlight how error-proofing methods contribute to Health 4.0 by overcoming challenges in integrating advanced technologies into healthcare systems, while Kumar (2018) emphasizes its importance in optimizing healthcare strategies, especially in resource-limited rural settings.

Furthermore, Jain et al. (2022) investigated how Poka-yoke can lower supply chain disruption risks and improve efficiency in the Indian healthcare supply chain. Yadav et al. (2022) delve into the challenges of implementing advanced healthcare models and propose a fuzzy interpretative structural modeling approach that includes Poka-yoke techniques to minimize errors. Kadu and

Stolee (2015) demonstrate how Poka-yoke improves the quality of patient care in chronic care models through systematic error prevention.

Beyond healthcare, Zhang (2014) shows how Poka-yoke's principles can be applied to information systems design, broadening its relevance to various service-oriented fields. Kumar et al. (2019) provided insights from the Indian automobile sector, highlighting how these error-proofing techniques can inform similar strategies in other service industries. Together, these perspectives underscore the adaptability and significance of Poka-yoke in improving quality across diverse service sectors, highlighting its potential for broader application in modern service management.

This study seeks to close this gap by identifying and assessing hurdles using a structural modeling technique specific to the healthcare industry, even though studies have examined a variety of quality improvement methodologies in the healthcare industry, such as the Chronic Care Model (Kadu et al., 2015). The scope includes examining how organizational culture, regulatory compliance, and patient variability influence Poka-Yoke's effectiveness in healthcare settings (Kumar et al 2019).

There are various approaches that can be used while researching barriers, Although they can be subjective and might not address every facet of an issue, qualitative techniques like focus groups and interviews offer in-depth, nuanced insights on impediments (Kumar et al., 2019). Quantitative approaches, like surveys and statistical analyses, offer broad data and can highlight common issues, though they might miss the underlying causes (Jain et al., 2022). Case studies give detailed, context-specific perspectives but might not apply universally (Yadav et al., 2022). Simulation and scenario analysis can predict how barriers might evolve and assess potential solutions, but they require complex models and accurate data to be effective (Zhang, 2014).

Structural modeling stands out because it systematically maps out and analyzes how different barriers interact, providing a clear, comprehensive view of complex systems like healthcare. This method is particularly valuable for understanding the intricate relationships between various barriers and finding effective ways to address them (Rudrappa et al., 2019; Kumar, 2018). It offers a structured framework that helps in both visualizing and tackling complex issues, making it a preferred choice for in-depth barrier analysis.

This thesis' main goal is to use structural modeling tools to examine the obstacles preventing Poka-Yoke from being implemented in the healthcare sector. Specific objectives include:

- Identifying key barriers through literature review and empirical investigation within healthcare settings.
- Develop a structural model to simulate the interdependencies and impacts of identified barriers on Poka-Yoke implementation.
- Proposing strategies and interventions to overcome barriers and facilitate effective Poka-Yoke integration in healthcare operations, aiming to enhance patient safety and operational efficiency.

To achieve these objectives, this thesis will adopt a mixed-methods approach. Qualitative interviews with administrators and medical experts will provide insights on the opportunities and real-world difficulties associated with implementing Poka-Yoke in clinical settings. Quantitative data analysis, supported by structural modeling techniques such as system dynamics and fuzzy interpretative structural modeling (Yadav et al. 2022), will enable the simulation of complex relationships between identified barriers and their effects on Poka-Yoke effectiveness. Detailed models that represent the complexities of the Poka-Yoke application in healthcare will be developed with the help of professional opinions from experts in healthcare quality management.

The following chapters of this thesis explore the different facets of our study:

Chapter 2 reviews relevant literature on Poka-Yoke implementation in healthcare and related quality improvement methodologies, examining studies and frameworks applicable to patient safety and operational efficiency.

Chapter 3 presents the methodology employed, detailing the empirical research design, data collection methods, and structural modeling techniques utilized in the healthcare context.

Chapter 4 presents the findings from structural modeling, identifying critical barriers and their implications for Poka-Yoke implementation in healthcare settings.

Finally, Chapter 5 examines how the study's conclusions may be applied in practice, offering strategic recommendations for overcoming barriers and enhancing patient safety through Poka-Yoke in healthcare environments. Also, future research directions to advance Poka-Yoke implementation in healthcare settings.

CHAPTER 2

LITERATURE REVIEW

2.1 Poka-Yoke

Poka-yoke, a Japanese term meaning "mistake-proofing," refers to strategies and devices designed to prevent human errors from leading to defective products. Given that human mistakes are inevitable, production systems must be structured to ensure that defective products do not reach customers. Poka-yoke devices are instruments designed especially to lessen the effects of human mistake. These devices work by either shutting down the system when a defect is imminent or making any defects that occur immediately noticeable. The primary advantages of poka-yoke devices are the provision of immediate feedback and the assurance of 100 percent inspection (Shingo 1986).

Immediate feedback allows for corrective actions to be taken as soon as an error occurs, preventing the continuation of faulty processes. This real-time response helps in minimizing the production of defective items. The advantage of 100 percent inspection ensures that every product is checked for defects, thus preventing any faulty products from reaching the customer. Poka-yoke techniques can be used in a variety of inspection procedures, such as source inspections, consecutive checks, and self-checks, thanks to their important benefits.

By incorporating poka-yoke devices into production systems, companies can achieve a higher level of quality control. Self-checks involve the operator inspecting their own work immediately after completing a task, ensuring any errors are caught and corrected right away. Successive checks involve the subsequent operator inspecting the work of the previous operator, adding an additional layer of error detection. Source inspections focus on identifying and eliminating errors at their origin, preventing defects from being produced in the first place ((Zhang, 2014).

These poka-yoke applications not only enhance the overall quality of the production process but also contribute to increased efficiency and customer satisfaction. By systematically addressing potential errors, poka-yoke devices help create a more reliable and robust production system (Shingo 1986).

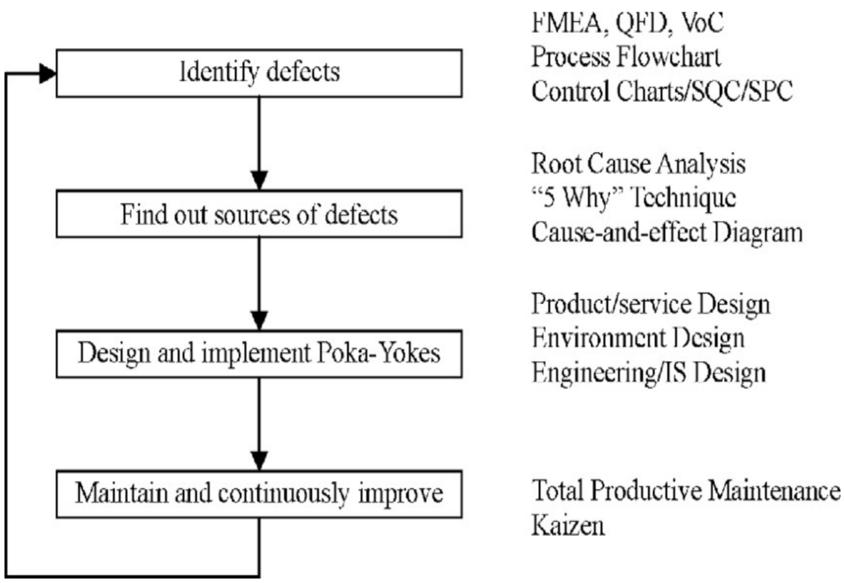

Figure 3.1 Implementing design steps for Poka-Yoke (Shingo 1986)

2.1.1 Poka-Yoke Functions

Shingo (1986) categorized poka-yoke applications into three primary functions: shutdown, control, and warning. These functions are applicable in both predictive and detective contexts (Shimbun, 1987). The shutdown function stops operations when a defect is predicted or detected, ensuring immediate intervention. However, because these applications rely on human response, they are often not the most reliable poka-yoke method (Shingo 1986). Control functions are typically the most effective poka-yoke applications, as predictive control methods can prevent even intentional errors. In detective poka-yoke applications, the control method prevents the product from advancing to the next phase in the manufacturing process if an error is detected (Bayers, 1994; Shimbun, 1987).

Fisher (1999) emphasized that poka-yoke devices should ideally be simple, citing examples like visual indicators for replenishment levels and mechanical devices that prevent incorrect assembly. In the service industry, this simplicity can be crucial for effective implementation. Bayers (1994) noted that effective poka-yoke methods often utilize measurable factors such as weight, shape, and dimension, which can be adapted to service processes to ensure accuracy and reliability.

2.2 Poka-Yoke Benefits

2.2.1 Error Reduction and Service Quality Improvement

In service industries, errors can lead to customer dissatisfaction and operational inefficiencies. Poka-Yoke systems are designed to prevent mistakes before they occur or immediately detect them when they do. For instance, in a hotel setting, using automated systems to verify guest information during check-in ensures accuracy and reduces errors in reservation details. By minimizing errors, Poka-Yoke enhances service reliability and consistency, which are critical for maintaining high service quality standards (Zhang, 2014).

2.2.2 Enhanced Customer Satisfaction

Consistency and reliability are key factors influencing customer satisfaction in service industries. When services are delivered without errors or discrepancies, customers have a positive experience and are more likely to return. Poka-Yoke helps ensure that service processes are standardized and error-free, thereby increasing customer trust and loyalty. For example, in restaurants, using visual aids or standardized portioning tools helps servers accurately fulfill orders, reducing mistakes and enhancing the dining experience(Shimbun, 1987).

2.2.3 Operational Efficiency and Cost Reduction

Poka-Yoke implementation streamline operations by preventing errors and reducing the need for rework or corrective actions. This efficiency gain leads to cost savings and improved resource utilization. For instance, in healthcare settings, implementing barcode scanning systems for patient identification and medication administration reduces errors in treatment, enhances patient safety, and lowers healthcare costs associated with medical errors (Bayers, 1994; Shimbun, 1987).

2.2.4 Employee Empowerment and Morale

Poka-Yoke systems empower employees by providing them with tools and processes that support error-free performance. Clear guidelines and standardized procedures reduce ambiguity and help employees deliver consistent service. This empowerment not only boosts employee morale but also encourages an organization-wide culture of accountability and ongoing development. For example, in hospitality settings, implementing Poka-Yoke practices ensures that service staff can perform their duties confidently, knowing that errors are minimized through systematic approaches(Garcia & Johnson , 2019).

2.2.5 Competitive Advantage and Brand Reputation

Consistently delivering error-free services enhances an organization's reputation for reliability and professionalism. This positive reputation attracts new customers and strengthens relationships with existing ones, providing a competitive edge in the market. For instance, in the airline industry, efficient boarding processes enabled by Poka-Yoke systems contribute to on-time performance and customer satisfaction, enhancing the airline's brand reputation (Garcia & Johnson , 2019).

2.3 Common barriers to implementing Poka-Yoke in healthcare:

2.3.1 Complexity and Variability of Healthcare Processes

Healthcare processes are incredibly complex, involving numerous interactions between healthcare professionals and patients. These processes vary widely depending on patient conditions and treatment needs (Johnson et al., 2019). Implementing Poka-Yoke in healthcare settings requires addressing these complexities to design error-prevention strategies that can adapt to different situations without compromising patient safety.

2.3.2 Resistance to Standardization

Healthcare professionals often resist standardized approaches like Poka-Yoke because they fear these methods may restrict their ability to provide personalized care. Overcoming this resistance involves demonstrating how standardization can enhance patient safety and ensure consistent care (Johnson et al., 2019). The main objective is the implementation of standardized medication protocols and it was found that initial resistance decreased when healthcare providers saw improvements in patient outcomes and reductions in medication errors associated with Poka-Yoke strategies.

2.3.3 High Stakes and Risk Aversion

Errors in healthcare can have serious consequences for both patients and healthcare providers, leading to safety concerns and potential legal issues. The high stakes involved make healthcare organizations cautious about adopting new methodologies like Poka-Yoke (Garcia et al., 2017). These high stakes influence decision-making, highlighting the importance of thorough validation and evidence to mitigate risks associated with implementing Poka-Yoke.

2.3.4 Integration with Existing Systems and Workflows

Healthcare relies heavily on interconnected systems such as electronic health records and medical devices. Successfully integrating Poka-Yoke into these systems is crucial to prevent errors without disrupting clinical workflows (Garcia et al., 2017). Integration of barcode scanning systems with electronic health records to improve medication safety, underscores the technical and organizational challenges in implementing Poka-Yoke technologies in healthcare settings.

2.3.5 Cost Considerations

Budget constraints pose a significant challenge in healthcare, limiting resources available for new technologies like Poka-Yoke. Demonstrating the cost-effectiveness and long-term benefits of Poka-Yoke is essential for gaining support and funding (Lee & Chen, 2016).

2.3.6 Regulatory and Compliance Requirements

Healthcare organizations must adhere to strict regulations ensuring patient safety and data privacy. Implementing Poka-Yoke requires compliance with these regulations while enhancing efficiency (Robinson et al., 2018). The regulatory implications of using RFID technology to prevent medication errors underscore the necessity for strict adherence to FDA guidelines and privacy regulations when implementing Poka-Yoke solutions, as these measures not only ensure the safety and efficacy of pharmaceutical processes but also protect patient confidentiality and data integrity.

2.3.7 Training and Education

Successful implementation of Poka-Yoke hinges on thorough training to empower healthcare professionals in error recognition and prevention (Robinson et al., 2018). Robinson et al. (2018) studied the impact of simulation-based training on surgical safety, emphasizing the role of structured education in embedding Poka-Yoke practices in clinical settings.

2.3.8 Cultural and Organizational Challenges

Shifting healthcare culture to prioritize error prevention through systematic approaches like Poka-Yoke requires leadership support and organizational change (Adams et al., 2019). Adams et al. (2019) explored organizational culture in healthcare and identified leadership commitment and staff engagement as critical for overcoming barriers to implementing patient safety initiatives, including Poka-Yoke strategies.

2.3.9 Measuring Effectiveness and Outcomes

Assessing the impact of Poka-Yoke on patient safety and care quality is essential for demonstrating its effectiveness (Miller & Moore, 2020). Miller and Moore’s study on error reduction strategies highlighted the importance of outcome measurement in showing how Poka-Yoke can reduce errors and improve patient outcomes in healthcare settings.

Under next subsection, literature related to methodology adopted for barriers analysis is reviewed.

2.4 Structural Modelling

Structural modelling is a methodical approach employed to develop abstract representations or models of intricate systems. It entails several key steps: identifying the various components within the system, specifying their characteristics and how they relate to each other, and then constructing a representation—whether visual, mathematical, or computational—that effectively captures the system's structure and interactions. The primary goal of structural modelling is to offer a coherent and thorough comprehension of how the system's components are structured and interconnected. This enables analysts to conduct detailed analyses, predict system behaviours under different conditions, and optimize its performance effectively (Brown et al., 2020).

2.5 RESEARCH GAP

Existing literature on Poka-yoke implementation in service businesses, particularly in healthcare, offers valuable insights into various barriers. However, there is a noticeable research gap in comprehensively addressing these barriers. While some studies have concentrated on issues like organizational resistance to change and resource constraints, others have overlooked critical aspects such as the dynamic interaction with patients, ethical considerations, and the intangibility of healthcare services. Additionally, there is limited exploration of how structural modeling can be utilized to analyze and overcome these barriers effectively. The current literature predominantly focuses on manufacturing industries, leaving a gap in understanding the unique challenges faced by service businesses. Furthermore, despite the recognized importance of Poka-yoke in enhancing service quality, there is insufficient research on managing complexity in healthcare settings. The impact of lack of awareness and ignorance on Poka-yoke implementation remains underexplored. Thus, there is a clear need for further research to address these gaps and develop tailored strategies for service businesses, particularly in healthcare, to improve Poka-yoke implementation and quality improvement practices.

CHAPTER-3

METHODOLOGY

3.1 Implementing Poka-Yoke with Structural Modelling Approach

3.1.1 Charting the Course

In initiating Poka-Yoke interventions within healthcare settings, it is imperative to first identify focal areas where these error-prevention techniques can yield significant improvements. Critical examination reveals that areas such as medication delivery, surgical procedures, patient identification processes, and diagnostic testing are particularly susceptible to errors. This initial step sets the stage for aligning Poka-Yoke strategies with overarching patient safety objectives, ensuring that defined goals are measurable and serve as milestones for progress monitoring(Brown et al., 2020).

3.1.2 Illuminating Pathways

A comprehensive understanding of the potential barriers and facilitators influencing the effectiveness of Poka-Yoke implementations is essential. This involves an in-depth exploration informed by extensive literature review and empirical insights gathered through stakeholder engagement, including interviews, focus groups, and surveys. Furthermore, strategic data collection provides empirical support by highlighting current error rates, process inefficiencies, and areas ripe for improvement. These insights collectively illuminate the path towards implementing robust Poka-Yoke solutions(Kumar et al., 2020).

3.1.3. Mapping the Terrain

Development of a visual blueprint through structural modeling techniques such as Interpretative Structural Modeling (ISM) or Fuzzy Cognitive Maps (FCM) becomes paramount at this juncture. These modeling tools enable a comprehensive visualization of the intricate interdependencies and feedback loops within healthcare systems. By mapping these relationships, key drivers and potential unintended consequences are identified, thus guiding the strategic deployment of Poka-Yoke interventions(Chang et al., 2017).

3.1.4. Targeting Strategic Solutions

Prioritization of Poka-Yoke interventions is guided by their potential impact on identified key drivers elucidated within the structural model. This strategic alignment ensures that resources are optimally allocated towards initiatives that promise maximal improvements in patient safety and operational efficiency. Tailoring solutions to fit the unique requirements of healthcare processes involves iterative testing and refinement through pilot implementations. This phased approach allows for adjustments and enhancements before full-scale deployment(Chang et al., 2017).

3.1.5. Facilitating Care Transformation

Implementation of Poka-Yoke solutions on a broader scale necessitates comprehensive stakeholder engagement to foster ownership and ensure alignment with frontline healthcare providers' perspectives. Establishing robust monitoring and evaluation mechanisms is crucial for measuring the effectiveness of interventions, using metrics such as reduced error rates, improved patient safety indicators, and enhanced process efficiencies. Continuous feedback loops facilitate ongoing refinement and adaptation of Poka-Yoke solutions, ensuring their sustained relevance and efficacy amidst evolving healthcare challenges(Zhang et al., 2017).

This chapter addresses the methods used to prioritize the key challenges identified, based on the insights from experts associated with OEM dealers, freelancers, and depot garages of fleet service providers. Interpretive Structural Modelling (ISM) and the Analytic Hierarchy Process (AHP) are utilized to achieve this. The following sections outline their procedural steps in brief. These approaches strategically achieve an ideal result by combining quantitative methodologies with qualitative skills and understanding.

3.2 ISM (Interpretive Structural Modelling) Approach

Interpretive Structural Modelling (ISM) is an interactive management method designed to help research groups address complex issues (Warfield, 1974; Sage, 1977). This model is flexible enough to allow for parameter changes with little effort and allows decision-makers to precisely map their ideas while creating the issue statement. All participants may easily grasp the results because the ISM model also creates a visual representation of the significance of the selected parameters. ISM is a methodology that identifies and summarizes the relationships among specific elements defining an issue or problem, thus imposing order on the complexity of these elements (Singh et al., 2003). As a computer-assisted learning process rooted in relational mathematics (Warfield, 1974), ISM converts vague, poorly articulated mental models of a system into clear, well-defined hierarchical models (Alawamleh and Popplewell, 2012). It establishes interrelationships among system variables to create a hierarchy of importance from a managerial perspective (Attri et al., 2012).

The step-by-step procedure is detailed in the following:

Step 1 Brainstorming: Using surveys or group techniques, determine a set of case-related components and variables.

Step 2 Create Contextual Relationships: Identify the element that follows or leads the variables.

Step Construct a Structural Self-Interaction Matrix (SSIM) to display the pairwise interactions between the variables.

Step 4 To make a reachability matrix, convert all SSIM entries to integers.

Step 5 Change to Conical Form: Reformat the reachability matrix.

Step 6 To convert it into an ISM model, just swap out the element nodes for statements.

Step 7 Review and Modify: Make any required changes after checking the model for conceptual contradictions.

3.3 AHP (Analytic Hierarchy Process) Method

A dynamic approach for handling complicated and ambiguous issues, especially those that defy quantitative analysis, is the Analytic Hierarchy Process (AHP). It offers a thorough and rational framework for structuring problems involving decision-making, which involves characterizing and quantifying its elements, connecting them to overarching objectives, and assessing potential solutions (Juntian, 2008). AHP was created by Saaty in 1974 and has a foundation in psychology and mathematics. According to Tzeng and Huang (2011), it is a model for subjective decision-making processes that incorporate a number of criteria inside a hierarchical structure. When a team of professionals tackles complicated problems including human perceptions and judgments, AHP is quite beneficial, just like other structural models (Quin, 2013). Three guiding principles form the basis of the AHP process: first, the model should be structured; second, the options and criteria should be evaluated in comparison; and third, the priorities should be synthesized. Based on the relationships between factors, the method divides the elements into objectives, criteria, and plan hierarchies (Quin, 2013). The standard hierarchy can be further divided to form a detailed hierarchical structure model. A common characteristic of the items at each level of the hierarchy is correlated with that level. The "objective" of the problem is represented at the top level, the assessment criteria and sub-criteria are represented at the middle levels, and the "alternatives" or "choices" are found at the bottom level (Ramanathan, 2001). To ascertain the weights of relevance for the lowest-level criteria in relation to the highest-level aim, the model can be examined both statistically and qualitatively. To get objective results, AHP uses pairwise comparisons to determine the final combined weights.

The following phases are involved in using AHP (Saaty, 1974) to weight evaluation:

Step 1: Begin with "N" elements, to create a pairwise comparison matrix, called “B1”, which is an "N x N" square matrix. The relative importance of element "i" in relation to element "j" is represented by each element a_{ij} in this matrix. When i is compared to itself, a_{ij} equals 1(i.e., a_{ii} =1). Additionally, the relationship is reciprocal, so a_{ji} is equal to $1/a_{ij}$. Saaty's 1–9 scale is used in this matrix for comparisons, as illustrated in Table 3.1 (Saaty, 1974).

Step 2: Determine the geometric mean for each matrix row before determining the normalized weight (WE_i) for each element, denoted as (GM_i). Then, normalize these geometric mean values according to equations (1) and (2) to obtain the weights in the comparison matrix.

Table 3.1 Value assignment for matrix element pairwise comparisons

Verbal assessment relative significance of items "i" and "j"	Numerical rating
is just as significant as	1
marginally more significant than	3
is far more significant than	5
far more significant than	7
very far more significant than	9

$$GMi = \left(\prod_{\substack{i=1 \\ j=1}}^{N} aij \right)^{1/N}$$

$$WE_i = \frac{GMi}{\sum_{i=1}^{N} GM_i}$$

Step 3: Compute matrices B_3 and B_4 such that $B_3 = B_1 \times B_2$ and $B_4 = B_3 / B_2$, where $B_2 = [WE_i]^T$.

Step 4: Determine the matrix's average, or greatest eigenvalue, λ_{max}. .

Step 5: Calculate the consistency index (CI) by dividing (N - 1) by (λ_{max} - N). Less variation from consistency is indicated by a smaller CI value.

Step 6: According to Satty (1974), the random index (RI) for the system's constituent parts can be obtained using Table 3.2.

Step 7: (λ_{max} –N)/(N-1) is the consistency index (CI). A smaller CI value denotes a less significant departure from consistency. The number of parameters in this case is "N."

Step 8: As proposed by Saaty (1974), the random index (RI) for the elements of the system can be found by consulting Table 3.2.

Step 9: Determining consistency ratio by dividing CI by RI. A CR of 0.1 or less is often regarded as satisfactory, suggesting that the decision makers' evaluation of the relative weight and relevance of the variables was quite reasonable (Madaan and Mangla, 2015).

Table 3.2 Values of the random index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.85	0.9	1.12	1.24	1.32	1.41	1.45	1.51

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 ISM Implementation

The literature survey identifies barriers, which are then evaluated and analyzed using the ISM approach. The steps involved will be thoroughly explained in the ensuing subsections.

4.1.1 Structural self-interaction matrix (SSIM)

The Structural Self-Interaction Matrix (SSIM) provides a contextual basis for a link between industry-specific criteria or variables (Mandal and Deshmukh, 1994). After identifying barriers in healthcare sector responses are collected from experts shown in table 4.1 to develop the SSIM.

Table 4.1 Details of Experts Contacted

Name	Industry Type	Designation	Experience	Role
Expert 1	Healthcare	Operations Manager	20	Managing daily operations
Expert 2	Nursing	Nursing Officer	18	Nursing staff training
Expert 3	Pharmacy	Operations Manager	11	Pharmacy processes Management
Expert 4	Healthcare	Process Analyst	5	Analysing process efficiencies
Expert 5	Healthcare	Consultant	4	Advising on process improvement strategy

Because specialists have different backgrounds, these answers vary as well. The responses are arranged by comparing any two factors pairwise and indicating their correlations with particular symbols (W, B, Y, and P). The relationships identified are then arranged into a matrix known as the SSIM. The relationships between two elements (E_i) and (E_j)) are represented symbolically are defined as follows:

W: Element (E_i) influencing element (E_j)

B: Element (E_j) influencing element (E_j)

Y: Both elements (E_i) and (E_j) influence one another

P: Elements (E_i) and (E_j) are not related

The current study's SSIM has been created and is shown in Table 4.3. The letter "P" in the comparison of components C1 through C9 denotes that these factors are totally unrelated to each other. The relationship between C1 and C8, on the other hand, is represented by the symbol "W" which shows that C8 depends on C1, implying that C1 affects C8 but not the other way around. Similarly, the link between C3 and C6 is denoted by the letter "B" indicating that C3 is independent of C6 but that C6 is influenced by C3. The link between C3 and C5 is bidirectional or interdependent, denoting that C3 affects C5 and vice versa, as indicated by the symbol "Y".

Table 4.2 Barriers to implementing Poka-Yoke in healthcare

Sr. no	Challenges	Notation
1	Complexity and Variability of Healthcare Processes	C_1
2	Resistance to Standardization	C_2
3	High Stakes and Risk Aversion	C_3
4	Integration with Existing Systems and Workflows	C_4
5	Cost Considerations	C_5
6	Regulatory and Compliance Requirements	C_6
7	Training and Education	C_7
8	Cultural and Organizational Challenges	C_8
9	Measuring Effectiveness and Outcomes	C_9

Table 4.3 SSIM Matrix

Challenges	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
C_1	P	W	W	W	W	W	W	Y	W
C_2	P	W	W	W	W	W	W	W	
C_3	W	P	P	B	Y	W	W		
C_4	P	P	Y	V	P	W			
C_5	P	P	Y	Y	W				
C_6	P	P	V	W					
C_7	Y	Y	W						
C_8	P	W							
C9	W								

4.1.2 The Reachability matrix

According to Mandal and Deshmukh (1994), the SSIM is converted into a binary matrix called the Reachability Matrix. This is done by swapping the symbols Y, B, W, and P with "0" and "1" according to their established meanings. In particular, the Reachability Matrix will have an entry of "1" for the ith row and jth column and "0" for the jth row and ith column if the SSIM entry for the ith row and jth column is "W". Similarly, if the SSIM entry is "B," the ith row and jth column in the Reachability Matrix will have "0" and the jth row and ith column will have "1". If the SSIM entry is "Y," the Reachability Matrix will show "1" for both the ith row and jth column as well as the jth row and ith column. On the other hand, if the SSIM entry is "P," the jth row and ith column will both be "0." The Reachability Matrix is the outcome of this method, as shown in Table 4.4.

Table 4.4 The Reachability matrix

Challenges	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
C_1	0	1	1	1	1	1	1	1	1
C_2	0	1	1	1	1	1	1	1	1
C_3	1	0	0	0	1	1	1	0	0
C_4	0	0	1	1	0	1	0	0	0
C_5	0	0	1	1	1	0	1	0	0
C_6	0	0	1	1	1	0	1	0	0
C_7	1	1	1	0	1	1	0	0	0
C_8	0	1	1	0	0	0	0	0	0
C_9	1	0	1	0	0	0	0	0	0

4.1.3 Level Partitioning Matrix

To ascertain the elements' hierarchical locations within the ISM structure, level partitioning is used (Warfield, 1974). According to Rade et al. (2017), this classification separates items into various ISM model tiers. Partitioning the reachability matrix into blocks of vertices at the same level within the model's causal framework yields the hierarchy of the causal structure (Warfield, 1974). Using the reachability matrix from the previous section, this process, known as level partitioning, separates the elements into two sets: the Driver Set (Reachability Set) and the Dependent Set (Antecedent Set). The factor itself and any other factors it may affect are included in the Driver Set, whereas the factor itself and any other elements it depends on are included in the Dependent Set. The intersection of these two sets is then determined. The factors with the greatest rank are those whose intersection set corresponds to their Driver Set, and so on. It is through this technique that a level partition matrix is created.

Finding the barrier that has the fewest obstacles in the Driver Set and is similar to the Dependent Set (antecedent set) and Driver Set (reachability set) is the first iteration. They are referred to as top-level obstacles. The detected obstacle is removed from further iterations following the initial one. The next level is found by repeating the same procedure. Until each barrier's level is established, this iterative process keeps going.

For the current investigation, a final level partitioning matrix is created and shown in Table 4.5.

Table 4.5 The Level partition matrix

Challenges	Driver	Dependent	Intersection set	Level
C_1	$C_1,C_2,C_3,C_4,C_5,C_6,C_7,C_8$	C_1, C_2	C_1, C_2	VII
C_2	$C_1,C_2,C_3,C_4,C_5,C_6,C_7,C_8$	C_1, C_2	C_1, C_2	VII
C_3	C_3,C_4,C_5,C_9	C_1,C_2,C_3, C_5,C_6	C_3	VI
C_4	C_4, C_6,C_7	C_1,C_2,C_3, C_4, C_7	C_4, C_7	III
C_5	C_3, C_5,C_6,C_7	C_1,C_2,C_3, C_5,C_6,C_7	C_3	VI
C_6	C_3, C_5,C_6,C_7	C_1,C_2, C_4,C_5,C_6	C_6	V
C_7	C_4,C_5, C_7,C_8,C_9	$C_1,C_2, C_4,C_5,C_6, C_7,C_8,C_9$	C_5	IV
C_8	C_7,C_8	C1,C2,C8,C7	C8	II
C_9	C_7,C_9	C_3, C_7,C_9	C_9	I

The most difficult challenges are the "Complexity and Variability of Healthcare Processes" and "Resistance to Standardization." Following closely is "High Stakes and Risk Aversion," with "Regulatory and Compliance Requirements" falling in line after it. These four barriers require the greatest allocation of resources and attention to ensure optimal management efficiency. At the highest level is "Measuring Effectiveness and Outcomes," which exhibits the least reliance on other barriers.

4.2 Implementing AHP

AHP modeling is currently being used to evaluate and analyze the challenges preventing Poka-yoke from being implemented. This assignment will be methodically completed in the following phases.

4.2.1 Pair-wise comparison of matrix

In the AHP modeling method, factors are systematically evaluated in pairs to ascertain their relative importance, resulting in a pairwise comparison matrix. Experts make sure that diagonal entries are set to unity by giving each aspect a score based on their experience. To create the lower triangular matrix, the upper triangular matrix is reciprocated. For example, a rating of 5 for the cell that compares factors C1 and C4 means that the expert believes that C1 is five times more significant than C4. The pairwise matrix produced by this method is displayed by matrix "B1".

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	1	1	1	5	5	1	5	8	8
C_2	1	1	1	5	5	1	6	6	9
C_3	1	1	1	1	6	6	5	5	7
C_4	0.2	0.2	1	1	1	2	1	2	6
= C_5	0.2	0.2	0.17	1	1	1	1	3	7
C_6	1	1	0.17	0.5	1	1	1	4	7
C_7	0.2	0.17	0.2	1	1	1	1	2	2
C_8	0.12	0.17	0.2	0.5	0.33	0.25	0.5	1	1
C_9	0.12	0.11	0.14	0.17	0.14	0.14	0.5	1	1

4.2.2 The Standardized matrix

Following the construction of the pairwise matrix in AHP modeling, the geometric mean for each parameter across rows is computed to produce a standardized matrix. Criteria weights are then calculated by dividing the geometric mean of each parameter by the sum of these geometric means. The resulting criteria weights are then analyzed in descending order to establish the ranking of factors. This method produces a standardized matrix indicating the weighting and ranking of barriers, as depicted in Table 4.6 for this study.

Table 4.6 Weighting and Ranking of barriers

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**GM**	**WE**
C_1	1	1	1	5	5	1	5	8	8	2.714	0.2217
C_2	1	1	1	5	5	1	6	6	9	2.718	0.2219
C_3	1	1	1	1	6	6	5	5	7	2.643	0.2158
C_4	0.2	0.2	1	1	1	2	1	2	6	0.995	0.0813
C_5	0.2	0.2	0.17	1	1	1	1	3	7	0.806	0.0658
C_6	1	1	0.17	0.5	1	1	1	4	7	1.101	0.0899
C_7	0.2	0.17	0.2	1	1	1	1	2	2	0.670	0.0547
C_8	0.12	0.17	0.2	0.5	0.33	0.25	0.5	1	1	0.353	0.0288
C_9	0.12	0.11	0.14	0.17	0.14	0.14	0.5	1	1	0.2441	0.0199

4.2.3 Calculating Consistency ratio

Finding the consistency ratio, which indicates whether the pairwise matrix that was first constructed is consistent or inconsistent, is crucial to guaranteeing the accuracy of the rankings. Therefore, we construct the matrices B_2, B_3, and B_4.

$B_2 = [0.222, 0.222, 0.216, 0.090, 0.081 , 0.066, 0.055, 0.029, 0.020]^T$

$B_3 = [B_1] \times [B_2] = [2.15, 2.17, 2.23 ,0.86 ,0.64, 0.99, 0.51, 0.27, 0.19]^T$

$B_4 = [B_3] \div [B_2] = [9.69, 9.75, 10.34, 10.62, 9.78, 10.97, 9.40, 9.32, 9.68]^T$

$$\lambda_{max} = 9.95$$

As discussed above the consistency ratio was calculated and found to be "0.08," which is within the acceptable range.

4.3 Implementation of ISM

Table 4.7 presents the ranking of challenges according to both methodologies: ISM and AHP.

Table 4.7 Findings from AHP and ISM

Ranking	Interpretive structural modeling	Analytical hierarchal process
1	C_1, C_2	C_1
2	C_3	C_2
3	C_6	C_3
4	C_5	C_6
5	C_7, C_4	C_4
6	C_8	C_5
7	C_9	C_7
8		C_8
9		C_9

According to the ISM ranking, the factors "Complexity and Variability of Healthcare Processes"(C_1), "Resistance to Standardization"(C_2) and "High Stakes and Risk Aversion"(C_3) holds the most importance and factors like "Cultural and

Organizational Challenges “ and “Measuring Effectiveness and Outcomes” are least significant, meaning they have no influence over the other factors.

According to the AHP ranking, the factors “Complexity and Variability of Healthcare Processes” (C_1) and “Resistance to Standardization” (C_2) have approximately equal criteria weights and factor “High Stakes and Risk Aversion” (C_3) does not lag much behind, these three factors put together, have 66% weight. These three factors are therefore crucial, which means that if Poka-yoke is to be used in the healthcare industry, one must concentrate on them for successful outcomes. The factor carrying the least criteria weights is “Cultural and Organizational Challenges” (C_9) which suggests that the other factors are not influenced by this one.

According to the findings from both models, the factors “Complexity and Variability of Healthcare Processes” (C_1), “Resistance to Standardization” (C_2) and “High Stakes and Risk Aversion” (C_3) as being extremely important from a managerial and maintenance perspective.

Technology plays a vital role in improving patient safety. It includes health information systems, decision support tools, and electronic health records. These technologies aim to enhance data accuracy. They also improve communication among healthcare providers. Ultimately, they support better decision-making in healthcare. Notably, there is some consensus, all grouped around the points that patient safety is paramount, the potential of lean principles within health care is significant. Equally, the relevance of structural modelling techniques varies pretty widely. It is only the application of technology that accentuates the change in the landscape, with due respect to the quality and safety of healthcare. This project report, at this juncture, is willing to look at these insights while proposing a structural modelling approach for the implementation of Poka-Yoke in the healthcare sector for identifying and addressing barriers.

It is therefore assumed that there are enormous opportunities for use in healthcare settings to better quality standards and safety for patients. Once the barriers are identified and the facilitators are employed, healthcare organizations can design and apply Poka-Yoke strategies to improve quality and safety in care delivery and thus derive many benefits for patients and health professionals alike. In this regard, a structural modelling perspective would be pretty helpful in unravelling such complex interrelations among these factors and in designing and implementing successful Poka-Yoke interventions.

This report will provide a starting point for the study and exploration of poka-yoke in this sector. Sharing the experience of ongoing research in ways of implementation and studying how this implementation affects the patients is essential then to disseminate best practices across the spectrum of health.

CHAPTER 5

CONCLUSION

To effectively implement poka-yoke in the healthcare sector, it is essential for organizations to address barriers in a prioritized sequence based on their impact. By tackling the most influential barriers first, healthcare organizations can develop a strategic plan that resolves foundational issues early on, thereby facilitating a more seamless and effective implementation of poka-yoke strategies.

The adoption of poka-yoke techniques in healthcare presents a valuable opportunity to enhance patient safety and care quality. Poka-yoke, initially designed for manufacturing environments, aims to minimize errors by integrating fail-safes into processes. In healthcare, this translates to reduced medical errors and improved patient outcomes, making it crucial for organizations to address any obstacles to its implementation.

Understanding and overcoming these barriers, while also leveraging facilitators—such as supportive leadership, existing technology, and a culture focused on safety—are key to developing and applying effective poka-yoke solutions. Structural modeling plays a critical role in this process by providing insights into the intricate relationships between barriers and facilitators. This approach allows for a deeper understanding of how these factors interact, aiding in the design and implementation of successful poka-yoke interventions.

In conclusion, a prioritized approach to barrier resolution, combined with strategic use of facilitators and structural modeling, is essential for the successful implementation of poka-yoke in the healthcare sector. This methodology not only supports improved patient safety and care quality but also contributes to a more efficient and reliable healthcare system. The findings from this analysis offer a practical framework for guiding future efforts in error prevention and process optimization within the service industry.

5.1 Limitations and Future Scope

This research has several limitations. Firstly, the data collection was confined to specific healthcare institutions, which may not adequately represent the diverse range of healthcare services across various regions and countries. This geographical and institutional limitation potentially affects the generalizability of our findings. Additionally, the sample size was relatively small and may not encompass the full spectrum of stakeholders in the healthcare sector, which can lead to less robust conclusions. This limited sample diversity might have resulted in the exclusion of certain critical perspectives and barriers. The study also concentrated on a predefined set of barriers, possibly overlooking other significant obstacles that could influence the implementation of Poka-yoke in healthcare settings. Moreover, the complexity and inherent assumptions of the structural modelling approach used in the study might not capture all the nuances of real-world interactions within healthcare services, resulting in overly simplistic interpretations. Ethical and privacy considerations further restricted the depth of data collection, particularly regarding sensitive patient information, which could have provided valuable insights into patient interaction and feedback mechanisms. These limitations highlight the need for cautious interpretation of the study's findings and underscore the importance of broader, more inclusive future research efforts. This report provides a starting point for further research and exploration of poka-yoke in the healthcare sector. Continued research efforts are needed to develop effective implementation strategies, evaluate the impact of poka-yoke on patient outcomes, and disseminate best practices across different healthcare settings.

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