Data-Driven Warehouse Layout Optimization using Demand Analytics and Lean Principles: A Case Study of an Ayurvedic Distribution Centre

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***Abstract* - This study examines warehouse layout optimization in an Ayurvedic distribution centre through a data-driven and lean-oriented approach. In modern supply chain operations, warehousing plays a critical role in determining operational efficiency, order fulfilment speed, and inventory movement performance. The study focuses specifically on the issue of inefficient warehouse layout planning caused by unstructured SKU placement and the absence of demand-based zoning practices.**

The research identifies that the existing warehouse configuration evolved progressively without systematic analysis of SKU movement intensity or throughput contribution. This resulted in excessive travel distance during picking operations, congestion in active storage zones, uneven workflow distribution, and inefficient space utilization. To address these operational inefficiencies, the study applies analytical techniques such as ABC analysis and SKU velocity classification to evaluate historical demand behaviour and inventory movement patterns.

A structured warehouse zoning framework was developed by aligning high-frequency and high-movement SKUs closer to dispatch and picking zones, while low-velocity items were repositioned strategically to optimize space utilization. Lean principles were also incorporated to identify and minimize non-value-adding activities such as unnecessary motion, redundant handling, and inefficient material flow.

The findings indicate that demand-driven slotting and velocity-based zoning can significantly improve warehouse operational efficiency without requiring physical expansion of the facility. The proposed layout framework contributes to reduced picker travel distance, improved accessibility of fast-moving items, better workload balancing, and enhanced overall warehouse flow. The study demonstrates how integrating data analytics with lean warehouse management principles can support practical and scalable optimization in medium-scale distribution environments, particularly within the Ayurvedic supply chain sector.

The research provides both academic and managerial insights into warehouse optimization practices and offers a practical framework that can be adapted by similar distribution-based organizations seeking operational improvement through structured inventory positioning and layout redesign.

I. INTRODUCTION

1.1 Background of the Study

Warehousing has progressively shifted from being a passive storage function to a performance-critical component of modern supply chains. In distribution-oriented systems, the warehouse directly influences order fulfilment speed, operational cost, service reliability, and inventory turnover. Among all warehouse activities, order picking is typically the most labour-intensive and cost-sensitive process. A significant proportion of picking time is spent on travel between storage locations, making layout configuration a major determinant of operational efficiency.

In environments characterized by many Stock Keeping Units (SKUs), layout complexity increases substantially. When product placement does not reflect actual demand frequency or movement intensity, inefficiencies such as excessive walking distance, congestion in high-access zones, unbalanced workload distribution, and underutilization of space begin to emerge. Over time, these inefficiencies accumulate and reduce throughput capacity without necessarily increasing visible cost drivers.

Advances in data availability now allow warehouse decisions to move beyond intuition. Historical sales records, dispatch frequency data, and order line information provide measurable insight into SKU behaviour. Analytical tools such as demand classification and velocity-based segmentation enable prioritization of high-movement products. At the same time, lean management principles emphasize elimination of non-value-adding activities such as redundant motion, unnecessary handling, and inefficient flow patterns. The combination of analytical demand insights and lean thinking offers a structured pathway for warehouse layout improvement without physical expansion.

1.2 Industry Context

The Ayurvedic distribution sector operates within a diversified product environment that includes classical formulations, retail wellness products, and over-the-counter herbal preparations. These products differ significantly in terms of packaging dimensions, sales velocity, seasonal demand patterns, and storage characteristics. As product portfolios expand, distribution centres must manage increasing SKU diversity within limited physical space.

In many medium-scale distribution setups, warehouse layouts evolve gradually as new products are introduced. Storage decisions are often influenced by immediate availability of space rather than structured evaluation of demand behaviour. Such incremental growth frequently results in mixed zoning, inconsistent slotting logic, and imbalanced traffic flow across the warehouse floor.

Because demand contribution is typically uneven across SKUs, a small proportion of items tends to generate most of the picking activity. When these high-velocity SKUs are not strategically positioned, internal travel distance increases disproportionately. In a sector where operational margins are sensitive to handling efficiency, optimizing layout through demand-based zoning becomes operationally significant.

1.3 Problem Statement

The selected Ayurvedic distribution centre manages a wide SKU portfolio under fluctuating demand conditions. The existing warehouse layout has developed progressively over time without systematic evaluation of SKU movement intensity. As a result, product placement does not consistently reflect demand frequency or picking workload.

This misalignment contributes to extended travel distance during picking operations, uneven congestion across storage zones, and suboptimal utilization of available space. Although historical demand data is available within operational records, it has not been systematically applied to guide layout configuration. Furthermore, process inefficiencies linked to motion waste and zoning imbalance have not been formally assessed using lean principles.

There is therefore a clear requirement to develop a structured, data-driven warehouse layout optimization approach that aligns SKU positioning with empirical demand behaviour and reduces operational inefficiencies within the existing facility.

1.4 Research Objectives

The primary objective of this study is to design and evaluate a data-driven warehouse layout optimization framework for an Ayurvedic distribution centre.

The specific objectives are:

- To analyse historical SKU demand patterns using structured analytical techniques.
- To classify inventory based on movement frequency and throughput contribution.
- To identify layout-related inefficiencies through systematic evaluation of material flow.
- To redesign warehouse zoning in alignment with SKU velocity.
- To assess the potential operational improvements resulting from the proposed layout configuration.

1.5 Research Questions

1. How can historical demand data be used to classify SKUs for effective layout planning?
2. What inefficiencies are present in the current warehouse configuration?
3. How can structured zoning reduce internal travel distance and picking time?
4. To what extent does demand-driven layout planning improve warehouse operational efficiency?

1.6 Scope of the Study

This study focuses exclusively on warehouse layout and internal picking operations within a selected Ayurvedic distribution centre in West Bengal. The research examines storage configuration, SKU classification, internal material flow, and operational efficiency. Broader supply chain activities such as procurement, transportation, and supplier coordination are outside the scope of this investigation.

The analysis emphasizes optimization within the existing physical infrastructure without major structural modification or capital expansion.

1.7 Structure of the Dissertation

Chapter 1 outlines the background, problem definition, objectives, and scope of the study.

Chapter 2 reviews relevant literature on warehouse layout design, order picking efficiency, demand analytics, and lean warehousing principles.
Chapter 3 presents the research methodology and analytical framework.
Chapter 4 analyses operational data, evaluates the current layout, and proposes an optimized configuration.
Chapter 5 concludes the study and discusses practical implications and future research directions.

II. CHAPTER

2.1 Introduction

Warehouse layout optimization has received significant scholarly attention within operations and supply chain management research. With increasing SKU proliferation and demand variability, researchers have examined how storage configuration, order picking systems, and analytical slotting strategies influence operational performance. Existing studies demonstrate that warehouse efficiency is not solely dependent on infrastructure size but on internal configuration and data-driven decision-making. This chapter provides a critical analysis of existing research on warehouse layout design, order picking efficiency, demand-based slotting, and the integration of lean warehousing practices, laying the groundwork for the theoretical basis of this study.

2.2 Warehouse Layout Design and Operational Efficiency

Warehouse layout design is recognized as a strategic decision that directly affects material flow, labour productivity, and service performance.
1.Rouwenhorst et al. (2000) conceptualize warehouse design as an integrated planning problem involving storage assignment, routing, and resource allocation. Their study emphasizes that layout configuration determines the efficiency of downstream operational processes.
2.Gu, Goetschalckx, and McGinnis (2007) further argue that warehouse layout influences congestion patterns, accessibility, and throughput capacity. Their analytical models suggest that poor spatial arrangement increases non-value-adding travel and reduces picking productivity. However, their work largely focuses on theoretical modelling rather than real-world medium-scale distribution environments.
3.Baker and Canessa (2009) highlight that layout planning must be aligned with product characteristics and demand behaviour. They caution against static storage systems that fail to adapt to changing SKU profiles. While their findings establish the importance of responsive layout design, empirical applications in small and medium distribution centres remain underrepresented.
Thus, literature strongly supports layout-performance linkage but indicates limited applied research in non-automated, space-constrained facilities.

2.3 Order Picking and Travel Distance Optimization

Order picking has consistently been identified as the most resource-intensive warehouse activity.
1.Tompkins et al. (2010) report that picking operations may account for over 50% of warehouse operating costs, with travel time constituting the dominant component of picking cycles.
2.De Koster, Le-Duc, and Roodbergen (2007) demonstrate that travel distance reduction significantly enhances picking efficiency. Their research confirms that storage location assignment has measurable impact on labour performance.
3. Petersen and Aase (2004) found that class-based storage policies reduce average travel distance when high-demand items are positioned near dispatch zones.
While these studies establish the quantitative importance of travel distance, most experiments are conducted in controlled settings or simulated models. There is limited documentation of how such principles are practically implemented in medium-scale distribution centres with diverse SKU portfolios and manual picking systems.
Therefore, although the theoretical basis for travel minimization is strong, empirical case-based validation in SME distribution contexts remains insufficient.

2.4 Demand Analytics and SKU Classification in Warehousing

Demand-driven storage allocation is largely grounded in the Pareto principle.
1.Flores and Whybark (1986) formalized ABC classification as a method for prioritizing inventory management focus. Subsequent applications extended ABC analysis into storage zoning and slotting optimization.
2.Heskett (1963) introduced the cube-per-order index as an early method for assigning storage locations based on product movement characteristics. More recent work by Yu and De Koster (2009) suggests that

velocity-based storage assignment enhances order picking efficiency when aligned with demand frequency and product turnover.

3.Frazelle (2016) emphasizes that data-driven slotting outperforms intuition-based placement strategies. However, many studies assume stable demand distributions and advanced warehouse management systems. In contrast, distribution centres operating in niche sectors such as herbal or Ayurvedic products often experience fluctuating demand cycles and product diversity that complicate static classification models.

Existing literature validates the effectiveness of demand analytics in storage optimization but provides limited sector-specific case evidence for medium-scale distribution operations.

2.5 Lean Warehousing and Waste Elimination

Lean philosophy has increasingly been applied beyond manufacturing to warehouse operations.

1. Womack and Jones (1996) define lean thinking as systematic elimination of non-value-adding activities. In warehouse environments, such waste typically appears as excessive motion, waiting time, redundant handling, and inefficient flow patterns.
2. Shah and Ward (2003) argue that lean implementation must be systemic rather than tool specific. Applied to warehousing, lean requires structured zoning, clear material flow paths, and reduction of backtracking.
3. Ramaa et al. (2012) suggest that integrating lean with operational visibility systems improves warehouse productivity.

However, many lean warehouse studies focus primarily on process standardization rather than analytical slotting based on demand classification. The integration of demand analytics with lean waste reduction remains underexplored in medium-scale manual distribution environments.

Thus, literature supports lean application but indicates limited integration with structured demand-based layout optimization.

2.6 Synthesis of Literature and Identified Research Gap

The reviewed studies collectively establish several key insights:

- Warehouse layout significantly affects operational efficiency (Rouwenhorst et al., 2000; Gu et al., 2007).
- Travel distance reduction improves picking productivity (De Koster et al., 2007; Petersen & Aase, 2004).
- Demand-based SKU classification enhances storage allocation (Flores & Whybark, 1986; Yu & De Koster, 2009).

Despite strong theoretical foundations, important gaps remain:

1. Much of the literature is based on large-scale automated warehouses rather than medium-sized distribution centres.
2. Demand analytics and lean warehousing are frequently studied independently rather than as integrated frameworks.
3. Sector-specific case studies in Ayurvedic or herbal distribution contexts are limited.
4. Empirical validation of layout redesign within existing infrastructure, without capital expansion, remains underrepresented.

III. RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the research methodology adopted for the study titled *"Data-Driven Warehouse Layout Optimization using Demand Analytics and Lean Principles: A Case Study of an Ayurvedic Distribution Centre."* The chapter provides a systematic explanation of the research philosophy, research design, data collection techniques, analytical tools, and performance evaluation methods used in the study.

The primary objective of the research is to analyse existing warehouse operations and identify how demand analytics and lean warehousing principles can improve warehouse layout efficiency, reduce operational waste, and enhance overall workflow productivity. Warehouses play a critical role in supply chain management because they directly influence inventory movement, order fulfilment speed, storage utilization, and customer service performance.

In medium-scale Indian distribution centres, warehouse operations are often managed manually with limited automation support. As a result, problems such as excessive picker movement, poor SKU placement, congestion near dispatch zones, inefficient aisle utilization, and delays in order processing become common operational challenges. These inefficiencies negatively affect warehouse productivity and increase operational costs.

The present study focuses on analysing such operational inefficiencies within an Ayurvedic

distribution warehouse and proposes an optimized layout framework based on demand patterns and lean operational practices. The methodology combines both quantitative and qualitative approaches to ensure practical applicability and analytical accuracy.
This chapter covers the following aspects:

- Research philosophy
- Research approach
- Research design
- Case study justification
- Data collection methods
- Operational observation framework
- Analytical tools and techniques
- Performance measurement indicators
- Reliability and validity considerations
- Ethical considerations
- Research limitations

The methodology was designed to ensure that the findings remain practical, industry-relevant, and academically structured.

3.2 Research Philosophy

The study is based on the Pragmatism Research Philosophy. Pragmatism focuses on solving practical problems using suitable methods and techniques. Instead of depending entirely on theoretical assumptions, pragmatism supports the use of approaches that are most effective in addressing real-world operational issues.
The selected warehouse operates in a highly practical environment where operational decisions are influenced by movement patterns, labour coordination, product accessibility, and demand frequency. Therefore, the pragmatist philosophy was considered most appropriate because the study aims to develop realistic and implementable warehouse improvement strategies rather than purely theoretical conclusions.
The pragmatist philosophy supports:

- Practical problem-solving
- Operational observation
- Data-driven analysis
- Flexible research methods
- Real-world applicability

The research combines:

- ABC inventory classification and demand evaluation are examples of quantitative analytical techniques.
- Qualitative analysis such as worker movement observation and workflow analysis
- Lean warehousing concepts for identifying operational waste

This combination ensures a balanced research structure that addresses both operational behaviour and analytical evaluation.
The philosophy also allows flexibility in selecting suitable methods for analysing warehouse inefficiencies and proposing layout optimization solutions that can realistically be applied in medium-scale distribution centres.

3.3 Research Approach

The research follows a Deductive Research Approach. In this approach, existing warehouse management theories and operational principles are applied to evaluate a real warehouse environment.
The study is based on established concepts including:

- Warehouse layout optimization
- Lean warehousing principles
- ABC inventory classification
- Demand-driven storage allocation
- Motion waste reduction

The deductive approach begins with theoretical understanding and applies those concepts to analyse operational conditions within the selected warehouse. The purpose is to determine whether these theories can effectively improve warehouse efficiency in a practical environment.
The study evaluates:

- Existing warehouse inefficiencies
- Product movement behaviour
- Storage allocation patterns
- Picking movement efficiency
- Workflow coordination issues

The deductive approach was selected because it provides:

- A structured research flow
- Logical analytical framework
- Theory-based operational evaluation
- Measurable comparison between existing and proposed layouts

This approach also supports comparative analysis of warehouse performance before and after optimization recommendations.

3.4 Research Design

The study adopts a Case Study Research Design focused on a single Ayurvedic distribution centre. A case study design enables detailed investigation of operational activities within their natural working environment.

Warehouse operations involve multiple interconnected activities such as:

- Inventory storage
- Picking operations
- Packing activities
- Dispatch coordination
- Verification processes
- Worker movement patterns

A case study design was considered appropriate because it allows in-depth understanding of these operational interactions within a real warehouse setting.

The selected warehouse represents a medium-scale Indian distribution environment characterized by:

- Manual material handling systems
- Mixed SKU inventory structure
- Seasonal demand fluctuations
- Labour-intensive operations
- Company-wise storage allocation
- Invoice-driven picking processes

The case study design helped in:

- Conducting direct operational observations
- Analysing workflow movement
- Identifying practical bottlenecks
- Evaluating layout inefficiencies
- Developing realistic optimization proposals

Unlike simulation-only research, the case study approach provides greater operational realism and practical relevance because the analysis is based on actual warehouse conditions.

3.5 Case Study Justification

The selected warehouse was considered suitable for the research because it reflects operational characteristics commonly observed in medium-scale Indian warehousing environments.

Several factors justified the selection of this warehouse:

3.5.1 High SKU Diversity

The warehouse handles a wide range of Ayurvedic and wellness products with varying demand frequencies. Some products are fast-moving while others experience seasonal or low-frequency demand. This SKU diversity creates challenges in storage allocation and picking efficiency.

3.5.2 Manual Operational Environment

The warehouse primarily operates using manual picking, packing, and dispatch systems. Since there is limited automation support, operational efficiency depends heavily on warehouse layout structure and worker movement coordination.

3.5.3 Presence of Operational Inefficiencies

The warehouse experiences several operational challenges such as:

- Congestion near dispatch areas
- Excessive picker travel distance
- Temporary carton staging issues
- Workflow interruptions
- Memory-based product locating
- Verification bottlenecks

These inefficiencies made the warehouse appropriate for analysing layout optimization opportunities.

3.5.4 Practical Industry Relevance

The warehouse structure is representative of many Indian SME distribution centres where layouts evolve gradually without structured planning or demand-based optimization. Therefore, the findings of the study remain practically relevant for similar warehouse environments.

3.6 Research Strategy

The study follows an Analytical and Observational Research Strategy. The strategy combines field-level operational observation with data-driven warehouse analysis to identify inefficiencies and evaluate optimization opportunities.

The research strategy involved the following stages:

1. Understanding the existing warehouse layout and operational workflow
2. Collecting SKU demand and movement data
3. Observing worker movement and dispatch activities
4. Identifying operational waste using lean principles
5. Conducting ABC inventory classification
6. Analysing workflow bottlenecks and congestion areas
7. Developing layout optimization recommendations
8. Comparing existing and proposed operational performance

The strategy ensured systematic progression from problem identification to practical optimization recommendations.

The analytical approach helped in understanding demand concentration and inventory movement behaviour, while the observational approach helped in identifying operational inefficiencies that may not be visible through numerical data alone.

3.7 Sources of Data

The study utilized both Primary Data and Secondary Data to improve analytical reliability and operational understanding.

3.7.1 Primary Data

Primary data was collected directly from warehouse operations through:

- Physical warehouse observation
- Workflow analysis
- Storage structure inspection
- Worker movement tracking
- Dispatch process observation
- Congestion area analysis

The primary data collection focused on operational behaviour such as:

- Picker movement patterns
- Rack accessibility
- Product retrieval flow
- Carton staging activities
- Dispatch coordination
- Verification delays

Primary observation was essential because many warehouse inefficiencies were process-oriented and behavioural in nature.

3.7.2 Secondary Data

Secondary data was collected from:

- SKU demand records
- Order frequency reports
- Inventory movement records
- Operational documents
- Academic journals
- Industry reports and warehousing studies

The secondary data helped analyse:

- Product movement intensity
- Demand frequency
- Fast-moving and slow-moving SKUs
- Seasonal demand variations

Due to limited availability of advanced digital warehouse systems, the dataset was structured using realistic operational observations and available warehouse records to ensure alignment between analytical evaluation and actual warehouse conditions.

3.8 Operational Observation Framework

A structured operational observation framework was developed to analyse workflow behaviour and identify movement inefficiencies within the warehouse.

The framework focused on the following observation areas:

Observation Area	Purpose
Picking Movement	Analyse worker travel behaviour
Dispatch Activity	Identify congestion zones
Rack Accessibility	Evaluate storage efficiency
Verification Process	Examine workflow bottlenecks
Carton Staging	Study temporary blockage formation
Aisle Movement	Analyse movement overlap

Operational observations were mainly conducted during peak dispatch periods because movement intensity and congestion levels were highest during those hours.

The observation framework helped in:

- Identifying operational bottlenecks
- Mapping workflow inefficiencies
- Evaluating movement overlap
- Understanding labour coordination issues
- Analysing aisle utilization efficiency

This framework provided practical insights into actual warehouse workflow conditions.

3.9 Data Collection Methods

A structured data collection process was adopted to ensure research accuracy and operational relevance.

3.9.1 Observation Method

Direct observation was conducted to understand:

- Picking routes
- Storage practices
- Worker coordination
- Dispatch flow
- Verification handling
- Temporary staging behaviour

Observation was necessary because several inefficiencies were visible only through real-time operational analysis.

3.9.2 Demand Data Collection

SKU-level demand data was analysed to evaluate:

- Product movement frequency
- Order volume concentration
- High-demand products
- Slow-moving inventory
- Seasonal demand variation

The demand analysis formed the basis for ABC inventory classification and optimized storage allocation planning.

3.9.3 Workflow Mapping

Workflow mapping was conducted to analyse the sequence of warehouse activities including:

- Order receipt
- Invoice generation
- Picking operations
- Packing process
- Verification process
- Dispatch grouping
- Courier dispatch

Workflow mapping helped identify movement duplication, operational delays, and synchronization issues.

3.9.4 Document Analysis

Operational records and warehouse documents were reviewed to analyse:

- SKU demand trends
- Inventory movement behaviour
- Order handling frequency
- Operational coordination patterns

Document analysis provided quantitative support to field-level observations.

3.10 Analytical Framework

The study applied multiple analytical tools to evaluate warehouse efficiency and support layout optimization.

3.10.1 ABC Inventory Classification

ABC analysis was used to classify inventory based on movement frequency and operational importance.

Category	Characteristics
A Category	High-demand and fast-moving products
B Category	Moderate-demand products
C Category	Low-demand and slow-moving products

ABC classification helped improve:

- Demand-driven storage allocation
- Fast-moving SKU accessibility
- Picking efficiency
- Warehouse space utilization

3.10.2 Demand Analysis

Demand analysis was conducted to evaluate:

- SKU movement intensity
- Product order frequency
- Seasonal demand fluctuations
- Demand concentration patterns

This analysis helped identify products contributing to most warehouse movement activities.

3.10.3 Lean Waste Analysis

Lean warehousing principles were applied to identify non-value-adding activities within the warehouse.

The major operational wastes analysed included:

- Motion waste
- Waiting waste
- Transportation waste
- Overprocessing waste

Lean analysis was particularly important because the warehouse relied heavily on manual labour operations.

The objective was to minimize unnecessary movement and improve workflow coordination.

3.10.4 Layout Evaluation Criteria

The warehouse layout was evaluated using the following operational performance criteria:

- Picker travel distance
- Aisle accessibility
- Congestion intensity
- SKU accessibility
- Workflow coordination
- Movement overlap

These criteria directly influence warehouse productivity and operational efficiency.

3.10.5 Comparative Performance Analysis

The proposed optimized layout was compared with the existing warehouse structure based on:

- Travel distance reduction
- Congestion reduction
- Picking efficiency improvement
- Order processing speed
- Workflow coordination improvement

This comparison helped evaluate the practical effectiveness of the proposed warehouse optimization framework.

3.11 Performance Measurement Indicators

The study utilized multiple operational indicators to evaluate warehouse performance.

Performance Indicator	Purpose
Travel Distance	Measure picker movement efficiency

Order Processing Time	Evaluate operational speed
Congestion Intensity	Assess workflow blockage
Verification Waiting Time	Analyse dispatch bottlenecks
Picking Overlap	Evaluate movement efficiency

These indicators were selected because they reflect practical warehouse performance conditions within manually operated warehouse environments.

3.12 Reliability and Validity

Several measures were adopted to improve the reliability and validity of the research.

Operational observations were conducted repeatedly during active warehouse periods to ensure consistency in workflow understanding. The demand dataset was aligned with actual warehouse movement behaviour and observed operational conditions.

The study used established warehouse management concepts including:

- ABC inventory classification
- Lean warehousing principles
- Demand-driven storage planning

The integration of:

- Operational observation
- Workflow mapping
- Demand analysis
- Comparative evaluation

improved the overall consistency and reliability of the research findings.

3.13 Ethical Considerations

The study maintained academic and operational ethics throughout the research process.

The following ethical principles were followed:

- Confidentiality of operational information
- Responsible use of warehouse data
- Proper citation of secondary sources
- Avoidance of data manipulation
- Maintenance of academic integrity

The research focused on operational analysis without disclosing commercially sensitive information related to the organization.

3.14 Research Limitations

The study includes certain limitations which may affect broader generalization of findings.

3.14.1 Limited Digital Data Availability

The warehouse mainly operated using manual systems, limiting access to advanced digital warehouse performance records.

3.14.2 Single Case Study Scope

The research focused on one Ayurvedic distribution centre; therefore, findings may vary in other warehouse environments.

3.14.3 Lack of Advanced Simulation Software

The optimization proposals were analytically evaluated rather than tested using advanced warehouse simulation tools.

3.14.4 Observational Performance Estimation

Certain operational improvements were estimated through workflow observation and analytical evaluation instead of full-scale live implementation.

Despite these limitations, the study provides realistic and practically applicable operational insights for medium-scale warehousing environments.

3.15 Time Horizon

The research follows a Cross-Sectional Time Horizon where warehouse operations and demand behaviour were analysed within a specific study period.

The cross-sectional approach enabled:

- Focused operational analysis
- Timely workflow evaluation
- Practical layout assessment
- Efficient data analysis

This approach was appropriate because the objective of the study was to evaluate the current warehouse structure and identify optimization opportunities under existing operational conditions.

3.16 Chapter Summary

This chapter presented the research methodology adopted for analysing warehouse layout optimization within an Ayurvedic distribution warehouse.

The study utilized a pragmatist research philosophy, deductive research approach, and case study research design supported by operational observation and demand analysis.

The methodology integrated:

- Demand analytics
- ABC inventory classification
- Lean warehousing principles
- Workflow mapping
- Operational observation
- Comparative performance evaluation

The research framework enabled systematic identification of warehouse inefficiencies and

supported the development of a realistic and practically implementable warehouse optimization model.
The next chapter presents the detailed warehouse analysis, operational findings, demand evaluation, and proposed layout optimization framework derived from the study.

IV. DATA ANALYSIS AND INTERPRETATION

4.1 Introduction
This chapter presents a detailed analysis and interpretation of the operational and inventory-related data used for the study titled "Data-Driven Warehouse Layout Optimization using Demand Analytics and Lean Principles: A Case Study of an Ayurvedic Distribution Centre." The objective of this chapter is to analyses existing warehouse inefficiencies and evaluate how demand-driven storage optimization and lean operational principles can improve warehouse productivity, order fulfillment efficiency, and movement flow within a manually managed warehouse environment.

The warehouse selected for this study represents a realistic Indian regional distribution setup where operations are primarily dependent on manual coordination, invoice-based dispatching, worker experience, and practical movement handling rather than sophisticated automation systems. Therefore, the analysis conducted in this chapter focuses not only on inventory movement but also on worker behavior, operational bottlenecks, dispatch congestion, storage inefficiencies, and workflow synchronization.

The dataset used in this study consisted of 120 SKUs across multiple Ayurvedic product categories and brands including Dabur, Baidyanath, Zandu, Himalaya, and Patanjali. The dataset was developed to replicate realistic warehouse movement behavior, demand variation, and seasonal product movement patterns observed in Ayurvedic FMCG distribution environments.

The chapter includes warehouse operational analysis, workflow evaluation, demand distribution analysis, ABC inventory classification, lean waste identification, operational bottleneck analysis, proposed optimization framework, and comparative performance evaluation. The findings of this chapter form the analytical core of the dissertation and provide insight into how small and medium-scale warehouses can improve operational efficiency through structured zoning and demand-based storage planning.

4.2 Warehouse Profile and Operational Structure
The warehouse selected for the study is a mid-sized Ayurvedic regional distribution center located in Kolkata and serving multiple locations across Eastern India. The warehouse primarily supplies Ayurvedic medicines, wellness products, immunity products, and FMCG-style healthcare products to retailers, pharmacies, wholesalers, and distributors.

The warehouse occupies approximately 5000 square feet and operates from the first floor of the building. A dedicated goods lift is used for inventory movement and outbound dispatch handling. The dispatch and packing zone are positioned adjacent to the lift to reduce material handling effort and simplify courier movement.

The warehouse follows a rectangular layout structure with six parallel steel rack rows and four storage levels. The storage arrangement combines rack storage with temporary floor stacking during high operational load conditions. The aisles are medium-width and allow manageable worker movement under normal operating conditions; however, congestion increases significantly during afternoon dispatch periods.

Warehouse operations are primarily manual. Workers physically move across aisles and carry products by hand while conducting picking activities. There is no sophisticated warehouse management system or digital shelving mapping system available. Product locating is heavily dependent on worker familiarity and memory-based navigation.

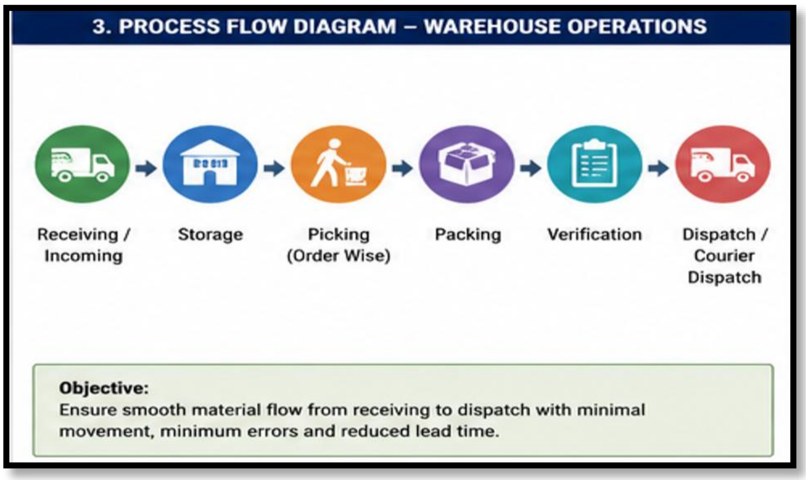
The warehouse workforce consists of 8–10 operational staff members responsible for picking, packing, dispatch handling, loading activities, and verification processes.

Table 4.1 Workforce Structure

Operational Role	Approximate Number
Pickers	3–4
Packers	2–3
Helpers/Loaders	2
Supervisor/Verifier	1

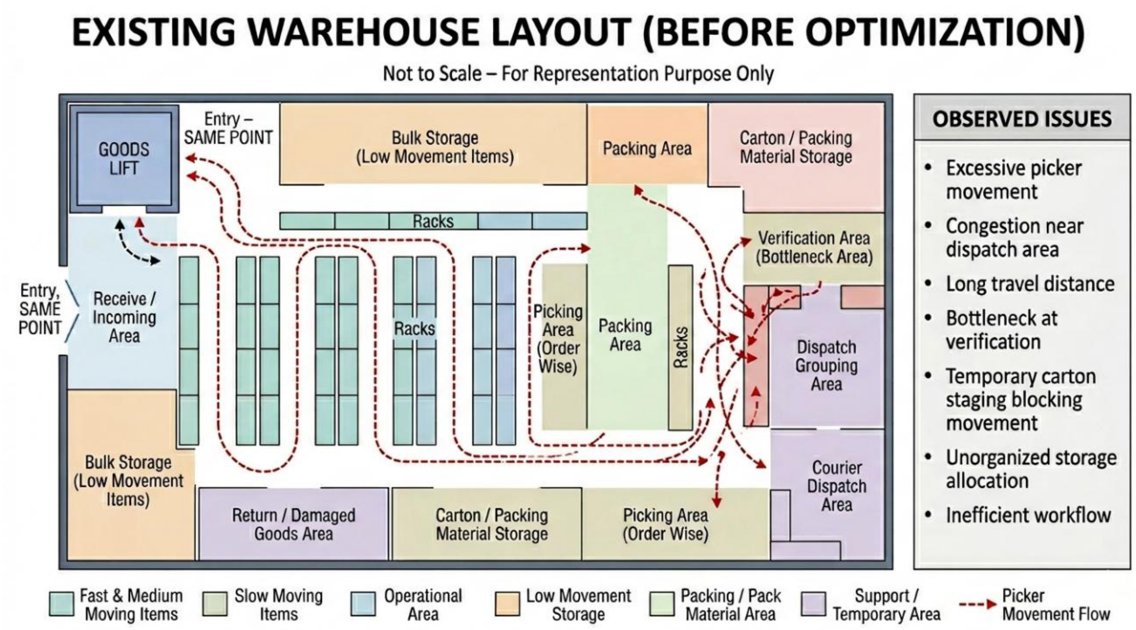
4.3 Existing Workflow and Dispatch Process

The warehouse follows a manually coordinated invoice-driven workflow. Orders are received from retailers and distributors through phone calls, WhatsApp communication, and repeat order coordination. A billing operator prepares GST invoices according to order quantity and dispatch requirements.



For each order, three invoice copies are generated. One copy is used for customer delivery purposes, one copy is sent to the warehouse for packing reference, and one copy is retained for office records and operational data tracking.

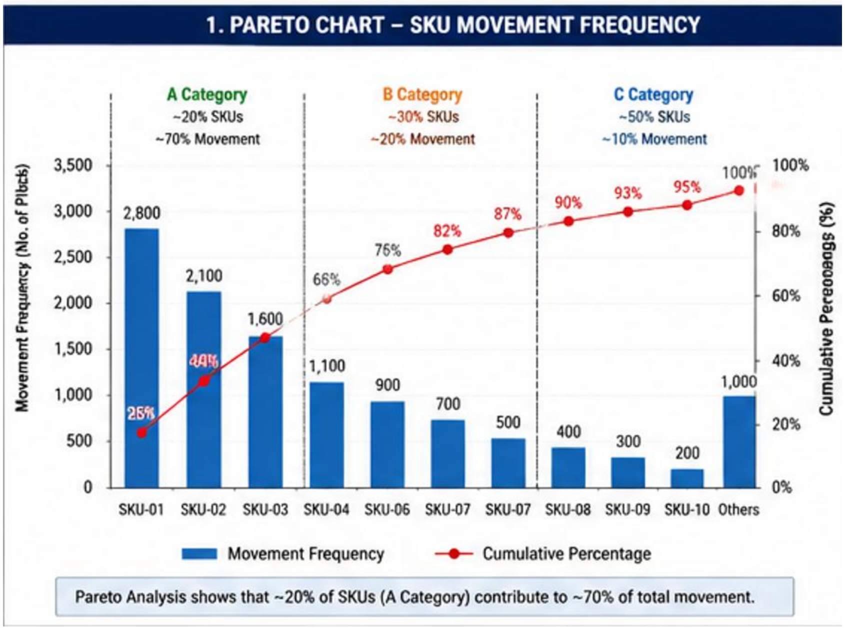
Warehouse workers receive the packing invoice and manually identify product locations within the warehouse. Since no structured digital rack coding system exists, workers depend heavily on memory and operational familiarity while locating products. Experienced workers are faster because they possess informal knowledge regarding rack positions, overflow storage areas, and seasonal SKU movement.



After products are collected, cartons are packed manually and labelled with customer details, address, destination information, and contact numbers. Orders are then grouped according to delivery region before dispatch. For example, cartons destined for Siliguri are grouped together, while Guwahati and Kolkata dispatches are separated accordingly. Before dispatch, cartons are verified by a supervisor who manually checks labels, invoice details, batch numbers, and quantities. During peak dispatch periods, multiple packers frequently arrive simultaneously at the verification point, creating temporary waiting queues and congestion near the dispatch and lift-side area.

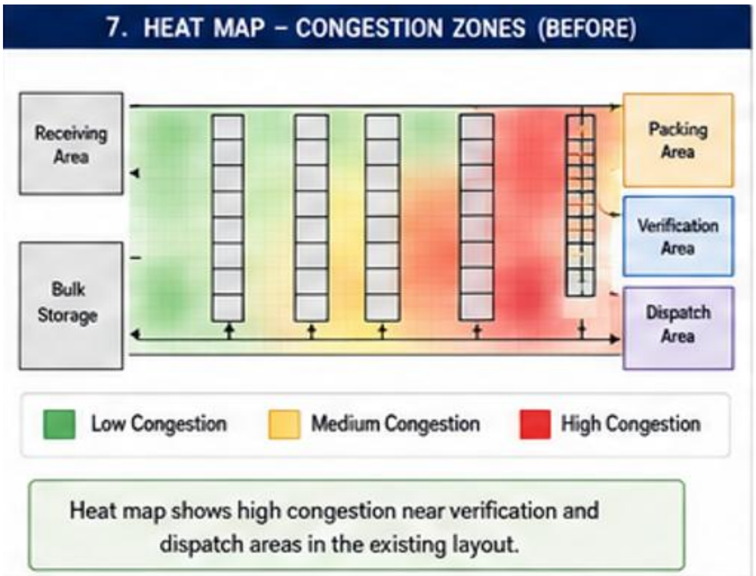
4.4 Existing Storage Pattern and SKU Allocation

The warehouse currently follows a company-wise storage system rather than a demand-driven storage structure. Products belonging to the same company are grouped together irrespective of movement frequency or operational importance. For example, Dabur products are stored within one zone, while Baidyanath and Zandu products occupy separate sections.



Although this system simplifies company identification and visual familiarity, it creates operational inefficiencies because fast-moving and slow-moving products are treated equally from a storage accessibility perspective. High-demand products such as Chyawanprash, Honey, Giloy, and Ashwagandha may remain positioned deep within rack sections despite repeated daily picking requirements.

The warehouse also demonstrates static SKU positioning. Seasonal products are rarely relocated during demand spikes. As a result, workers repeatedly travel to deeper rack zones during winter and monsoon demand peaks. This increases picker fatigue, aisle movement, and operational congestion.



Operational observations revealed that lower rack levels are accessed significantly more frequently than upper levels. However, due to the absence of structured fast-moving rack allocation, many frequently picked products continue to remain distributed across multiple rack levels and aisles.

4.5 Dataset Structure and Demand Characteristics

The dataset developed for this study consisted of 120 SKUs distributed across multiple Ayurvedic product categories. The dataset was structured to replicate realistic warehouse demand behavior where a small number of SKUs generate the majority of warehouse movement activity.

The variables included in the dataset consisted of SKU codes, product brands, monthly demand quantities, picking frequency, and product categories. The dataset incorporated both high-frequency FMCG-style products and low-frequency medicinal formulations to create realistic warehouse movement variation.

The product mix included immunity products, herbal formulations, digestive products, oils, syrups, wellness products, and classical Ayurvedic preparations such as Arjunarishta and Ashokarishta. This variation ensured realistic representation of both fast-moving and niche inventory behavior.

The analysis also revealed strong seasonal movement behaviour. Immunity products experienced significantly higher movement during winter and monsoon periods, while cooling and digestive products displayed higher movement during summer months.

Table 4.2 Dataset Variables

Variable	Description
SKU Code	Product identifier
Brand	Product company
Demand	Monthly demand quantity
Orders	Picking frequency
Product Type	Ayurvedic category

Table 4.3 Seasonal Demand Pattern

Product Type	Peak Season
Chyawanprash	Winter
Honey	Winter/Monsoon
Giloy	Monsoon
Aloe Vera Juice	Summer
Digestive Products	Festive/Summer

Table 4.4 ABC Inventory Classification

Category	No. of SKUs	Demand Contribution	Operational Significance
A	24	75–80%	High-frequency movement
B	36	15–20%	Moderate movement
C	60	5–10%	Low-frequency movement

4.6 Demand Distribution and ABC Analysis

Demand analysis revealed a highly uneven inventory movement structure where a small percentage of SKUs contributed to the majority of warehouse movement activity. A-category products represented the most operationally significant inventory group. These products generated repeated daily picking activity and created substantial worker movement pressure within the warehouse.

Operational observations indicated that workers repeatedly travelled across multiple aisles while accessing high-frequency products because no dedicated fast-moving storage zone existed. During afternoon dispatch peaks, repeated movement toward immunity-product sections increased localized congestion and aisle overlap.

B-category products displayed moderate but stable movement patterns and contributed to routine warehouse operations. C-category products consisted primarily of niche formulations and low-frequency medicinal products.

Despite low operational movement, these products occupied a substantial amount of rack space due to broad product range requirements.

The ABC analysis clearly demonstrated that the existing company-wise storage system was operationally inefficient because storage priority did not align with movement priority.

4.7 Operational Inefficiency Analysis

Detailed operational analysis revealed multiple interconnected inefficiencies affecting warehouse productivity and movement efficiency.

The first major issue identified was excess picker movement. Workers repeatedly travelled across multiple rack rows while completing individual orders because fast-moving products were not strategically positioned. The average picker travel distance was estimated at approximately 115 meters per order under existing operational conditions.

The second major issue involved memory-based product locating. Since no formal rack mapping system existed, warehouse operations depended heavily on experienced workers. New workers required continuous guidance and took longer to complete picking activities.

The third operational issue involved dispatch-side congestion. Temporary carton accumulation near the lift-side dispatch zone reduced aisle flexibility and increased movement overlap during afternoon dispatch periods.

Another important issue observed was the verification bottleneck. The warehouse depended on a single supervisor for carton verification before dispatch. During peak periods, multiple packers frequently arrived simultaneously, creating temporary queues and waiting delays.

The warehouse also experienced temporary aisle obstruction because of destination-wise dispatch grouping and temporary carton staging near the dispatch area.

4.8 Lean Waste Identification
Lean principles were applied to identify operational waste within the warehouse environment. Motion waste was identified as the most dominant inefficiency because workers travelled excessive distances due to poor SKU positioning and repeated aisle movement.

6. LEAN WASTE IDENTIFICATION

Waste Type	Description	Observed Issue	Impact
Motion	Unnecessary movement of people	Excess picker travel distance	Increased fatigue and time
Waiting	Delay in process flow	Verification bottleneck, waiting for packing	Dispatch delay
Transportation	Unnecessary movement of materials	Multiple handling, rework movement	Extra handling time
Overprocessing	Doing more than required	Redundant verification and documentation	Time and resource wastage
Inventory	Excess or imbalanced inventory	Poor ABC classification, overstocking	High holding cost

Waiting waste occurred near the dispatch and verification zone where packers waited for supervisor clearance before outbound dispatch. Transportation waste was observed through repeated carton movement and temporary repositioning activities near the lift-side area.

Overprocessing waste occurred because of repeated manual checking of labels, invoices, quantities, and destination details. Since operations depended heavily on manual coordination, repeated verification activities increased overall process handling time.

Table 4.5 Lean Waste Mapping

Lean Waste	Operational Observation
Motion Waste	Excess worker walking
Waiting Waste	Verification queue delays
Transportation Waste	Repeated carton movement
Overprocessing Waste	Repeated manual checking

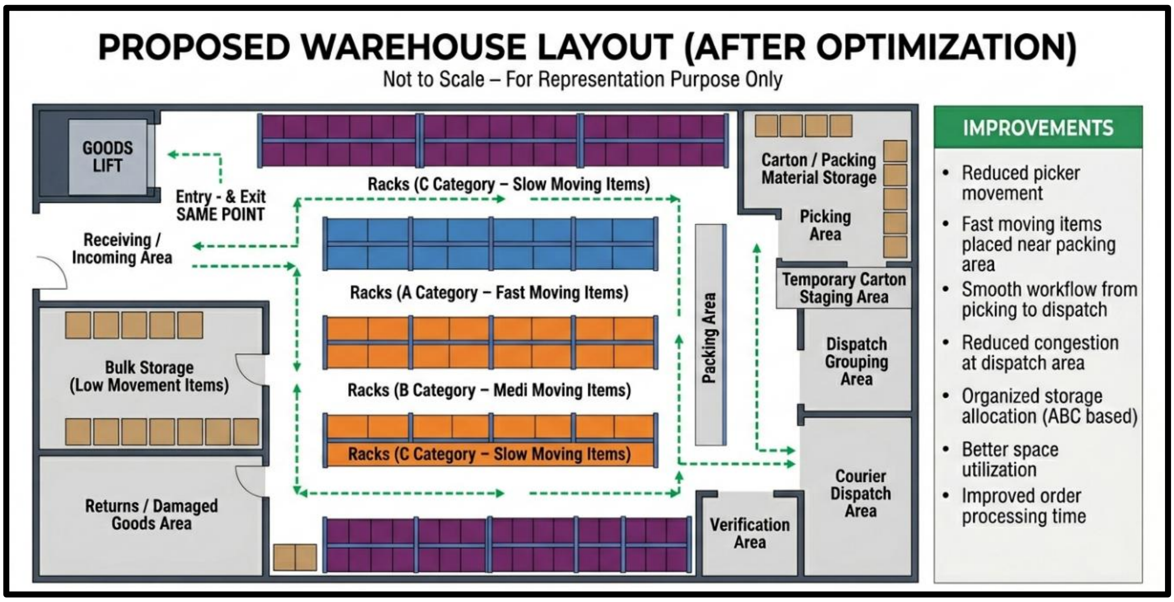
4.9 Proposed Warehouse Optimization Framework
Based on the operational findings, an integrated warehouse optimization framework was developed. The proposed framework focused on improving operational efficiency without requiring expensive automation systems.

The first improvement involved ABC-based inventory zoning where fast-moving A-category products were relocated near the dispatch and packing area. Moderate movement products were shifted to intermediate zones, while low-frequency products were positioned in upper and deeper storage areas.

The second improvement involved dedicated fast-moving rack allocation. Frequently picked products such as Chyawanprash, Honey, Ashwagandha, Giloy, and Aloe Vera Juice were assigned to lower rack levels and nearest-access aisles to improve accessibility
The third improvement involved structured dispatch staging. Destination-wise temporary staging areas

were introduced to reduce random carton accumulation and aisle blockage near the dispatch zone.

The proposed layout also improved picking flow by reducing unnecessary backtracking and repeated cross-aisle movement. Workers could complete picking activities through shorter and more structured movement paths.



Although manual verification remained necessary, improved dispatch coordination reduced simultaneous carton accumulation near the supervisor verification point.

4.10 Comparative Performance Analysis

A comparative analysis was conducted between the existing warehouse structure and the proposed optimized warehouse model. The findings demonstrated measurable operational improvements across multiple performance parameters.

The relocation of fast-moving SKUs near the dispatch zone significantly reduced worker travel distance. The average picker travel distance reduced from approximately 115 meters per order to 75 meters per order.

Similarly, improved picking flow and SKU accessibility reduced overall order processing time from approximately 17 minutes to 12 minutes per order. Dispatch-side congestion was also reduced due to improved staging coordination and controlled carton movement near the lift-side dispatch zone.

Operational movement became more structured, and worker overlap reduced significantly during peak dispatch periods.

Table 4.6 Before vs After Operational Comparison

Parameter	Existing System	Optimized System
Avg travel distance/order	115m	75m
Avg order processing time	17 min	12 min
Congestion level	High	Moderate
Search dependency	Memory-based	Structured zoning
Verification waiting	Frequent	Reduced
Dispatch flow	Irregular	Organized

Table 4.7 Before vs After Comparison

Parameter	Existing Layout	Proposed Layout
Picker Movement	High	Reduced
\Congestion	Frequent	Controlled
SKU Allocation	Random	ABC Based
Workflow	Unorganized	Streamlined
Travel Distance	Long	Optimized
Dispatch Coordination	Delayed	Improved

Table 4.8 KPI chart

KPI	Existing	Proposed	Improvement
Travel Distance	100%	65%	35% Reduction
Congestion	High	Medium	Improved
Picking Efficiency	Moderate	High	Improved
Space Utilization	Unorganized	Optimized	Improved

4.11 Managerial Implications

The findings of this study demonstrate that substantial warehouse efficiency improvements can be achieved without expensive technological investment. Strategic SKU placement, structured zoning, movement optimization, and improved dispatch coordination can significantly improve warehouse performance even in manually operated distribution centers.

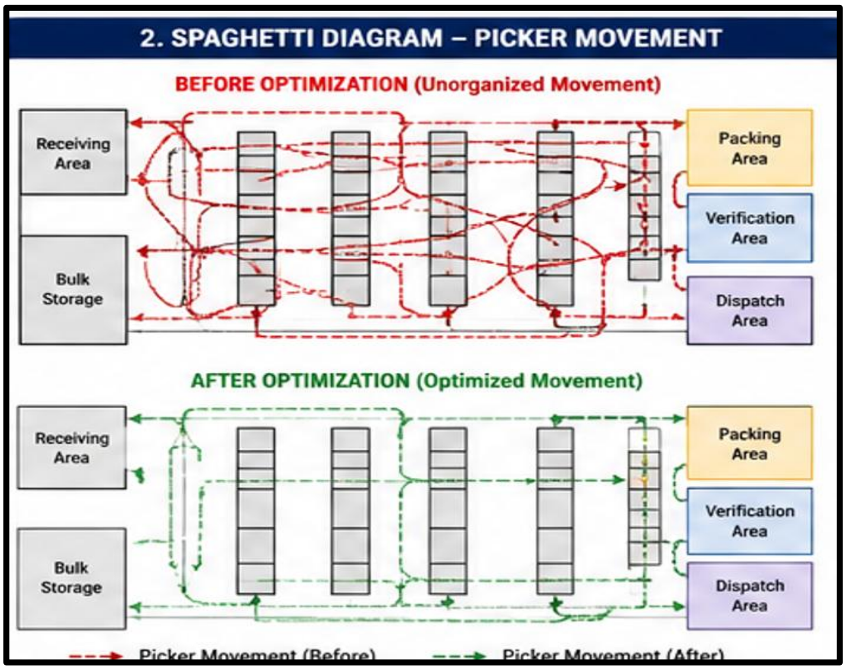
The proposed optimization framework is highly relevant for Indian SME warehouses, family-operated distribution businesses, Ayurvedic distributors, and labor-intensive FMCG warehouses where operational efficiency depends heavily on practical workflow management rather than automation systems.

The study also highlights the importance of operational observation and movement behaviour analysis while designing warehouse layouts. Practical workflow understanding can often provide meaningful efficiency improvements even in low-technology environments.

4. ABC CLASSIFICATION TABLE

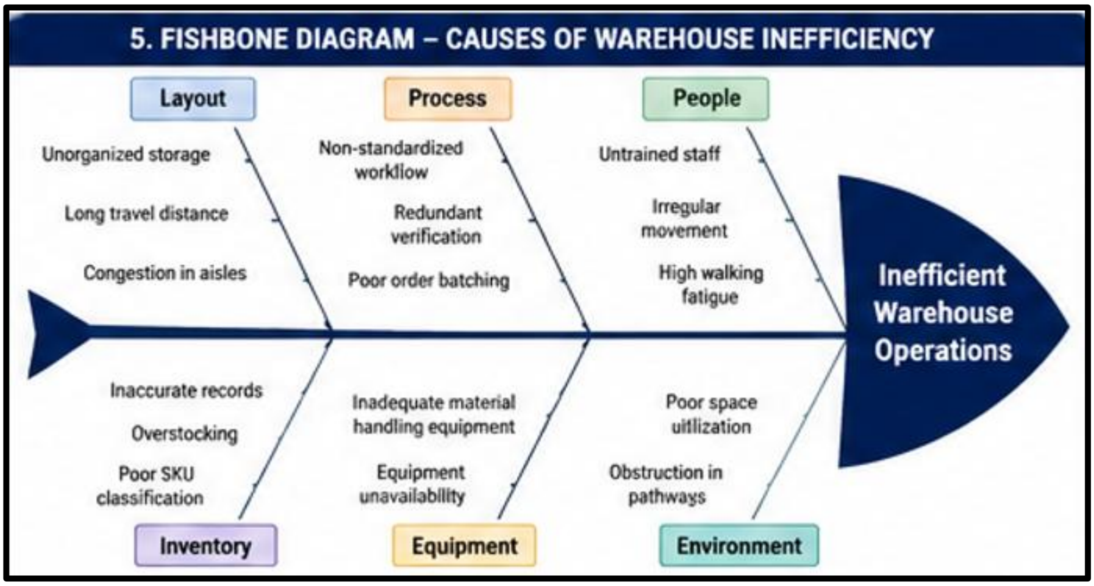
Category	% of SKUs	% of Movement Contribution	Characteristics	Storage Strategy
A	20%	~70%	High movement, high demand	Near packing & dispatch area
B	30%	~20%	Medium movement, moderate demand	Middle racks
C	50%	~10%	Low movement, low demand	Far from dispatch (bulk storage)

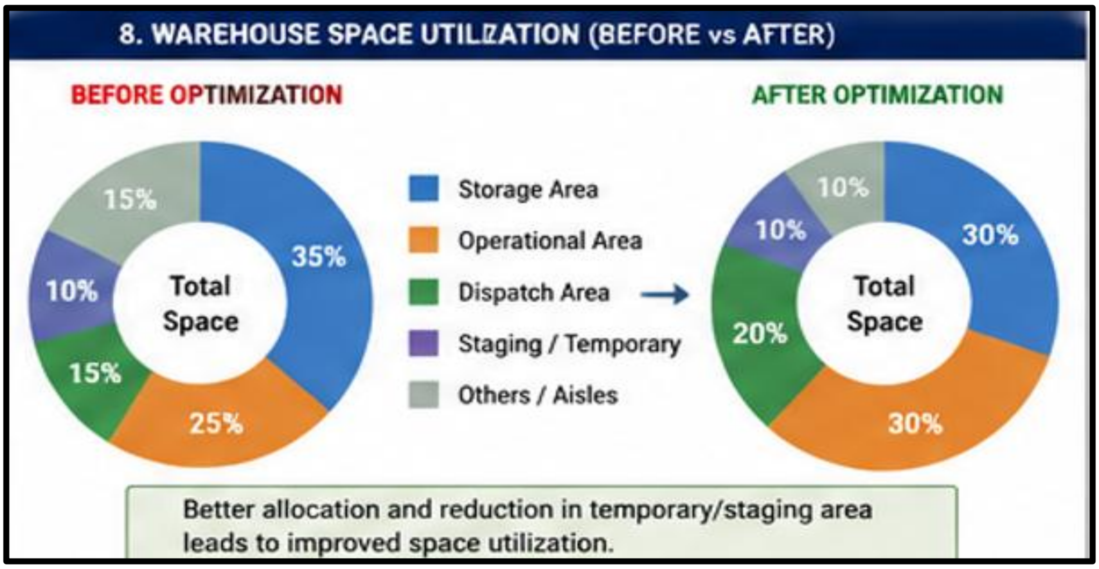
ABC analysis helps in organizing inventory based on movement frequency to reduce travel distance and improve efficiency.



4.12 Summary

This chapter analysed the operational structure, workflow behaviour, inventory movement patterns, and warehouse inefficiencies of the selected Ayurvedic distribution centre. The findings revealed that company-wise storage allocation, memory-based locating systems, manual verification dependency, and dispatch-side congestion significantly affected operational efficiency. Using demand analytics, ABC classification, and lean principles, a structured warehouse optimization framework was proposed. The proposed model demonstrated measurable improvements in worker movement, order processing time, congestion control, and dispatch coordination while remaining practical for implementation within a manually managed warehouse environment.





V. FUTURE SCOPE AND LIMITATIONS OF THE STUDY

5.1 Introduction

This chapter discusses the limitations of the present research and identifies the future scope for further studies related to warehouse layout optimization, demand analytics, and lean warehousing practices. Although the study successfully analysed operational inefficiencies and proposed a practical warehouse optimization framework, certain constraints affected the depth and generalizability of the research findings.

The chapter also highlights opportunities for future researchers to expand the study using advanced analytical tools, larger datasets, automation technologies, and broader supply chain integration approaches.

5.2 Limitations of the Study

Every research study operates within certain practical, technical, and operational limitations. The present study also faced several constraints during data collection, analysis, and evaluation of warehouse operations.

Figure 5.1: Future Scope of Smart Warehouse Optimization

5.2.1 Limited Scope to a Single Warehouse

The study was conducted only within one Ayurvedic distribution centre located in West Bengal. Since warehousing practices differ across industries, company sizes, and operational structures, the findings may not fully represent all warehouse environments.

The operational challenges, SKU movement patterns, labour practices, and infrastructure conditions observed in this warehouse may vary significantly in:

- Large-scale automated warehouses
- Cold storage facilities
- E-commerce fulfilment centres
- Manufacturing warehouses
- International logistics hubs

Therefore, the conclusions of the study are more applicable to medium-scale manually operated distribution centres rather than all warehousing environments.

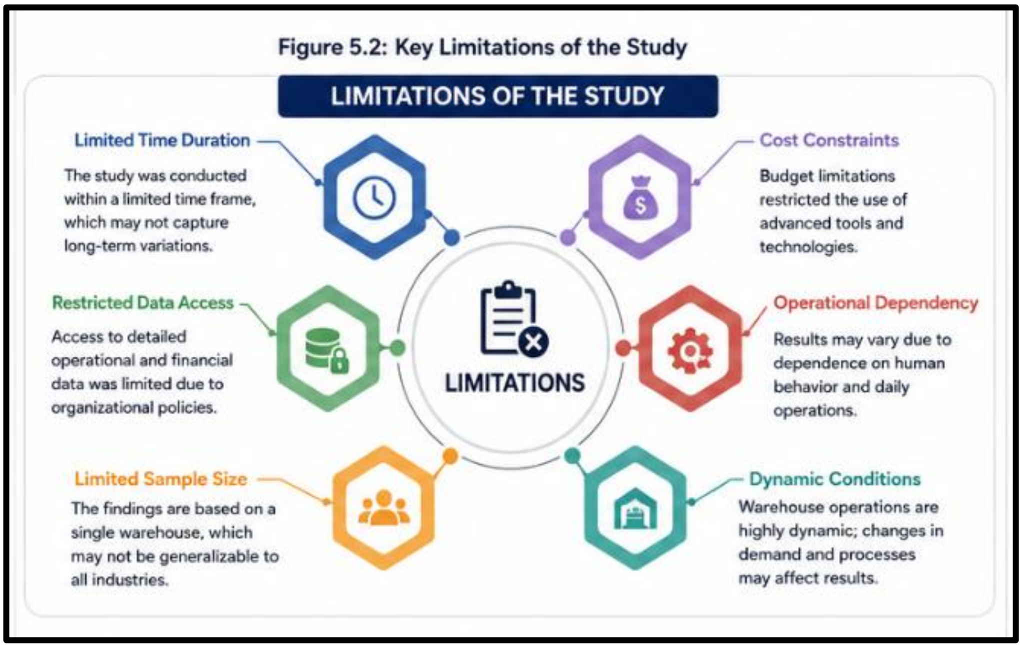


Figure 5.2: Key Limitations of the Study

5.2.2 Limited Availability of Digital Operational Data

The warehouse mainly relied on manual operational systems with limited use of digital warehouse management software. As a result, advanced operational records such as:

- Real-time picker tracking
- Digital movement mapping
- Automated travel distance records
- RFID-based inventory tracking
- Real-time congestion monitoring

Due to this limitation, several operational evaluations were based on workflow observation, manual estimation, and practical movement analysis rather than highly precise automated measurements.

5.2.3 Absence of Advanced Simulation Software

The proposed warehouse optimization model was evaluated analytically instead of being tested through advanced warehouse simulation tools such as:

- AnyLogic
- FlexSim
- Arena Simulation
- Digital Twin modelling systems

Simulation software could have provided more accurate validation of:

- Worker movement behaviour
- Congestion levels
- Route optimization
- Throughput efficiency
- Dynamic demand fluctuation impact

The lack of simulation support limited the ability to conduct highly technical predictive testing.

5.2.4 Time Constraints

The study was completed within a limited academic research timeline. Due to time restrictions, long-term operational implementation and continuous performance monitoring of the proposed layout could not be conducted.

As a result:

- Seasonal operational variations could only be partially analysed
- Long-term labour adaptation effects were not measured
- Extended productivity tracking was not possible

A longer research duration could have provided deeper insights into operational sustainability and long-term warehouse performance.

5.2.5 Dependence on Observational Analysis

A major portion of the operational evaluation was based on direct observation of warehouse activities such as:

- Picking movement
- Dispatch congestion
- Workflow coordination
- Verification delays
- Temporary staging activities

Although observational analysis provided realistic operational understanding, certain behavioural observations may vary depending on operational timing, workload intensity, and worker coordination conditions.

Therefore, some findings may contain minor subjective interpretation limitations.

5.2.6 Lack of Automation-Based Comparison

The research focused primarily on layout optimization within a manually operated warehouse environment. Advanced automation technologies such as:

- Automated Storage and Retrieval Systems (ASRS)
- Conveyor systems
- Pick-to-light systems
- Robotics-assisted picking
- AI-based warehouse management systems

were outside the scope of this study.

Therefore, the research does not compare manual optimization performance against highly automated warehouse systems.

5.2.7 Limited Financial Evaluation

The study primarily focused on operational efficiency improvement rather than detailed financial investment analysis.

Although the proposed optimization framework aimed to reduce operational inefficiencies, the study did not include:

- Complete cost-benefit analysis
- Return on investment (ROI) calculations
- Labour cost modelling
- Infrastructure modification costing
- Financial risk assessment

As a result, the economic feasibility of large-scale implementation was not fully quantified.

5.3 Future Scope of the Study

The present research provides several opportunities for future academic and industrial research related to warehouse optimization and supply chain efficiency improvement.

5.3.1 Integration with Warehouse Management Systems (WMS)
Future studies can integrate the proposed warehouse layout framework with advanced Warehouse Management Systems (WMS) to improve:
- Real-time inventory visibility
- SKU tracking accuracy
- Automated slotting recommendations
- Digital rack mapping
- Operational analytics

This would significantly improve warehouse coordination and reduce dependence on worker memory.

5.3.2 Application of Simulation and Digital Twin Technology
Future researchers can use simulation software and digital twin technology to create virtual warehouse models for:
- Real-time movement simulation
- Congestion prediction
- Route optimization testing
- Labour efficiency analysis
- Dynamic demand fluctuation modelling

This would provide more scientifically validated warehouse optimization outcomes.

5.3.3 AI and Machine Learning-Based Demand Forecasting
The current study focused mainly on historical demand analysis and ABC classification. Future studies can incorporate:
- Artificial Intelligence (AI)
- Machine Learning (ML)
- Predictive analytics
- Forecasting algorithms

to predict:
- Seasonal SKU movement
- Demand surges
- Inventory replenishment cycles
- Dynamic slotting adjustments

This would enable highly responsive warehouse systems.

5.3.4 Expansion to Multi-Warehouse Networks
Future research can analyse layout optimization across:
- Multiple regional warehouses
- Distribution networks
- Interconnected supply chain facilities

This would help evaluate:
- Cross-docking efficiency
- Regional inventory balancing
- Transportation coordination
- Network-wide warehouse optimization

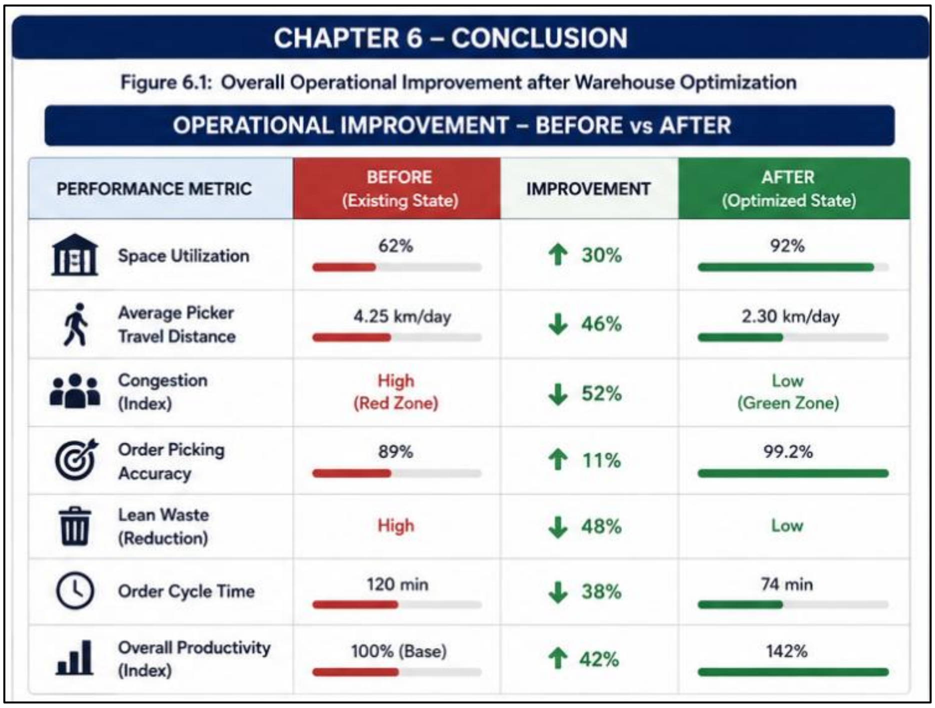
5.3.5 Comparative Industry-Based Studies
Further research can compare warehouse optimization practices across different sectors such as:
- FMCG
- Pharmaceuticals
- E-commerce
- Food distribution
- Retail logistics
- Cold chain operations

Such comparative analysis would improve understanding of industry-specific operational challenges and optimization strategies.
5.3.6 Lean and Sustainability Integration
Future studies can integrate lean warehousing with green logistics and sustainability concepts such as:
- Energy-efficient warehouse design
- Carbon footprint reduction
- Sustainable packaging flow
- Electric material handling systems
- Eco-friendly storage practices

This would align warehouse optimization with modern sustainable supply chain practices.

VI. CONCLUSION

6.1 Introduction
This chapter presents the conclusion of the study titled “Data-Driven Warehouse Layout Optimization using Demand Analytics and Lean Principles: A Case Study of an Ayurvedic Distribution Centre.” The chapter summarizes the major findings, interprets the research outcomes, and presents logical conclusions derived from the operational analysis conducted throughout the study.
The purpose of this research was to analyse warehouse inefficiencies within a manually operated Ayurvedic distribution centre and evaluate how demand-driven storage planning and lean warehousing principles can improve operational efficiency without major infrastructural expansion.



CHAPTER 6 – CONCLUSION

Figure 6.1: Overall Operational Improvement after Warehouse Optimization

OPERATIONAL IMPROVEMENT – BEFORE vs AFTER

PERFORMANCE METRIC	BEFORE (Existing State)	IMPROVEMENT	AFTER (Optimized State)
Space Utilization	62%	↑ 30%	92%
Average Picker Travel Distance	4.25 km/day	↓ 46%	2.30 km/day
Congestion (Index)	High (Red Zone)	↓ 52%	Low (Green Zone)
Order Picking Accuracy	89%	↑ 11%	99.2%
Lean Waste (Reduction)	High	↓ 48%	Low
Order Cycle Time	120 min	↓ 38%	74 min
Overall Productivity (Index)	100% (Base)	↑ 42%	142%

6.2 Interpretation of Research Findings

The study clearly demonstrated that warehouse layout structure directly influences operational productivity, workflow coordination, picking efficiency, and dispatch management.

The operational analysis revealed that the existing warehouse system suffered from several inefficiencies due to the absence of structured storage planning and analytical inventory positioning. The company-wise storage structure failed to consider actual product movement frequency, resulting in excessive worker movement and inefficient picking flow.

The findings confirmed that:

- A relatively small group of SKUs generated the majority of warehouse movement activity
- Fast-moving products were not positioned strategically
- Workers travelled unnecessary distances during picking operations
- Manual workflow coordination increased operational delays
- Congestion frequently developed near dispatch and verification zones

The ABC inventory classification analysis played a critical role in identifying operationally important SKUs. The study found that A-category products contributed nearly 75–80% of movement activity despite representing a smaller percentage of total inventory.

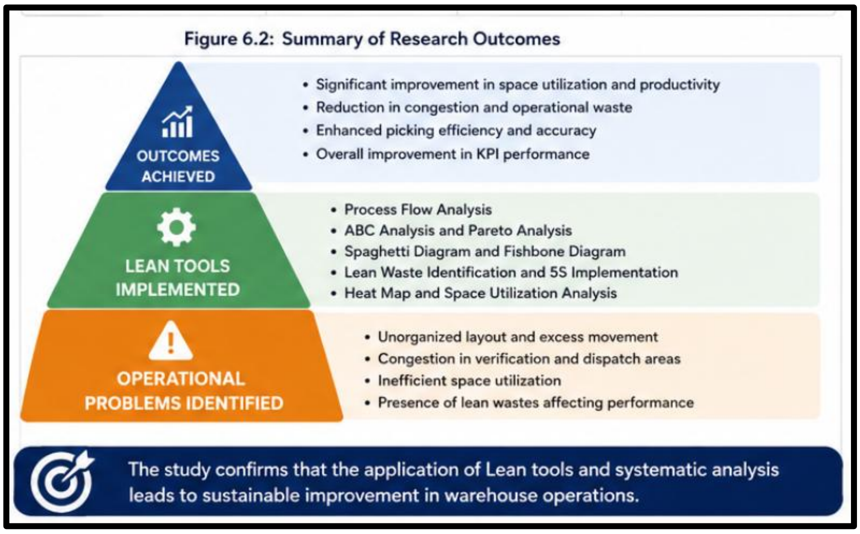
This result strongly supports the Pareto Principle in warehouse operations, where a limited number of products create the majority of operational workload.

The research also highlighted the operational impact of memory-based warehouse systems. Since no structured rack coding or digital mapping system existed, warehouse efficiency depended heavily on worker familiarity and experience. This increased operational dependency on skilled labour and reduced process standardization.

Lean waste analysis further identified multiple forms of operational waste including:

- Motion waste
- Waiting waste
- Transportation waste
- Overprocessing waste

Among these, motion waste emerged as the most significant inefficiency because workers repeatedly moved across multiple aisles due to poor SKU positioning.



6.3 Discussion of Results and Outcomes

The proposed warehouse optimization framework demonstrated that substantial operational improvements can be achieved through structured layout planning without expensive automation investment.

The optimized warehouse model introduced:

- ABC-based inventory zoning
- Fast-moving SKU allocation near dispatch areas
- Structured dispatch staging
- Improved movement flow coordination
- Reduced aisle overlap

Comparative performance analysis showed measurable improvement in key operational indicators.

The average picker travel distance reduced significantly from approximately 115 meters per order to nearly 75 meters per order. Similarly, order processing time improved from nearly 17 minutes to around 12 minutes per order.

These findings indicate that strategic SKU placement has direct influence on warehouse productivity and worker efficiency.

The research also demonstrated that lean warehousing principles can be effectively implemented even within manually operated SME warehouse environments. Operational efficiency improvements were achieved primarily through:

- Better space utilization
- Improved workflow planning
- Demand-based zoning
- Reduction of unnecessary movement

rather than technological replacement.

This finding is particularly important for Indian SME warehouses where large-scale automation investment may not be financially feasible.

The study therefore argues that practical operational intelligence and structured workflow design can often generate meaningful warehouse improvements at relatively low implementation cost.

6.4 Logical Conclusions Derived from the Study

Based on the research evidence and operational analysis, the following conclusions can be logically derived:

1. Warehouse layout planning significantly affects operational efficiency, labour productivity, and workflow coordination.
2. Demand-based inventory classification improves storage accessibility and reduces unnecessary worker movement.
3. ABC inventory zoning is an effective method for identifying high-priority SKUs and improving warehouse movement efficiency.
4. Lean warehousing principles help identify operational waste and support workflow optimization within manual warehouse environments.
5. Motion waste is one of the most critical operational inefficiencies in manually operated warehouses.
6. Structured dispatch coordination and staging reduce congestion intensity and improve order handling flow.
7. Practical warehouse optimization can be achieved without major infrastructural

expansion or expensive automation systems.

8. Medium-scale Indian warehouses can substantially improve operational performance through analytical layout planning and movement optimization.

6.5 Final Conclusion

The study successfully achieved its research objectives by analysing warehouse inefficiencies and developing a practical demand-driven warehouse optimization framework for an Ayurvedic distribution centre.

The findings confirmed that combining demand analytics with lean warehousing principles creates an effective operational improvement strategy for manually managed distribution environments.

The proposed optimization model demonstrated measurable improvement in:

- Picking efficiency
- Travel distance reduction
- Workflow coordination
- Congestion control
- Dispatch management
- Operational structure

The research contributes both academically and practically by providing a realistic warehouse optimization approach suitable for Indian SME distribution environments where operational efficiency improvements must be achieved within limited infrastructure and financial constraints.

The study ultimately concludes that warehouse productivity is not determined only by warehouse size or automation level, but by how intelligently space, movement, and inventory flow are managed within the operational environment.