DEVELOPMENT AND IMPLEMENTATION OF LEAN SERVICE TOOLS AND TECHNIQUES IN INDIA POST MAIL SERVICE – A CASE STUDY

Thesis

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

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DECLARATION

by the Ph.D. Research Scholar

I hereby declare that the Research Thesis entitled, **'Development and Implementation of Lean Service Tools and Techniques in India Post Mail Service Industry – A Case Study'** which is being submitted to the National Institute of Technology Karnataka, Surathkal in partial fulfilment of the requirements for the award of the **Degree of Doctor of Philosophy in Operations Management** is a *bonafide report of the research work carried out by me.* The material contained in this Research Thesis has not been submitted to any University or Institution for the award of any degree.

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CERTIFICATE

This is to *certify* that the Research Thesis entitled **'Development and Implementation of Lean Service Tools and Techniques in India Post Mail Service Industry – A Case Study'** submitted by **Vadivel S M, (Reg. No.165071SM16F09)** as the record of the research work carried out by him is *accepted as the Research Thesis submission* in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy.

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DEDICATED

To

India Post Service

&

My wife Suganya P, Son Nithesh Kumar S V

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VADIVEL S M

ABSTRACT

Purpose of the Study: The primary role of the post office is collecting, scanning, sorting, transmission; and delivery of mail with consistent, speed, and security. The Indian postal service has taken a significant role in sorting and transporting the mails throughout the countries. Though the degree of the sorting process varies from country to country, the ultimate aim is to make letter-sorting a fully customized one. For example, developed countries such as the USA, Japan are using the automatic sorting machine to increase their delivery speed, whereas, in India, sorting is being done manually because of abundant labor availability. The processing, transmission, and delivery of mail are the core activities of the postal department. In India, daily mails are collected from almost 5,79,595 letterboxes and are processed through a network of 389 mail offices by roads, rails, and airline transportation.

In this research, we proposed implementing lean service concepts for productivity enhancement in a service enterprise at the Indian Postal Head Sorting Center - National Sorting Hub (NSH), Mangalore. Recently, NSH has worked on the Mail Network Optimization Project (MNOP) to improve the standardization and operational processes in terms of mail processing, transmission, and delivery.

Methodology: Successful lean tools that have been used in manufacturing industries were adopted for the service industry and applied here. VSM is one of the graphic visual tools to find the broad and complete representation of an organization used for better understanding and interventions in operations.

Facility Layout Design (FLD) using MCDM Methods: There were many problems which have been identified in the existing layout such as, backtracking of mails while handling a high volume of articles during the current process flow, poor working environment which causes discomfort during regular working hours and employees are not agreeable for a long working hours, sorting the mail is challenging for the postal employees, the whole process is time consuming, the present production delivery articles are not satisfactory as compared to the target. This study attempts to rectify the problems by modifying the layout and improving operational performance using MCDM methods. The critical parameters for selecting the optimal layouts are lean service, working environment, and ergonomics. The MCDM methods such as AHP, TOPSIS, Fuzzy TOPSIS, GRA has been used for finding the optimal layout considering quantitative and

qualitative data. The postal administrations had spent almost INR 2 Lakhs for implementing the selected optimal layout.

Implementation of Lean Service Tools and Techniques: Applicable lean service elements are incorporated in NSH, manual sorting centre, and in eliminating waste by taking suitable courses of action. Here, the cellular approach (Nagare cell) was used to reduce the walking distance in the sorting section. Reduction in cycle time and employees shoulder pain was taken care of by executing fixed scanner; 5S for housekeeping concepts for everything; everything in its place. Visual management was utilised for visualizing the objects in the workplace. Single piece flow was adopted for reducing the backtracking of the mails. Workload balancing was availed for maintaining load uniformity while distributing to all the employees by using systematic scheduling and careful analysis.

Findings: The impact of the change and adherence to the recommendations were monitored continuously. After twelve weeks, an audit of the effect performed, and the following were observed. Cycle time had reduced by 15.13% from 371 sec, flow speed had increased by 11.36% from 590, individual article processed per person had increased by 11.36% from 8620.

Lean Service Assessment: The impact of the lean system on operational performance has been assessed in mail service operations in India. Measuring operational performance in mail service operations is a big challenge in the postal service industry. Hence, a cross-sectional survey was conducted and the relationship and impact of Lean Service Practices (LSP), Lean Workplace Environment Practices (LWEP), and Lean Social Practices (LSoP) was measured on operational performance in India post service industry.

Findings: The results indicate that there is a strong correlation between LSP ($r = 0.728$), LWEP ($r = 0.722$), and LSoP ($r = 0.654$) and operational performance. Significant impact has been observed on LSP ($\beta = 0.484$) on Operational performance, then LWEP ($\beta = 0.387$) and followed by LSoP ($\beta = 0.182$) on operational performance. The practical effect of the findings of a lean service system has been implemented for enhancing the operational performance of the business.

Simulation Techniques and Taguchi methods: This study aims to present an innovative method in designing Lean Service Systems (LSS) in India's post-service industry, using Taguchi and simulation to reduce the system's complexity; using logic and systematic building blocks simulation models developed from LS elements through Arena software. Five control factors considered for the system's performance were takt time, process ratio, production lead time, value-added time, and inventory. The simulation used for imitating the real model guides the

future production system and the Taguchi method used for the robust system to determine the optimal parameter values.

Postal Sustainable Design by Quality Function Deployment (QFD): The need of the hour today is to incorporate sustainable principles to the public postal service facilities to withstand in the market. Here, the objective is to develop a model to explore the Quality Function Deployment (QFD) concept and technique to be incorporated in India post service operations. It aims to support sustainability by finding customer factors (queries) that affect Service Quality (SQ) design/dimensions. This survey was helpful, to understand how India's post can remain strategically sustainable for the next few decades. This study improves QFD tools for the postal service quality design known as the House of Quality Sustainable Design (HOQSD) model. This model highlights and bolsters the sustainability principles and performs the integration of customer priorities, information, and their knowledge.

Keywords: India Post Manual Sorting Center, National Sorting Hub (NSH), Mail Operations, Lean Service (LS), Workplace Environment, Ergonomics, Facility Layout Design (FLD) and Planning, Multi-Criteria Decision Making Methods (MCDM), Operational Performance, Value Stream Mapping (VSM), Production Performance Metrics, Simulation Technique, Taguchi Method, Quality Function Deployment (QFD), House of Quality Sustainable Design (HOQSD).

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Glossary

Branch post office (BO) is the smallest unit of the postal organization serving the public in an area. It is lower in status than a sub-post office (SO).

Head post office (HO) is chief among the group of post offices called sub and branch post offices and has accounts jurisdiction over them.

Intra Circle Hub (ICH) is lower in status than a NSH post office. NSH post offices are attached to a definite ICH post office.

Mail is the system used by the post office for collecting and delivering letters.

Mail box is kept at the entrance of the houses where the postman delivers letters.

National Sorting Hub (NSH) is part of speed postal service, abbreviated as NSH. It manages sorting offices on land and transit sections in all modes of transportation.

PIN CODE stands for Postal Index Number. India post has adopted six digit code as a part of address. It makes it easier and quicker for sorting and delivery of mail (or post) to the correct address.

Post is the national organization responsible for postal services.

Postal order is a piece of paper representing a sum of money which a person buys at post office when he/she wants to send money to someone by post. The recipients sign it and get the money or transfer it to his/her account.

Post Bag (PB) is a facility availed by large organizations. They pay rent for post bags through which letters are delivered to them.

Post Box (PB) is a numbered metal/wooden cabinet available on rent, in a post office where letters are kept until called for.

Post code is a short sequence of numbers or letters or their combination at the end of an address. It facilitates speedy sorting and delivery of mail; In the USA it is called Zip code and in France it is code postal.

Post office is a building where one can go to use any of the services provided by the national postal service.

Sorting office is a place where letters, packages, etc are taken after posting and sorted according to their delivery addresses. It comes under the Railway Mail Service.

Abbreviations

AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
ASP	Assistant Superintend
APMC	Automatic Mail Processing Centre
BNPL	Book Now Pay Later
COD	Cash on Delivery
CPMG	Chief Post Master General
CRC	Computerized Registered sorting Centre
DEA	Data Envelopment Analysis
DEMATEL	Decision Making Trial and Evolution Laboratory
DM	Decision Making
FLD	Facility Layout Design
FTOPSIS	Fuzzy TOPSIS
GA	Genetic Algorithm
GRA	Grey Relational Analysis
HOQSD	House of Quality Sustainable Design
IPS	Indian Postal Service
ICH	Intra Circle Hubs
KPI	Key Performance Indicators
LM	Lean Manufacturing
LS	Lean Service
LSP	Lean Service Practices

LSS	Lean Service System
LSoP	Lean Social Practices
LWEP	Lean Workplace Environment Practices
MNOP	Mail Network Optimization Project
MCDM	Multi Criteria Decision Making Technique
MSD	Musculoskeletal Disorders
NSH	National Sorting Hub
NON-TD	Non-Town Delivery
NVA	Non-Value-Added Activities
PMG	Post Master General
PD	Postal Division
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
QFD	Quality Function Deployment
RMS	Railway Mail Service
REL	Relationship Chart
SMART	Simple Multi Attribute Rating Technique
SOP	Standard Operating Procedure
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TD	Town Delivery
VIF	Variance Inflation Factors
VSM	Value Stream Mapping

Notations

CI	Consistency Index
CR	Consistency Ratio
λ_{max}	Eigen value (maximum)
FN	Fuzzy Number
FST	Fuzzy Set Theory
GRC	Grey Relational Coefficient
GRGe	Grey Relational Generating
GRG	Grey Relational Grading
N	Comparison matrix size
RI	Random Index
TFN	Triangular Fuzzy Number

CHAPTER 1

INTRODUCTION

Chapter 1 introduces the research area and its sub-divided sections: background of the research, needs of the research, objectives of the research, significance of this study, and finally concludes with the outline of the thesis.

1.0 Background of the Research

The Postal industry comes under the Indian public sector managed by the Central Government. It is a primary service-oriented industry that utilizes the advantage of labour-intensive work in India and provides a better service through integration with other departments such as airways, railways, and roadways. Indian Postal service is one of the essential service industries; it has an extensive network of 1,54,866 post offices and it is the vast postal network in the world. They are providing parcels, logistics, mail, financial and retail services across the nation. It plays an essential role in bolstering socio-economic development. The postal department has a total 1,54,866 post offices; of which, 1,39,040 were in rural and 15,826 in urban areas up to March 2011 (Ramachandran.K,2011).

The postal service is a mission-driven organization, and it has customer demands which require services around the clock, seven days per week (i.e., 24 x 7). In this present scenario, postal organizations are facing the decline of traditional mail volumes and an increase in the parcel volumes. Still, the postal service is striving to meet customer needs, and it must downsize its network to stop unexpected volume losses. In the US parcel delivery market, the foreign posts face aggressive low-cost competition, according to the US postal service report (2015). Some countries fully trust on part-time workers. For example, nearly 80 percent of postal workers in the Netherlands in 2010 and 2011 were part-timers. However, developing countries such as India hired employees as full-time and part-time workers for the manual sorting process to exploit the advantage of labour availability. Regularly, the Indian Postal department receives more than 50,000 articles, which is difficult to store and sort, unless there is an efficient method.

During recent times, the postal service traditional business has declined, and the digital world and e-commerce have transformed the competitive marketplace. Hence, the postal employees and management have willingly come to adopt the innovative method and new technology to sustain the postal service for the future. For the last few years, with the help of Information Technology, mail information is being processed quickly, which has resulted in increased delivery speed of articles to the customers. Customers can track their articles and parcels, adopting logistics information precisely and predict the reaching time of articles and parcels to their address with the help of barcode technology. Developed countries use Teletext, automatic sorting machines, etc. to increase their delivery speed. Developing countries like India hire a manual workforce for the sorting process in most of the states. Even though each country differs in its sorting process, the essential goal is to create an efficient sorting process.

Postal organizations need to change from the traditional method to a non-traditional way to improve operational performance through productivity in the long run. According to Ibrahim et al. (2016), most of the problems can be solved to improve production efficiency with a low-cost investment and common-sense approach. Lean Manufacturing (LM) is a method to find and remove non-value-added activities (waste) and enhance production performance with employees' coordination. LM applies through kaizen (continuous improvement) activities with the help of employee involvement and requires less cost for its implementation (Hasle et al. 2012).

1.1 Indian Postal Service

The Indian Postal service was created in 1948-49 in Group – A cadre. The responsibilities were mentioned, such as mail arrangements, control of town sub-offices, postal facilities, complaints and investigations concerning head post offices.
The postal service offers mail services such as registered, unregistered, express parcel, speed post, greeting post, media post, and logistics post. It also provides other services such as money order, postal savings, postal saving certificate, and philately bureaus, etc. (Figure 1.1)

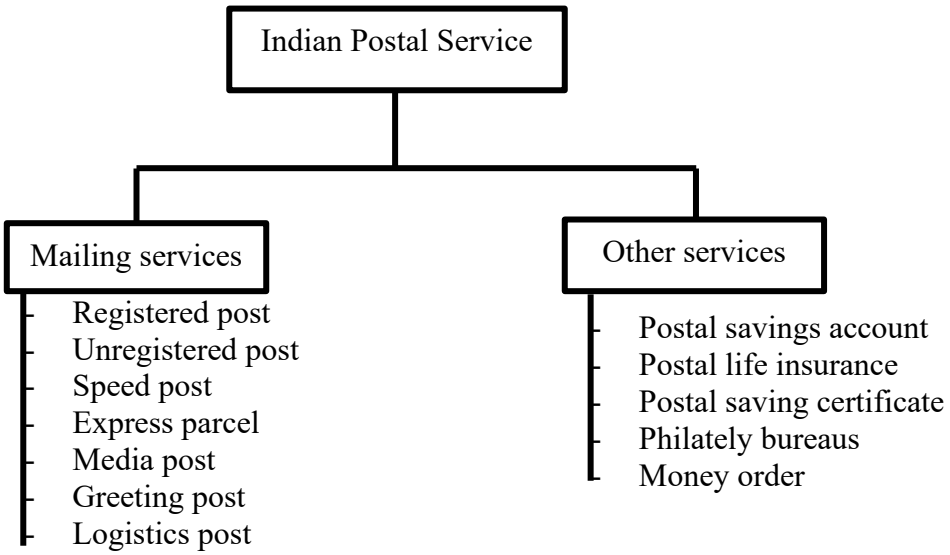


Figure 1.1: India Post Mail and other Services

1.2 Indian Postal Service – A Case Study NSH, Mangalore

In the year 2013, India Post introduced hub & spoke mechanism for speed post articles under Mail Network Optimization Project (MNOP). Eighty-nine main centers of the country selected as speed post hubs named as National Sorting Hubs (NSHs) and 105 important centers within postal circles were selected named as Intra Circle Hubs (ICHs). NSHs are responsible for dispatching inward mails to connected delivery post offices (spokes), and the same lines can send outward letters to within and outside the circle. India Post has 23 postal circles, generated from post offices & ICHs connected to it. ICHs also function on the same lines but cannot dispatch outward mails within its circle. Outward mails received at ICHs from its connected post offices routed through respective NSH. Here, in South Karnataka NSH, Mangalore has been considered as a case study.

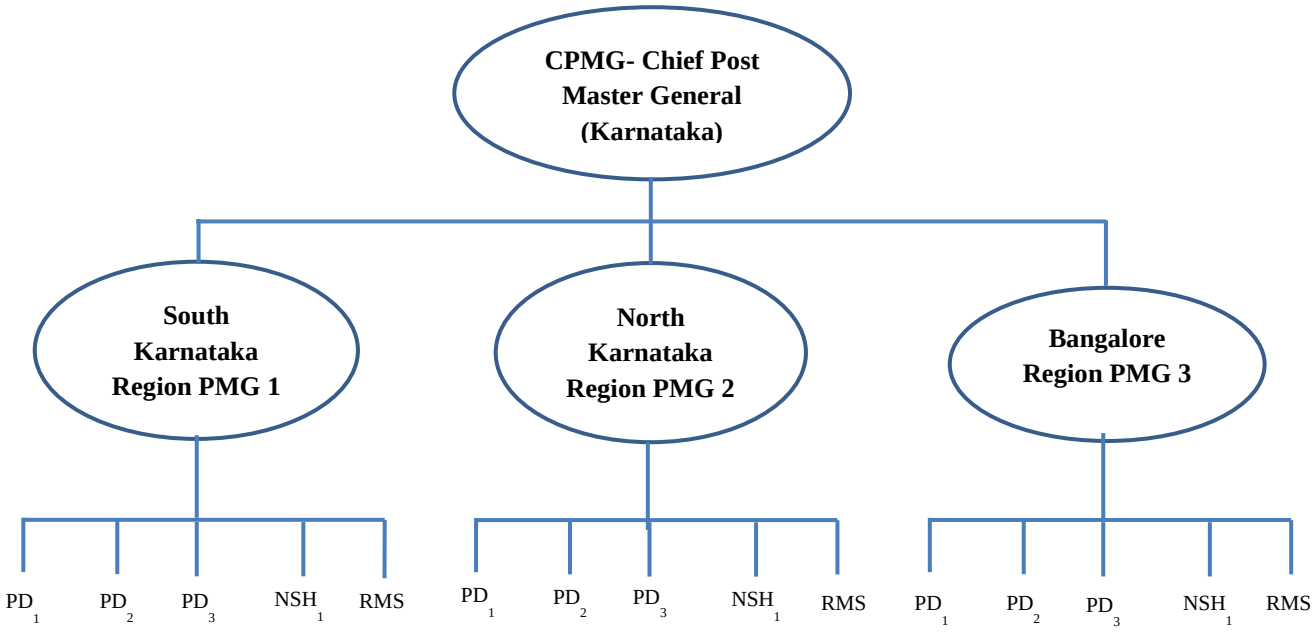
1.3 Administrative - Hierarchy of Karnataka State Postal Circle

- All the postal offices in every circle are under the control of the superintendent of the postal division.
- Superintendent is under the administrative control of regional Post Master General (PMG).
- All the Regional PMGs are under the administrative control of Chief Postmaster Generals (CPMG). In all circles, there will be one CPMG.

E.g.: - CPMG Karnataka Circle.

CPMG Tamil Nadu Circle.

South Karnataka under the control of PMG covering the region has 13 Postal divisions (PD), 3 National Speed Post Hub (NSH) divisions, 1 Railway Mail Service (RMS) division, 1 Postal Stores Depot (PSD) division, 1 Intra Circle Hub (ICH) division. The administrative hierarchy of Karnataka postal service is indicated in Figure 1.2



Source: Indian Postal Service

Figure 1.2: Administrative Hierarchy of Karnataka Postal Service

1.4 The Need of the Research

During the year 2012-2014, Mangalore NSH was first among the 89 NSHs in the country in the handling of speed posts. It covers Mangalore, Puttur, and Udupi postal divisions and handled 15,000 speed post articles a day. The ranking was based on the points given by a software adopted by the India Post (Source: Mangalore first in handling speed post, The Hindu Magazine, Indian Postal service, Dec 22, 2012). Consequently, the performance went down due to the revised target (25,000 speed post articles a day) set by the administrations in NSH, Mangalore to reduce the customer delivery time and make speed post delivery faster. Hence, in this research, an attempt has been made to increase the delivery of articles by implementing lean service in NSH Mangalore. Details of the proposed case study and methodology are discussed further in the subsequent sections.

1.5 Significance of the Study

There are three main reasons why lean service initiatives are essential to the Indian Postal service to improve operational performance. According to the Mail Network Optimization Project (MNOP) conducted by McKensy Company (2010) in India Post service as follows:

1. Indian Postal service is an essential public utility for the people. It utilizes all forms of transportation such as rail, road, air, and ship to transport the mails and parcels. Hence, it plays a significant role in providing social support through money transfer, handling payment of utility bills, submission of passport, etc. Although such value-added services are available for the public there is a need that it has to be fulfilled and it should reach on time.
2. India Posts losing 12% of volume and market share significantly from 2004/05 to 2008/09 in a million items. Also, customers have rated the India post having low reliability and earnings.
3. India Posts' financial performance is poor (-27%) compared to other players such as TNT, Singapore post, Deutsche post regarding Earnings before interest, and tax report.

1.6 Research Questions

This research work focused on answering the following fundamental questions:

RQ1. What are the requirements for implementing lean service tools and techniques in the Indian Postal service?

RQ2. How to develop the appropriate framework for lean service, and which can be implemented in Indian Postal service for process improvement?

RQ3. How to assess the lean service implementation and its effect on operational performance in Indian Postal service?

RQ4. What is the relationship between lean workplace environmental practices and operational performance?

RQ5. What is the relationship between lean social practices and operational performance?

1.7 Research Objectives

In order to respond to the research questions projected in the previous section, the following research objectives have been expressed:

RO1: To assess the requirements for implementing lean service tools and techniques in Indian Postal service

RO2: To apply the selected framework in order to improve the operational performance in Indian Postal service

RO3: To evaluate the lean service implementation and its effect on operational performance in Indian Postal service

RO4: To explore the relationship between lean workplace environmental practices and operational performance

RO5: To understand the relationship between lean social practices and operational performance

1.8 Scope of the Study

- Increasing competition from the courier industry, rapid change in communication methods, customer satisfaction, globalization, etc. are challenges for the postal service to sustain in the long run. Hence, lean service is a sustainable strategy, and a non-traditional method helps to compete in the market.
- The lengthy existing procedures/rules involved in the internal operations are time-consuming.
- Standardization of operating procedure needs to be focused, and errors committed by the employees are on a high side.
- The working environment has cramped accommodation for its workers, old and uncomfortable furniture, poor lighting, outdated tools, the old building infrastructure, and shabby appearance, etc. are the shortage of facilities in the post department. Implementing lean service through the understanding of the VSM current state and enhancing operational performance is an essential factor in improving the facility layout.
- Almost all the foreign postal administrations such as Japan, the UK, the USA, South Korea, etc. have already embarked on modernizing postal services and have achieved greater efficiency in customer satisfaction. The transformation in their administration practices has dramatically changed to providing efficient, speedy, responsive counter services.
- From the Indian Postal service, customers are concerned about quality service with a high response manner in the shortest lead time. In this way, lean service helps to improve productivity in back end operations by delivering the mails to the addressee in the shortest lead time.
- Improving physical working conditions such as lighting, ventilation facilities, providing ergonomic chairs, maintaining good housekeeping, and quality work culture gives an excellent image to the public and this also improves operational efficiencies. Lean working environment practices helps to boost the postal system a better working environment.

1.9 Outline of the Thesis

The thesis is organized as follows:

Chapter 2 – Literature Review and Conceptual Framework Development

In this chapter, a detailed literature review about the background of the study, descriptions about lean principles, the importance of lean in service sectors, lean service definition and its content analysis, lean service implementation in India, lean service challenges, literature map and finally research gaps have been explained. The lean service conceptual framework illustrated was implemented in NSH Mangalore, Karnataka, India. Also, a suitable research hypothesis has been formulated.

Chapter 3 - Research Methodology

This chapter explains the research approach, data collection method, research tool, scale development, validity, and reliability of the instrument, which is also explained clearly—that this research study purely is based on a case study with a specific conclusion.

Chapter 4 - Detailed Observations in National Sorting Hub

This chapter discusses the detailed observations that were collected from National Sorting Hub (NSH), Mangalore, South Karnataka, India, from October to December 2017. Process flow, existing layout problems, and areas for improvement have been noted from value stream mapping (VSM).

Chapter 5 - Facility Layout Design by MCDM Medhods

This chapter details about generating optimal facility layout design using Multi-Criteria Decision Making (MCDM) methods such as AHP, TOPSIS, fuzzy TOPSIS, GRA. Also, managerial implications, limitations, and recommendations for further research have been discussed.

Chapter 6 – Implementation of Lean Service Tools and Techniques and its Impact on Operational Performance

This chapter focuses on appropriate lean tools and techniques implemented in NSH, India Post service, and actions taken for removing the wastes (NVA activities). Then, after the implementation of lean service and production performance measures were monitored and also its impact measured through a questionnaire study.

Chapter 7 – Development of Simulation Model for Design of Lean Service System Design in India Post Service

This chapter explains the importance of the VSM simulation through and hybrid Taguchi methods by applying it in NSH, India Post service. VSM method helps to find and eliminate wastes. Then, the simulation method was used for improving the existing production by imitating the actual production model. Finally, the Taguchi method was used for optimizing production performance parameters and analysis.

Chapter 8 – Development of Postal Sustainable Design using QFD Methodology

In this chapter, the scholar discusses sustainable postal design using QFD techniques to develop the House of Quality Sustainable Design (HOQSD) model. The objective is to study the importance of Indian Postal service sustainable initiatives in their strategic plan 2021 – 25.

Chapter 9 – Conclusion

The final chapter includes conclusions, limitations of the research, and directions for further research.

CHAPTER 2

LITERATURE REVIEW

2.0 Background of the Study

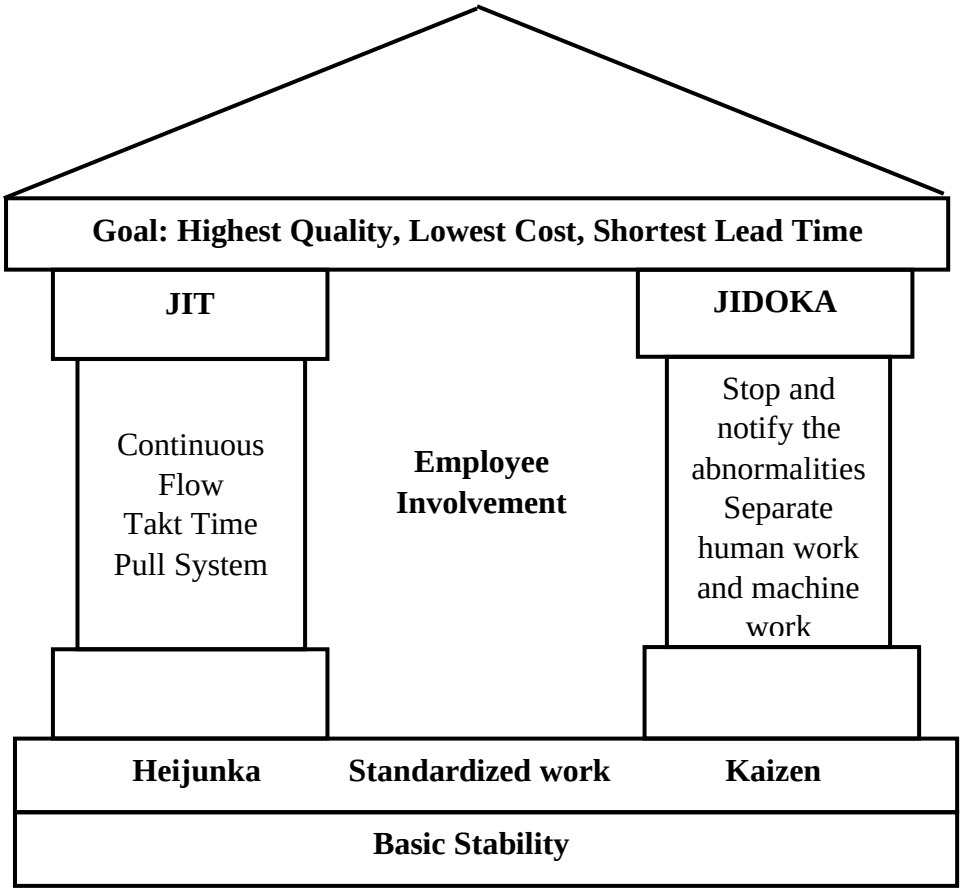
The globally renowned ‘lean concept' has been stated by Womack & Jones in the book, "Machines that Changed the World." Lean Manufacturing (LM) focused on finding and eliminating the Non-Value-Added (NVA) activities (waste) in a product or service organization to create value for the customers. The wastes are known as "TIMWOODS". (Transport, Inventory, Motion, Waiting, Over-processing, Overproduction, Defects, and underutilization of resources). This waste is something that customers do not wish to pay, known as Non-Value-added Activities (NVA). Almost, well-known leading manufacturing companies have progressively implemented LM concepts. The benefit of LM could have the same or more output with lesser inputs, i.e., material, machinery, manpower, space, and time. A typical LM conserves fewer than half of the required inventory on hand and lesser defects while manufacturing a better variety of goods (Womack, 1991). The LM techniques facilitated more production volume in numerous industries, particularly in automobile industries and their vendors.

According to Lewis (2000) statement, "Lean is a set of management philosophies for increasing production to reduce wastes" (NVA). The LM requires multiskilled employees, leadership, employee's coordination, and commitment, etc. Toyota Production System (TPS) is the starting point of lean practices in manufacturing, slowly improved to identify and remove the wastes in the process flow inside the companies (Womack, 1991).

Toyota Motors founder, "Kiichiro Toyota," was extremely attracted by Henry Ford's mass production strategy. But, unfortunately, due to the economic situation in Japan after world war II, he has forced to adopt batch production instead of mass production of the vehicle (Dale & Lwaarden,2007). This situation helped Toyota built numerous model vehicles in a low volume with minimizing cost in shorter lead times. Hence, this LM concept helps to produce high-quality cars with low price with different models to satisfy

customer needs (Dale & Lwaarden, 2007). TPS showed the house of lean, which was crafted by "Taiichi Ohno and Eiji Toyota."

As shown in Figure 2.1, the top of the roof denotes the LM goal of removing the wastes in the process development through contributing product quality and creating value to the customers. Active participation of the employee in the organization which is in the middle of the TPS house, has to strive for the organization's goals. In the TPS house, each pillar represents Just In Time (JIT) and Jidoka. JIT is to reduce lead time, an inventory of materials and Jidoka is to identify the glitches instantly when there are any abnormalities in the production line.



Source: Balle and Reginer (2007)

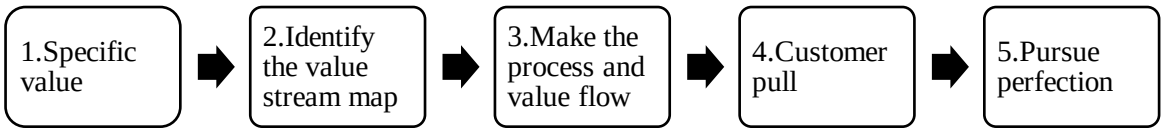
Figure 2.1: Toyota Production System House

Lastly, the foundations are standardization, continuous improvement (Kaizen), and load leveling (Heijunka) of the process with the essential stability of the TPS house. It is helpful to new employees during their training, and it visually explains how the LM will function in their system.

2.1 The Five Lean Principles

Loughrin (2010) mentioned that either manufacturing or service firms should observe continuous improvement with the help of five lean principles (Figure 2.2) to enhance their operational performance. They are:

1. To determine the value from the customer's view. Service firms not only focused on their services but also develop their service range based on the thoughtfulness of customers' needs.
2. From the customer's point of view, organizing the processes starts with procuring the raw materials to satisfy the customer.
3. Creating value flow from people, open culture, and their processes to avoid waste and increase value to the products.
4. Leverage pull system
5. Seeking perfection means employees' coordination on the focusing goals with no compromise on quality and the elimination of waste.



Source: Womack & Jones, 1998

Figure 2.2: The Five Principles of Lean

There are five principles, initially established for manufacturing can be practically applied in service industries also. The given five lean principles are also adopted here in postal service operations. The second and third principles are vital as it emphasized the identification of value stream and the mail flow in postal service (Vadivel SM & Balasubramanian, 2014).

2.1.1 Lean in Service Sector

Currently, the service sector is a globally dynamic component, paying more than 50% of the Gross Domestic Product (GDP) of top economies in the countries (Anon, 2013). The service characteristics exhibited are inseparability, heterogeneity, intangibility, simultaneity, and perishability (Lovelock and Gummesson, 2004). Service organizations usually look for customer demand that differs each day, such as mail processing facilities, airline service, healthcare, and support customer care (Bard, Binici, and Anura, 2003). For example, mail processing facilities require process enhancement as demands keep varying quickly being brought about by new challenges brought forth by accelerated IT growth, customers' expectations, and rising liberalization of the market. In every organization to keep customer focus, firms are putting effort into improving the service quality by incorporating lean principles to increase profitability and customer goodwill. Lean in the service sector plays a significant role in growing customers' value by offering services with more exceptional quality and speed up the process by utilizing the lesser and right amount of resources (George,2003).

2.1.2 Lean Service Implemented in Service Sectors

Many works of the literature suggested that lean is implemented and also assessed in different service sectors. For example, Alnajem et al. 2019; Hussain & Malik, 2016; Agarwal et al. 2016, Robinson et al. 2012 have implemented this study in Hospitals such as emergency, cardiac catheterization laboratory, etc. Narayanamurthy et al. (2017) and Thomas et al. (2017) have implemented this in the higher educational institute sector to

improve the course plan and to reduce absenteeism in class. Vlachos and Bogdanovic (2013) and Rauch et al. (2016) have implemented partial LS elements in a Hotel to improve the hospitality. Davidson et al. (2014) and Procter and Radnor, Z. (2014) implemented in the area of the public sector in the UK to remove the NVA and to improve the working system of public service. Unfortunately, many of the employees are not able to cope up with the target resulting pressure in their routine work. Table 2.1 shows a summary of papers related to lean services implemented in the service sectors.

Table 2.1: Lean Service System Applied to Service Industries

S.No	Author(s) and Year	Industry	Remarks
1.	Alnajem, M. et al. (2019).	Emergency department	They have identified and validated their results based-on experts' opinions on lean six main categories, such as human resources, patient relations, top management and leadership, supplier relations, processes, and Kaizen.
2.	Gijo, E. V., & Antony, J. (2019).	Information Technology	The authors implemented LSS in the DMAIC method to decrease the complaint time from 12.5 to 8.5 hr. The cost impact INR2.5 million indirectly financial savings projected.
3.	Narayanamurthy, G., et al. (2017).	Education Institute	After implementing lean service (LS) in an educational institute, elective course work evaluation considered. Interestingly, both batches found absenteeism, but Batch 2 was less number. Batch 1 has without LS whereas Batch 2 has with LS implementation.
4.	Thomas, A., et al. (2017).	Higher Education Institute (HEI)	This study implemented Lean Six Sigma (LSS) in HEI's and focused

			primarily on the curriculum design on undergraduate engineering programs. The impact of LSS showed an improvement in teaching and learning methods.
5.	Hadid, W. et al. (2016).	UK based service firms	This paper investigated the LS on operational and financial performances in UK service firms. The results indicated that LSPs, LSoPs have a positive effect on operational performance. Interaction effect both LSPs and LSoPs and they have a more positive impact on operational performance.
6.	Hussain, M., & Malik, M. (2016).	Hospital	They implemented LS in the UAE Healthcare system. The authors identified waste minimization in public and private hospitals.
7.	Rauch, E. et al. (2016).	Hotel	Interestingly, the authors tried the lean management tool in the hospitality sector positively. Among the lean tools, they found that VSM,5S tools are the most useful.
8.	Lameijer, B. A. et al. (2016).	Financial Industry	Through a qualitative case study of five companies and 25 interviewers were asked the impact of lean six sigma. The result showed that simplify the accounts to remove wastes and implementation should be gradual to incremental.
9.	Iberahim, H., et al. (2016).	Mail processing service, Malaysia.	They implemented sustainable Kaizen activities for the enhancement of labour productivity in postal service.

			Leadership, process redesign, and SOP were correlated, but it does not influence on labour productivity.
10.	Agarwal, S. et al. (2016).	Cardiac Catheterization Laboratory	After incorporating lean six sigma inside the lab, there is substantial improvement in physician downtime, turn-time, on-time physician arrival, on-time patient arrival, on-time start in the side.
11.	Hartono, Y. et al. (2015).	Book Publisher	ISM method was used to identify the ten success variables defined in the lean supply chain in Anti Offset.
12.	Piercy, N., & Rich, N. (2009).	Call service center	The authors proposed the lean techniques to understand the basic VSM to eliminate wastes. They found a significant enhancement in quality and cost in the call service center.
13.	Wang, F. K., & Chen, K. S. (2010).	Banking sector	The authors implemented LSS DMAIC and TRIZ methodology in the banking sector. Reduced waiting time for opening an account. Also, it changes business policies and infrastructure for sustainable performance. The impact of LSS cost saving around the US $828,000.
14.	Robinson, S. et al. (2012).	Healthcare sector	'SimLean' approach is developed through education, facilitation, and evaluation to improve patient service quality.
15.	Vlachos, I., and Bogdanovic, A. (2013).	European hotel industry	The authors conducted a Lean assessment in Small and Medium Hotels in 19 European countries. Seven VSM assessed, and each

			VSM technique, deducting and reducing NVA throughout the chain.
16.	Davidson, N. et al. (2014).	UK Ministry of Defence	The authors tried to adopt lean concept in the Ministry of Defence in the UK. The authors suggested three relevant propositions, such as waste, value flow, and pull system for the public sector.
17.	Procter, S., & Radnor, Z. (2014).	UK public services	While implementing lean in the UK public sector they were unable to meet their target. Hence pressure developed to finish the target among the employees.
18.	Shamsuzzaman, M. et al. (2018).	Telecom service sector	After incorporating LSS, the average order fulfillment lead time for sales orders (SO) decreased from 10.3 to 5.9 days, and VAS orders decreased from 1.5 to 0.5 days.
19.	Chen, H., Liu, S., & Oderanti, F. (2020).	Agri-Food Industry	Various lean performance objectives were achieved through subject matter experts and mobilization methods by using AHP for the food supply chain.
20.	Nicholson, A., & Pakgohar, A. (2020).	UK University law college	The authors attempted to implement lean management principles in the law clinic process to reduce the source intensity and improve the educational value for the students.

2.1.3 Service Characteristics

i. Invisibility
ii. Intangibility
iii. Simultaneous production and consumption
iv. Consumer involvement
v. Complexity and variability
vi. Measurement difficulty

2.1.3.1 Tangible and Intangible Factors in Lean Service

Higor dos Reis Leite & Guilherme Ernani Vieira (2015) identified the difference between tangible and intangible factors. Tangible factors: visible by the touch, actual or real rather than visionary or imaginary, e.g., physical beings can be touched, such as products, tools, and equipment, inventory of materials, machinery, employees, material bin, register files, and documents. Intangible factors: intangible factors are not quantifiable, untouchable. e.g., factors that affect a decision, employee morale, safety, system reliability, employee satisfaction, environmental effects, employee culture.

2.1.4 Lean Service Definition and Content Analysis

There is no clear definition of lean service in the operationalized form in the service sector (Shradha Gupta, 2016). Hence, an operational definitions of lean service have been summarized in Table 2.2. Also, the content analysis of the lean services definitions is indicated in Table 2.3.

Table 2.2: Operational Definition of Lean Service from the Literature

Sl.No	Author(s)	Lean Service terminology
1	Spanbauer S.J. (1995)	Completely change the attention from the shop floor to service features by adding value to customers and remove the waste.
2	NIST (2000)	It is a logical method in finding and removing waste (NVA) through Kaizen at customer pull to achieve perfection.
3	Bowen & Youngdahl (1998)	Improve the process quality with the help of technological adoption rather than replacement.
4	Swank (2003)	By identifying and eliminating NVA, a lean system inspires service organizations to get more output with less input, such as space, labour, and capital.
5	George (2003)	The lean system accelerates the velocity of the process by eliminating NVA in any of the service firms.
6	Ahlstrom (2004)	The LS emphasis fundamental values are more than the operational level.
7	Hines et al. (2004)	The LS denoted as a philosophy at the strategic level rather than a set of tools and practices.
8	Radnor & Bucci (2007)	Reforming service transfer methods so that NVA can be eliminated. Reduced the variability, increase flexibility, enhance productivity, and decrease lead-time.
9	Shah and Ward (2007)	The lean system is a combination of the socio-technical system to remove NVA. Also, focusing on less space, internal variability, and customer-supplier.
10	Womack et al. (2007)	Lean philosophies comprise customer focus, Kaizen activities, and eliminate waste through value creation. For an efficient value chain, service firms powerfully combined upstream and downstream processes.
11	Hallgren and Olhager (2009)	LM is a management program designed primarily for the efficacy of increasing operations.
12	Piercy and Rich (2009)	It pursues to remove NVA from the processes to enhance customer value.

13	Wei (2009)	LS is the application of lean thinking in the service industry. The process is not producing the materials or shape of materials transformation instead of the service process.
14	Radnor (2010)	A philosophy of management practice based on successively refining processes by either enhancing customer value or eliminating NVA (Muda), process variation (Mura), and poor working conditions (Muri).
15	Rexhepi & Shrestha (2011)	The lean service denotes removing NVAs from the service processes to speed up the efficacy.
16	Qu et al. (2011)	Mandatory to remove the service process waste so that cost can be decreased, and provided improved services as required by the customer.
17	Bicheno, J. (2012)	The actual lean system reduced the negative process variation by engaging the flexible, multi-skilled workforce, and ‘‘Gemba-style’’ leadership.
18	Suarez-Barraza, et al. (2012)	Lean service is a proactive strategy that aims to eliminate waste and focus on customer satisfaction rather than correcting failures.
19	Agarwal et al. (2013)	The basic principle of the LSS is by removing NVAs. Through that, numerous advantages can be attained, such as decreasing operating costs, higher productivity and efficiency, better flexibility, greater customer satisfaction, and cost-effectiveness.
20	MG.Kanakana (2013)	Lean as a system covering several principles, practices, tools, and techniques. Through a systematic approach, would enhance resource utilization, quality of producing goods and services.
21	Vijaya Sunder (2013)	LSS method favoured over lean or six sigma or any other Kaizen activities for process enhancements in the service industry.
22	Andres-Lopez et al. (2015**)**	Reassessment of lean thinking activities for service industries.
23	Weingarten et al. (2015)	The LS is a multi-dimensional system based on a set of principles and practices. The lean purpose is to enhance the value of the customers by removing NVAs.
24	Hadid W et al. (2016)	The lean service rotates around, refining the value of the customer and instantly replying to their changing needs.

Table 2.3: Content Analysis of Lean Service Terminology

S. No	Authors	The different varieties of components											
		Process improvement with flexible information system	System Or lean thinking	Map process to identify and reduce wastes	Define Value from a customer's perspective	Value flow without interruptions	Standar dized work	Balanced level loading	Quality in process with continuous improvement	Striving for zero defects	Pull productio n through JIT to reduce inventory	Visualize process and reduce process variation	Develop multi-skilling employees and adopt to lean system
1	Spanbauer, S.J. 1995			✓	✓						✓		
2	NIST, 1998			✓					✓		✓		
3	Bowen and Youngdahl, 1998			✓	✓						✓		✓
4	George, 2003	✓		✓									
5	Swank, 2003						✓	✓				✓	
6	Ahlstrom, 2004			✓					✓	✓		✓	✓
7	Apte & Goh, 2004	✓		✓	✓	✓	✓		✓	✓	✓		✓
8	Hines et al. 2004		✓										
9	Hopp and Spearman, 2004								✓		✓		
10	Spear, 2005										✓		
11	Womack and Jones, 2005			✓	✓	✓			✓				

12	Kimetal. 2006			✓	✓	✓			✓		✓		
13	Balle and Regnier, 2007				✓		✓		✓	✓	✓		✓
14	Kollbergetal, 2007				✓	✓			✓		✓		
15	Radnor & Bucci, 2007	✓		✓									✓
16	Shah and Ward, 2007			✓							✓		
17	Womack et al. 2007			✓	✓				✓				
18	Proudloveetal, 2008			✓	✓	✓			✓		✓		
19	Hallgren and Olhager, 2009											✓	
20	Piercy and Rich, 2009			✓	✓								
21	Wei, 2009		✓										
22	Radnor, 2010			✓					✓		✓		
23	Rexhepi & Shrestha, 2011			✓								✓	
24	Qu et al. 2011			✓	✓								
25	Bicheno, J. 2012	✓									✓	✓	✓

26	Suarez-Barraza, et al. 2012			✓	✓								
27	Wael & Hadid, 2012	✓	✓										
28	Agarwal et al, 2013	✓			✓							✓	
29	Kanakana, 2013		✓						✓				
30	Vijaya Sunder, 2013	✓							✓				
31	Andres-Lopez, et al., 2015		✓										
32	Wiengarten et al. 2015			✓	✓								
33	Hadid et al. 2016				✓								

2.1.5 Application of Lean Service

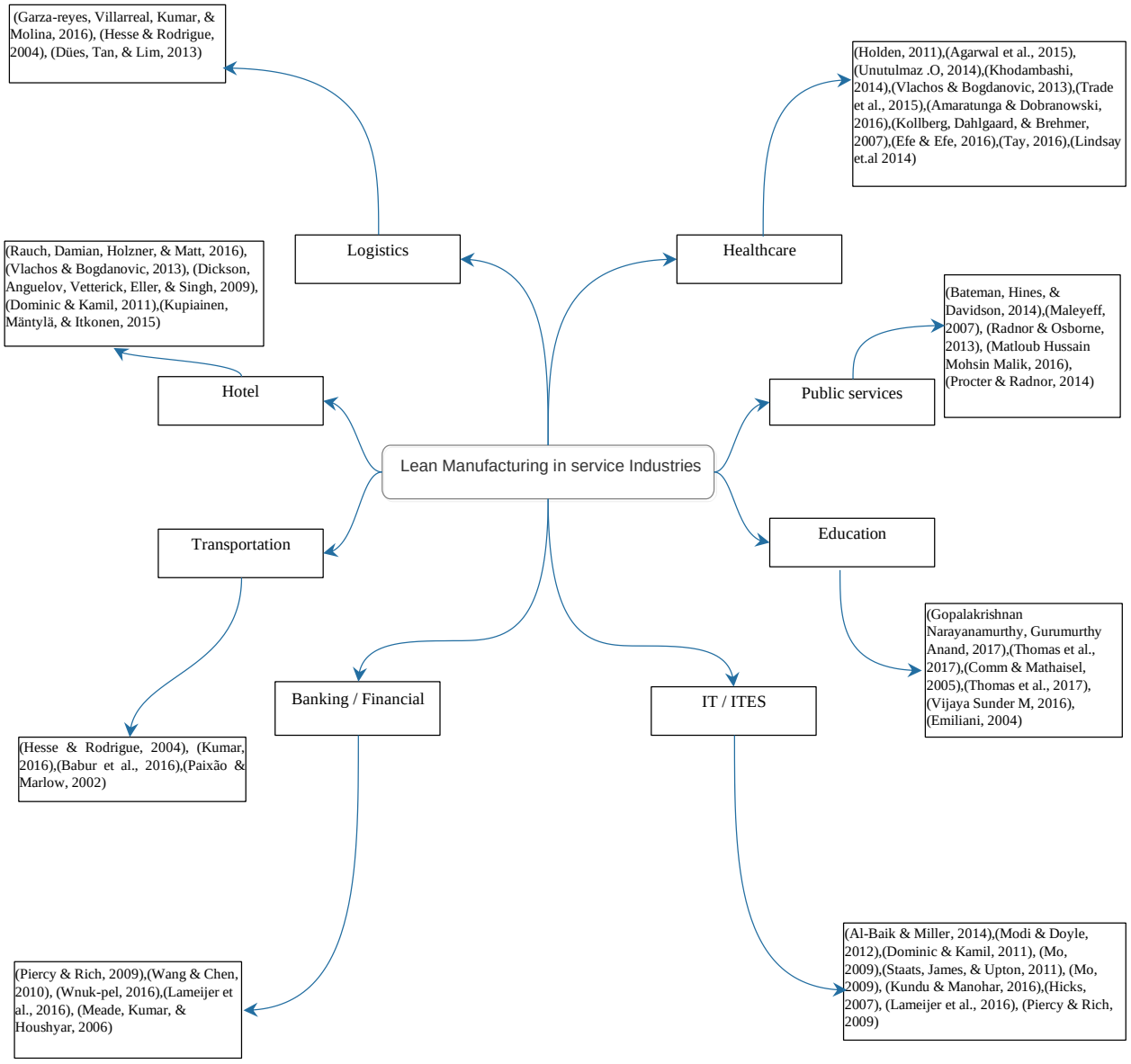


Figure 2.3: Lean Manufacturing Application in Service Industries

To date, the LM application is not only limited to the manufacturing of goods but also is widely adopted in service operations. From the studies on the implementation of lean service, it is noted that interesting trends started in 2005 and the cases are found across

service industries such as healthcare, education, public services, hotel, financial and IT industries, etc. (Figure 2.3).

2.1.6 Lean System in India

The main findings of some authors regarding the implementation of lean system tools and techniques both in manufacturing as well as in-service sectors such as automotive, healthcare, education, mailing service, etc. are given in Table 2.4.

Table 2.4: Brief Literature on the Lean System Implemented in India

S.No	Authors' name & Year	Main Findings
1	Kumar et al. 2006	They have implemented LSS frameworks in automotive industries to improve quality by reducing process variability and wastes.
2	Varkey P, Kollengode A, 2011	They introduced an emerging framework to an Indian hospital to improve the quality perception of patients through the council of India.
3	Angel Díaz et al. 2012	Aravind eye hospital implemented lean service in Madurai, Tamilnadu state. They performed lean service through the simplified patient brochure, 5S, VSM to improve the process and quality of customer care.
4	Manimay Ghosh, 2013	They surveyed the adoption of lean in Indian manufacturing companies and its effect on operational performance. The result showed that decreased product lead time and enhanced productivity for the incorporation.
5	James, Reynold Jones, Robert,2014	Toyota Kirloskar Motors (TKM) company Bangalore, India, tried to implement the LM concept in their company. Unfortunately, they failed to understand the social environment of the Indian work culture inside the

		organization.
6	Gopalakrishanan Narayanamurthy, Anand Gurumurthy, 2014	They assessed the readiness of the systemic leanness for the hospital. They emphasized that lean service will be beneficial for the patients if the hospital sincerely implemented the lean system.
7	Monica Sharma Shradha Gupta,2015	They have investigated through questionnaire reliability and validity study on the current LS frameworks from Indian service sectors such as Healthcare, Financial, Telecom, and IT/ITES. They summarized that a new lean service conceptual framework has to be developed for each service sector.
8	Richard Miller & Nirisha Chalapati, 2015	They found that most of the patients are spending their own money on healthcare and scheduling difficulties for the treatment that has to be taken within a day. Several wastes were found out which will affect the hospital's attitude of patient care.
9	Vadivel S.M & Balasubramanian.V 2015	They have implemented lean service concepts in the manual head sorting center, Chennai. Production efficiency improved by 41% compared to the existing method. They have incorporated lean and ergonomics concepts to enhance the delivery of articles per person.
10	Thanki et al. 2016	The authors used AHP to examine the effect of lean and green practices on performance benefits. Also, to assess the impact of lean and green models on the total performance of SMEs. Concluded that TPM was found out the most significant lean practice, whereas ISO 14001 was the essential green practice.

2.1.7 Lean Service in the Public Sector

From the book, "The Machine that Changed the World," authored by Womack and Jones acknowledged that lean is the world-wide popular technique, which initially started from the manufacturing sector and is progressively improving in the service sector. Now, it is popular in the public sector, such as central and local government. Academicians and practitioners have documented many kinds of literature support almost all organizations. (James- Moore and Gibbons, 1997; Bowen and Yougdahl, 1998).

- Radnor and Walley (2008) suggested that lean concepts can be implemented from industrial practices to public services for the benefit of people.
- In the UK, Hartley & Skelcher (2008) promoting lean for the public sector enhancement to the politicians for their better reputation.
- Krings et al. (2006) implemented lean in the public sector for the police employment process, and another case study happened in the US for the hygienic drain recruitment process. But then, Young and McClean, 2008 identified the main barriers to implement lean in the public sector is to identify the customers. Generally, in the public sector context, each sector has a crucial challenge to apply lean and this depends on management support, cost investment, employee involvement, etc.
- Radnor et al. (2012) highlighted the two critical barriers to implement lean in public sectors, such as finding the customer from several investors and lacking financial support.

In this study, an attempt has been made to implement lean in the public sector of Indian Postal service as a case study handling speed post articles in NSH, Mangalore, Southern part of India.

2.1.8 Lean Challenges while Implementing in Organizations

There are substantial numbers of literature that has discussed the challenges while implementing the lean system in the service sector as follows:

- Layer et al. (2009) addressed the multi-skilled labour requirement
- The employee has to work overtime to fulfill the target given by the administration. Marodin & Saurin (2013).
- Employee involvement in their activities to implement lean is a key challenge mentioned by Shoaf et al. (2004).
- Arezes & Dinis-carvalho (2010) commanded that generating and following the standard cycle time. Hence, employees may feel that losing their own work pace.
- Achanga et al. (2006) described that shortage of finance and training programs such as employee training, skill development, knowledge enhancement on lean, and creating quality work culture.

2.2 Literature Map

This literature survey can be depicted in the form of a literature map indicating and finding the important papers, along with author and year, as shown in Figure 2.4.

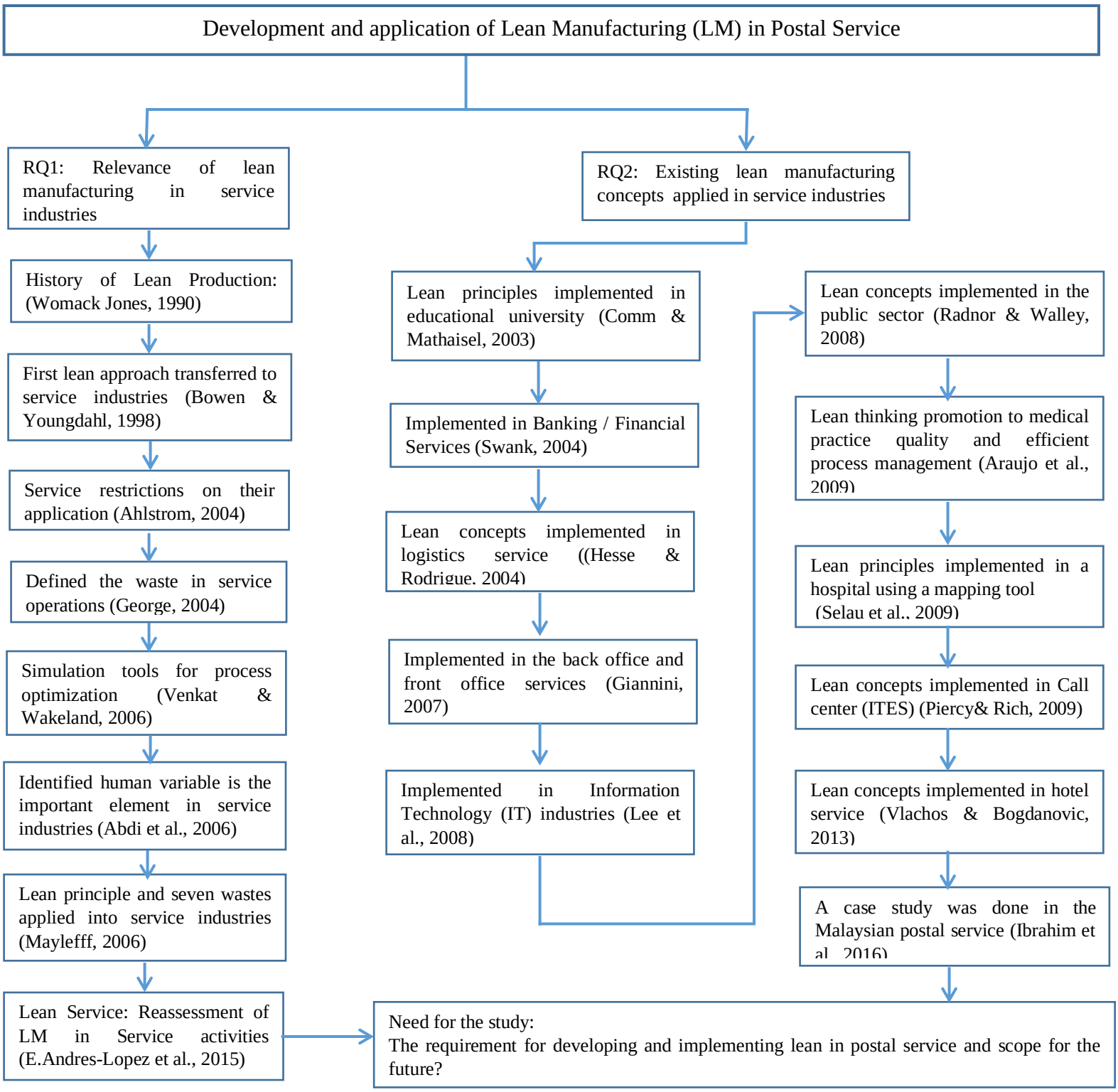


Figure 2.3: Literature Map

2.3 Research Gaps

1. There is a lack of standard models/conceptual frameworks in lean manufacturing applications in service industries (Shradha Gupta, Monica Sharma & Vijaya Sunder M, 2016). Hence, this study attempts to find the best model to implement lean tools and techniques in postal services.
2. There is a lack/less work has been done on assessing the applications of lean manufacturing in service industries (V, Suresh, & Aramvalarthan, 2016). Hence, this study aims to identify the lean assessment in a public sector called Indian Postal service.
3. Developing countries like India, serving large populations with limited resources, need process improvements, and methodologies to improve the quality of service and reduce non-value-added activities. (Shradha Gupta, Monica Sharma & Vijaya Sunder M, 2016). Hence, this study attempts to improve the process and build a framework for lean service in Indian Postal service.
4. In Indian Postal service, physical working conditions such as cramped workspace, poor lighting, and ventilation, lack of cleanliness, outdated tools, poor ergonomic chairs, etc. are the barriers for not attaining production goals in terms of labor productivity (Ramachandiran.K, 2011).
5. Several literature studies are addressing the lean system, but there are very few studies addressing the relationship/impact among lean systems and performance measures (Gallear, 2016).

2.4 Framework Development for Lean System in India Post Service

2.4.1 Lean Service Practices (LSPs)

In every organization to keep customer focus, firms are putting effort into improving the service quality by incorporating lean principles to increase profitability and customers goodwill. Lean in the service sector plays a significant role in increasing customers value by offering services with higher quality and by speeding up the process by using the

lesser and right amount of resources (George, M,2003). Initially, some features of a lean service system were endorsed by Bowen and Youngdahl, 1998 from the lean manufacturing system. Progressively, lean service implementation started exciting trends over 2002 and increased in healthcare, education, public services, hotel, financial and IT industries, etc. However, most of the literature showed that the applicability of lean practices in service industries showed promising results. But it doesn't show a comprehensive set of LSPs in service industries, particularly mail service operations. Such sets are required for the lean practitioners and scholars to know the impact of operational performance in the India Post service industry. The authors have chosen mostly used service industries lean tools, which were incorporated in mail service operations for improving operational performance and its impact is measured here.

2.4.2 Lean Workplace Environment Practices (LWEPs)

Globally, the workplace environment and its relationship on job satisfaction have been defined in different circumstances over the years. The results of a Danish study proposed that an organization could grow its efficiency through the improvement of the workplace environment (S.Buhai, E. Cottini, and N. Nielseny,2008). Physical environmental conditions are essential factors while implementing lean in an organization, especially for the manual sorting process. Employees' involvement while incorporating lean is a significant success factor that develops a healthy workplace environment (Ramachandiran.K,2011). Spector, 1997 witnessed that most companies do not wish to pay attention to their work environment within their firms, affecting employees' performance. This paper shows that the workplace environment has a direct impact on operational performance. Bakotic & Babic (2013) identified that the workplace environment is a significant issue for job satisfaction.

Chandrasekhar (2011) reasoned that firms need to give more attention to workplace improvement to improve internal productivity through the organization's profit. For example, the lighting source is an essential source for daily routine in a sorting section for reading and sorting the mails through postal pin code. Research also revealed that poor

lighting causes poor job performance, such as dim, high glare, and poor light in the specific sorting section (Hemphälä, H., & Eklund, J. 2012). Temperature plays a vital part in the working environment how the physical body of the human is to keep an ideal temperature. Another study by Beshir et al. (1981) clarified that too much heat exposure significantly reduces the employees' performance within 30 minutes. Ossama A. et al, 2006 mentioned that ventilation is essential for a healthy, comfort job to the working employees. Some contaminants like dust and odors can form significant unpleasant feelings, discomfort. Hence it leads to productivity loss as well as job performance. In present conditions, India's post is taking necessary strategic actions to create a better workplace environment such as postal appearance for more trustworthiness, reliability for customers, improving the processing facilities for the betterment of the postal employees.

2.4.3 Lean Social Practices (LSoPs)

Lean social practices (LSOPs) help human resource features. Abdou, A. et al. 2006 showed that LSoPs had a positive effect on operational performance in the manufacturing sector. For example, a multi-skill employee can handle simultaneous operations such as scanning and sorting during the bottleneck time. However, postal management has to give proper training, motivation, and employee empowerment to the postal employees. Therefore, management support is required for the employees for the rewarding system. In addition to this, Shah and Ward, 2003, Cua et al., 2001, Yasin et al., 2003 authors empirically tested LSoPs practices and proved that positive impact on operational performance.

2.4.4 Operational Performance

Growing complications in manufacturing or service environments and faster delivery of the products or service with enhancing quality makes the organizations often rethink their operations strategy. Additionally, quality management practices play a role in improving operational performance for the firms' competitive advantage. (H. Kaynak,2003; Y. Lagrosen, and S. Lagrosen,2005). Shah and Ward,2003 made an association of LSPs with

operational performance. Further, the author suggested that an operational performance should be analyzed better by considering relatively multi-dimensional practices to each dimension. Some empirical studies evaluated the relationship/impact among lean system practices and operational performance (J.L. Callen et al. 2000; R.R. Fullerton, and C.S McWatters,2002; M.Ketokivi, and R.Schroeder, 2004). Conventionally, operational performance is characterized by the operations strategy for competitive priorities (R. Narasimhan, and A. Das, 2001). Here, in postal service to improve the operational performance for delivering mail articles they use the following operation strategies:

• Optimize India Post's mail network from collection to delivery

• Standardize processes with a focus on quality improvement and reduction of complexity

• Establish an effective performance management structure using key performance indicators (KPIs) and regular reviews.

Conceptual framework of LSS on Operational Performance in NSH Post office as shown in Figure 2.5.

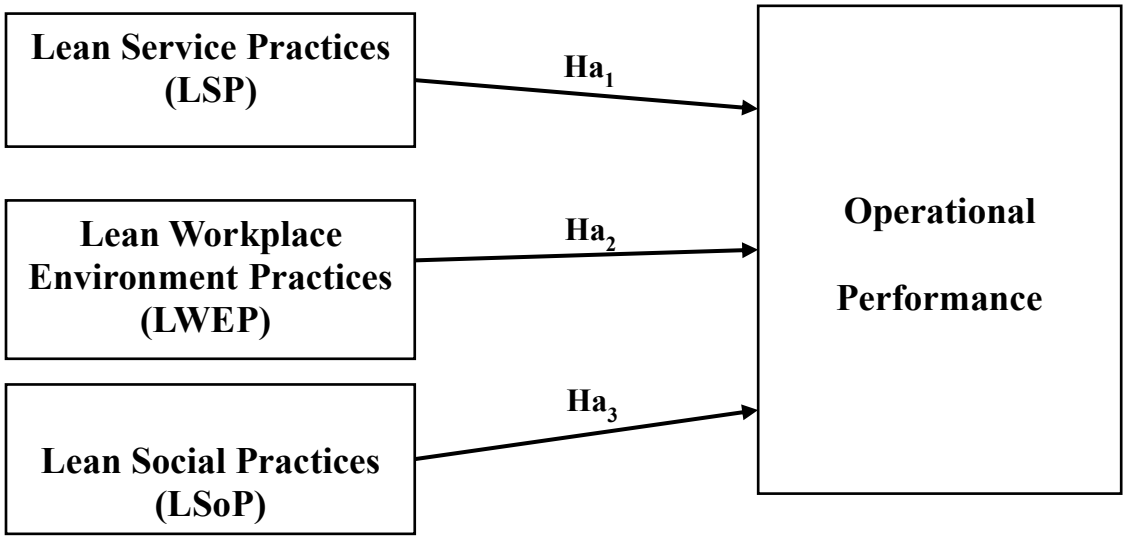


Figure 2.5: Conceptual Framework of Lean Service System on Operational Performance to be Implemented in NSH Post Office

2.4.5 Research Hypotheses

Ha_1: There is a significant impact on lean service practices and positive relationship on operational performance in India Post service.

Ha_2: There is a significant impact on lean workplace environmental practices and positive relationship on operational performance in India Post service.

Ha_3: There is a significant impact on lean social practices and positive relationship on operational performance in India Post service.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Approach

This study applies a combination of exploratory, descriptive, and experimental approaches. The main objective of exploratory research is to discover a problem to provide more understanding of the definite problem. The exploratory study analyzed the barriers or critical success factors of lean service while implementing. The descriptive study describes the characteristics of lean concepts, wastes, and relevant tools applied for the postal service organizations. The experimental research aims to evaluate the suitable lean tools and techniques and its impact before and after the lean implementation in Indian Postal service.

3.2 Case Study Research

Generally, a case study comprises a complete examination throughout the case. There are two categories of case studies. The first category deals with a lower number of cases and comes up with common conclusions. The second category deals with a single case, arising from detailed conclusions (Gummesson, 2000). This case study is grounded in the second category.

3.3 Data Collection Method

The primary data was collected from Karnataka, Mangalore region National Sorting Hub (NSH). The data were related to existing production performance measures and postal employees' demographic details. During the lean implementation process, a part of facility layout design related questionnaires was circulated to all the postal working employees to understand and find out the changes required in the existing layout. After the successful lean incorporation, opinions of postal employees were studied to measure a set of lean service tools and the impact on operational performance in India Post service.

3.4 Research Tool

According to postal contextual study through literature review, independent and dependent variables and its related items were identified. A 5-point Likert scale was used to measure these items. Through observation and survey methods, the research objective was fulfilled by quantitative data. A cross-sectional study was also conducted after lean service implementation. Respondents (postal employees) were directed with a questionnaire consisting of items related to lean service implementation. The structured questionnaire consisted of nominal, ordinal, and interval scales that were used to meet the required objectives. The collected data were analyzed with frequency tabulation, correlation, and multiple regression analysis using SPSS 23.0 package to assess the relationship and effect between independent and dependent variables. Table 3.1 shows the measuring variable details.

Table 3.1: Lean Service System Measuring Variables

S. No	Independent Variable	Dependent Variable
1	Lean Service Practices (LSP)	Operational Performance
2	Lean Workplace Environment Practices (LWEP)	
3	Lean Social Practices (LSoP)	

3.5 Scale Development

Postal employees' demographic information was collected from the nominal scale and the ordinal scale. Based on the literature review, the first eleven items of Lean Service Practices (LSP) measured are shown in Table 3.2. Then, the second nine items were measured for Lean Workplace Environmental Practices (LWEP). After that, the third nine items were measured for Lean Social Practices (LSoP). Finally, the fourth eleven items were measured for Operational Performance.

Table 3.2: Measuring Variables for Lean Service System (LSS) Items

Constructive items for LSS	
1. Lean Service Practices (LSPs) – Adopted from Hadid W et al. 2016	
LSP	Value stream mapping
	5S
	Improving facility layout
	Cellular layout
	Single piece flow
	Visual identification
	Workload balancing
	Process redesign
	Reduce cycle time
	Reduce lead time
	Improve flexibility
2. Lean Workplace Environment Practices (LWEPs) - Adopted from Various Literature Sources	
LWEP	Lighting facilities - El-Zeiny, 2012, Garbie, 2014
	Ventilation - Garbie, 2014, El-Zeiny, 2012
	Visual identification - Shah & Ward, 2007
	Noise control - Rossi et al., 2013, Vadivel S M,2015
	Temperature - Gonçalves & Salonitis, 2017
	Cleanliness - Kanamori et al., 2016
	Workspace - M. Sharma et al., 2016
	Drinking water facilities - Alvarez & Rubicon, 2015
	Equipment availability - Shah & Ward, 2007

3. Lean Social Practices (LSoPs) - Adopted from Hadid W et al. (2016)

LSoP	Effective communication system
	Employee empowerment
	Employee commitment
	Performance measurement system
	Employee involvement
	Multi-skill employees
	Leadership
	Management support
	Training

1. Operational Performance (OP) - Adopted from Hadid W et al. (2016)

Operational Performance	Improvement in space utilization
	Improvement in employee's performance
	Employees understanding the process
	Improvement in productivity
	Improvement in lighting facilities
	Improvement in ventilation facilities
	Improvement in housekeeping
	Reduction in inventory
	Reduction in cycle time
	Reduction in human errors

The above items were measured using a 5-point Likert scale anchored from 1 (Strongly disagree) to 5 (Strongly agree). The Likert scale is an easy and quick way to construct. It is more reliable and provides a higher volume of data than many other scales. (Nemoto, T., & Beglar, D, 2014).

3.6 Validity and Reliability of the Instrument

The instrument used in this research has a proven ‘content and criterion validity,’ as they are derivates of standard instruments used before in different service firms. However, the questionnaire has been modified wherever necessary to make it more precise and understandable.

3.6.1 Content Validity

Content validity can be defined as the extent to which a particular scale measures all the facets of a given construct. Content validity is also known as logical validity. It is a process to check the validity of the contents of the scale.

3.6.2 Construct Validity

Construct validity assesses whether the scales were measuring what they are designed to measure. The questionnaire was mailed to a group of 3 subject experts in top-level management, middle-level management, and bottom-level shop floor employees. They were asked to assess the understandability, readability, and suitability of the instrument.

3.6.3 Reliability

Cronbach’s alpha values are higher than 0.70, demonstrating that all constructs have adequate reliability assessment scores for internal consistency and scale reliability (Hair et al. 1998).

CHAPTER 4

DETAILED OBSERVATIONS IN NATIONAL SORTING HUB

In this chapter, detailed observations were collected from National Sorting Hub (NSH), Mangalore, South Karnataka, India, from October to December 2017. Process flow, existing layout problems, and areas for improvement have been noted from Value Stream Mapping (VSM) tool.

4.1 Data Collection

The following data were collected from October to December 2017. Data consists of working time, Mail variety, types of equipment availability, and workforce allocation. The method of data collection was quantitative, and the duration taken was three months. Two shifts are running in a day. Postal employees have to produce 10,000 articles per day. There were five sections which included deposit or receiving, scanning, sorting, sealing, and dispatch divisions. Figure 4.1 shows the existing layout of the NSH Mangalore.

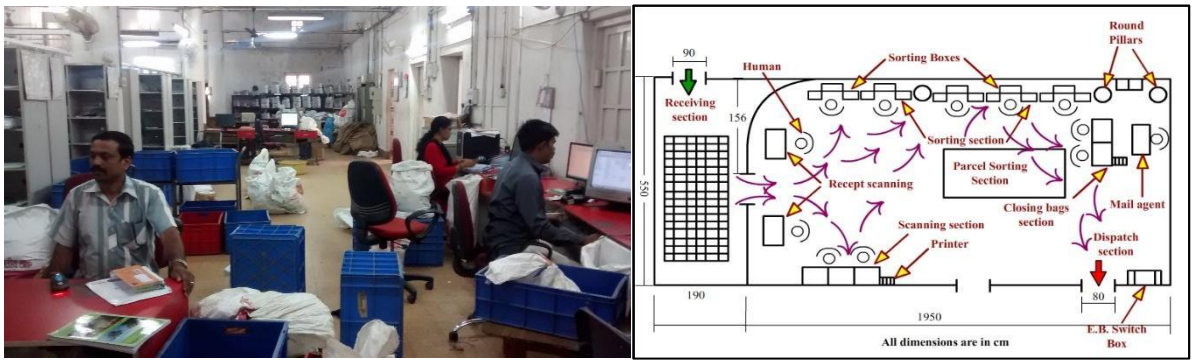


Figure 4.1: Existing Layout of National Sorting Hub (NSH), Mangalore. Arrows Indicated the Processing Flow of the Articles within the Postal Office Sections.

Cycle time for an article, layout working area, floor space, and equipment (Bins, Baskets, Tables, Sorting Cases) sizes were noted during the data collection. Workplace environmental (Temperature, Noise, Ventilation) and visual ergonomics problems (Lighting, Aesthetics) were

noted down during the data collection through the survey method. We found that sorting the mails is a bottleneck operation that creates stress among the postal employees.

4.2 Processing Flow Chart

A process flow chart was generated, and a sequence of operations was noted down (Figure 4.2). The total cycle time for the articles through time study is found, as shown in Table 4.2. During the collection of existing production details, eight types of waste, such as Transportation, Inventory, Motion, Waiting, Over Production, Over Processing, Defect, and Underutilization of Skills abbreviated as TIMWOODS has been observed and noted. It will be explained clearly in Chapter 6. We note that the sorting operation takes more cycle time, almost 125 seconds per 50 articles count.

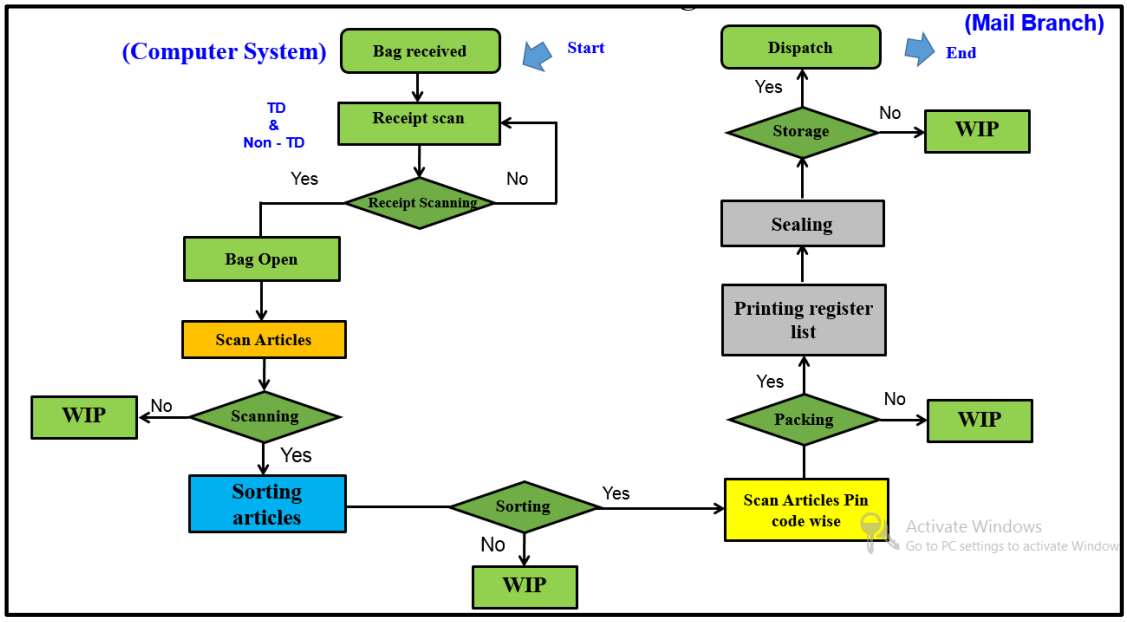


Figure 4.2: Process Flow Chart in the Manual Sorting Center, NSH. Starting from the Bag Receiving to Dispatch Section.

Table 4.1 shows the manual sorting center's active areas of the departments. The scanning and sorting sections were major occupied areas of NSH Post office.

Table 4.1: Active Areas of the Department

S.No	Divisions	Area (Sq.ft)
1	Receiving scanning	37
2	Scanning – Town Delivery (local mails)	102
3	Scanning - Non -Town Delivery	48
4	Sorting – Town Delivery	107
5	Sorting - Non-Town Delivery	62
6	Packing and Dispatch	43

Table 4.2: Current Cycle Time for Each Operation

S. No	**Operation**	**Seconds**
1.	Bag receiving	60
2.	Scanning I	85
3.	Sorting	125
4.	Scanning II	72
5.	Sealing and Dispatch	28
	Total	370
	In min.	6.167

Table 4.2 shows that the processing time takes 370 seconds for 50 articles count starting from the bag receiving to dispatch section.

4.3 Value Stream Mapping (VSM)

VSM gives the entire bird view operations in detail (Figure 4.3). It has identified the waste (NVA) and is planning to remove it while implementing lean service in the NSH Mangalore post office.

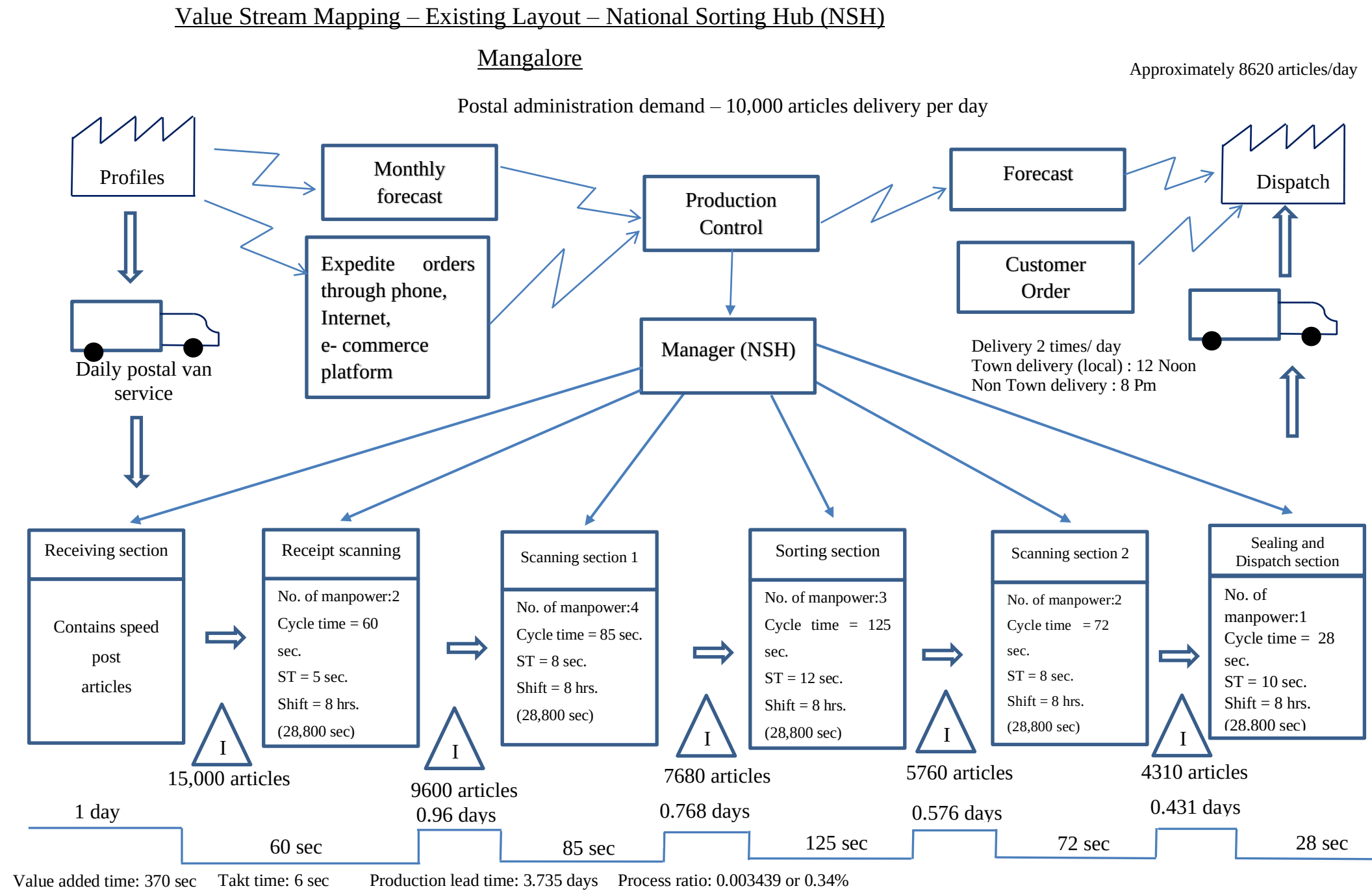


Figure 4.3: Current State VSM – NSH Mangalore

4.3.1 Process Flow Map (PF - Map)

The PF - Map gives precise information about the material (mail) and information flow inside the internal operations in NSH. As shown in Figure 4.4, the existing production details such as flow speed, productivity, synchronizing ratio, line efficiency, and workforce utilization, etc. have been noted.

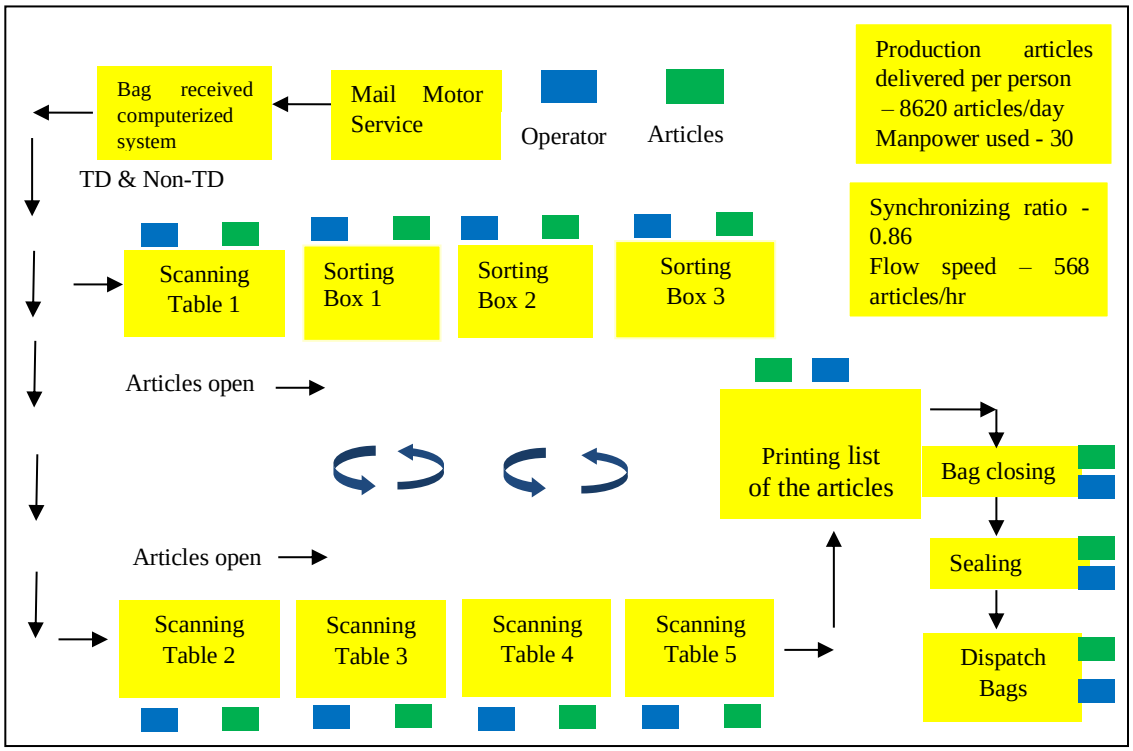


Figure 4.4: PF-Map for Manual Sorting Center, NSH - Mangalore. The Blue Box Indicates the Operator Standing in the Workstation, and the Green Box Indicates Mail Flow within the System. Existing Production Performance Metrics are Shown in the Upper Right Corner.

4.3.2 Human - Machine Flow Map (HMF – Map)

The HMF - Map provides the Human and Machine interface. Figures 4.5 and 4.6 show the improvements needed in the scanning and sorting section about environmental, housekeeping, and ergonomics related problems.

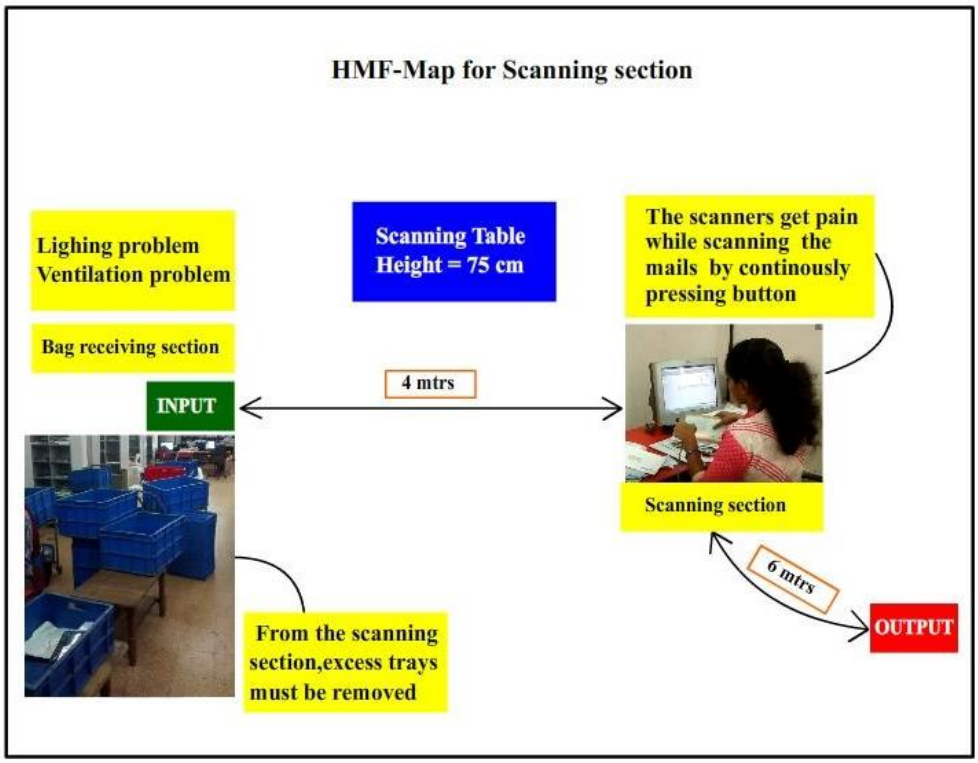


Figure 4.5: Human-Machine Flow Map for the Scanning Section

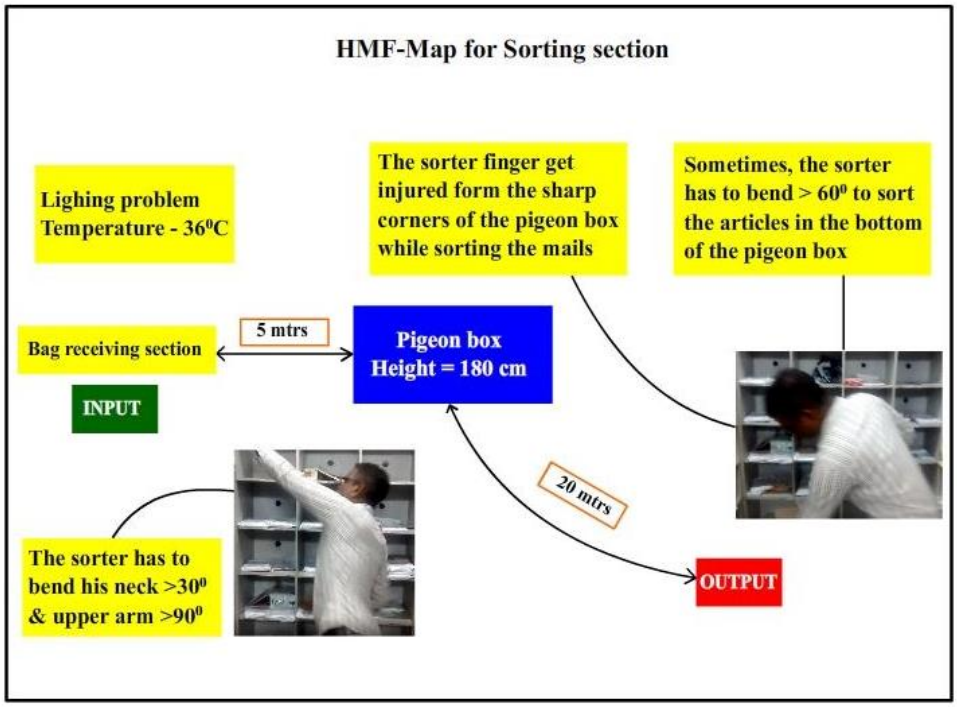


Figure 4.6: Human-Machine Flow Map for Sorting Section

4.3.3 Adjacent Flow Map: (AF – Map)

The AF - Map stretches scope for improvement in adjacent sections. For example, Figure 4.7 provides clear details of how distance should be increased, and parcel sorting should be customized between the mail sorting and parcel sorting sections.

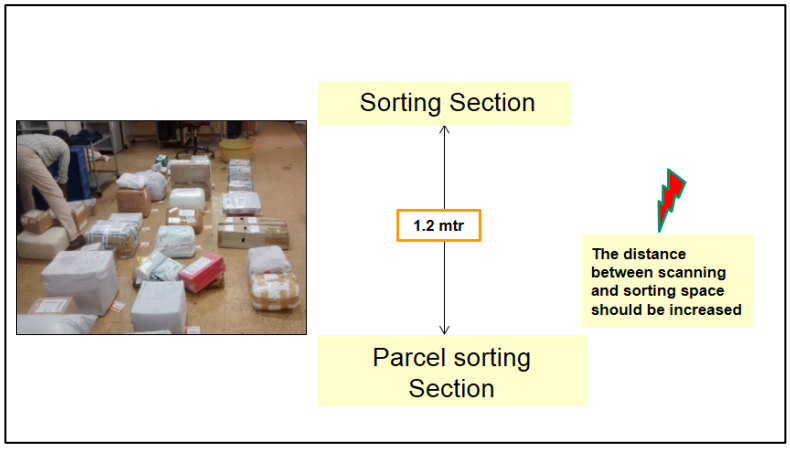


Figure 4.7: Adjacent Flow Map for Mail Sorting – Parcel Sorting Section. The Thunder Symbol Indicates Sections that Need to be Improved.

4.3.4 Problems in the Existing Layout:

- Throughput time is longer between sorting and dispatch section
- Mail flow is not smooth
- There is a chance of mixing received and dispatch bags
- Limited space between sorting of parcel bags and sorting case
- Housekeeping has to be improved
- Sometimes, the dispatch section acts as a receiving section
- Sorting case pin code tags are not readable
- Scanning method has to be improved to reduce the cycle time
- Lighting and ventilation facilities are poor and should be changed

4.4 Types of Mail Variety

NSH handles speed posts such as Mails, Parcels, Cash on Delivery, and Book Now Pay Later Logistics as mentioned in Table 4.3.

Table 4.3: Variety of Mails Processing in NSH Speed Post Office in the Backend Operations

S. No	Service type
1	Speed Post Letters/Mails –
	Town Delivery (TD) articles - Local Mails
	Non-Town Delivery (Non - TD) articles
2	Speed Post Parcels
3	Speed Insured Articles
4	Cash on Delivery (COD)
5	Book Now Pay Later (BNPL) Logistics

4.5 Existing Layout Production Details

Postal employees delivered approximately at an average of 8620 articles per day, as shown in Figure 4.8. Sometimes, due to a shortage of human resources, article production gets lowered or when there are human resources, but due to a lack of receiving articles, the desired target is not achieved.

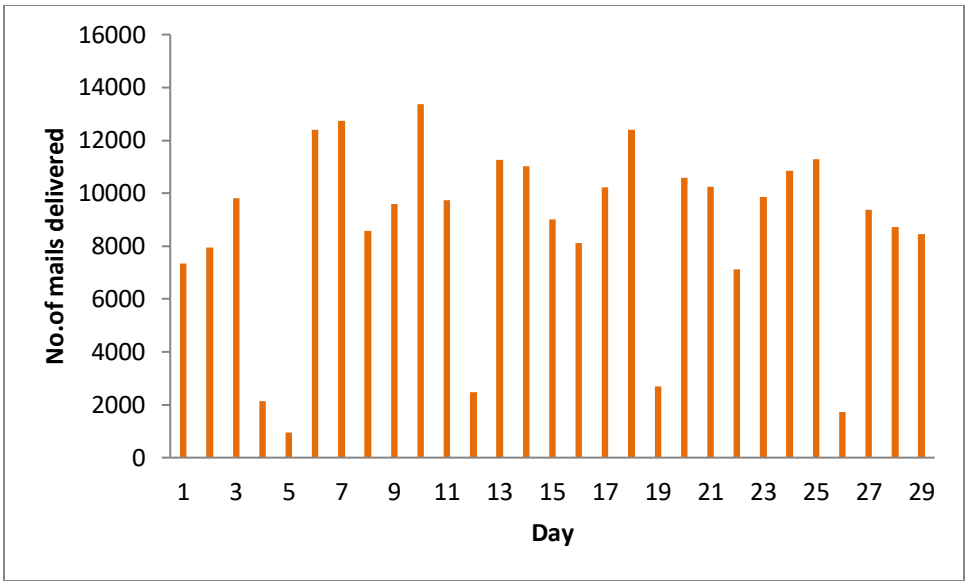


Figure 4.8: Average Number of Articles Delivered in a Day

4.6 Improvement Required Areas

- Alternative facility layout
- Ventilation facility
- Comfortable work posture
- Sorting box - Tag modification
- Removal of excess trays
- Separation of speed parcel sorting section
- Removal of unused things
- Implementation of 5S (Housekeeping) concepts.

The provision of current and ergonomic equipment to the postal employees would bring significant enhancements in the internal postal operations, leading to better productivity. Also, incorporating lean service tools and techniques could increase the production efficiency from traditional operation methods. Hence, customer satisfaction may achieve a greater extent through speedy, effective services.

Figure 4.9 shows the existing moving scanning method. Through an interview with the scanners, it is understood that present scanning methods have some disadvantages: Hand, Shoulder, Finger, Wrist pain, etc. Hence, instead of moving the scanner, it is proposed to fix the scanner in a place like a supermarket to reduce the cycle time and prevent from Musculoskeletal Disorders (MSD) problems.

Figure 4.9: Existing Moving Scanning Method in NSH Head Sorting Center

4.7 Summary

In this chapter, detailed observations in NSH, Mangalore, dealing with speed post articles are discussed. The existing production details collected from October to December 2017. Environmental and ergonomics related problems were noted down. Consequently, improvement areas have been identified using the VSM tool. Lean service tools have been implemented for the existing layout and performance measures which were monitored after four months in April 2018.

CHAPTER 5

FACILITY LAYOUT DESIGN BY MCDM METHODS

This chapter gives details about generating optimal facility layout design using Multi-Criteria Decision Making (MCDM) methods such as AHP, TOPSIS, fuzzy TOPSIS, and GRA. Also, managerial implications, limitations, and recommendations for further research have been explained.

5.1 Introduction

According to McKenzy, India Post mail network optimization project report 2010, India Post has lost significantly 12% of volume and market share during 2004-05 to 2008-09 in million items. Postal organizations need to change from traditional to non-traditional way to improve operational performance through productivity enhancement in the long run. Modification of the facility layout is used as a part of a competitive strategy that results in increasing productivity, improving customer service, attract and to retain the postal employees.

Creating a Facility Layout Design (FLD) is a multi-objective problem task and it involves many inputs, either quantitative or qualitative. FLD problem contains algorithms, or it will generate the alternate layouts within the layout space. According to Yang and Kuo (2003), neither an algorithmic nor a procedural layout design methodology is usually useful in solving a practical design problem. Therefore, the MCDM method can be implemented to find the optimum layout to improve operational performance through lean system evaluation.

Here, it is proposed that three MCDM techniques are used to solve an FLD such as Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), fuzzy TOPSIS and GRA. A case study of speed post in India Post-National sorting hub (NSH) Mangalore, Karnataka, is selected for empirical testing. AHP is a structured technique for organizing and analyzing optimal layout decisions by a

pairwise comparison based on an expert's judgment. TOPSIS is a practical method of solving performance ratings with specific values. The Fuzzy TOPSIS and GRA are ideal methods for obtaining the solution when the performance ratings are imprecise and inaccurate.

5.2 Literature Review

In the recent literature reviews of facility layout design problems, it has been observed that the FLD problems are included in location science under the MCDM environment (Farahani et al., 2010; Mardani, A. et al., 2015). For example, Cambron and Evans (1991) formed the wide-range of multiple criteria involved in the facility location selection using the AHP method i.e., efficient movement of material flow, personnel flow, noise control, space utilization, and safety provision to the employers, etc.

Yang.T and Kuo.C. (2003) used the AHP and DEA methods to highlight the problem of choosing a location for the Integrated Chip (IC) packing company. For the same IC Packing company, Yang.T and Hung.C (2007) applied TOPSIS and Fuzzy TOPSIS to improve the solution for the existing design. Grobelny (1987), Evanst et al., (1987), Dweiri and Meier (1996), Raoot and Rakshit (1991) used a fuzzy set theory for the construction type layout design. Besides, a linguistic variable is transformed into some qualitative design criteria, and a close relationship between departments has been identified.

Karry et al. (2000) applied GAs and fuzzy set theory for the planned buildings in the construction site. Kim et al. (2013) confirmed that TOPSIS when combined with fuzzy TOPSIS, could be useful to rank the optimal locations for the waste treated water in South Korea. For that purpose, they have considered social, technical, environmental, and economic factors. Chauhan. A and Singh. A (2016) emphasized the hybrid MCDM approach for healthcare waste disposal facility location problems in a hospital, Uttarakhand, North India. The author applied interpretive structural modeling (ISM) for understanding the interrelationships among the criteria, fuzzy AHP for calculating the global weights and fuzzy TOPSIS for prioritizing the best location of healthcare waste disposal.

Tayal, A. and Singh, S.P. (2017) applied DEA and TOPSIS method for evaluating manufacturing facility layout to increase the system performance. In that paper, DEA was used to identify the performance layouts and TOPSIS was used to prioritize the layouts based on criterion and weightage. A summary of the literature review on MCDM methodologies has been given in Table 5.1.

Table 5.1: Comparative Study of MCDM Methods on FLD Problems

S.No	MCDM Methods / Authors	AHP	ANP	DEA	DEMATEL	ELECTRE	GP	PROMOTHEE	SAW	SMART	TOPSIS	VIKOR	Fuzzy Set theory	Hybrid MCDM
1.	Grobelny (1987)												*	
2.	Evanst et al. (1987)												*	
3.	Raoot and Rakshit (1991)												*	
4.	Cambron and Evans (1991)	*												
5.	Dweiri and Meier (1996)												*	
6.	Karry et al. (2000)												*	
7.	Yang and Kuo, (2003)	*		*										
8.	Yang, T., and Chou, P. (2005)										*			

9.	Yang and Hung, (2007)						*	*		
10.	Özcan, T., Çelebi, N. and Esnaf, Ş. (2011)	*		*			*			
11.	Kim et al. (2013)						*	*		
12.	Amol Singh (2016)	*					*	*	*	
13.	Tayal, A. and Singh, S.P. (2017)		*				*			
14.	Wichapa N. and Khokhajaikiat P. (2017)				*			*		

Notes: AHP - Analytical Hierarchy Process, ANP - Analytical Network Process,
DEA – Data Envelopment Analysis, DEMATEL - Decision Making Trial and Evaluation Laboratory,
ELECTRE - Elimination and Choice Translating Reality, GP – Goal Programming,
PROMETHEE - The Preference Ranking Organization Method for Enrichment of Evaluations,
SAW - Simple additive weighting, SMART – Simple multi-attribute rating technique,
TOPSIS - Technique for an order of preference by similarity to an ideal solution,
VIKOR - Visekriterijumska optimizacija kompromisno resenje (Multi criteria Optimization and Compromise Solution).
Fuzzy set theory – combinations of fuzzy set theory i.e., fuzzy AHP, fuzzy ANP, fuzzy TOPSIS, fuzzy DEMATEL, etc.
Hybrid MCDM – Combining two or more MCDM methods.

Multiple objectives consist of several contradictory objectives that cannot be attained instantaneously. This has always focused on performance decision-making spaces and clarified computational optimization algorithms (Yang and Hung, 2007). Additionally, the studies had been directed to linear programming for addressing the issue of facility location. The multiple attribute problems have fewer numbers of fixed alternatives. In

multiple attribute problems, the alternatives must gratify at a definite level of objectives and the decision-makers theoretically select the best alternative. Therefore, the present study is a multiple criteria problem of multiple attribute types which has been carried out to address the issue of facility location selection in Indian Postal service - NSH. The ultimate purpose is for improvement in operational performance.

AHP, TOPSIS, and fuzzy TOPSIS were used to handle a wide range of applications and a chance to prove for addressing MCDM specific problems (Yang, T., and Chou, P. 2005).

5.2.1 Comparative Study

The basic structures made from the comparative analysis of DM methods are demonstrated in Table 5.2.

Table 5.2: Comparative Study of AHP,TOPSIS, and Fuzzy TOPSIS Methods

Characteristic	AHP	TOPSIS	Fuzzy TOPSIS
1.Core process	Creating hierarchical structure and pairwise comparison matrices	Calculating the distance to the positive and negative ideal point	Calculating the distance to a fuzzy positive and fuzzy negative ideal point
2.The necessity to quantify the relative importance of criteria	Yes	Yes	Yes
3. Determining of weights	Pairwise comparison matrices. scale 1–9	No specific method. Linear or vector normalization	Fuzzy set theory
4. Number and type of outranking relations	N(N - 1)/2	1	1

5.Consistency Check	Providing	None	None
6. Problem Structure	Minor number of alternative and criteria, quantitative or qualitative data	Major number of alternative and criteria, objective and quantitative data	Major number of alternative and criteria, objective and quantitative or qualitative data
7. Final Solutions	Global, net ordering	Global, net ordering	Global, net ordering
8. Advantages	Easy to use; scalable; hierarchy structure can easily adjust to fit many sized problems.	Has a simple process; easy to use and program; the number of steps remains the same irrespective of the number of attributes.	Allows for imprecise input; takes into account insufficient information.
9.Areas of application	Performance-type problems, resource management, Strategy and corporate policy, public policy, and planning.	Energy, economics, environmental, water management, and transportation issues.	Engineering, economics, environmental, social, medical, and management.

Sources: Saaty (1980), Hwang and Yoon (1981), Shih et al. (2007), Özcan, T., Çelebi, N. and Esnaf, Ş. (2011), Velasquez, M. and Hester, P.T. (2013), Nădăban, S., Dzitac, S. and Dzitac, I. (2016).

1.3 Research Gaps

- The study conducted by Yang and Hung (2007) highlighted the general multiple criteria explained in the selection of facility location i.e. material handling distance, shape ratio, adjacency score, accessibility, flexibility, and maintenance. Also, Farahani et al. (2010) stated about several multiple criteria and has also mentioned in the decision making

processes such as finance (product value, quality, and cost), environment (air, water, and sound pollution), facility utilization, resources accessibility, legal regulations, and political matters, etc, in their paper on facility location problems. However, there is no detailed study that could be reviewed for the identification of criteria of postal service operational performance facility location.

- None have applied MCDM methods in the selection of facility layouts in the postal service context for the improvement of production through lean service, workplace environment, and ergonomics, etc. For example, Yang and Kuo, (2003) and Yang and Hung, (2007) applied facility layout design in the IC packaging company. Whereas, Wichapa and Khokhajaikiat (2017) and Chauhan. A and Singh. A (2016) applied hybrid MCDM for the selection of healthcare waste disposal facility locations.
- Similarly, none of the papers highlighted the importance of the ergonomics (human factors engineering) criteria for the selection of facility layout.

5.4 Research Methods

For the optimal layout selection, numerous journal review papers were studied to identify the research gap to enable the selection of the important criteria, sub-criteria, and its alternative layout has then been evaluated. The basic problem of decision-making is to choose the optimal layout from a set of competing alternatives that are evaluated under the selected criteria. Structured hierarchical standardization of criteria, sub-criteria, and alternatives to solve facility layout problems had been evaluated in the AHP (Cambron and Evans 1991). TOPSIS and fuzzy TOPSIS have been widely used for solving various applications and have given inspiration for solving multi-attribute issues (Yang T and Chou P, 2005). The research methodological framework of MCDM methods is illustrated in Figure 5.1.

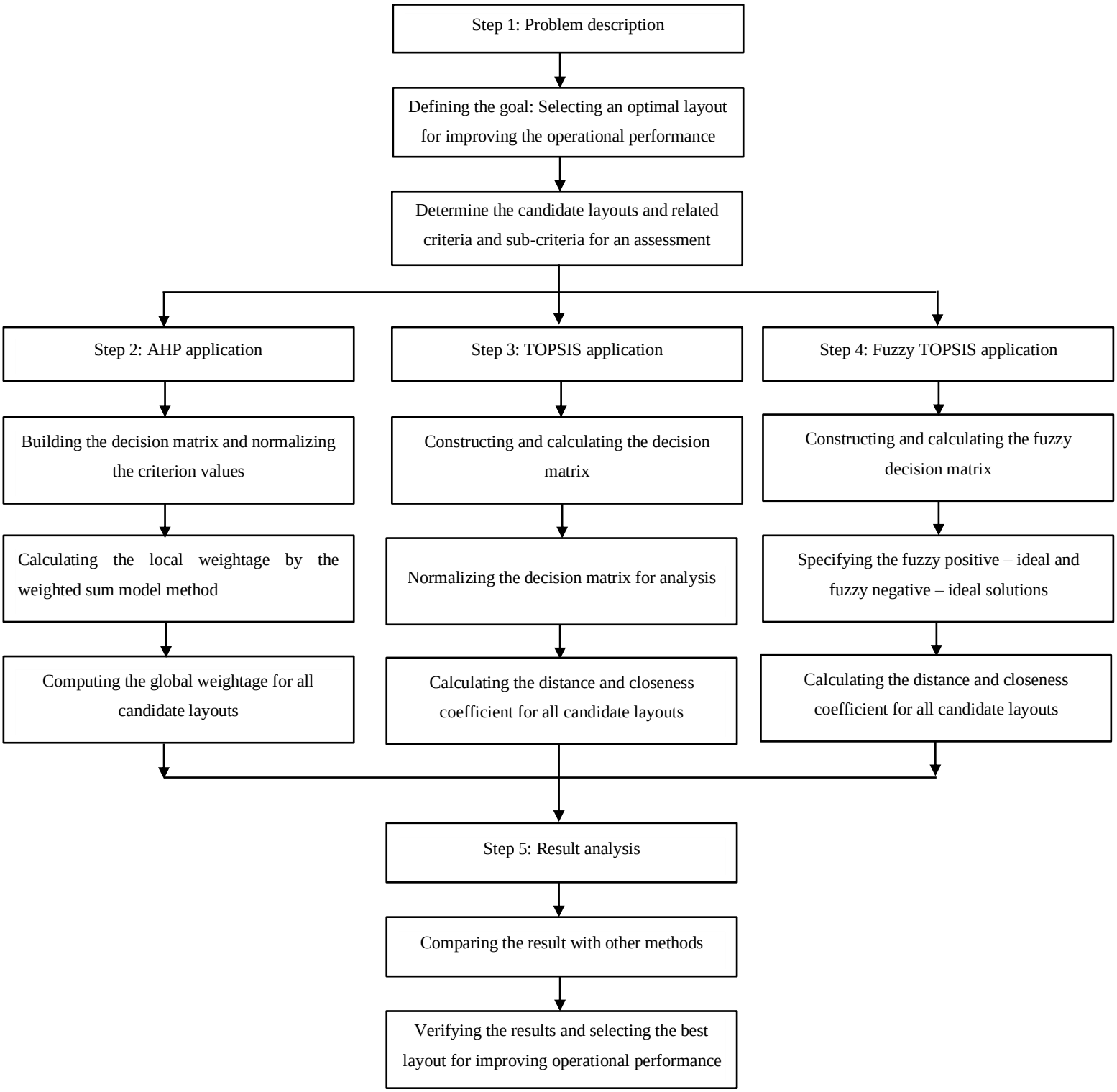


Figure 5.1: Methodological Flow of the Study

5.4.1 AHP Method

5.4.1.1 Decomposition of Structural Hierarchy

Decomposition breakdowns a problem into controllable elements individually. It begins with inherent descriptions of the problem (selection of optimal layout) and proceeds logically to the criteria such as lean service, workplace environment and ergonomics. After the goal is decomposed into a manageable element, it should be structured into a hierarchy. Certain things must be prioritized while building the hierarchy as given below:

- Goal (selection of best layout) kept on the top of the hierarchy
- Decompose the goal into sub-goals (Lean Service, Workplace Environment and Ergonomics branch)
- Further, decompose sub-goals into necessary sub-criteria to measure the goals
- Alternatives added to the bottom of the hierarchy (Layout 1 to 8)

5.4.1.2 Preference Measurement and Priority Synthesis

A comparative scale is used for the pair-wise comparisons of the attributes in each level of hierarchy formation. Pair-wise comparisons are made using verbal statements about the strength of dominance (importance or likelihood) of one attribute to other attributes symbolized using the Saaty rating scale [1-9] as shown in Table 5.3.

Table 5.3: Saaty Rating Scale [1-9]

1-9 Rating Scale	
Priority scale	Definition
1	Equal priority
3	Moderate priority
5	Strong priority
7	Very strong priority
9	Extreme priority
2,4,6,8	For compromises between the above
Reciprocals of above	In comparing elements X and Y - if X is 3 compared to Y - Then Y is 1/3 compared to X

Then, the matrix structure has been formed to develop a local priority vector. After that, the local priorities have to be combined to obtain a global weight for the final decision. The priority vectors can be computed using – Eigenvalue / Eigenvector method, simple average method, weighted average method (Saaty,1980).

5.4.1.3 Consistency Ratio

The comparisons obtained on subjective assessment; a consistency ratio is needed to check the accuracy. A comparison matrix "A" is said to be consistent if $a_{ij} * a_{jk} = a_{ik}$ for all $i, j,$ and k. However, consistency is required. Too much flexibility is disagreeable because this method contracts with human judgment. Saaty (1980) demonstrated that for a consistent reciprocal matrix, the largest Eigenvalue is equal to the size of the comparison matrix, or $\boldsymbol{\lambda max = n}$. Then Saaty described the measure of consistency, called Consistency Index (CI) as deviation or degree of consistency using eq.1.

$$\mathbf{CI} = \frac{(\boldsymbol{\lambda max - n})}{(\mathbf{n-1})} \quad (1)$$

Further, CI is recommended for comparing it with the appropriate one. The appropriate Consistency Index is called Random Consistency Index (RI). Saaty randomly generated reciprocal matrix using scale 1/9, 1/8, …, 1, …, 8, 9 and got the random consistency index to see if it is about 10% or less. Then, Saaty suggested the Consistency Ratio, which is a comparison between the Consistency Index and Random Consistency Index using eq.2.

$$\mathbf{CR} = \frac{\mathbf{CI}}{\mathbf{RI}} \quad (2)$$

If the value of the Consistency Ratio is lesser or equal to 10%, the inconsistency is adequate. If the Consistency Ratio is greater than 10%, the subjective judgment is needed to be revised or eliminated in the questionnaire.

5.4.2 TOPSIS Method

5.4.2.1 Principle of TOPSIS

Hwang and Yoon (1981) found that the TOPSIS method for the chosen alternative must be the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution to solve the MCDM problem. The TOPSIS model usually comprises of the following stages:

1. Build a decision matrix. This matrix illustrates the assessment of alternatives according to criteria.

$$D = \begin{array}{c} \\ E_1 \\ E_2 \\ E_3 \\ . \\ . \\ . \\ E_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & Cn \end{array} \\ \begin{bmatrix} f11 & f12 & \dots & f1n \\ f21 & f22 & \dots & f2n \\ f31 & f32 & \dots & f3n \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ fm1 & fm2 & \dots & fmn \end{bmatrix} \end{array}$$

where Ei denotes the alternative i, (i =1,2, .. . ,m); Cj represents the j^{th} criterion, (j =1, 2, ... , n), and fij is the crisp value showing the performance grading of each alternative Ei concerning each Cj criterion.

2. Normalize the decision matrix (R). The normalized value rij is computed as:

R = [rij]

$$rij = \frac{Fij}{\sqrt{\sum_{i=1}^{m} Fij^2}}, \quad \forall i = 1,2...,m ; \quad j = 1,2...,n. \tag{3}$$

3. Compute the weighted normalized decision matrix G (= [gij]) attained by multiplying the normalized decision matrix by its related weights. The weighted normalized value Gij is computed as:

Gij = wj x rij, ∀i = 1, m; j = 1, .n

Where wj indicates the weight of j^{th} criterion.

4. Find the positive ideal solution and the negative ideal solution.

$$T^* = \{g1^*, g2^*, \dots g3^* \dots, gn^*\}$$
$$= \{(max_i Gij | j \epsilon J1), (min_i Gij | j \epsilon J2) | i = 1, \dots . n\} \quad (4)$$

$$T^- = \{g1^-, g2^-, \dots g3^- \dots, gn^-\}$$
$$= \{(min_i Gij | j \epsilon J1), (max_i Gij | j \epsilon J2) | i = 1, \dots . n\} \quad (5)$$

5. Calculate the distance between each alternative positive and negative ideal solution.

$$Ti^* = \sqrt{\sum_{j=1}^{n} (Gij - Gj^*)}\text{^}2 \qquad i = 1,2,..,n. \quad (6)$$

$$Ti^- = \sqrt{\sum_{j=1}^{n} (Gij - Gj^-)}\text{^}2 \qquad i = 1,2,..,n. \quad (7)$$

6. Compute each alternative relative closeness

$$Ci^* = \frac{Ti^-}{Ti^* + Ti^-}, \qquad i = 1,2,...n. \quad (8)$$

7. The alternatives are ranked based on relative closeness.
The performance is better if there is a greater relative closeness of the alternatives.

5.4.3 Fuzzy TOPSIS Method

5.4.3.1 Fuzzy TOPSIS Model

The Fuzzy Set Theory (FST) is used to model ambiguity and unpredictability in DM processes resulting from a lack of complete information (Zadeh, 1965). The advantage of using a fuzzy approach is to allocate the relative position of attributes using Fuzzy Numbers (FN) instead of accurate numbers. The FST uses linguistic terms to represent the preferences of the decision-maker. This section expands the TOPSIS to the fuzzy environment.

Definition 1. A fuzzy set in the universe of discourse, X is characterized by a membership function m which is a real number in the interval [0, 1] with each element x in X. The function value μ_a (t) is referred to as the membership grade of t in $\tilde{a}$ (Zadeh, 1965).

Definition 2. A triangular fuzzy is defined by a triplet $\tilde{x}$ = (x1, x2, x3). This study uses Triangular Fuzzy Numbers (TFN). A TFN 'a' can be defined as a triplet (x1, x2, x3). Its framework representation and mathematical formula are as illustrated by Eq. (9) (Kaufmann A and Gupta M.M, 1985).

$$\mu\tilde{a}(t) = \begin{pmatrix} 0, & t \le a1, \\ \frac{t-a1}{a2-a1}, & a1 < t \le a2, \\ \frac{a3-t}{a3-a2}, & a2 < t \le a3, \\ 0, & t > a3, \end{pmatrix} \quad (9)$$

Definition 3. Let $\tilde{x} = (x1, x2, x3)$ and $\tilde{y} = (y1, y2, y3)$ be the two TFNs, then the vertex method is interpreted to compute the distance between them, as given in Eq. (10):

$$d(\tilde{x}, \tilde{y}) = \sqrt{1/3[(x1 - y1)^2 + (x2 - y2)^2 + (x3 - y3)^2)]} \quad (10)$$

Property 1. Assuming that both $\tilde{x} = (x1, x2, x3)$ and $\tilde{y} = (y1, y2, y3)$ are real numbers, then the distance measurement is identical to the Euclidean distance (Chen C T, 2000).

Property 2. Let $\tilde{x}, \tilde{y}$, and $\tilde{z}$ be three TFNs. The FN $\tilde{y}$ is closer to FN $\tilde{x}$ than the other FN $\tilde{z}$ if, and only if, d $(\tilde{x}, \tilde{y}) < d(\tilde{x}, \tilde{z})$,

(Chen C T, 2000)

The basic operations of FTNs are as follows:

$$\tilde{x} \times \tilde{y} = (x1 \times y1, x2 \times y2, x3 \times y3) \text{ for multiplication.} \quad (11)$$

$$\tilde{x} + \tilde{y} = (x1 + y1, x2 + y2, x3 + y3) \text{ for addition.} \quad (12)$$

$$\tilde{x} - \tilde{y} = (x1 - y1, x2 - y2, x3 - y3) \text{ for subtraction.} \quad (13)$$

$$\frac{\tilde{x}}{\tilde{y}} = \left(\frac{x1}{y1}, \frac{x2}{y2}, \frac{x3}{y3}\right) \text{ for division.} \quad (14)$$

The fuzzy MCDM can be expressed elegantly as Eqs in the matrix format Eqs. (15) and (16) respectively.

$$\widetilde{D} = \begin{array}{c} \\ E_1 \\ E_2 \\ E_3 \\ . \\ . \\ . \\ E_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{bmatrix} \tilde{f}11 & \tilde{f}12 & \ldots & \tilde{f}1n \\ \tilde{f}21 & \tilde{f}22 & \ldots & \tilde{f}2n \\ \tilde{f}31 & \tilde{f}32 & \ldots & \tilde{f}3n \\ . & . & \ldots & . \\ . & . & \ldots & . \\ . & . & \ldots & . \\ \tilde{f}m1 & \tilde{f}m2 & \ldots & \tilde{f}mn \end{bmatrix} \end{array} \quad (15)$$

$$\widetilde{W} = [\tilde{w}1, \quad \tilde{w}2, \quad \ldots. \quad \tilde{w}n] \quad (16)$$

where $\tilde{f}_{ij}$, i = 1, 2,.., m, j = 1, 2,…, n and $\widetilde{w}_j$, j = 1, 2,…,n are linguistic TFNs, $\tilde{f}_{ij} = (x_{ij}, y_{ij}, z_{ij})$ and $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$. Note that $\tilde{f}_{ij}$ is the performance grades of the i^{th} alternative Ei, concerning the j^{th} attribute, Cj and $\widetilde{w}_j$ denotes the weight of the j^{th} attribute, Cj.
The normalized fuzzy decision matrix represented by $\widetilde{W}$ is shown in Eq. (17).

$$\tilde{R} = [\tilde{r}ij]mxn. \quad (17)$$

The weighted fuzzy normalized decision matrix is presented as Eq. (18).

$$\tilde{G} = \begin{bmatrix} \tilde{g}11 & \tilde{g}12 & \dots & \tilde{g}1n \\ \tilde{g}21 & \tilde{g}22 & \dots & \tilde{g}2n \\ \tilde{g}31 & \tilde{g}32 & \dots & \tilde{g}3n \\ . & . & \dots & . \\ \vdots & \vdots & \ddots & \vdots \\ . & . & \dots & . \\ \tilde{g}m1 & \tilde{g}m2 & \dots & \tilde{g}mn \end{bmatrix}$$

$$\tilde{G} = \begin{bmatrix} \widetilde{w}1\tilde{r}11 & \widetilde{w}2\tilde{r}12 & \dots & \widetilde{w}n\tilde{r}1n \\ \widetilde{w}1\tilde{r}21 & \widetilde{w}2\tilde{r}22 & \dots & \widetilde{w}n\tilde{r}2n \\ \widetilde{w}1\tilde{r}31 & \widetilde{w}1\tilde{r}32 & \dots & \widetilde{w}n\tilde{r}3n \\ . & . & \dots & . \\ \vdots & \vdots & \ddots & \vdots \\ . & . & \dots & . \\ \widetilde{w}1\tilde{r}m1 & \widetilde{w}1\tilde{r}m2 & \dots & \widetilde{w}1\tilde{r}mn \end{bmatrix} \quad (18)$$

Because of the above-mentioned fuzzy theory, the proposed fuzzy TOPSIS procedure is as follows:

Step 1: Choose the linguistic ratings ($\tilde{f}_{ij}$, i = 1, 2,…, m, j = 1, 2,…, n) for alternatives with respect to the criteria and the appropriate linguistic variables ($\widetilde{w}$j, j = 1, 2,…, n) concerning the weight of the criteria. The fuzzy linguistic rating ($\tilde{f}_{ij}$) retains the property that the ranges of normalized TFNs belong to [0, 1]. Hence, there is no need for a normalization process. For this instance, the $\widetilde{D}$ defined by using Eq. (15) which is equivalent to that of $\tilde{R}$ defined by Eq. (17).

Step 2: Build a weighted normalized fuzzy decision matrix. The weighted normalized value (G) is calculated by using Eq. (18).

Step 3: Identify positive (T*) and negative (T^-) ideal solutions. The fuzzy positive-ideal solution (FPIS, T*) and the fuzzy negative-ideal solution (FNIS, T^-) are shown in Eqs. (19) and (20), respectively.

$T^* = \{\tilde{g}1^*, \tilde{g}2^*, \ldots \tilde{g}3^* \ldots., \tilde{g}n^*\}$

$= \{(max_i gij | i = 1,2, \ldots..m), (j = 1,2, \ldots.n\}$ (19)

$T^- = \{\tilde{g}1^-, \tilde{g}2^-, \ldots \tilde{g}3^- \ldots., \tilde{g}n^-\}$

$= \{(min_i Gij | i = 1,2, \ldots..m), (j = 1,2, \ldots.n\}$ (20)

Step 4: Calculate the separation measures. The distance of each alternative from ti* and ti^- can currently be calculated using Eqs. (21) and (22), respectively.

$ti^* = \sum_{j=1}^{n} d(\tilde{g}_{ij}, \tilde{g}j^*), \quad i = 1,2,..,m$ (21)

$ti^- = \sum_{j=1}^{n} d(\tilde{g}_{ij}, \tilde{g}j^-), \quad i = 1,2,...,m$ (22)

Step 5: Calculate similarities to the ideal solution. This step resolves the similarities with the ideal Eq. solution (23).

$FCi^* = \frac{ti^-}{ti^* + ti^-}$ (23)

Step 6: Order of Rank Preferences. Select an alternative with a maximum FCi* or rate the alternatives according to FCi* in descending order.

5.4.3.2 Fuzzy Membership Function

TFNs are commonly used in practical applications due to their model and computational simplicity (Yeh and Deng, 2004). Figure 5.2 Illustrates triangular fuzzy membership functions and its relavant values in Table 5.4.

Table 5.4: Transformations for Fuzzy Membership Functions

Rank	Attribute rating	Membership function
Very Low -VL	1	(0.00,0.10,0.25)
Low - L	2	(0.15,0.30,0.45)
Medium - M	3	(0.35,0.50,0.65)
High - H	4	(0.55,0.70,0.85)
Very High -VH	5	(0.75,0.90,1.00)

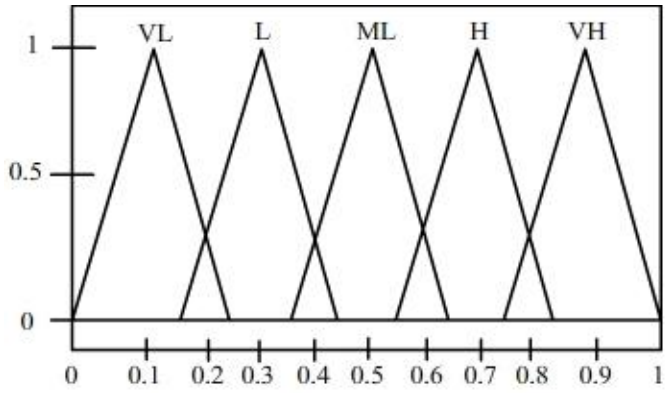


Figure 5.2: Fuzzy Triangular Membership Functions

The decision-makers are using linguistic variables to measure the importance of attributes and ratings of alternatives for different attributes. Here, only the precise value for performance ratings and attribute weights are evaluated. In the fuzzy TOPSIS, the existing values are intentionally transformed into fuzzy linguistic variables such as Very Low - VL, Low - L, Medium - M, High - H, and Very High - VH. The aim of the transformation process is, therefore, to compare the empiric results with other precise values in this analysis.

Hereafter, the TFN reasonably represents the five-level fuzzy linguistic variable used during evaluation. As a rule of thumb, each rank has an evenly spread membership function with an interval of 0.30 or 0.25. (Yang and Kuo, 2003). Based on these assumptions, a transformation table is shown in Table 5.4. To illustrate this, the fuzzy variable - VL has

connected with TFN with a minimum value of 0.00, mode of 0.10, and a maximum value of 0.25. A similar technique is executed to the other fuzzy variables - L, M, H, and VH.

5.4.4 Grey Relational Analysis (GRA) Method

The important procedure of GRA is initially transforming the performance of all alternatives into a comparability sequence (grey relational generating). After that, an ideal target sequence is identified. After that, the grey relational coefficient between all comparability sequences and the ideal target sequence is computed. Figure 5.3 shows the research methodology of GRA.

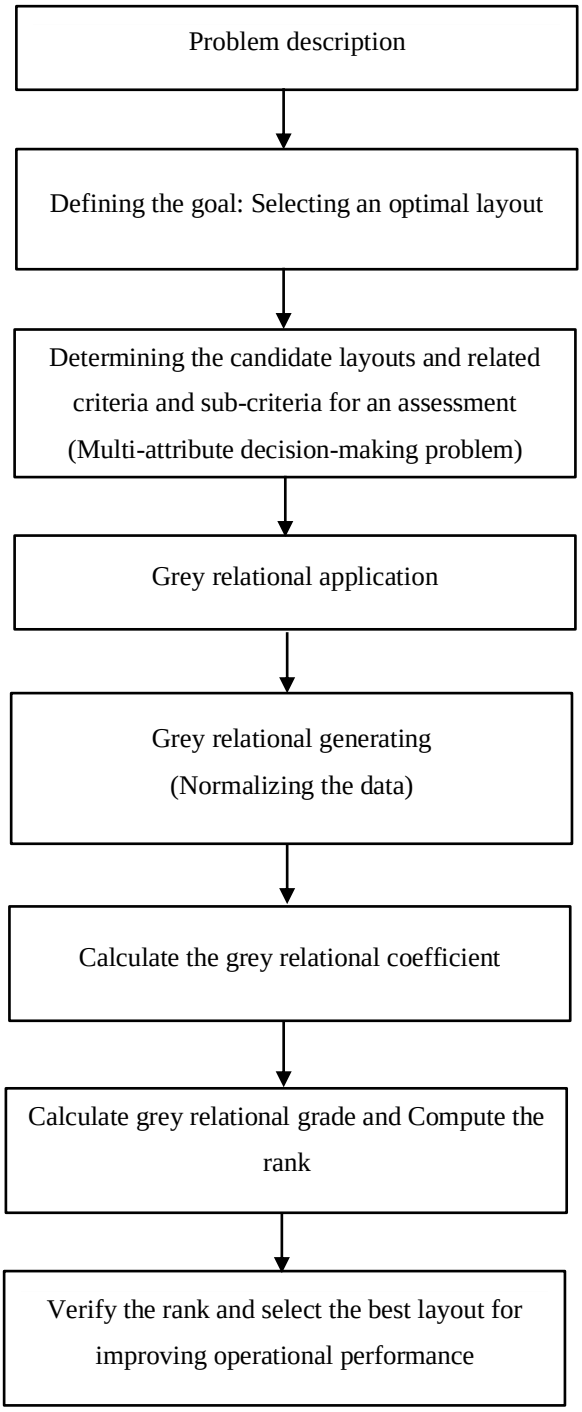


Figure 5.3: Research Methodology proposed for the Grey Relational Analysis

In the end, based on these grey relational coefficients, the grey relational grade between the ideal target sequence and each comparability sequence is computed. If a comparability sequence transformed from an alternative has the highest grey relational grade between the reference sequences then the highest value of the grey relational grade is selected as the best choice. The procedure of grey relational analysis is explained in the next section.

5.4.4.1 Mathematical Formulation of the Problem with GRA

Grey relational analysis procedure:

Step 1: Grey relational generating: Normalizing the data into a comparability sequence.

$$x_{ij} = \frac{yij - \underline{yj}}{\overline{yj} - \underline{yj}};\ i = 1,2,\dots,m \qquad j = 1,2,\dots,n \tag{24}$$

Eq. (24) is used for the-larger-the-better attributes

$$x_{ij} = \frac{\overline{yj} - yij}{\overline{yj} - \underline{yj}};\ i = 1,2,\dots,m \qquad j = 1,2,\dots,n \tag{25}$$

Eq. (25) is used for the-smaller-the-better attributes

$$x_{ij} = 1 - \frac{|yij - yj*|}{Max\left\{\overline{yj} - yj*, yj* - \underline{yj}\right\}};\ i = 1,2,\dots,m \qquad j = 1,2,\dots,n \tag{26}$$

Eq. (26) is used for the-closer-to-the-desired-value-yj* the-better.

Step 2: Grey relational coefficient calculation

$$\gamma(xoj, xij) = \frac{\Delta min + \zeta \Delta max}{\Delta ij + \zeta \Delta max};\ i = 1,2,\dots,m \qquad j = 1,2,\dots,n \tag{27}$$

In eq.27, $\gamma(xoj, xij)$ is the grey relational coefficient between xij and xoj,

and $\Delta ij = |x0j - xij|$

$\Delta min = Min\{\Delta ij, i = 1,2, \dots, m; j = 1,2, \dots, n\}$

$\Delta max = Max\{\Delta ij, i = 1,2, \dots, m; j = 1,2, \dots, n\}$

ζ is the distinguishing coefficient, $\zeta \epsilon (0,1)$

Step 3: Grey relational grade calculation

$$\Gamma(X0, Xi) = \sum_{j=1}^{n} wj\gamma(xoj, xij); \text{ for } i = 1,2, \dots, m \quad (28)$$

Here, $\sum_{j=1}^{n} wj = 1$.

5.5 Case study – National Sorting Hub (NSH) Mangalore

NSH is the segregation of speed post articles. There are 89 such hubs all over India mainly located at the Railway Mail Service (RMS) with a few exceptions. Each NSH can close bags for any of the NSH and it works as a hub and spoke wheel model method. NSH is further divided into ICSH or Intra Circle (Spoke) Sorting Hubs. The entire sorting and transit of mail happen across RMS which works 24 x 7 irrespective of any offs. Here, the facility layout comprises 6 various areas and a considerable flow of mails exists among 1 to 6 departments as is presented in Table 5.5. The relationship chart (REL) is used to illustrate the significance of two departments which are situated adjacent to each other. Table 5.6 shows the REL chart based on the preference ratings among the departments. For example, ‘a’ for absolutely necessary, ‘e’ is for especially important, ‘i’ for important, ‘o’ for ordinary closeness OK, and ‘x’ for unimportant. These facility layouts have been generated based on the REL Chart and the necessity of each department’s space.

Table 5.5: Active Areas of the Department

S.No	Sections	Area (Sq.ft)
1	Receiving section	37
2	Scanning – Town Delivery (Local mails)	102
3	Scanning - Non -Town Delivery	48
4	Sorting - Town Delivery	107
5	Sorting - Non -Town Delivery	62
6	Dispatch	43

Table 5.6: REL Chart Mail Flow (Between Departments)

From/To	1	2	3	4	5	6
1	-	a	a	x	x	i
2	i	-	o	a	i	x
3	x	i	-	i	a	x
4	i	a	i	-	i	x
5	x	i	a	i	-	x
6	i	i	i	x	x	-

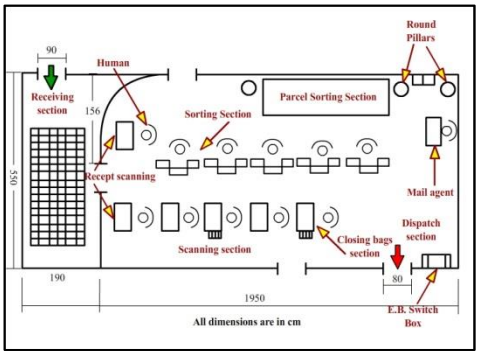
5.5.1 Problem Description

The existing layout has some problems which are mentioned as follows:

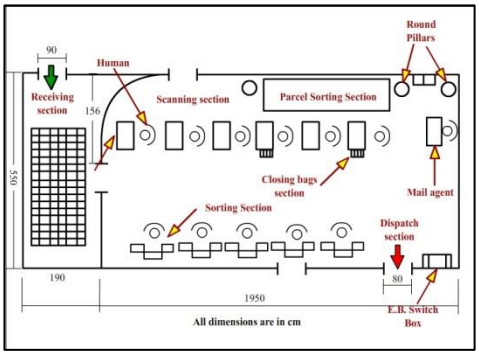
- Throughput time is longer (152.38 sec/articles) - verified by value stream map
- Employee not convenient for long time work - verified by questionnaire study
- Sorting the mail is difficult for the postal employees -verified by value stream map
- There is a chance of mixing of received and dispatch bags (scope for confusion)
- Present production delivery articles (8620 articles/day) are not satisfactory as compared to the target.

5.6 Facility Layout Design (FLD)

A Computer-Aided Design tool (CAD) is adopted to promote the model generation of alternative methods and to collect quantitative data such as space usage, handling materials (mails) as well as qualitative information calculated from the Saaty scale (1-9). In the beginning, measuring the following existing layout facilities such as lighting, ventilation, throughput time, emergency exit, workplace environment, and backtracking materials (mails) flow. Seven layouts were generated by CAD software for the need of improving operational performance in terms of production, improving workplace environment, and ergonomics for better workplace suitability for the postal employees. Observation from the Figure 5.4, Layout 1 has been proven as convenient for supervision, Layout 2 has improved utilization of space and comfort level, Layout 3 has amenities of providing ceiling fan and light facilities, Layout 4 has a convenient mail flow arrangement of and minimum throughput time. Layout 5 has an efficient space utilization. Layout 6 has a minimum backtrack and a separate section of local and other than local mails. Layout 7 has ease of housekeeping compared to other layout design and finally, Layout 8 has an existing layout for the convenience of postal employees. In summary, each layout has some distinctive merits and demerits. Hence, decision-makers have to choose wisely to select an optimal one.



Alternate layout 1



Alternate layout 2

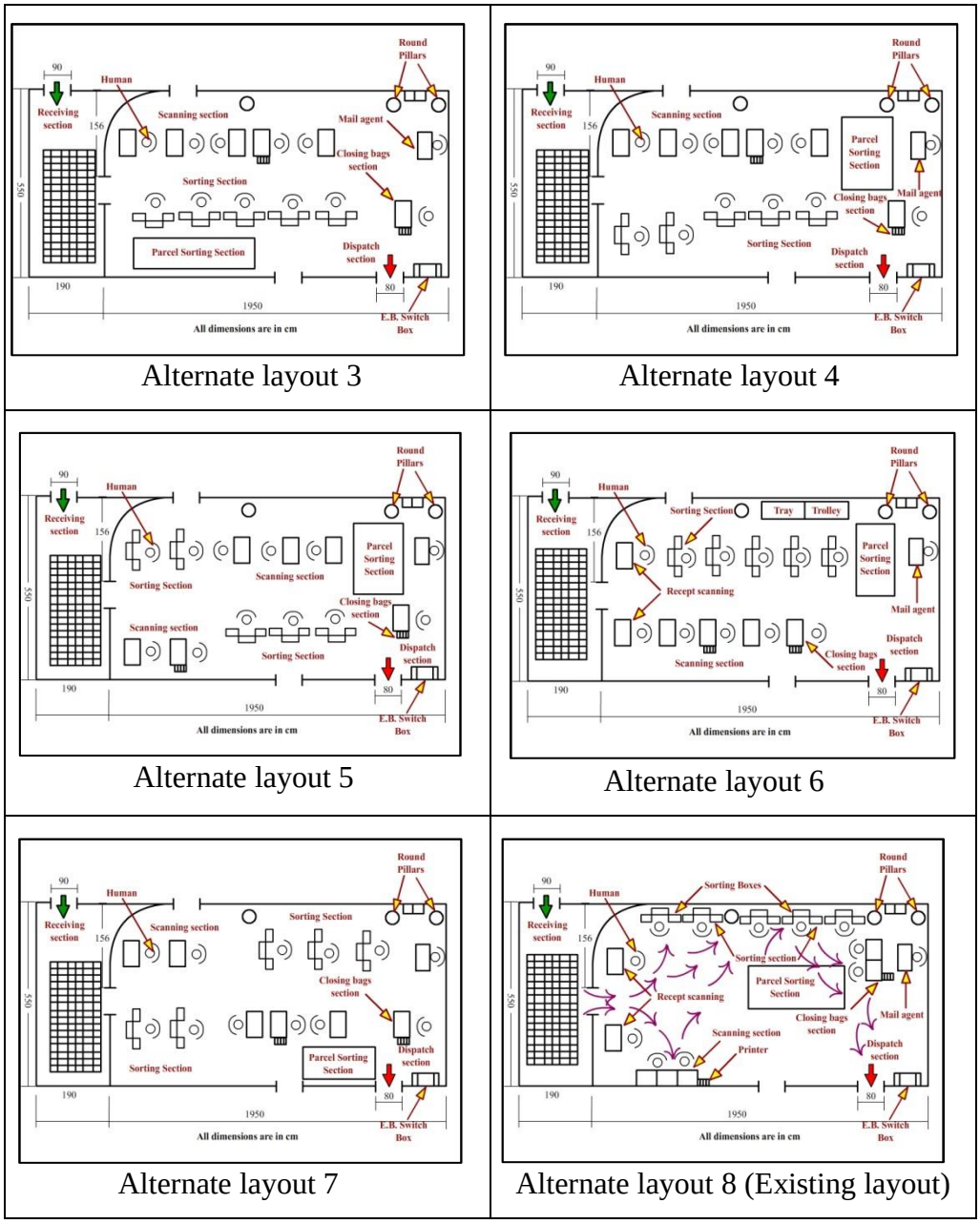
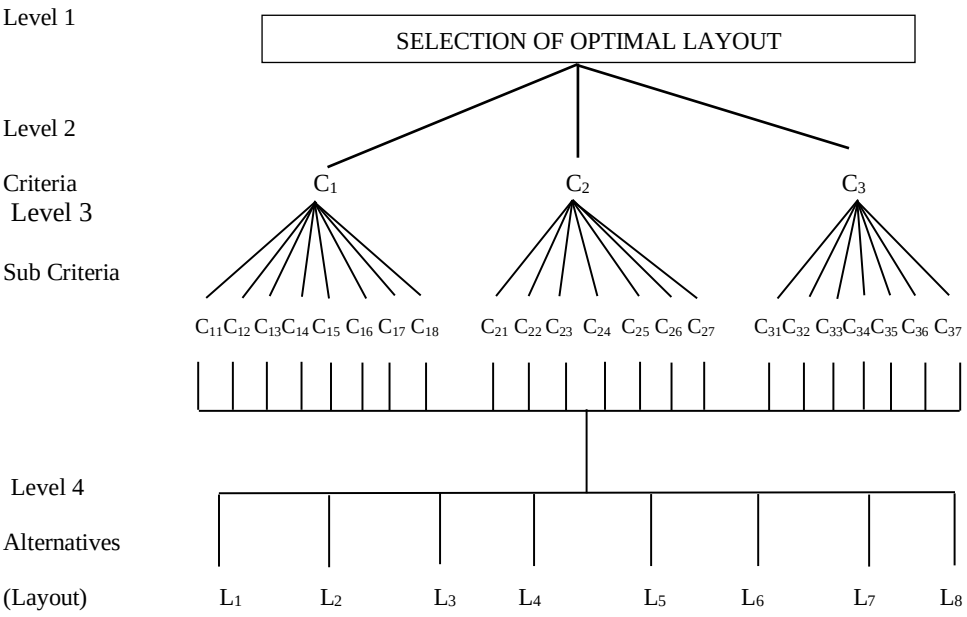


Figure 5.4: Design from CAD Software Showing the Alternative Layouts [1-7] and Existing Layout [8].

5.7 Hierarchy Formation for the AHP Method

The three criteria are mainly applied to judge the optimal layout from the seven alternative layouts design and an existing one (layout 8). For example; the efficient movement of materials (mails) is the most common and valuable criterion used to judge alternative layouts. The REL charts show the most important route (i.e.) the process flow in the existing layout via. Receiving section - Scanning - Sorting - Dispatch. This MCDM examined the seven layout design alternatives and an additional existing layout. These alternatives are provided at the bottom of the decision tree hierarchy. Thus, a complete hierarchy was formed and is shown in Figure 5.5 and is given in Table 5.7.



Legend:

C_1: Lean Service **C_2: Workplace Environment** **C_3: Ergonomics**

C_{11}: Efficient movement of mail C_{12}: Efficient movement of personnel
C_{13}: Throughput time C_{14}: Mail handling time
C_{15}: Efficient space utilization C_{16}: Efficient process flow C_{17}: Flexibility C_{18}: Inventory reduction

C_{21}: Light facilities C_{22}: Ventilation facilities C_{23}: Noise control
C_{24}: Pollution control C_{25}: Aesthetics C_{26}: Safety
C_{27}: Equipment availability

C_{31}: Emergency exit C_{32}: Security C_{33}: Ease of supervision
C_{34}: Work Posture C_{35}: Comforts C_{36}: Accessibility
C_{37}: Ease of maintenance

Alternatives:
L_1 – Layout 1, L_2 – Layout 2, L_3 - Layout 3, L_4 – Layout 4, L_5- Layout 5,
L_6 – Layout 6, L_7- Layout 7, L_8 – Existing layout.

Figure 5.5: Hierarchy Formation of the Optimal Layout Selection

Table 5.7: Brief Information about each Criterion and Sub-Criterion with Reference

S.No	Criteria	Sub-criteria	Reference
1	Lean Service		
		C_{11}: Efficient movement of materials (mails)	(Cambron and Evans, 1991),(Rexhepi and Shrestha, 2011)
		C_{12}: Efficient movement of personnel	(Cambron and Evans, 1991),(Vadivel, 2015)
		C_{13}: Throughput time	(Eisele *et al.*, 2015),(Black, 2007)
		C_{14}: Material (Mail) handling time	(Pourvaziri and Pierreval, 2016),(Chan, Chan and Ip, 2002)
		C_{15}: Efficient space utilization	(Cambron and Evans, 1991)
		C_{16}: Efficient process flow	(Chadha, Singh and Kalra, 2012)
		C_{17}: Flexibility	(Cambron and Evans, 1991),(Yang and Kuo, 2003)
		C_{18}: Inventory reduction	(Meade, Kumar and Houshyar,2006),(Martínez-Jurado and Moyano-Fuentes, 2014)

2	Workplace Environment		
		C_{21}: Light facilities	(El-Zeiny,2012), (Garbie,2014)
		C_{22}: Ventilation facilities	(El-Zeiny, 2012) (Garbie, 2014)
		C_{23}: Noise control	(Cambron and Evans, 1991)
		C_{24}: Pollution control	Field survey
		C_{25}: Aesthetics	(Cambron and Evans, 1991)
		C_{26}: Safety	(Cambron and Evans, 1991)
		C_{27}: Equipment availability	(Shah and Ward, 2007), (Arslankaya and Atay, 2015)
3	Ergonomics		
		C_{31}: Emergency exit	Field survey
		C_{32}: Security	(Cambron and Evans, 1991)
		C_{33}: Ease of supervision	(Cambron and Evans, 1991)
		C_{34}: Work Posture	(Das and Grady, 1983), (Rossi *et al.*, 2013)
		C_{35}: Comforts	(Rossi *et al.*, 2013),(Hu and Wang, 2004)
		C_{36}: Accessibility	(Yang and Kuo, 2003)
		C_{37}: Ease of maintenance	(Yang and Kuo, 2003)

5.7 Data Collection

The questionnaire forms were given to post officers including managers, head sorters, scanners, and sorters, assistant superintends. 150 were distributed, among them, 135 returns (90%) were received. Out of 135 returns, 10 returns were excluded due to incomplete information, 15 returns were excluded due to inconsistency, and the resulting 110 usable returns were used for an analysis (73.3%).

5.8 AHP Numerical Calculation

Pairwise comparisons are made and then converted into the framework of a matrix. This is used to derive a local priority vector as an estimate of relative magnitudes that are associated with the elements being compared. Local priority vectors are derived for all pairwise comparison matrixes. Synthesized local priorities are used to derive a global measure of priority, which is used for making the final decision. The overall priority alternative is calculated by the Eq. (29). Tables 5.8 and 5.9 shows the calculation of local and global weights.

Overall rating = Σ (Priority of alternative concerning sub-criteria) X (Relative priority of sub-criteria). (29)

Table 5.8: Calculation of the Local Weights

		LOCAL WEIGHTS								
CRITERIA	SUB CRITERIA	WEIGHT	Layout 1	Layout 2	Layout 3	Layout 4	Layout 5	Layout 6	Layout 7	Existing
Lean Service	Efficient movement of mail	0.40728	0.09430	0.08170	0.11400	0.09320	0.09610	0.07280	0.08350	0.08270
0.45129	Inventory reduction	0.07389	0.10072	0.10173	0.08633	0.10009	0.09592	0.10360	0.09785	0.11511
	Efficient movement of personnel	0.18437	0.03650	0.14339	0.03585	0.19119	0.04837	0.08922	0.20076	0.06582
	Throughput time	0.03391	0.09046	0.10299	0.09460	0.10270	0.10128	0.09785	0.10643	0.10093
	Mail handling time	0.02454	0.06250	0.04167	0.18750	0.06250	0.10417	0.06250	0.08333	0.08333

	Efficient space utilization	0.08525	0.09333	0.07772	0.13527	0.10039	0.08601	0.86416	0.08259	0.08129
	Efficient process flow	0.10717	0.09979	0.10036	0.10085	0.09940	0.09714	0.10039	0.10010	0.10089
	Flexibility	0.08043	0.09934	0.10126	0.10092	0.10252	0.10083	0.10169	0.10041	0.10255
Workplace Environment 0.35000	Light facilities	0.32966	0.06496	0.16239	0.03609	0.04640	0.08120	0.32478	0.05413	0.10826
	Ventilation facilities	0.18202	0.11381	0.34142	0.03794	0.05690	0.04877	0.17071	0.04268	0.06828
	Noise control	0.05715	0.09934	0.10126	0.10092	0.10252	0.10083	0.10169	0.10041	0.10255
	Pollution control	0.04833	0.09964	0.19929	0.02491	0.06643	0.19929	0.19929	0.03321	0.04982
	Aesthetics	0.12423	0.10619	0.08493	0.12805	0.10417	0.09534	0.09133	0.09401	0.07670
	Safety	0.14329	0.10645	0.09438	0.10012	0.10430	0.09392	0.10501	0.09507	0.09094
	Equipment availability	0.11243	0.10609	0.09418	0.10013	0.10410	0.09462	0.10521	0.09506	0.09087
Ergonomics 0.20571	Emergency exit	0.41484	0.22064	0.18239	0.12306	0.12503	0.08726	0.07362	0.07449	0.03535
	Security	0.08720	0.19825	0.19520	0.14715	0.11801	0.07761	0.06022	0.07845	0.02347
	Ease of supervision	0.07491	0.04096	0.04096	0.20478	0.05119	0.20478	0.04096	0.06826	0.04096
	Work Posture	0.21016	0.10609	0.09418	0.10013	0.10410	0.09462	0.10521	0.09506	0.09087
	Comforts	0.04219	0.09934	0.10126	0.10092	0.10252	0.10083	0.10169	0.10041	0.10255
	Facilities	0.09201	0.09934	0.10126	0.10092	0.10252	0.10083	0.10169	0.10041	0.10255
	Ease of maintenance	0.07796	0.21562	0.19635	0.12383	0.12071	0.07541	0.05891	0.05985	0.04174

Table 5.9: Overall Global Rating of the Facility Layouts Alternatives

	GLOBAL WEIGHTS							
Overall Priority	0.10755	0.13200	0.09455	0.09918	0.08868	0.14459	0.07647	0.06907
Rank	3	2	5	4	6	1	7	8

Inference:

$A_6>A_2>A_1>A_4>A_3>A_7>A_5>A_8$.

From the above AHP method, optimal layout 6 has been adopted for final selection.

5.10 Application of TOPSIS Method

The decision matrix shown in Table 5.10 has been considered for the TOPSIS analysis. Created on the first step of the TOPSIS procedure, each element is normalized by Eq. (3). The resulting normalized decision matrix for the TOPSIS analysis is shown in Table 5.11. The second step needs the attribute weight details to compute the weighted normalized ratings. The decision for the attribute weighting is taken from local weightage. The third step determines the weighted normalized decision matrix after that continues to Steps 4 and 5. The results are shown in Table 5.12. Finally, from Table 5.12 results, alternative ranks are measured.

Table 5.10: Decision Matrix for TOPSIS Analysis

Weight	0.45	0.35	0.2
Criteria	Lean Service	Workplace Environment	Ergonomics
Layout 1	9	7	6
Layout 2	9	8	7
Layout 3	8	7	7
Layout 4	7	8	8
Layout 5	7	6	7
Layout 6	9	8	9
Layout 7	7	7	6
Layout 8	7	6	5

Table 5.11: Normalized Decision Matrix for TOPSIS Analysis

No.	Lean Service	Workplace Environment	Ergonomics
Layout 1	0.40	0.35	0.30
Layout 2	0.40	0.39	0.35
Layout 3	0.36	0.35	0.35
Layout 4	0.31	0.39	0.41
Layout 5	0.31	0.30	0.35
Layout 6	0.40	0.39	0.46
Layout 7	0.31	0.35	0.30
Layout 8	0.31	0.30	0.25
Wij	0.45	0.35	0.20

Table 5.12: TOPSIS Analysis Results

Alternatives	Lean Service	Workplace Environment	Ergonomics	Ti’	Ti*	Ci*
Layout 1	0.1806	0.1208	0.0608	0.0448	0.0350	0.5618
Layout 2	0.1806	0.1381	0.0710	0.0567	0.0203	0.7365
Layout 3	0.1605	0.1208	0.0710	0.0333	0.0333	0.5000
Layout 4	0.1405	0.1381	0.0811	0.0460	0.0414	0.5265
Layout 5	0.1405	0.1036	0.0710	0.0203	0.0567	0.2635
Layout 6	0.1806	0.1381	0.0913	0.0667	0.0000	1.0000
Layout 7	0.1405	0.1208	0.0608	0.0200	0.0532	0.2733
Layout 8	0.1405	0.1036	0.0507	0.0000	0.0667	0.0000
Tj*	0.18	0.14	0.09			
Tj-	0.14	0.11	0.06			
W = (0.45,0.35,0.2)						

Inference: $A_6>A_2>A_1>A_4>A_3>A_7>A_5>A_8$.

Ultimately, the ‘ Layout A_6’ is accepted for the final design.

5.11 Application of Fuzzy TOPSIS Method

From Table 5.11, numerical performance rankings are implemented one more time for the fuzzy TOPSIS analysis. Transform the performance rankings into fuzzy linguistic variables as described in section 5.4.3, the performance rankings in Table 5.15 are normalized into the range of [0,1] by Eqs. (25) and (26) (Cheng C H, 1999):

(i) The larger, the better type:

$$rij = \frac{[xij - min\{xij\}]}{[max\{xij\} - min\{xij\}]}. \quad (30)$$

(ii) The smaller, the better type:

$$rij = \frac{[max\{xij\} - xij]}{[max\{xij\} - min\{xij\}]}. \quad (31)$$

Here, C1, C2, and C3 all are larger-the-better type. Then, Table 5.13 can be transformed into Table 5.14.

Table 5.13: Normalized Decision Matrix for Fuzzy TOPSIS Analysis

Alternatives	C1	C2	C3
A1	1.00	0.50	0.25
A2	1.00	0.75	0.50
A3	0.75	0.50	0.50
A4	0.50	0.75	0.75
A5	0.50	0.25	0.50
A6	1.00	0.75	1.00
A7	0.50	0.50	0.25
A8	0.50	0.25	0.00

Table 5.14: Decision Matrix using Fuzzy Linguistic Variables

Alternatives.	C1	C2	C3
A1	H	M	L
A2	VH	H	M
A3	H	M	M
A4	M	H	H
A5	M	L	M
A6	VH	H	VH
A7	M	M	L
A8	M	L	VL
Wt	VH	H	L

Next, the fuzzy membership function is discussed in Section 5.4.3.2 and is illustrated in Table 5.13 and Table 5.14. For example, if the numeric rating is 0.75, then its fuzzy linguistic variable is "H". This transformation is the same for the attribute weight also. The fuzzy linguistic variable is then transformed into a fuzzy triangular membership function as shown in Table 5.15. The fuzzy attribute weight is also shown in Table 5.14. The second step is to calculate the weighted fuzzy decision matrix. Using Eq. (11), the fuzzy multiplication equation, the resulting fuzzy weighted decision matrix is presented in Table 5.16.

The third step of the fuzzy TOPSIS analysis is finding the fuzzy positive-ideal solution (FPIS, T*), and the fuzzy negative-ideal solution (FNIS, T^-) as: $\tilde{t}_j = (1,1,1)$ and $\tilde{t}_j = (0,0,0)$, j= 1,2,..n. Consequently, in Table 5.17, the elements are normalized positive TFNs and their ranges belong to the closed interval [0, 1].

The distance of each alternative from ti* and ti^- can be presently computed using Eqs. (21) and (22). This is the fourth step of the fuzzy TOPSIS analysis. The last step solves the resemblances to an ideal solution by Eq. (23). The resultant fuzzy TOPSIS analyses are briefly illustrated in Table 5.17.

Table 5.15: Fuzzy Decision Matrix and Fuzzy Attribute Weights

Alternatives	**C1**	**C2**	**C3**
A1	(0.55,0.70,0.85)	(0.35,0.50,0.65)	(0.15,0.30,0.45)
A2	(0.75,0.90,1.00)	(0.55,0.70,0.85)	(0.35,0.50,0.65)
A3	(0.55,0.70,0.85)	(0.35,0.50,0.65)	(0.35,0.50,0.65)
A4	(0.35,0.50,0.65)	(0.55,0.70,0.85)	(0.55,0.70,0.85)
A5	(0.35,0.50,0.65)	(0.15,0.30,0.45)	(0.35,0.50,0.65)
A6	(0.75,0.90,1.00)	(0.55,0.70,0.85)	(0.75,0.90,1.00)
A7	(0.35,0.50,0.65)	(0.35,0.50,0.65)	(0.15,0.30,0.45)
A8	(0.35,0.50,0.65)	(0.15,0.30,0.45)	(0.00,0.10,0.25)
Weight	(0.75,0.90,1.00)	(0.55,0.70,0.85)	(0.15,0.30,0.45)

Table 5.16: Fuzzy Weighted Decision Matrix

Alternatives	C1	C2	C3
A1	(0.41,0.63,0.85)	(0.19,0.35,0.55)	(0.02,0.09,0.20)
A2	(0.56,0.81,1.00)	(0.30,0.49,0.72)	(0.05,0.15,0.29)
A3	(0.41,0.63,0.85)	(0.19,0.35,0.55)	(0.05,0.15,0.29)
A4	(0.26,0.45,0.65)	(0.30,0.49,0.72)	(0.08,0.21,0.38)
A5	(0.26,0.45,0.65)	(0.08,0.21,0.38)	(0.05,0.15,0.29)
A6	(0.56,0.81,1.00)	(0.30,0.49,0.72)	(0.11,0.27,0.45)
A7	(0.26,0.45,0.65)	(0.19,0.35,0.55)	(0.02,0.09,0.20)
A8	(0.26,0.45,0.65)	(0.08,0.21,0.38)	(0.00,0.03,0.11)

Table 5.17: Fuzzy TOPSIS Analysis

Alter-natives	C1	C2	C3	ti*	ti'	Fci*
A1	(0.41,0.63,0.85)	(0.19,0.35,0.55)	(0.02,0.09,0.20)	1.7687	1.1684	0.3978
A2	(0.56,0.81,1.00)	(0.30,0.49,0.72)	(0.05,0.15,0.29)	1.6363	1.2845	0.4398
A3	(0.41,0.63,0.85)	(0.19,0.35,0.55)	(0.05,0.15,0.29)	2.0330	1.2316	0.3773
A4	(0.26,0.45,0.65)	(0.30,0.49,0.72)	(0.08,0.21,0.38)	1.626	1.2608	0.4367
A5	(0.26,0.45,0.65)	(0.08,0.21,0.38)	(0.05,0.15,0.29)	2.1871	0.9214	0.2964
A6	(0.56,0.81,1.00)	(0.30,0.49,0.72)	(0.11,0.27,0.45)	1.531	1.4028	0.4782
A7	(0.26,0.45,0.65)	(0.19,0.35,0.55)	(0.02,0.09,0.20)	2.1119	0.9946	0.3202
A8	(0.26,0.45,0.65)	(0.08,0.21,0.38)	(0.00,0.03,0.11)	2.2985	0.7971	0.2575
ti*	(1,1,1)	(1,1,1)	(1,1,1)			
ti-	(0,0,0)	(0,0,0)	(0,0,0)			
W	(0.75,0.90,1.00)	(0.55,0.70,0.85)	(0.15,0.30,0.45)			

For Steps 4 and 5 calculations, FC_1 calculation is mentioned below as an example:

$$t1* = \sqrt{\frac{1}{3[(1-0.41)^2+(1-0.63)^2+(1-.85)^2]}} + \sqrt{\frac{1}{3[(1-0.19)^2+(1-0.35)^2+(1-0.55)^2]}} + \sqrt{\frac{1}{3[(1-0.02)^2+(1-0.09)^2+(1-0.20)^2]}}$$

= 1.7687

$$t1- = \sqrt{\frac{1}{3[(0-0.41)^2+(0-0.63)^2+(0-.85)^2]}} + \sqrt{\frac{1}{3[(0-0.19)^2+(0-0.35)^2+(0-0.55)^2]}} + \sqrt{\frac{1}{3[(0-0.02)^2+(0-0.09)^2+(0-0.20)^2]}}$$

= 1.1684

From Table 5.17, alternative rank for the eight alternative layout design is as mentioned as follows: *Inference:* $A_6>A_2>A_4>A_1>A_3>A_7>A_5>A_8$

Here, the current precise values are transformed into fuzzy linguistic variables, and the proposed fuzzy-TOPSIS analysis is obtained. Empirical results proved that the feasible layout is A_6 by a fuzzy TOPSIS method.

5.12 Grey Relational Generating

The main goal of Grey Relational Generating (GRG) is to transmit the original data into comparability sequences. Flow distance is a smaller-the-better attribute, and adjacency score, flexibility, accessibility, and maintenance are all larger-the-better attributes, and shape ratio is a closer-to-desired-value-the better (the desired value being 1). The grey relational generating process adopts Eq. (25) for the data of performance values of flow distance; Eq. (24) for the data of performance values of space utilization, lean service, workplace environment, and ergonomics, etc., and Eq. (26) for the data of performance values of shape ratio where yj* is equal to 1. For example, in the case of the flow distance attribute, the maximum and minimum values are 1500, 1060 from alternative No.1. Using Eq.(25), the results of grey relational generating of alternative No.1 is equal to (1500-1480)/ (1500-1060) = 0.045. The entire results of grey relational generating are shown in Table 5.18.

Table 5.18: Summary of Grey Relational Generating for a Facility Layout Problem

Alternate layout no.	Flow distance (cm)	Space utilization	Shape ratio factor	Lean service	Workplace environment	Ergonomics
1	0.045	0.550	0.6356	0.395	0.437	0.3705
2	0.727	0.850	0.0151	0.779	0.093	0.4171
3	0.500	0.500	0.9843	0.000	0.918	0.1869
4	0.000	0.800	0.3696	0.216	0.458	0.5706
5	0.364	0.700	0.9747	0.034	0.305	1.0000
6	0.273	1.000	0.7899	1.000	0.000	0.2721
7	0.682	0.650	0.8472	0.764	0.036	0.4854
8	1.000	0.000	0.0000	0.064	1.000	0.0000
X_0	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

5.12.1 Grey Relational Coefficient Calculation

In Table 5.18, X_0 is reference sequence. After calculating Δ_{ij}, Δ_{max} and Δ_{min}, all grey relational coefficients can be calculated by Eq. (27). For example, Δ_{11} = | 1- 0.045| = 0.9545, Δ_{max} = 1 and Δ_{min} = 0, if ζ = 0.5, then c (x_{01},x_{11}) = (0 + 0.5x1)/(0.9545 + 0.5x1) = 0.3438. The entire results for the grey relational coefficient are shown in Table 5.19.

Table 5.19: Summary of The Grey Relational Coefficient for a Facility Layout Problem

Alternate layout no.	Flow distance (cm)	Space utilization	Shape ratio factor	Lean service	Workplace environment	Ergonomics
1	0.3438	0.5263	0.5784	0.4523	0.4702	0.4427
2	0.6471	0.7692	0.3367	0.6936	0.3555	0.4617
3	0.5000	0.5000	0.9696	0.3333	0.8590	0.3808
4	0.3333	0.7143	0.4423	0.3893	0.4797	0.5380
5	0.4400	0.6250	0.9518	0.3411	0.4183	1.0000
6	0.4074	1.0000	0.7041	1.0000	0.3333	0.4072
7	0.6111	0.5882	0.7659	0.6795	0.3415	0.4928
8	1.0000	0.3333	0.3333	0.3481	1.0000	0.3333

GRA is applied as a solution to this problem. Results obtained from the GRA theory obtained is tabulated in Table 5.20.

5.12.2 Grey Relational Grade Calculation

In this case, the significance of all performance attributes was assumed to be equal. Hence, the weights of the six performance attributes were all the same (1/6). By using Eq. (28), the grey relational grade can be calculated and this is shown in Table 5.20.

Table 5.20: Results of Grey Relational Analysis for a Facility Layout Problem

Alternate layout no.	GRG	Rank
1	0.4689	8
2	0.5440	6
3	0.5904	3
4	0.4828	7
5	0.6294	2
6	0.6420	1*
7	0.5798	4
8	0.5580	5

From Table 5.20, the values explain the priority ranking of facility layout alternatives based on the determined method and conclude that A_6 is the final layout design and the second-best choice is A_5. Hence, the proposed methodology provides guidelines for a systematic approach to reduce the number of alternatives and thereby provides a better decision-making process. The management has adopted and implemented optimal layout 6 design for its strategic operational performance improvement layout in NSH Mangalore based on this research study.

5.13 Result Analysis

Multi-criteria decision-making methods are applied in an extensive area. Numerous methods developed for this purpose are deployed based on the structure of the decision problem and the preferences of the decision-maker. Initially, in this study; comparative analysis of the three most broadly used basic methodologies, namely, AHP, TOPSIS, and Fuzzy TOPSIS has been conducted and the basic characteristics of these methods have been exhibited. Further, the need for selecting a feasible layout on the basic issues of operational performance, where multi-criteria decision making is applied and has been explained. The facility location problem is examined as a case study in the Indian Postal service sector at NSH Mangalore, India.

AHP, TOPSIS, Fuzzy TOPSIS, GRA methodologies are applied for the solution of this problem. Results obtained from AHP, TOPSIS, Fuzzy TOPSIS, and GRA are tabulated in Table 5.21. Further, Table 5.21 values explain the priority ranking of facility layout alternatives based on the determined method. The AHP method inferences A_6 and A_2 are the top rank alternatives which are the same as TOPSIS. In the fuzzy TOPSIS, it is observed that the same top two alternative A_6 and A_2 are repeated. All these four methods conclude that A_6 is the final layout design and the second-best choice is A_2. Hence, the proposed methodology provides guidelines for a systematic approach to reduce the number of alternatives, and thereby provide a better decision-making process. The management has adopted and implemented optimal layout 6 design for its strategic operational performance improvement layout in NSH Mangalore based on this research study. Hence, the practical contribution of this research could be justified.

Table 5.21: Preference Ranking of Layout Alternatives Depending on Decision Methodologies

	AHP	TOPSIS	Fuzzy TOPSIS	GRA
Layout 1	3	4	3	8
Layout 2	2	2	2	6
Layout 3	5	5	5	3
Layout 4	4	3	3	7
Layout 5	6	7	7	2
Layout 6	1*	1*	1*	1*
Layout 7	7	6	6	4
Layout 8 (Existing Layout)	8	8	8	5

Note: * Feasible layout 6 had been implemented in NSH Mangalore in April 2018.

Although AHP supports better decision making, some minor issues were identified in applying this methodology, such as AHP has ranking irregularities (rank reversal) when variants are used. For that purpose, the TOPSIS and Fuzzy TOPSIS methods were approached as per the expert's opinion. When precise values are known, the TOPSIS method is a suitable method to solve the layout design problem. Suppose, if values are imprecise or vague, the fuzzy TOPSIS, GRA is a better choice to solve this problem.

5.14 Managerial Implications

From an implication point of view, capturing real qualitative information from the postal employees can be a difficult task, which may not give a unified answer. In real-time, management may prefer different layout design results. However, the recommended methodology guides a systematic approach to reduce the number of alternatives, and guidelines necessary for the decision-making process. Interestingly, the National Sorting Hub (NSH), Mangalore, speed post service, has adopted this analysis results. The management agreed and also implemented the feasible layout (A_6) for the aid of operational performance improvement. For the change of layout design implementation, NSH Mangalore had spent around INR 2.0 Lakhs. The impact of the enhancement in operational

performance and workplace environment was estimated to repay is not more than 45 days after incorporation.

A case study of the Indian Postal mailing service was adopted for empirical testing. Empirical results exhibited that the recommended methods are feasible in solving the practical layout design problem. The aim of this study was focused to improve operational performance layout selection compared to existing performance measures. Additionally, this study can be helpful in future NSH postal service strategic planning. The theoretical contribution of this study may be noted as the identification of three criteria from the literature and field survey along with the MCDM using AHP, TOPSIS, and fuzzy TOPSIS. TOPSIS is a practical method for the recommended problem and is appropriate for precise performance ratings. When the performance ratings are imprecise and vague, then the fuzzy TOPSIS,GRA are the preferred methods. The FLD problem is an important decision-making problem to reduce material flow and layout costs. The MCDM tools help for solving this kind of issue. Hence, this study presented MCDM methods to select the feasible layouts among the alternatives to improve operational performance. This model also exhibited significant overall improvement in production, workplace environment, and ergonomics conditions.

5.15 Limitations of the Research

In the selection of suitable facilities layout, multi-criteria decision-making methods guides as a Decision Support System (DSS). Firstly, results shown in the NSH speed postal service cannot be generalized for other firms such as Railway Mail Service (RMS), private courier service industries, etc. Hence the decisions may vary depending upon the firm's circumstances. Secondly, financial factors such as material flow factor cost, total layout cost are not included for the evaluation of the layout. Thirdly, sensitivity analysis has not been done to see how well the alternatives perform concerning each of the attributes.

5.16 Recommendations for Future Research

Firstly, simulations can be used to find out each layout's operational performance efficiency and evaluating the performance of queuing systems to find an optimal layout. Secondly, considering both quantitative and qualitative factors for the layout design which may result in selecting the best layout. Thirdly, these FLD problems can be solved with other MCDM methods such as Analytical Network Process (ANP), Fuzzy ANP, DEA, ELECTRE for better results, and comparative efficiency. This research is based on a case study carried out in speed post service in India. This work may be extended to manufacturing industries and other service sectors such as Healthcare, Information Technology, Municipal Corporation, Telecom, Transportation, etc. Academicians, Researchers, and Practitioners can be benefited from this research by understanding the MCDM methods to evaluate the facility layout and select the best one as per the requirements of the respective organizations.

5.17 Summary

This chapter presents the MCDM methodology to select the feasible layout (Layout 6) among the eight alternatives. The advantage of this research is to choose the best layout solutions under lean service, workplace environment, and ergonomics divisions using relevant criteria and sub-criteria. Alternatives were compared and assigned with ranks using the MCDM model. The postal department has adopted ‘Layout 6’, as it is ranked number one as per MCDM methods. Thus, this was implemented in April 2018 in NSH speed post center, southern India. In this way, the practical implications of the model, as mentioned above, could be justified. Also, this model exhibited overall operational performance in terms of production, workplace environmental conditions, and housekeeping. This chapter used a systematic approach based on AHP, TOPSIS, Fuzzy TOPSIS, and GRA, which could be useful in the layout selection process and also the practical method to implement feasible layout.

CHAPTER 6

IMPLEMENTATION OF LEAN SERVICE TOOLS AND TECHNIQUES AND ITS IMPACT ON OPERATIONAL PERFORMANCE

This chapter focuses on appropriate lean tools and techniques implemented in NSH, India Post service, and actions taken for removing the wastes (NVA activities). Then, after the implementation of lean service and production performance measures were monitored and also its impact measured through a questionnaire study.

6.1 Applicable Lean Service Tools and Techniques

Table 6.1 shows the appropriate Lean Service (LS) tools and techniques that were implemented in manual sorting center NSH.

Table 6.1: Suitable LS Tools and Techniques Implemented in NSH

Preparing the flow Tools	
Takt time	The number of products to be produced divided by customer demand.
5S	Put the things in a proper place—a place for everything; Everything in its place to enhance the housekeeping. 5S contains sorting, set in order, sweeping, standardization and self-discipline.
SOP	Standardization of operating procedure. Each operation should be standardized and definite work.
Single piece flow	The process inside the organization should be in a single flow. There is no backtracking of the mails.
Setup time reduction	The reduction of tool setting time to the absolute minimum leads to a decrease in cycle time.
Mapping and Analysis Tools	
VSM	VSM tool is to identify both value and NVA activities. It gives a bird view of the entire process flow and production performance metrics.
Process Mapping	A flow chart of the entire process of material and human movements

Quality Ensuring Tool	
Visual Management	Visualize the objects in the proper workplace. Even an unfamiliar person can know about the current details of the shop floor.
Process Improvement Tools	
Facility layout change	To improve the production rate and facilitates workstation and reduce human walking distance.
Kaizen/ Continuous improvement	A kaizen event is a small incremental activity typically takes 3-5 days of employee involvement in a specific task/job.
Cellular approach (Nagare Cell)	Inline and simplify the process flow using the Nagare cell approach to reduce the space and increase the production efficiency by grouping the articles such as TD and Non-TD sorting sections.
Workload balancing	Giving the load uniformly to all the employees using systematic scheduling and careful analysis.

Initially, postal employees did their sorting operation in a line sequence. The movement of the personnel during the sorting process takes longer throughput time between Town Delivery (TD) articles and Non-TD articles sorting cases. After modifying the facility layout, TD and Non-TD separated and implemented a cellular approach (grouping the sorting case into TD and Non-TD sorting case). After that, the throughput time and walking distance of employees' movement reduced. Initially, they were not providing separate sections such as trolley, basket, and empty bags. After implementing a lean system, these sections were provided and the improved housekeeping through 5S and visual management. For all these modifications, the postal administration has been well supported, and they have approximately spent INR 2.0 Lakhs.

6.2 Elimination of Eight Types of Waste

Table 6.2 shows eliminating wastes by suitable courses of action taken. Here, they were combined, separated, isolated, modified the sections to reduce or to remove the NVA.

Table 6.2: Identification of Wastes (NVA) and Action Engaged by the Postal Administration

8 forms of waste	Postal Service	Action was taken (Improved code)
Transportation	Unnecessary moving mails (Backtracking of mails)	M, N, O, P
Inventory	Storage of delivery mails, receiving mails, Storage of outdated sorting cases, instruments, etc.	N, O
Motion	Search for mails, documents, bending down for sorting mails, stretching to reach a scanner, repeating movements due to incorrect operation sequence.	M, N, O
Waiting	Waiting for mail for scanning sorting operations. The personnel wait for instructions, printing, instruments, etc.	M, N
Over-production	Unnecessary printing, scanning, sorting, etc.	M, N
Over-processing	Use of excessively strict rules, Preparation of reports, more authorization procedures	M, N, O, P

Defects .	Memo with fine, nonconforming documentation, instructions/procedures carried out in the wrong way, misinterpreted sorting, etc.,	M, N
Underutilization of skill	Resources	N, Q

Improvement code:

M - Workstations combined

N - Modifications of Layout & Moving of Workstation (Decrease in Material Handling distance & Employeee movement)

O - Relocation of station

P - Workstations divided

Q - Job balanced among workstations

The transportation time and inventory between the adjacent sections also were considered as one of the wastes.

6.3 Cycle Time Reduction

Table 6.3 shows that the processing time takes 314 seconds for 50 articles count, which started from the bag receiving to dispatch section after implementing the lean service. The cycle time was reduced after 4-month observations. Here, workstations 2 and 3 are the majorly reduced cycle time, such as scanning and sorting operation. On a trial basis, a fixed scanner has been used for the article scanning to reduce the cycle time and shoulder pain of the scanners. Hence, the scanning cycle time was reduced from 85 to 72 sec.

Table 6.3: After Implementing Lean Service Operations Cycle Time

S. No	Operation	Seconds
1.	Bag receiving	60
2.	Scanning I	72
3.	Sorting	98
4.	Scanning II	66
5.	Sealing and Dispatch	18
	Total	314
	In min.	5.233

It was found that in the sorting section, over-processing is the significant waste (bottleneck) during the operations. '**Blue Tag'** has been implemented for TD articles pin code sticker and '**Red Tag'** for Non-TD articles for easy identification of the pin code place in the sorting or pigeon box. Also, a focus light has been provided to improve the visual ergonomics for the address's readability with pin code. Thus, this modification has reduced the cycle time from 125 sec to 98 sec.

6.4 Facility Layout Modifications

Facility Layout Design (FLD) selection problem was solved either when a company starts looking for a new site or when trying for a new business to that area or interchanging departments. This study presents the MCDM model for the India Post seeking operational excellence through modifying the inter-changing departments and simplifies the process through a single piece flow. Hence, the MCDM model can provide to help the decision-makers examine the numerous layout designs, assessing layout alternatives, and choose the optimal one.

The hierarchy structure chain starting with goals is followed by criteria, sub-criteria, and ending with alternatives (complete hierarchy chain). The MCDM model provides the decision-makers' priorities focusing on layout characteristics, employees' managerial experience, and judgment. This research work was initiated by Indian Postal service to improve operational excellence through the production and betterment of the workplace environment. The main goal of the MCDM decision model is to satisfy the decision-makers from alternative designs of facility layout problems. In reality, FLD is a complex problem to select optimal one from a set of layout design alternatives.

The data provided in these FLD problems explored with suitable data sets from India Post service by identifying the issues and modifying the entire existing layout. Figure 6.1 illustrated the modified layout in a 3D model. The modifying layout has some advantages, as follows:

- Improved production rate 9.62% from 8620 delivery articles
- Improved housekeeping and visual ergonomics
- Improved workplace environment
- Improved mail flow with in organization

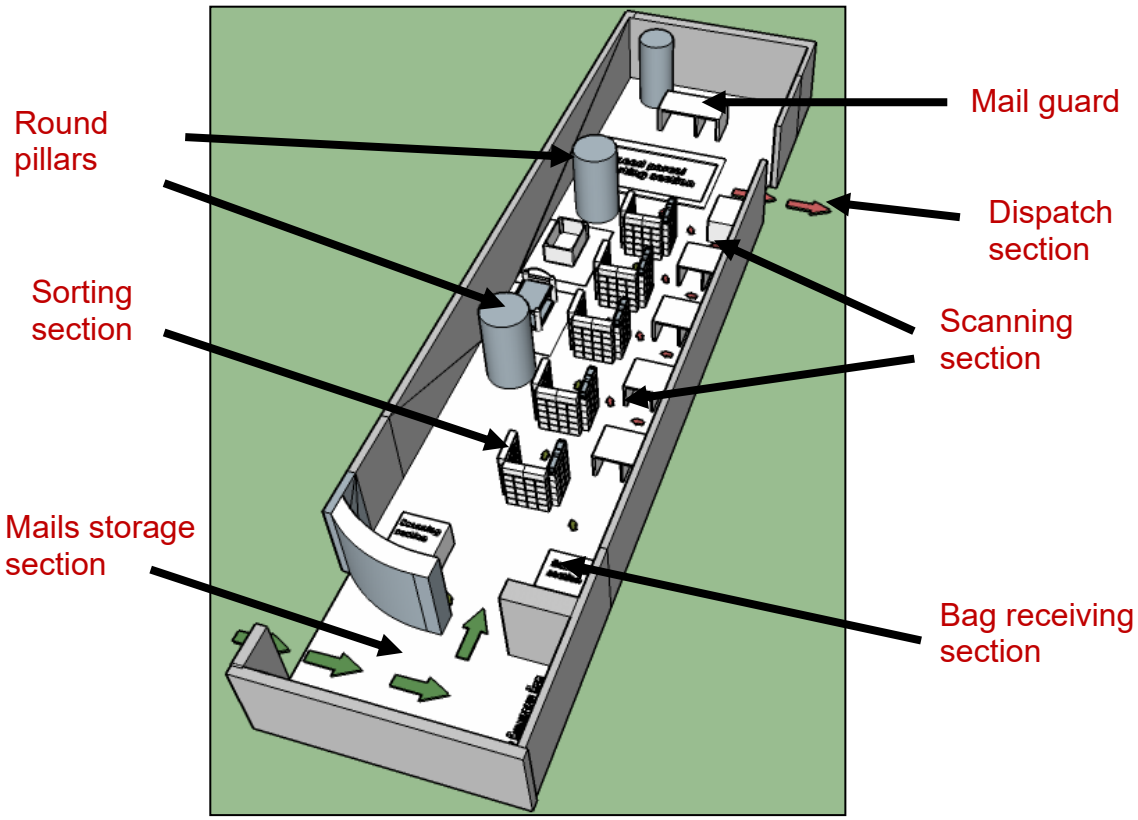


Figure 6.1: Implemented Feasible Layout – NSH Office, Green Arrows Indicate Receiving the Mails, While Red Arrows Indicate Dispatch of Mails.

The MCDM layout model helps the managers analyze the hierarchical structure entirely and thoroughly in advance. Managers can gather the required information, time allocation, cost expansion, and getting support from the employees. Meanwhile, managers can get a lacking of data by visualizing the complete hierarchy structure during a brainstorming session among the postal employees. The layout changes or finding the new location is subject to the location site or layout characteristics and the management requirements.

A general complaint from practitioners is that giving righteous judgment or comparing layouts on qualitative factors is purely based on subjective consistency. Hence, providing the right result is beyond the nature of human beings. In a practical sense, the proposed MCDM applied layout model was attractive to the managers in the way of pair-wise comparison mechanism. Hence, managers give the relative grading rather than absolute

preference, at a time, on qualitative items. It is observed that the projected MCDM applied layout model is exciting and practically provides insight to industrial engineers and managers. The layout model, which has been implemented successfully in NSH, can be a benchmarking for the other postal service to enhance operational performance.

6.5 Production Measures

Relevant production metrics have been considered to determine the production performances in NSH, such as flow speed, individual articles delivery in a day, synchronizing ratio, takt time, space utilization, etc. Table 6.4 exemplified the production performance measures before and after lean service implementation. Figure 6.2 shows the comparison of the delivery of articles before and after lean service implementation.
Production measures are calculated as follows:

- The flow speed is the ratio of the number of units produced to the line/system's loading hours.
- The takt time is the available working time to the delivered articles demand per day.
- The synchronizing ratio is Production at tier divided by delivery to the tier.

Table 6.4: Production Performance Before and After Lean Service Implementation

Descriptions	Existing layout	Lean implemented layout	Improvement observed past 12 weeks	Improvement observed past 60 weeks
Processing time per person/day	8620	9450	9450/day (9.62%) ↑	9600/day (11.36%) ↑
Flow rate / hr	538.75	590.62	590.62/hr (9.62%) ↑	600/hr (11.36%) ↑
Cycle time	371 sec	314 sec	314 sec (15.13%) ↓	314 sec (15.13%) ↓
Takt time	6 sec	5.52 sec	5.52 sec (8%) ↓	5.43 sec (9.5%) ↓
Synchronizing ratio	0.86	0.94	0.94 (9.30%) ↑	1.01 (17.44%) ↑
Space occupied	416 sq.ft	389 sq.ft	389 sq.ft (6.4%) ↓	389 sq.ft (6.4%) ↓

↑ - Increment ↓ - Decrement

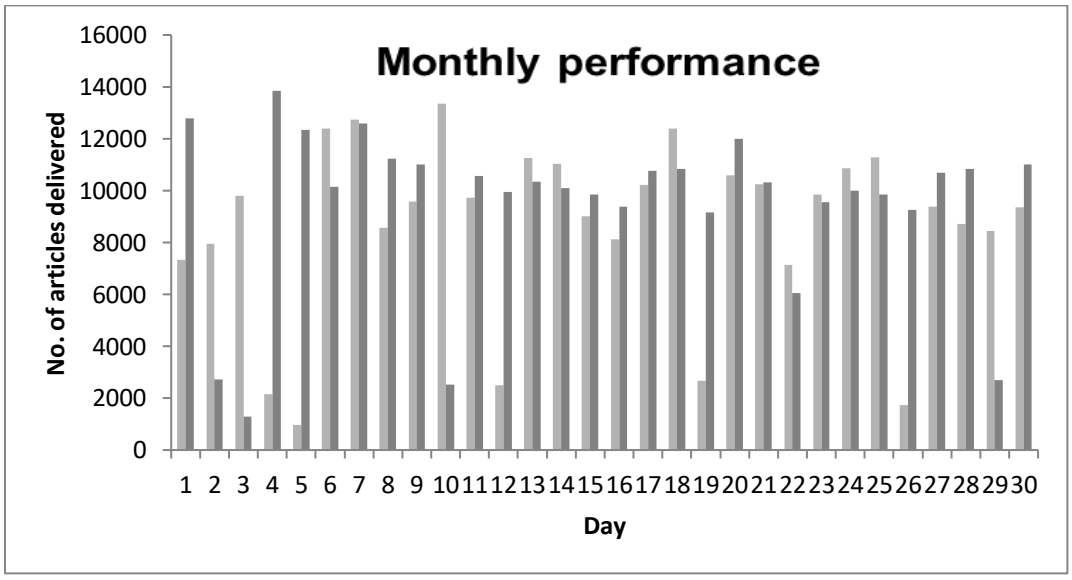


Figure 6.2: Performance in April (2018) – Lean Implemented Layout

After lean implementation (avg.9450 articles/day)

Before lean implementation (avg.8620 articles/day)

6.6 Workplace Ergonomics

In the sorting section, visual ergonomics have improved by providing CFL light for better lighting conditions and focusing on the easy readability of the pin code stickers in the sorting or pigeon box.

6.6.1 Changes in Scanning Method

Existing method: Moving scanning	New method: Fixed scanning
	

Figure 6.3: Proposed Scanning Method in the Scanning Section

In the scanning section, they have been using a moving scanner for scanning the articles, earlier. From the interview, it is understood that the bulk number of articles in a day makes them feel uncomfortable, causing pain in the shoulder, elbow joints, and wrists. Hence, a new fixed scanning method was proposed, as shown in Figure 6.3, on a trial basis. After this, the employees were comfortable by adopting the fixed scanning method, thereby reducing the cycle time by 23.62%, and it also prevents Muskelotical Disorder (MSD) problems.

6.7 Implementing Housekeeping Concepts

Housekeeping concepts were implemented throughout the NSH, which facilitated productive work in the whole organization as shown in Table 6.5. The habit of keeping the equipment in its proper place, sticking posters, and hanging or sticking inspiring positive quotes thereby making an effective use of the bulletin boards and notice boards. Also, providing current production performance details and posting pictures of the best employee of the month in terms of his/her production performance and maintaining good housekeeping in their place has been creating awareness from the employees. Motivating the employees who have been responsible for their working environment should be clean and tidy. Both the internal and external environment should be attractive and functional aesthetics. Now, the lean implemented layout modifications have a strong impression of all working employees as well as on the visitors to the postal office. Also, the sanitization of the dining room and restroom should be hygienic and should always maintain good housekeeping. It is strongly believed that this incorporated housekeeping as a part of lean activity leads to yield high performance in productivity when compared to existing layout performance.

Table 6.5: Implementing Housekeeping Concepts in NSH Office

Initial	After
	
Existing Layout	Present Layout

 Sorting Section - Local	 Sorting Section - Local
 Empty Tray Return Area	 Empty Tray Return Area
 Empty Bag Return Area	 Empty Bag Return Area

 Sorting Section	 Sorting Section

6.8 Impact of Lean Service System on Operational Performance in India Post Service

This assessment aims to study the relationship and impact of the Lean Service System (LSS) on operational performance in mail service operations in India. Measuring the operational performance in mail service is a big challenge in the postal service industry. Therefore, a cross-sectional survey was conducted and measured to study the relationship and impact of Lean Service Practices (LSP), Lean Workplace Environment Practices (LWEP), and Lean Social Practices (LSoP) on Operational Performance (OP) in India Post service.

6.8.1 Questionnaire Study – Lean Service Assessment

A questionnaire (survey) has been given to the working employees of NSH Mangalore. Tables 6.6 and 6.7 show the postal employees' demographic details and the results of the questionnaire study. Here, the number of sample size for the questionnaire study is 150. Total postal employees working in NSH, Mangalore has been considered for this study.

Table 6.6: Demographics Details for the Study (n =150)

Profile of respondents (Postal employees)	Public Postal Service	
	Frequency (n=150)	Percent
Gender		
Female	30	20.0
Male	120	80.0
Age		
21-35	75	50.0
36-50	55	36.7
Above 51	20	13.3
Education Level		
SSLC	35	23.3
Secondary education	30	20.0
Graduate	60	40.0
Post Graduate	25	16.7
Work Experience		
Less than 3 years	45	30.0
4-14	55	36.7
15-25	20	13.3
More than 25 years	30	20.0
Employment Type		
Permanent	85	56.7
Temporary	65	43.3

6.8.2 Validity and Reliability of Scales

Cronbach's alpha tested the reliability of the overall LSPs, LWEPs, LSoPs, and Operational Performance items. The alpha meets the recommended levels of 0.70 for all LSS dimensions (Hair et al. 1998) showed the right internal consistency.

Table 6.7: Results of the Questionnaire Study

Construct	Items	Factors loading	Cronbach Alpha (α>0.7)	KMO (n > 0.6)	Mean	Standard Deviation
Lean Service			0.773	0.726	3.8278	0.8213
	Value stream mapping (VSM)	0.670				
	5S	0.621				
	Improving facility layout	0.796				
	Cellular layout	0.686				
	Single piece flow	0.721				
	Visual identification	0.663				
	Workload balancing	0.739				
	Process redesign	0.714				
	Reduce cycle time	0.821				
	Reduce lead time	0.645				
	Improve flexibility	0.645				
Workplace Environment			0.712	0.635	3.5407	0.9713
	Lighting facilities	0.752				
	Ventilation	0.710				

	Visual identification	0.668				
	Noise control	0.627				
	Temperature	0.671				
	Cleanliness	0.881				
	Workspace	0.832				
	Drinking water facilities	0.763				
	Equipment availability	0.705				
Social Practices			0.713	0.691	3.5407	0.9703
	Effective communication system	0.745				
	Employee empowerment	0.705				
	Employee commitment	0.652				
	Performance measurement system	0.626				
	Employee involvement	0.670				
	Multi-skill employees	0.883				
	Leadership	0.834				
	Management support	0.764				
	Training	0.707				

Operational Performance			0.797	0.726	3.8133	0.8087
	Improvement in space utilization	0.622				
	Improvement in employee performance	0.647				
	Employee understanding the process	0.642				
	Improvement in productivity	0.739				
	Improvement in lighting facilities	0.755				
	Improvement in ventilation facilities	0.672				
	Improvement in housekeeping	0.677				
	Reduction in inventory	0.681				
	Reduction in cycle time	0.641				
	Reduction in human errors	0.690				

From Table 6.7, the “LSPs” items have the maximum mean score (3.827), while “LSoPs” and “LWEPs” items have the minimum mean score (3.54).

6.8.3 Correlation Analysis

This analysis was computed to find the association between LSS and its relationship on operational performance. High, significant, and positive correlation was found between LSPs ($r = 0.728$, $p < 0.001$) and operational performance. Hence, there is a strong relationship between LSPs and operational performance. In addition, to this, significantly strong correlation was also found between LWEPs ($r = 0.722$, $p < 0.001$) and operational performance. Strong correlation was found between LSoPs ($r = 0.654$, $p < 0.001$) and operational performance in India post service industry. Overall, LSS has an important positive outcome on operational performance in NSH, Mangalore, Southern part of India. For more details, see Table 6.8.

Table 6.8: Pearson Correlation Matrix of Operational Performance

		Lean Service Practices	Lean workplace Environment Practices	Lean Social Practices
Operational performance	r	0.728	0.722	0.654
	p	0.000	0.000	0.000

Note: r – Pearson correlation coefficient; p is the level of significance $p < 0.001$.

6.8.4 Multiple Regression Analysis

Multiple regression analysis was used to analyze the impact between a single dependent variable and independent variables. The LSS has been categorized into two variables. The lean service practices, lean workplace environment practices, and lean social practices come under the independent variables, whereas operational performance comes under the dependent variable. Table 6.9 shows the model is highly significant and LSPs, LWEPs, and LSoPs altogether explain 69.3 percent of the total variation in operational performance, indicating a good model fit.

Table 6.9: Model Summary

Model	R	R square	Adjusted R square	Std.error of estimate
1	0.832[a]	0.693	0.687	0.29077

[a] Predictors: (constant) Lean Service practices, Lean Workplace environment practices, Lean Social Practices.

The standardized regression coefficients(β) indicate there is a significant impact on the LSS (Independent Variables) on operational performance (Dependent Variable).

Table 6.10: Beta Coefficient of Operational Performance Dimensions

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity statistics	
		B	Std. Error	Beta (β)			Tolerance	VIF*
1	(Constant)	-1.943	0.444		-4.376	.000		
	LSP	1.058	0.119	0.484	8.893	.000	0.709	1.410
	LWEP	0.227	0.070	0.307	3.234	.002	0.234	4.281
	LSoP	0.168	0.082	0.182	2.047	.042	0.267	3.752

Note: VIF*: Variance Inflation Factors. Dependent variable: Operational performance.

Here, in this result, lean service practices with the highest standardized beta, i.e., (0.484), have the most statistically significant influence on operational performance (Table 6.10). It was followed by a lean workplace environment practice value of 0.307, which is still statistically significant in effect on operational performance. Then it was followed by lean

social practices value is 0.182. Hence, concluding that LS implementation is not giving much impact on social practices such as effective communication systems, employee involvement, leadership skills, and training, etc.

6.9 Research Hypotheses Results

The hypotheses postulated were tested by correlation and multiple regression analysis. Table 6.11shows the hypotheses results.

Table 6.11: Results of Hypotheses Testing

Hypothesis	Description of Path	Correlation Coefficient (r) and p-value	Standardized Beta (β) Coefficients and p-value	Hypothesis Testing
H1	LSPs->OP	r = 0.728; p < 0.001	β = 0.484; p < 0.001	Supported
H2	LWEPs->OP	r = 0.722; p < 0.001	β = 0.307; p< 0.002	Supported
H3	LSoPs->OP	r = 0.654; p < 0.001	β = 0.182; p < 0.042	Supported

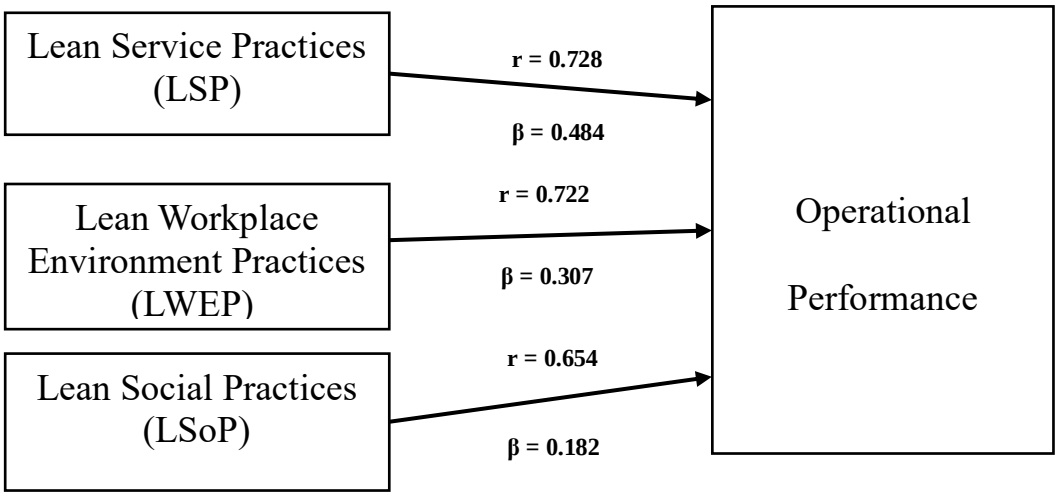


Figure 6.4: Path Model of Lean Service System on Operational Performance Implemented in NSH Post Office

Hypothesis H_1: There is a significant impact on lean service practices and positive relationship on operational performance in India Post service.

The path from lean service practices to operational performance ($\beta = 0.484$, $p<0.001$) was positive and significant and ($r = 0.728$, $p <0.001$) positive strong relationship. Hence H_1 is supported (Table 6.11 and Figure 6.4).

Hypothesis H_2: There is a significant impact on lean workplace environment practices and positive relationship on operational performance in India Post service.

The path from lean workplace environment practices to operational performance ($\beta = 0.307$, $p<0.002$) was positive and significant and ($r = 0.722$, $p <0.001$) positive strong relationship. Hence H_2 is supported (Table 6.11 and Figure 6.4).

Hypothesis H_3: There is a significant impact on lean social practices and positive relationship on operational performance in India Post service.

The path from lean social practices to operational performance ($\beta = 0.182$, $p<0.05$) was positive and significant and ($r = 0.654$, $p <0.001$) positive strong relationship. Hence H_3 is supported (Table 6.11 and Figure 6.4).

6.10 Summary

Suitable lean service tools were implemented in NSH to reduce wastes and improve the production, environmental, and housekeeping concepts. Pearson correlation coefficient results indicated that there was a strong correlation between LSP ($r = 0.728$), LWEP ($r = 0.722$), and LSoP ($r = 0.654$) and operational performance. Significant impact on LSP ($\beta = 0.484$) on Operational performance, then LWEP ($\beta = 0.387$) and followed by LSoP ($\beta = 0.182$) on operational performance. The practical effect of the findings of the LSS is successfully implemented to enhance the postal business operational performance. This study addresses to find the appropriate empirical model to test a LSS in India Post service industry, which is scant in the existing literature. Moreover, this study helps lean practitioners to design and develop the required lean tools/techniques to implement in different service sectors.

CHAPTER 7

DEVELOPMENT OF SIMULATION MODEL FOR DESIGN OF LEAN SERVICE SYSTEM IN INDIA POST SERVICE

This chapter explains the importance of the VSM simulation through and hybrid Taguchi methods by applying it in NSH, India Post service. VSM method helps to find and eliminate wastes. Then, the simulation method is advocated for improving the existing production by imitating the actual production model. Finally, the Taguchi method is opted for optimizing production performance measures.

7.0 Introduction

This study aims to present an innovative approach in designing a Lean System (LS) in the Indian Postal service industry using Simulation and Taguchi methods to reduce the complexity of the system. By using logic and systematic building blocks, simulation models have been developed from Lean Service (LS) elements using the Arena software suite. Five control factors were considered for the system's performance: takt time, process ratio, production lead time, value-added time, and inventory. Simulation is used to replicate the real model and to guide the future production system, and the Taguchi method is used for the robust system to find out the optimal parameter values. Simulation studies have been divided into two perspectives, "before LS" and "after LS" through Value Stream Mapping (VSM). It has been found that there is a 11.36 percent enhancement in delivering articles per person. A real case of postal service internal operational performance has been taken for the study. Simulation and Taguchi methods have been applied for standardizing optimum parameters. This study is the first one of its kind combining Value Stream Mapping - Simulation (VSM-Sim) with the Taguchi method to simulate and optimize the operational performance parameters in the mailing service operations.

7.1 Rationale of the Study

- The lengthy existing procedures/rules involved in the internal operations are time-consuming.
- Standardization of operating procedure needs to be focused, and errors committed by the employees are on a high side.
- The working environment has cramped accommodation for its workers, old and uncomfortable furniture, poor lighting, outdated tools, the old building (infrastructure) of the post office and its counters, lack of cleanliness and shabby appearance, etc. with a shortage of facilities in the post department. Implementing simulation through the understanding of the VSM current state and optimizing the parameters of the operational performance items is an essential factor to enhance the facilities.
- Almost all the foreign postal administrations such as Japan, the UK, the USA, South Korea, etc. have already embarked on modernizing postal services and have achieved greater efficiency in customer satisfaction. The transformation in their administration practices has dramatically changed to providing efficient, speedy, and responsive counter services.

7.2 Literature Review related to VSM and Simulation

Many pieces of literature supported the VSM application with simulation in manufacturing firms. Slowly, it will be used in a few service sectors. For example, Yang et al. (2015), Gurumurthy, and Kodali (2011) and Yuan-Feng et al. (2020) have mentioned the importance of VSM along with simulation in the manufacturing sector to increase production. Whereas, Cavdur et al. (2018) and Robinson et al. (2012) have used the system in public universities and hospitals to improve the maintenance and to repair the entire operations and to increase the patient service rate in the hospital. Gul, M, and Guneri A.F. (2015) mentioned the significance of simulation as an active system to enhance the operational policies, strategic and tactical decisions, particularly in the emergency department in hospitals. Further, Table 7.1 shows the description of literature support using

VSM with simulation techniques that were applied in different manufacturing and service sectors.

Table 7.1: Brief Literature Review related to VSM and Simulation

S.No	Author(s) and year	LS elements used	Industry	Remarks
1.	Cavdur, F. et al. (2018).	Lead time, Waste reduction, VSM, Optimum resource utilization.	Public university	Two simulation models established to analyze the system. They simulated the maintenance and repaired the university campus.
2.	Yang, T. et al. (2015).	Production unit, pacemaker process, batch production, and supermarket size.	Fishnet production	DOE and simulation model used for optimizing tools for the five control factors. Reduce WIP by 33.92%.
3.	Gurumurthy, A., & Kodali, R. (2011)	5S, Kaizen, Layout change, and Line balancing	Windows manufacturing plant	Basic LM elements compared to the performance measure. With the help of VSM and simulation tools, results showed that substantial enhancement in production and reduction in

				inventory, cycle time, floor space, workforce, etc.
4.	Lu, J. C. et al (2011)	Takt time, Cycle time, Pacemaker selection, Continuous flow, supermarkets principle, level scheduling, etc.	TFT-LCD manufacturing firm	MCDM (TOPSIS) and hybrid Taguchi technique used for finding the customer demand uncertainty (Noise factor). The simulation results indicated that the average cycle time was decreasing from 15.4 days to 4.82 days by comparing the current and Future VSM.
5.	Omogbai, O., & Salonitis, K. (2016).	Setup time, Changeover time, TPM, Activity processing time, Process scrap rate, Motion waste, Supplier lead time.	Print packaging manufacturing	They presented a discrete event simulation model for lean practices within a manufacturing system.
6.	Gnanavel, S. S. et al. (2015)	Process map, Cycle time, workload	Automotive ancillary unit	Ergonomically designed looping layout (Nagare cell)

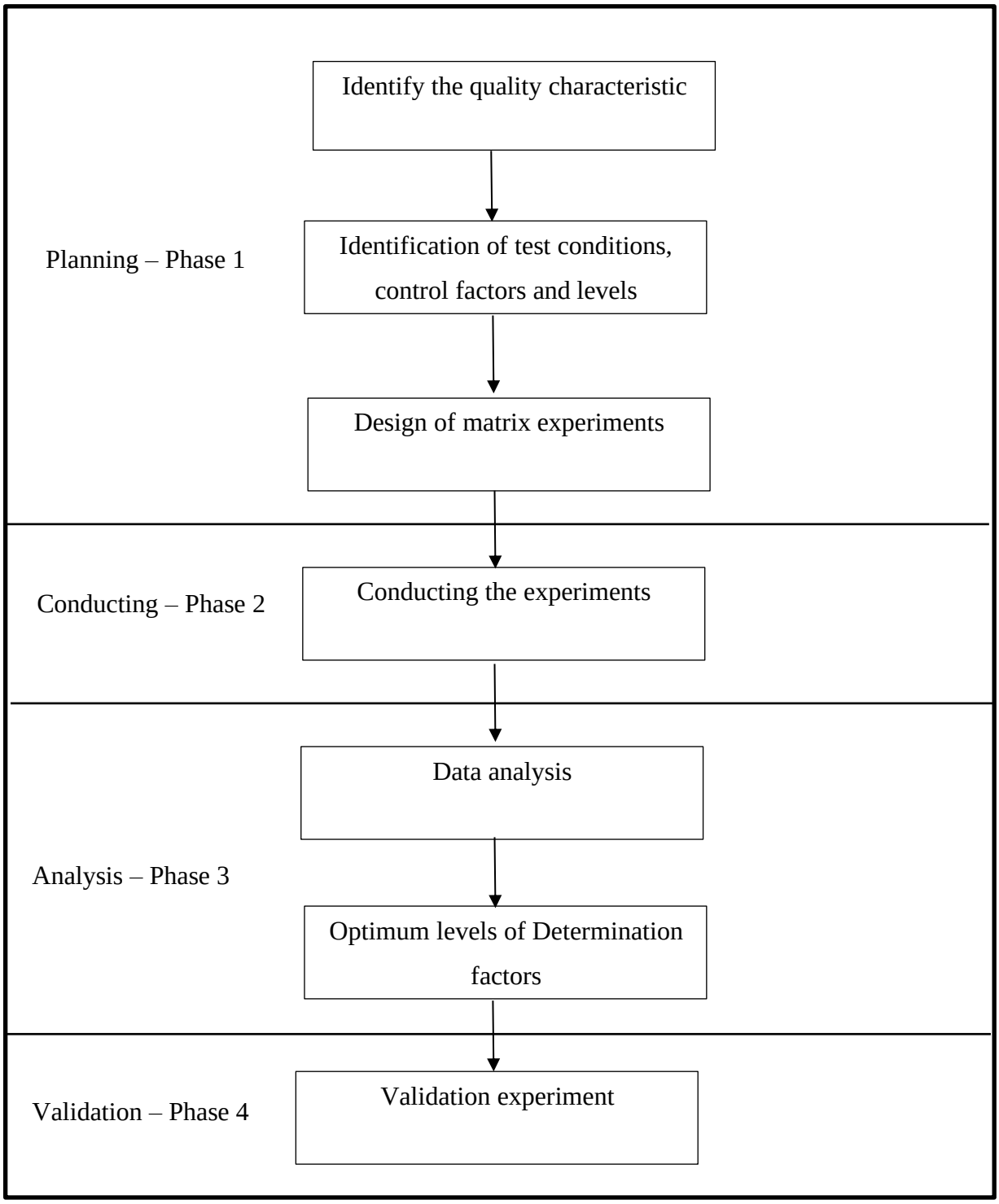
		leveling, throughput, layout design, Nagare cells.		simulated in the LM environment. The impact yielded 10% productivity by changing workplaces and work design without the addition of the workforce.
7.	Robinson, S., et al (2012).	Waste reduction, Process map,	Healthcare Industry	Discrete event simulation applied in hospitals in theoretical and empirical perspectives to increase the service quality of patient.
8.	Shakil, S. I., & Parvez, M. (2020).	Production lead time, inventory, and processing time.	Sewing Industry	From the current VSM, non-value-added activities identified. The rough set theory applied for focused on lean approach which area can be improved. The results show that OEE enhanced from 45 to 53.75%.
9.	Yuan-Feng Wen. et al. (2020)	Pulling strategy, Dispatching	Semiconductor crystal-ingot	Taguchi and simulation

		rules, Machine limitations, and Batch-size.	pulling manufacturing	optimization used for the robust system. The system performance-enhanced from 6.42 to 12.02 percent in service level and throughput.
10.	Baumer-Cardoso, M. I. et al (2020)	Kanban tools, and green model	Brazilian company job shop	Results showed a positive correlation between lean and green on operational performance indicators.
11.	Mahmood, A. (2020).	VSM with Simulation	Yarn Manufacturing process	Lean impacts reduced labor, increased synergy, and most importantly avoided blame game that is the mother of all problems in most of the textile mills.
12.	Melin, M., & Barth, H. (2020).	VSM and lead-time	Swedish dairy farm	Results showed a positive correlation between lean and green on operational performance indicators.

13.	Balaji, V. et al. (2020).	VSM	Industrial Internet of Things (IIoT)	VSM becomes dynamic in a sensor-based efficiency monitoring system. Bottleneck operations continuously monitored and try to eliminate through expert people.
14.	Deshkar, A. et al (2018).	TAKT time, processing time, production lead times, VSM.	Plastic bag manufacturing industries	The result showed that takt time reduced from 46 minutes to 26.6 minutes. VAT increased by 74.5%.
15.	Alzubi, E. et al (2019).	The manufacturing lead-time and Overall Equipment Effectiveness (OEE).	Wooden Furniture Industry	The manufacturing operation was increased by 15.8 % from the bottleneck operations.

7.3 Taguchi Method

Taguchi method is a statistical technique developed by Genichi Taguchi for a robust system. It aims to improve the quality process, decrease the number of experiments, and to reduce the process variation. Taguchi Orthogonal Array (OA) design is a general fractional factorial design. It works based on planning, conducting, and evaluating results of matrix experiments to find the optimum control factors level. Readers can read further details on Montgomery (2017). Figure 7.1 shows the proposed Taguchi method.



Source: Tugrul Ogulata, R., & Mavruz Mezarcioz, S. (2011)

Figure 7.1: The Taguchi Method for Optimization

Lin, C.W. (1987) described the product and process design using simulation and Taguchi methods in assembly-line problems in his paper. Monto-Carlo simulation was applied for various assembly process modules in that design. Taguchi method used to identify the significant factors of the component dimensions in the assembly line. Yang et al. (2020) have applied the Taguchi method to optimize the parameters of the system after simulation optimization. They have used batch-size control, machine limitations, pulling strategy, and dispatching rules as four control factors for operational performance. The result showed 6.42 and 12.02 percent improvement in service level and throughput.

Abd et al. (2016) applied the hybrid method combining Taguchi with fuzzy logic in robotic assembly cells to solve the scheduling problems. They used to control factors such as dispatching rule, sequencing rule, due date tightness, and cell utilization to minimize the number of experiments and reduce the cost. Similarly, Tsai (2002) have also used the Taguchi method for steel soaking-pit/rolling-mill plant to solve facility location decision-making problems. Saidi and Kadkhodayan (2020) have implemented this in copper in the leaching process of copper oxide in the H_2SO_4 solution for optimizing the operating conditions. Mulyadi et al. (2019) have used Taguchi to optimize the speed, feed rate, depth of cut, step over, stay on surface and radius link for CAD/CAM simulation of High-Speed Machining (HSM) operations.

7.4 Proposed Methodology

The proposed methodology used three techniques, as shown in Figure 7.2.

1. Value Stream Mapping - To find and eliminate the NVA.
2. Simulation model - To replicate the current state production system. To identify and to eliminate the waste and to improve the future state model.
3. Taguchi method - To optimize the main production metrics such as takt time, process ratio, production lead time, VA time, and inventory.

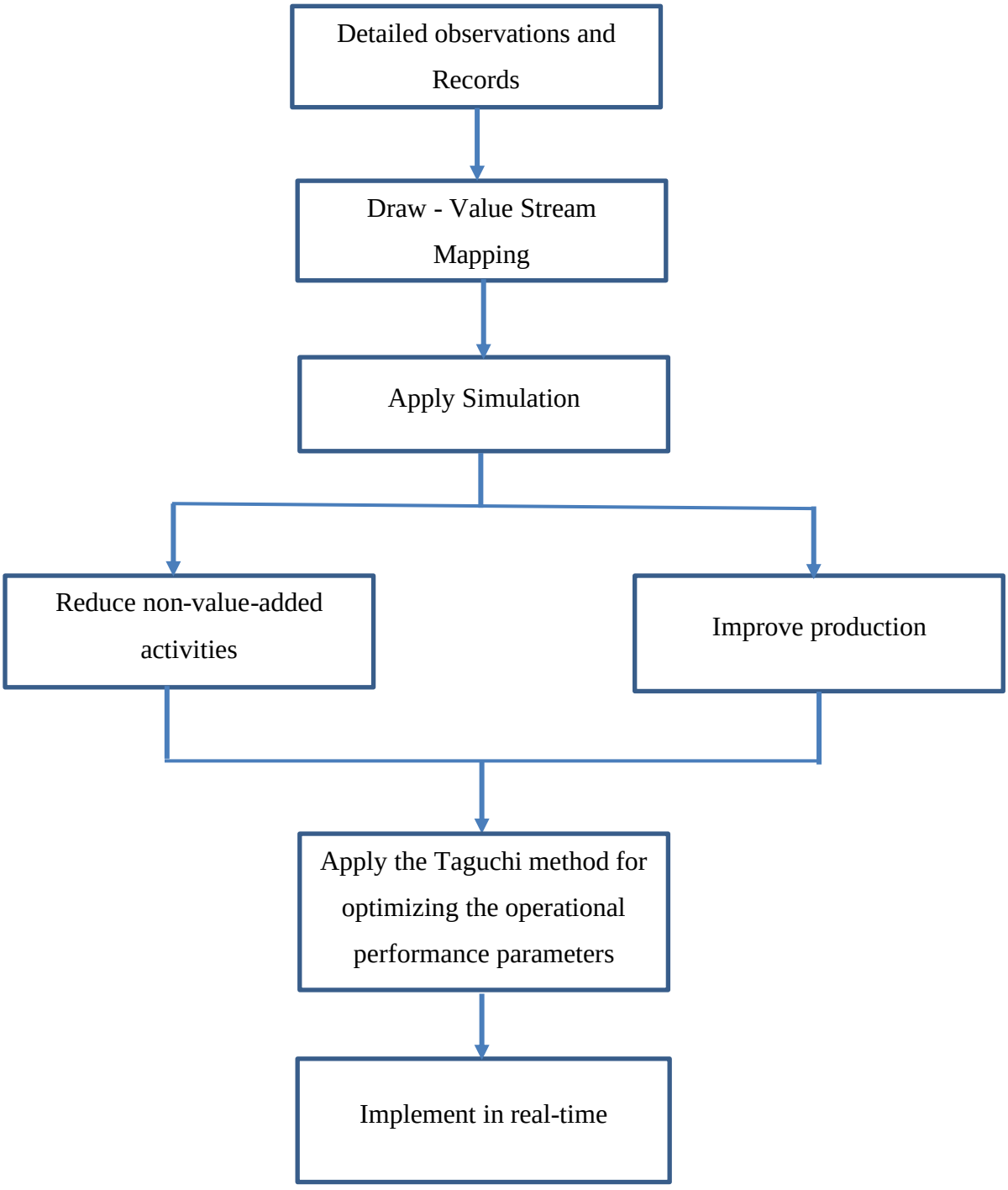


Figure 7.2: Schematic Illustration of the Proposed Methodology

7.5 Case Study: Problem Definition

Figure 7.3 shows the in-line sequence of articles which are processing inside the layout. It has been observed that there are several complications in the internal operations in the postal service operations.

- Delay in the delivery of articles to the addressee. The postal administration gets complaints from the customers about the delay in the delivery of articles.
- Unbalanced workloads for Technicians and labours.
- The distance traveled by the articles inside the layout is 1910 cm. It has to reduce significantly.
- An average delivery article per person is 8620. But postal administration is expecting to deliver at least 10,000 articles per day.
- The workforce has not been utilized correctly this is verified through the manager's interview (underutilization of skill)
- Production performance metrics can be significantly improved on aspects such as takt time, cycle time, VA time, process ratio, and production lead time, etc.

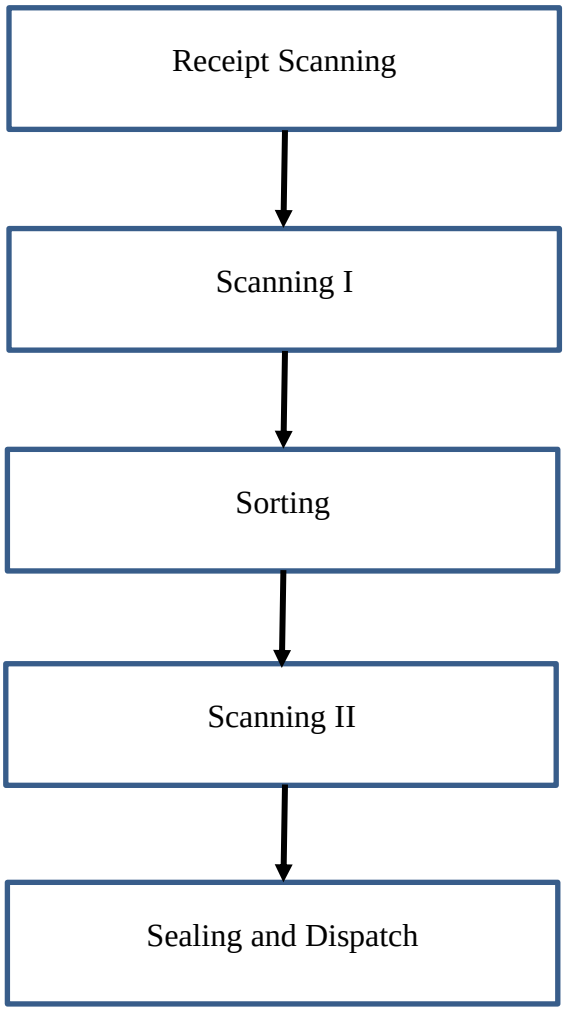


Figure 7.3: Inline Sequences of Articles Processing Inside the Layout

India Post introduced hub & spoke mechanism for speed post articles called as National Sorting Hubs (NSHs). This case study was conducted in one of the NSHs, namely, Mangalore, Karnataka, Southern parts of India. Figure 7.4 shows the existing layout of the process flow details. Initially, the postal van delivers the postal bags in bags receiving section. Then it will move to receipt scanning section for initial screening for the bag's confirmation. After that, it will go to the scanning section for individual articles scanning through a portable, fixed, and moving scanner. Followed that, it will go to the sorting section where all the articles will be sorted in the sorting box according to the pin code.

Each sorting box having 50 pigeon-holes contains blue tags (Local artilces – TD) and red tags (Non local articles – Non-TD) pin code labels. After the sorting process, once again, it will move to the scanning section for pin code wise scanning of the articles and will print the registration lists. Then, it will go to the sealing and packing section, where the plastic tag sealing is done, and finally, it will be ready for the packing (Dispatch) section. For more information, Figure 7.4 shows the existing layout NSH Speed post office.

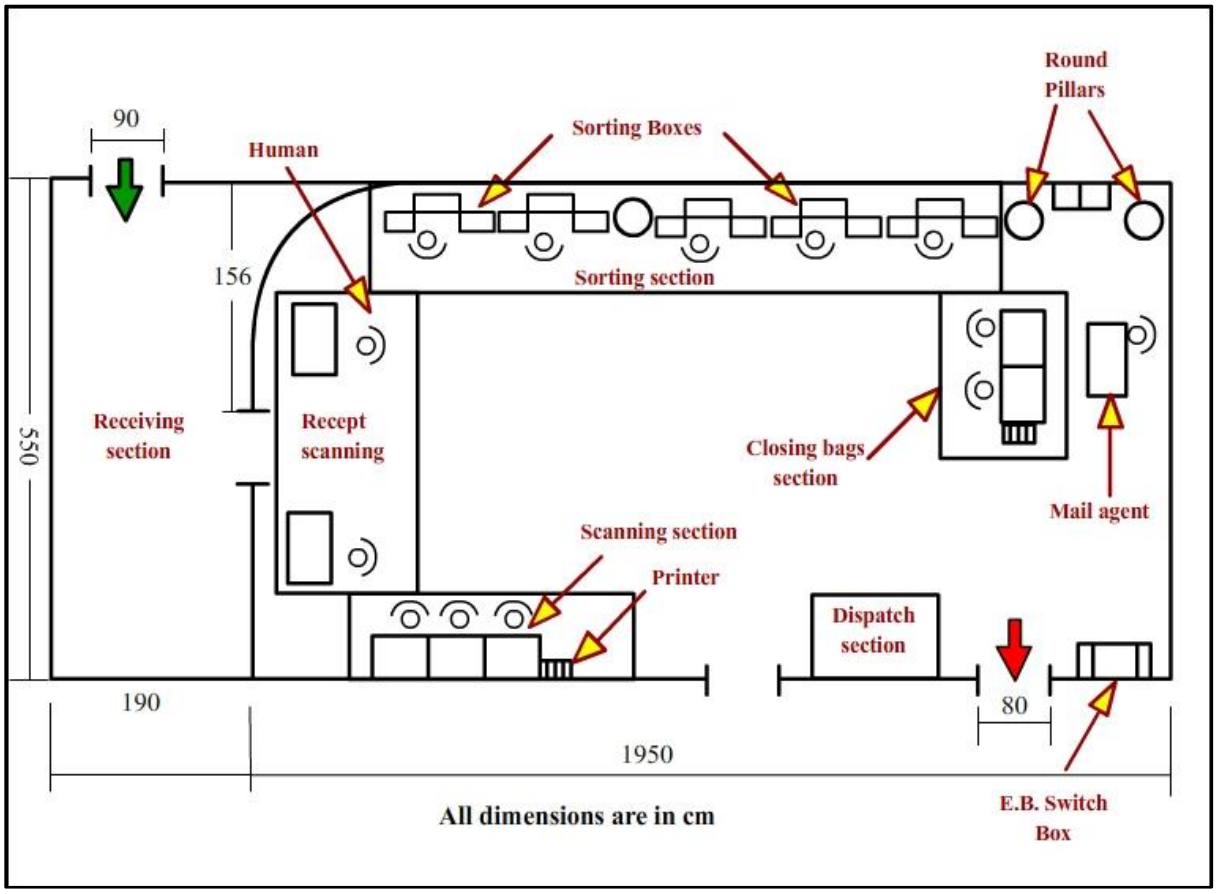


Figure 7.4: Existing Layout NSH Post Office

7.6. Design of LS System

7.6.1 Value Stream Mapping (VSM)

The existing VSM was re-created to identify and to eliminate the NVA, as shown in Figure 7.5. It is found that the sorting process has a bottleneck operation, which takes 125 sec. for sorting 50 articles count. Thus, it needs to decrease the operational timing. The production lead time was 3.735 days. The future state VSM is shown in Figure 7.8, and it signifies that NVA can be removed by remodifying the facility layout. In connection with this, the postal management team requires operational performance enhancement. Also, a brainstorming session was conducted with a focus on group activities. As per discussion among the group activities, sorting boxes were kept near the scanning section to reduce the distance in the from of nagare cell approach.

Then, it is further grouped as a local articles section (TD), and other than that, the non local articles section (Non-TD). Before sorting the boxes, they are kept in linear order, and the sorter has to go to sorting cases according to the pin code. Then, he/she has to sort the letters in the appropriate sorting box. A substantial amount of improvement has been found after modifying the layout. For example, production lead time for the service shows an 18 percent improvement rate at 2.965 days (18 percent improvement) VA time is reduced from 6.17 to 5.23 minutes, and takt time is reduced from 6 to 5.52 seconds. The researchers have simulated current and a future stated VSM to bring out the probable results, which is based on the average value of system parameters.

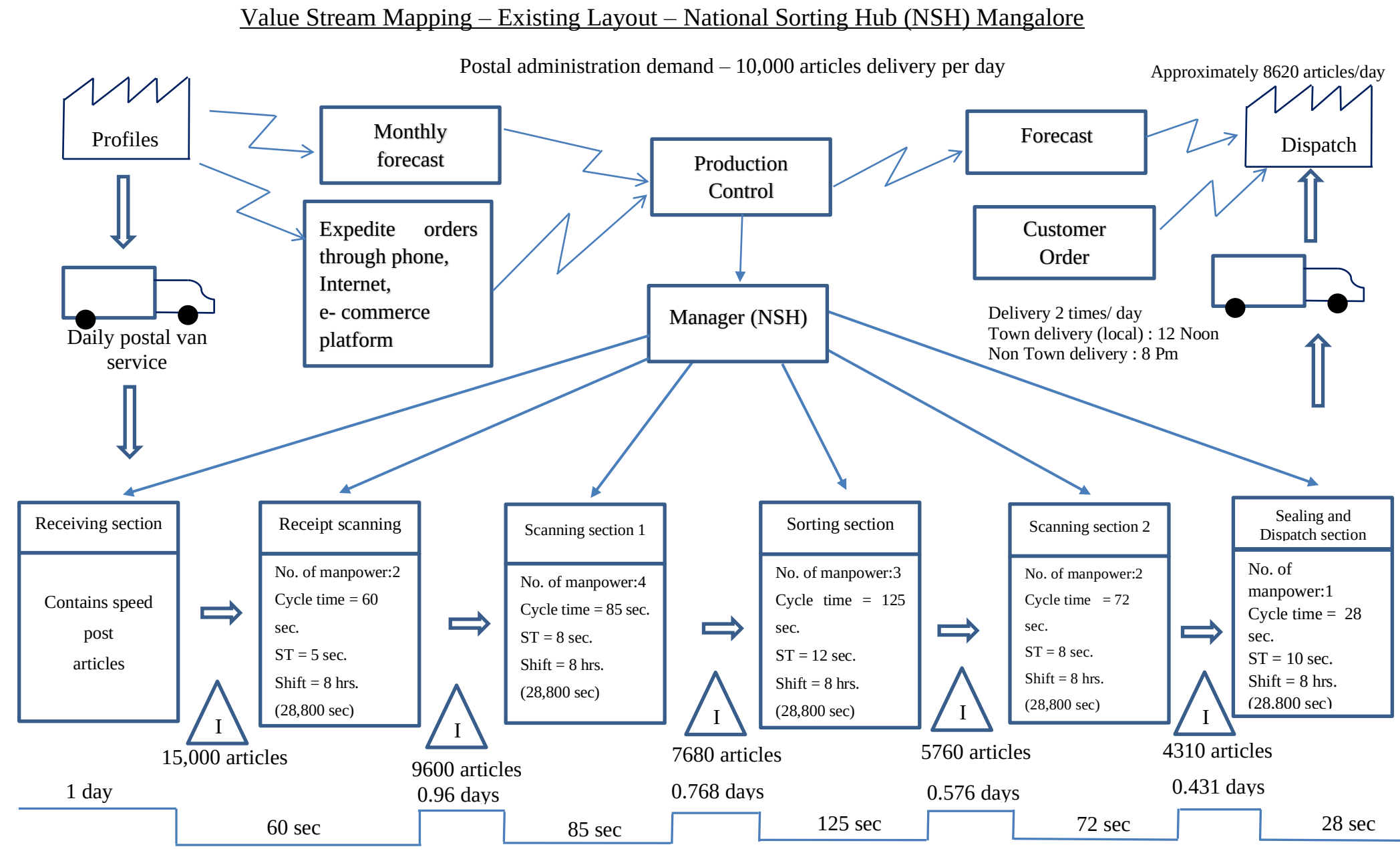


Figure 7.5: Current State VSM – NSH Mangalore

7.7 Simulation Model Development for LSS

7.7.1 Current State VSM Map

During the creation of current state VSM, the collected data were used for simulation model development. Also, data such as space availability, tool setup time, and the number of operators, etc. were collected. Table 7.2 shows the manpower needs and operations descriptions in each section in the postal organization. Mangalore post office is approximately 416 square ft., out of which 389 square ft., is currently used for internal operations.

7.7.2 Assumptions

Certain assumptions were made to confirm that the model replicates the real production activities in case organization NSH, Mangalore. The assumptions are as follows:

1. The Production time is 8 hours in each shift (Including two times break for tea 10-minutes and lunch break for 30 minutes).
2. Operation time is constant (Two similar scanners perform the same operation, then it is considered as constant)
3. Inter - arrival time is the cycle time
4. Active source (Inventory build-up in each workstation)

Table 7.2: Details of Workforce Necessity and Operations Described in the Individual Phase

S. No	Operational sequence	Workforce required		Operations description
		Trainers	Casual	
1.	Receipt scanning	1	2	Receives the articles from the postal van or storage space of the postal bags to proceed for the intake mails/parcels.
2.	Scanning operation - I	2	1	Scans the received articles irrespective of pin code.
3.	Sorting	3	0	Separates the articles based on the pin code in the sorting box. One sorting box contains 50 pigeon holes.
4.	Scanning operation - II	2	0	Scans the articles after sorting process as per the pin code.
5.	Sealing and Dispatch	1	3	Articles are packed and keeps it ready on the floor to send it out through postal van after scanning II operation.
	Total	9	6	

7.7.3 Current State VSM Map - Simulation Model

Figure 7.6 shows a screenshot of the logical simulation model, according to the current stage, VSM operational sequence. In this simulation model, templates of different sections are arranged in a logical order. The current state post office layout was replicated by placing the sections as per the process flow that is shown in Figure 7.6. In each section, the particulars of cycle time (inter - arrival time) and set up time (delay) are placed in the data boxes in terms of uniform distribution (min. time, max. time). From these real data, the current stage VSM is replicated.

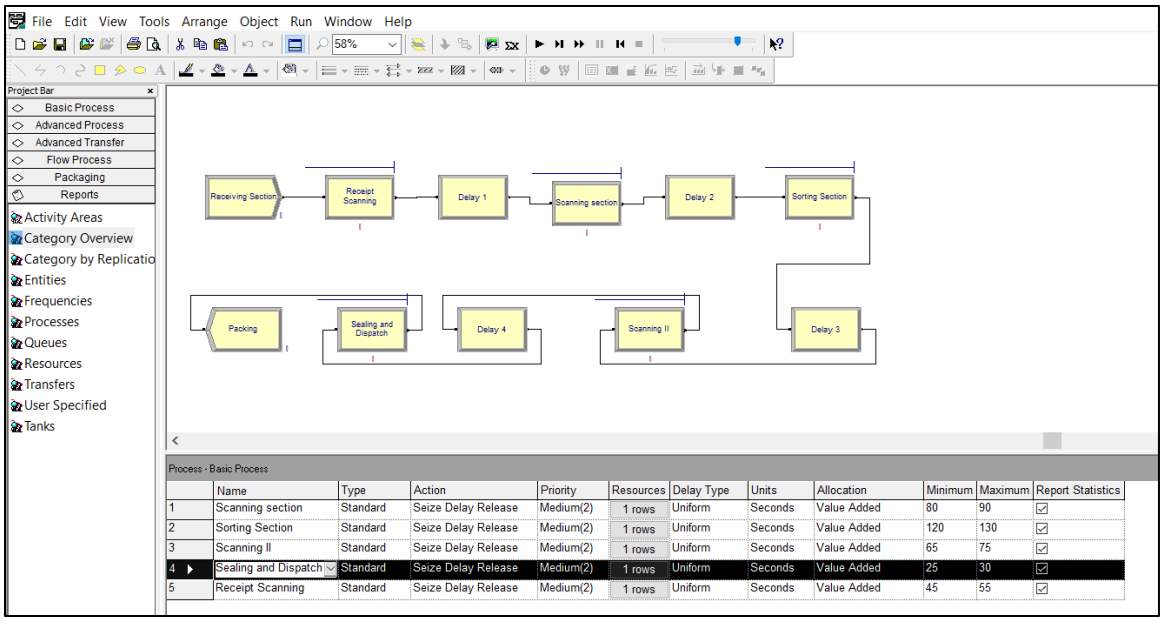


Figure 7.6: Simulation Logical Model - Current State VSM

7.7.4 Future state VSM Map

From the existing state VSM, several NVA (waste) were identified. For details, in section 7.5 postal case problem is explained clearly. Hence, the postal team wants to reduce waste and also to increase internal operational performance. For that, the following LS elements have been implemented.

Layout change – Removing unnecessary wastes such as transportation, waiting, over-processing, overproduction, etc. have resulted in a change in layout. The researchers have planned to utilize the total space from 416 sq. ft. to 389 sq. ft. thereby resulting in 6.4 percent of space reduction.

Line Balancing – Figure 7.5 as shown in the current stage VSM, the operations were not well balanced. For example, the time taken for the scanning operation has been 85 seconds, while the sorting process has been 125 seconds, and scanning operation II has been 72 seconds. Hence, line balancing is required to ensure that the cycle time is equally distributed, more or less equal to takt time. To attain this, placing these two sections adjacent to each side have been proposed. For instance, the Postal Manager had suggested receipt scanning and scanning operations and to have three technicians and three casual

labours. They found that the human resources of two casuals and two technicians are adequate for the combined sections, as both the scanning and sorting were done over-processing. However, the layout has to be modified to enhance these two stages, so that naturally will remove the inventory waste that was created earlier between these two work stations.

Similarly, they proposed to place the scanning and sorting operations nearby. Initially, they had two technicians in scanning II operations and one trainer and three casuals in the sealing and packing section (total of four employees). Postal administration valued that two casuals and one technician were adequate, as these two sections will be closer to each other in the future so that walking distance will be reduced in the new layout. In this way, various process improvements (Kaizen) have been made for line balance, and this has reduced the cycle time.

Kaizens – Continuous improvement activities have been implemented in all sorting, scanning, and sealing and packing operations to eliminate NVA activities. The following kaizen activities have been proposed in a case organization:

Use of Pin code Sorting Tag in Sorting section - Earlier, they were using a black text with a white background in the sorting cases, which was torn and it appeared shabby. The researchers have modified it as follows, for TD blue background with white text tags and for Non-TD red background with white text tags to improve the visual ergonomics in sorting case. Now, employees could easily read, understand, and based on the pin code, they can sort the articles quickly.

Ergonomic posture improvement in scanning and sorting section - From the RBG pain scale, it has been found that working continuously on a moving scanner for almost 8 hours leads to a hand and shoulder pain. A fixed scanner has been provided to reduce the hand and shoulder fatigue.

Sealing and Packing, Sorting sections enhancement – In the current stage VSM, it has been identified that sealing and dispatching section were taking 28 seconds cycle time. The process was studied in detail, and some of the following process improvements were suggested. Earlier, sealing was done by the wax seal, and this had caused respiratory

problems while sealing. Now, with the changing method, that is with the plastic sealing it takes a lesser cycle time of 18 seconds. The employee has to bend more than 60^0 and take articles from the bottom of the sorting case. The employee has to perform the sorting operations continuously for 8 hours, and this was difficult for the employee to sort the articles. Poor posture of employee results increased strain, and fatigue, which will result in MSD problems. The researcher has suggested to use the trolley, in which the bins are mounted at the top of a cart, and it can be sorted quickly without bending his neck and torso.

All the above improvements have been made to decrease the cycle time and setup time in scanning, sorting, packing, and sealing operations. Table 7.3 has exemplified the changes in modified layout.

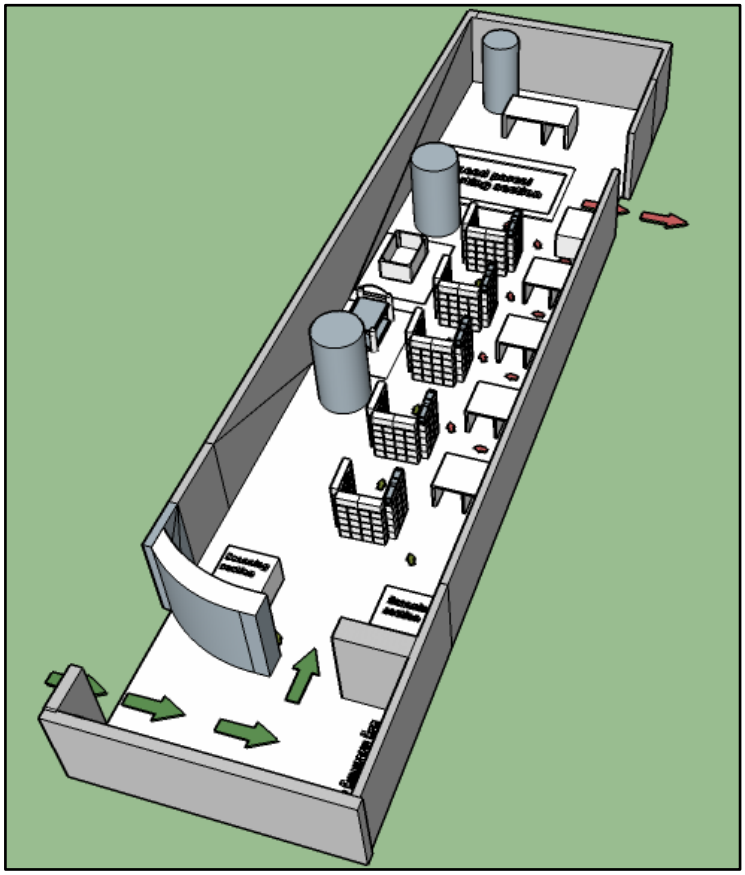
Table 7.3: Modified Layout Changes

S.No	Operational sequence	Manpower required		Operations description	Modifications
		Trainers	Casual		
1.	Receipt scanning	1	2	Receives the articles from the postal van or storage space of the postal bags to proceed for the intake mails/parcels.	• Distance reduced between the storage section and receipt scanning section.
2.	Scanning operation - I	1	0	Scans the received articles irrespective of pin code.	• On a trial basis, one fixed scanner used for scanning the articles to reduce the cycle time and fast process.

					• Distance reduced between the receipt scanning and the scanning section.
3.	Sorting	2	0	Separates the articles based on the pin code in the sorting box. One sorting box contains 50 pigeon holes.	• U shaped Nagare cell formed to reduce the distance. • Pincode tags were changed; blue background with white text for Local articles (TD) and Red background with white text for Non-Local articles (Non-TD).
4.	Scanning operation - II	1	0	Scans the articles after sorting process as per the pin code.	• Separate section as provided for scanning operation II
5.	Sealing and Dispatch	1	2	Articles are packed and keeps it ready on the floor to send it out through postal van after scanning II operation.	• Traditional sealing is changed to plastic tag sealing to prevent the respiratory problems.
	Total	6	4		

7.7.5 Simulation Model for the Future State Map

By carefully analyzing all the above improvements, the future state VSM (Figure 7.8) was developed from the current state. A modified layout has been drawn (Figure 7.7) to remove the unnecessary wastes, as is given in Table 7.4. Now, the travel distance of the postal employee and the delivery of articles were reduced.



Source: SketchUp, 3D Software

Figure 7.7: Simulation Layout Model in NSH Post Office

The processing of each cycle time has been assumed to be a uniform distribution of each operation, as shown in Table 7.4, as per the real data of the postal firm. It is found that uniform distribution was appropriate to represent the cycle time, and it was given as input data in Rockwell Arena software. From this empirical distribution, the entire current state of VSM has been analyzed.

Table 7.4: The Distribution of Cycle Time on Each Operation

S.No.	Process category	Cycle time (seconds)
1.	Receipt Scanning	UNIF (45,55)
2.	Scanning I	UNIF (80,90)
3.	Sorting	UNIF (120,130)
4.	Scanning II	UNIF (65,75)
5.	Sealing and Dispatch	UNIF (25,30)

The simulation was set at a run-length for 30 days and replication length at 20 to a steady-state data and to reach the confidence interval or to reduce the statistical sampling errors. The production time is 16-h; it is a steady-state model.

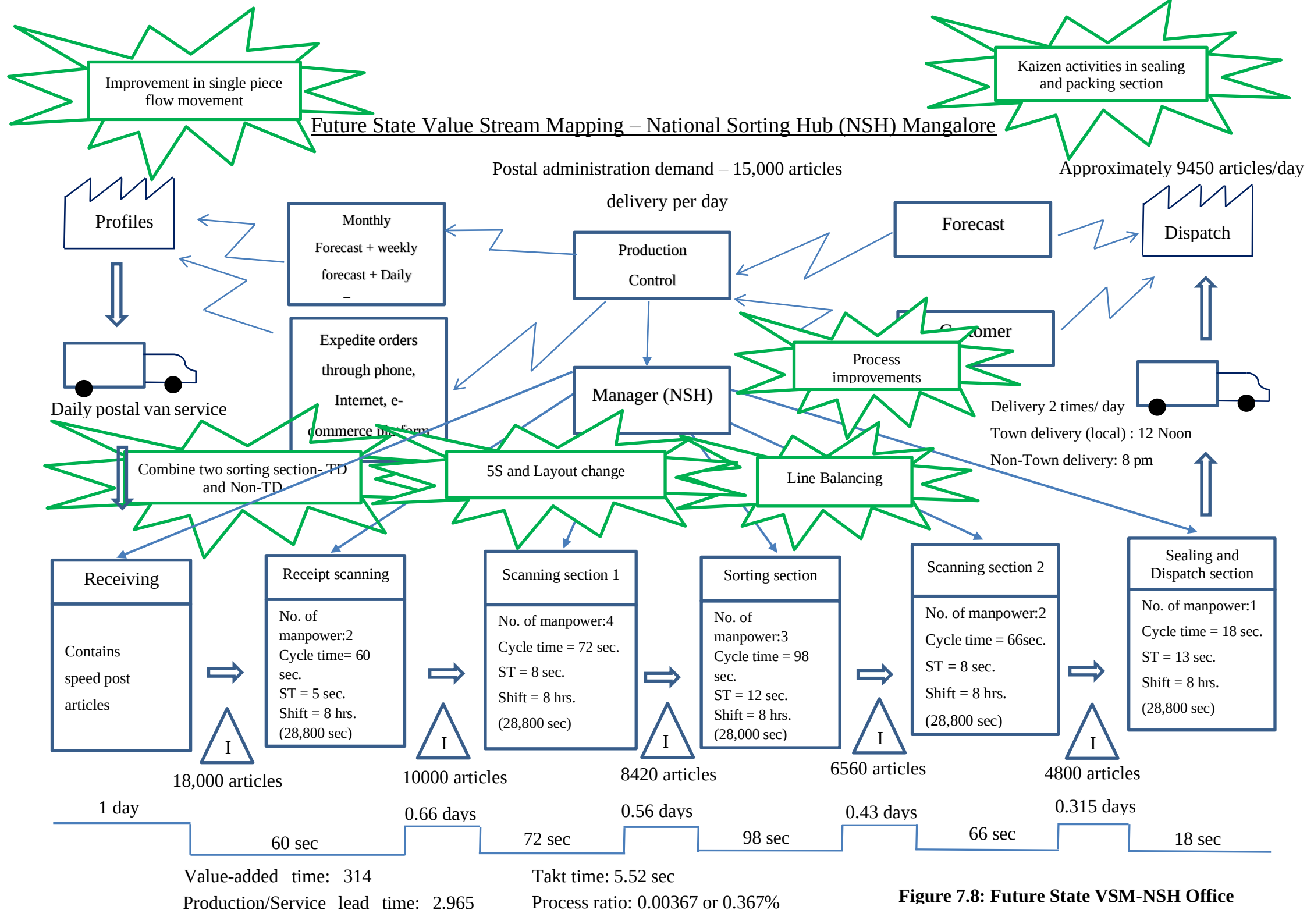


Figure 7.8: Future State VSM-NSH Office

7.8 Taguchi Method

Jugulum (2002) and Taho Yang et al. (2020) two-stage optimization procedure was applied to find the optimal combination of factors using the Taguchi method. For further details, read the above articles for Taguchi methods. From the production performance metrics, five important control factors were found, such as the Takt time, Process ratio, Production lead time, Value-added time, and Inventory processing. Table 7.5 shows the different levels of control factors.

Table 7.5: Level of Control Factors

S. No.	Control factors	Min.	Max.
A	Takt time	1.92	2.88
B	Process ratio	0.34	0.367
C	Production lead time	2.965	3.735
D	Value-added time	5.23	6.17
E	Inventory processing	20,000	50,000

7.8.1 Taguchi Analysis

Taguchi OA $L_{16}(2^5)$ is recommended for this study as shown in Table 7.6. Because of the differentiation between the original OA and the current problem, the $L_{16}(2^5)$ OA has been improved and proved to be fit for the current problem. The first five columns are tabulated, representing factors A, B, C, D, and E, respectively. The modified OA, also experimental results, are illustrated in Table 7.7. The ANOVA was further performed for the S/N ratio response, and it is illustrated in Table 7.8.

From Table 7.8, D (0.162) and E (0.298) are the p-values for factors that are less when compared to other p-values. Hence, it can be attributed to that substantial effect on the S/N ratio and confirmed that D and E are the first groups of control factors.

Table 7.6: Level of Control Factors $L_{16}(2^5)$ Orthogonal Array (OA)

Experiment No.	Takt time	Process ratio	Production lead time	Value-added time	Inventory processing
1	1	1	1	1	1
2	1	1	1	2	2
3	1	1	2	1	2
4	1	1	2	2	1
5	1	2	1	1	2
6	1	2	1	2	1
7	1	2	2	1	1
8	1	2	2	2	2
9	2	1	1	1	2
10	2	1	1	2	1
11	2	1	2	1	1
12	2	1	2	2	2
13	2	2	1	1	1
14	2	2	1	2	2
15	2	2	2	1	2
16	2	2	2	2	1

Table 7.7: Experimental Results for S/N Response

Experiment No.	Factor A	Factor B	Factor C	Factor D	Factor E	Before Simulation	After simulation	S/R	Mean
						Delivery of the articles/day	Delivery of the articles/day		
1	1	1	1	1	1	7342	10775	78.6703	9058.5
2	1	1	1	2	2	7942	8712	78.3819	8327.0
3	1	1	2	1	2	9807	9278	79.5832	9542.5
4	1	1	2	2	1	8141	9858	78.9656	8999.5
5	1	2	1	1	2	9257	10345	79.7852	9801.0
6	1	2	1	2	1	9402	10153	79.7853	9777.5
7	1	2	2	1	1	10734	10591	80.5566	10662.5
8	1	2	2	2	2	8566	10239	79.3616	9402.5
9	2	1	1	1	2	9580	10011	79.8142	9795.5
10	2	1	1	2	1	9358	8515	78.9944	8936.5
11	2	1	2	1	1	9738	10562	80.1078	10150.0
12	2	1	2	2	2	2487	9950	70.6606	6218.5
13	2	2	1	1	1	10250	9346	79.7950	9798.0
14	2	2	1	2	2	9032	10085	79.5682	9558.5
15	2	2	2	1	2	9008	9856	79.4657	9432.0
16	2	2	2	2	1	8119	9389	78.7755	8754.0

Similarly, further analysis has been found out for the effects of control factors to resolve the design problem. The equivalent response graph, as shown in Figure 7.9 is based on the results from Table 7.8. From the p - values, D1 and E1 are chosen as first group factor levels, followed by B (0.381) and A (0.402), and finally factor C (0.502). Table 7.9 shows the summary of the optimum factor levels

Table 7.8: ANOVA for the S/N ratio Response

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	1	312761	312761	0.77	0.402
B	1	343103	343103	0.84	0.381
C	1	198248	198248	0.49	0.502
D	1	932673	932673	2.28	0.162
E	1	491752	491752	1.20	0.298
Residual Error	10	4083241	408324		
Total	15	6361777			

Table 7.9: Optimum Factor Levels

S. No	Factor	Control level
1.	Takt time (A_1)	1.92 - Minimum
2.	Process ratio (B_2)	0.367 - Maximum
3.	Production lead time (C_1)	2.965 - Minimum
4.	Value-added time (D_1)	5.23 - Minimum
5.	Inventory processing (E_1)	20,000 - Minimum

Finally, the lean system operational performance optimal control factors design has been expressed in Table 7.9. The ideal factor levels are A_1, B_2, C_1, D_1, and E_1.

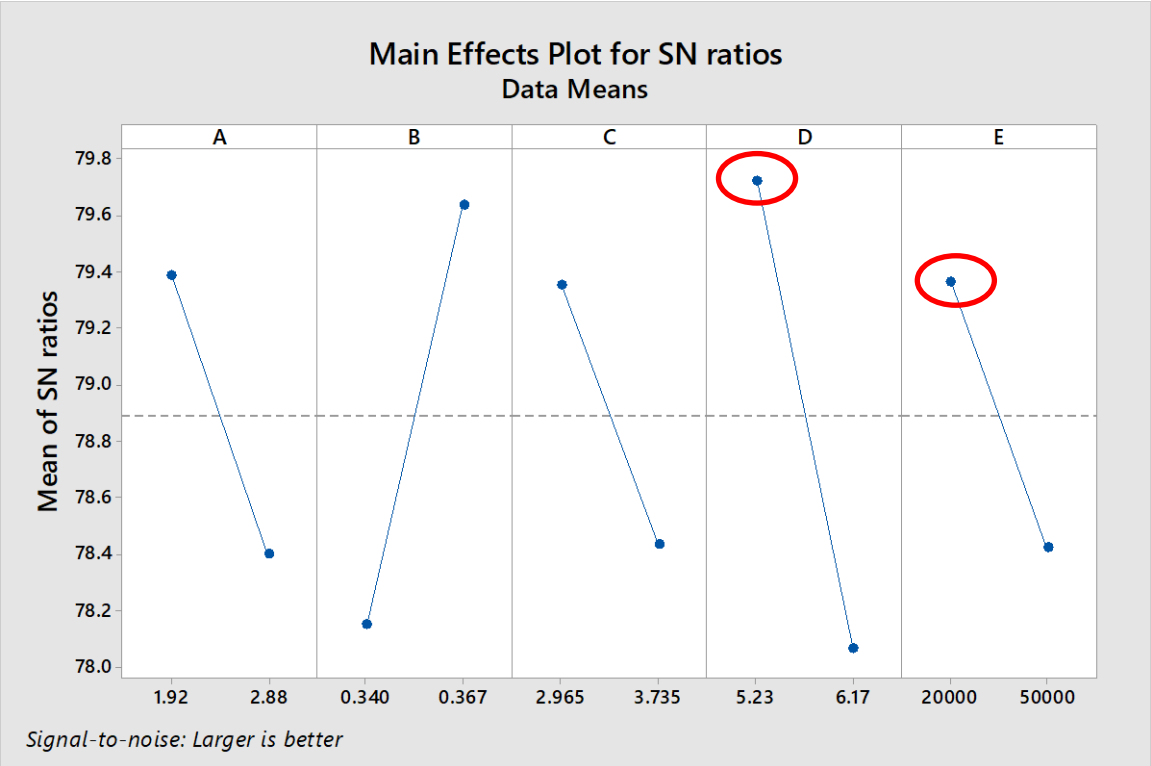


Figure 7.9: S/N ratio - Response Graph

7.9 Validation Experiments

The postal manager has verified the simulated values, which was almost matching with the current production system. For example, in reality, postal articles' production rate per shift is 4310. And in the simulation model, it was 4500 articles as it follows a uniform distribution. After changing the facility layout, it had drastically improved from 4310 articles to 4725, almost 9.62 percent increment. Also, employees are encouraged to implement 5S activities to sustain the workplace environment clean and tidy. Now, all the empty bags were kept in the trolley, and empty bins were placed in the bin section. Hence, these activities lead to production enhancement.

7.10 Results and Discussions

Table 7.10 shows the production performance metrics in comparison with Current and Future state VSM. The production rate measured as the number of articles was dispatched per shift (8 hours).

Table 7.10: Current and Future State VSM Comparison - Performance Measures

S. No.	Performance metrics	Current state VSM	Future State VSM
1.	Expected demand per day	10,000	20,000
	Actual delivery articles per day	8620	9450
2.	Before simulation – Initial inventory (in terms of days)		
	Receipt scanning	15,000 (1)	18,000 (1)
	Scanning I	9600 (0.960)	10,000 (0.660)
	Sorting	7680 (0.768)	8420 (0.560)
	Scanning II (pin code-wise)	5760 (0.5760)	6560 (0.430)
	Sealing and Dispatch	4310 (0.431)	4800 (0.315)
3.	VA time (in min.)	6.17	5.23
4.	Production lead time (in days)	3.735	2.965
5.	Process ratio (%)	0.340	0.367
6.	Takt time (in sec.)	2.88	1.92
7.	Cycle time (in sec.)		
	Receipt scanning	60	60
	Scanning I	85	72
	Sorting	125	98
	Scanning II (pin code wise scanning)	72	66
	Sealing and Dispatch	28	18
8.	After 1-month simulation		
	Delivery articles per day	8600	10,000
9.	Distance traveled by the articles (in cm)	1910	1270
10.	Manpower used	15 (9 Trained person + 6 causals)	10(6 Trained person + 4 causals)
11.	Floor space utilized (in sq. ft.)	416	389

Implementing a Lean Service System (LSS) in the postal service industry helps to enhance excellence productivity, and reduces the space, cycle time, lead time, throughput time, cost. Hence, the postal department made an excellent LSS

benchmarking, which positively affects profitability and customer retention. Taho yang et al. (2020) implemented a lean system in semiconductor crystal – ingot pulling manufacturing unit. For that, they have used VSM and Simulation for identifying the NVA and replicated the performance of the system. Also, the Taguchi method helps to identify the control factors of the system's optimization performance, such as dispatching rules, batch size control, machine limitations, and pulling strategy. The recommended methodology yielded 6.42 and 12.02 percent improvement in service level and throughput. In this present study, the India Post service manual sorting center called National Sorting Hub (NSH) has implemented this while dealing with speed post articles.

From the current VSM, various improvement areas such as layout modification, housekeeping (5S), Packing and Sealing, Sorting section, Line balancing of the workforce, Kaizen activities have been found. Also, a trial method for a fixed scanning system to reduce the shoulder pain of the scanners, ergonomic posture improvement in sorting section, etc. Simulation models replicate the original production system and check the various alternatives to improve operational performance. Finally, Taguchi methods help optimize the five control factors such as Takt time, process ratio, production lead time, VA time, Inventory processing, etc.

Anand Gurumurthy and Rambabu Kodali (2010) implemented a lean production system indoors and windows manufacturing for the batch production system. They have used once again VSM and simulation for improvement of the present manufacturing windows unit 40 to 60. Here, in the current study, there has been an improvement of 11.36 percent of delivery articles per person. Faith Cavdur et al. (2018) have implemented lean service based on the VSM – Simulation study in the construction and technical assistance of a public university. They have used e – VSM software for drawing the current maps and ProModel software for simulation models. Based on assumptions on the simulation models, the suggested alternative can reduce the technician's utilization in the office and delays in operations. On average, 31.66 percent decrease in technician utilization, and 3.92 days had decreased in the average system.

In this study, VSM has been created manually to identify the NVA and has been suggested for the improvement area of each section in the process flow. Arena

Simulation software was used for systematically building logical blocks with the assumptions of uniform distribution. Here, there has been a significant improvement in floor space utilization from 416 to 389 Sq. Ft (6.4%), which reduced the throughput distance by 12.56%, the workforce from 15 to 10 employees, and reduced the cycle time from 371 to 314 (15.13%). Gnanavel et al. (2015) implemented lean concepts in labour demanded work environment to improve the ergonomically designed 'Nagare' cell layout. They have developed a manual process flow map and arena simulation model to improve the actual production system. In the end, they concluded that a new layout could grow 10% productivity without an additional workforce by changing the working layout and work practices. In this study, it is suggested that the reduced power (5 employees) can be utilized to initiate the third as night time to increase production and balancing the line operations.

7.11 Conclusion

7.11.1 Managerial Implications

The present study has recommended a lean service system design for solving the internal operations of delivering articles in NSH Mangalore postal service. There are very few pieces of literature that have attempted to apply the LSS in service industries, particularly, for the postal service; this research work significantly bolsters the novel method. A practical case has been analyzed, and a suitable methodology has been proposed with the current and future state of VSM simulation models with Taguchi methods. VSM is used to identify and eliminate the NVA. Simulation models were used for imitating the real production system, and this has shown improvement in the future state of VSM production metrics by carefully analyzing the models. Taguchi methods are used to optimize the operational performance parameters of the Indian Postal service industry.

From the VSM mapping, it is found that significant parameters (control factors – takt time, process ratio, inventory level, value-added time, production lead time), a hybrid Taguchi method is used for enhancing the control factors design. It is found that there was a significant LSS performance improvement by 11.36 percent. The empirical results are promising, and there is a decrease in inventory, cycle time, space utilization,

workforce, etc. Thus, the VSM – Simulation and Taguchi models can be readily applied to any service or manufacturing industries. In particular, to the best of the author's knowledge, this study precisely studies the LS design problem for the postal service industry, and none of them were attempted before. In the future, the case organization can implement operations management topics such as cycle time reduction, layout design, forecasting demand, and schedule for achieving a superior competitive advantage to its competitors, and there can be open to future research opportunities.

7.11.2 Future Scope

In the future, the Indian Postal administration can enhance the production drastically by implementing semi-automation in the current facility layout. For example, they can adopt a simple belt drive or rope drive mechanism throughout the system with the provision of ON/OFF button. Suitable proximity sensors can be fixed to stop and continue the process using centralized control with a Program Logic Control (PLC) system. The detailed Bill of Materials (BOM) for the semi-automation system as follows:

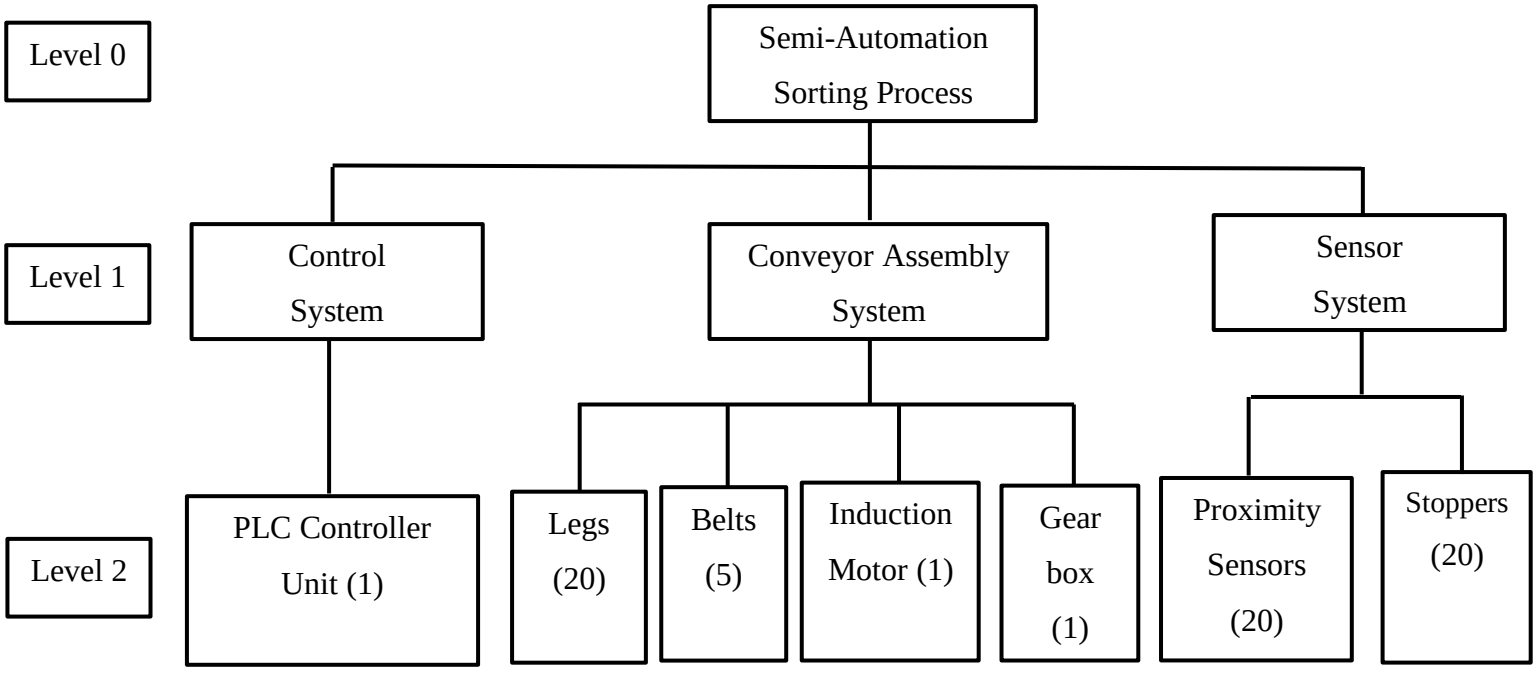


Figure 7.10: Hierarchy of BOM of Semi-Automatic Sorting Process in NSH Office

Table 7.11: BOM of Semi-Automatic Sorting Process in NSH Office

S. No	Part Name	Level	Quantity	Cost (Lakh)
1.	Centralized Control System (Human Machine Interface)	1	1	15
2.	Conveyor Assembly System	1	1	10
3.	Sensor System	1	1	5
4.	PLC Controller Unit	2	1	10
5.	Conveyor Legs	2	20	1
6.	Induction Motor	2	1	1
7.	Gear Box (speed reduction)	2	1	1
8.	Pallets (Box)	2	1	0.1
9.	Conveyor Belts	2	5	3
10.	Proximity sensors	2	20	2
11.	Stoppers	2	20	1

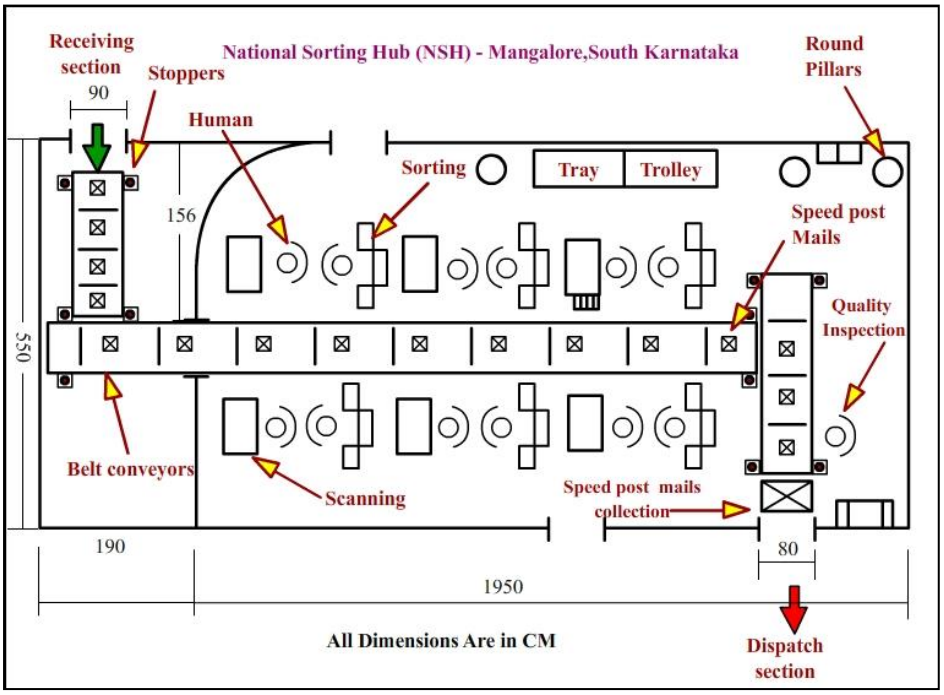


Figure 7.11: A Sample Model of the Semi-Automation Sorting Process

Figure 7.10 and Table 7.11 show a detailed Bill of Materials (BOM) for the semi-automation system. A sample model of the automation system is shown in Figure 7.11.

7.11.3 Limitations of the Study

First, for optimizing the parameters, only five factors with two-level operational performance attributes were taken into consideration. Second, the study is based on the case of a postal organization, i.e., NSH Mangalore; hence, results will be the specific conclusion.

7.12 Summary

A practical postal study case has been analyzed, and a suitable methodology has been proposed with the current and future state of VSM simulation models with Taguchi methods. VSM is used to identify and eliminate the NVA. Simulation models were used for imitating the real production system, and this has shown improvement in the future state of VSM production metrics by carefully analyzing the models. Taguchi methods are used to optimize the operational performance parameters of the Indian Postal service industry.

CHAPTER 8

DEVELOPMENT OF POSTAL SUSTAINABLE DESIGN USING QFD METHODOLOGY

In this chapter, detailed descriptions are given about sustainable postal design using QFD techniques to develop the House of Quality Sustainable Design (HOQSD) model. The objective is to study the importance of Indian Postal service sustainable initiatives in their strategic plan 2021 – 25.

8.0 Introduction

The essential function of the postal service is to deliver the articles at the doorsteps of the addressees by the shortest and quickest methods, in a secure manner. For that, the process of improving customer service in the logistics operations will be subject to postal management. Consequently, the Indian Postal administration has been adopting new technologies such as modernized counter machines, re-designing the counters, providing modern and ergonomic equipment, etc., which improves post office ambiance and improves the service quality, also. Although, increasing competition from the private postal industry, fast-changing communication with the revolution of information technology, globalization, liberalization of economies, etc. tends to incorporate postal service quality design for long-term sustainability.

Here, customer's opinions on sustainability initiatives embedded into postal service enhancement are been focused. The customer's priorities have been customized into the design principles and are converted into technical requirements through the QFD tool. To a great extent, research has been done on sustainable product design in manufacturing industries. But not much foci have been given to systematic implementation in service industries, and specifically, none of them have tried in the postal service industry.

The postal administration in developed countries such as the USA, Germany, Japan, New Zealand, and Australia have resolved this SQ, by diversifying their activities and services to their customers. Besides, they introduced new hybrid postal products, which

lead to customer satisfaction. In India, postal service quality is still in the growing stage. Therefore, there is a lot of scopes and significant opportunity to enhance the SQ, which leads to customer satisfaction. In such a way, QFD is a compelling tool for the development of sustainable postal service design in India Post. In this research, an attempt has been made for sustainable design, considering both postal employees and customers through a survey. In this way, developing QFD is an essential competitive tool for postal service as a successful business (Besterfield et al. 2003).

8.1 Sustainability / Sustainable Development – Definition

There are several definitions of sustainable development available in the literature. Among them, the popular one is by World Commission on Environment and Development (1987): "Economic development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs." In manufacturing industries, it aims to create manufactured products that use processes and practices that maximize profits, minimize negative environmental impacts, conserve natural resources and energy, and are safe for employees, consumers, and communities (NACFAM, 2019). Whereas in service sectors, sustainable service is the components of sustainable strategies and operations to decrease the negative environmental impact and increase the social and economic conditions considering whole life cycle analysis (Belz, F. M., & Peattie, K. J.2009).

8.2 The Rationale of the Study

There are 2 main reasons why sustainability initiatives are essential to the Indian Postal service:

1. Indian Postal service is an essential public utility for the people. It utilizes all forms of transportation such as rail, road, air, and ship to transport the mails and parcels. Hence, it plays a significant role in providing social support through money transfer, handling payment of utility bills, submission of passport, etc. Although such value-added services are available for the public there is a need that it has to be fulfilled and it should reach on time. Naturally, they need to minimize the carbon footprint and association emissions thereby contributing significantly to the environmental

dimension too. Thus, it is easy to see that postal service has a complete alignment with the triple bottom line framework of sustainability.

2. India Postal service relies on efficient and effective vehicle operations for mail delivery. For that, they are promoting new technologies and diversifying mail mix to reduce the greenhouse gas emissions and improve safety and service, which results in operational savings (India Post strategic plan, 2021-2025).

8.3 Objectives of the Study

The main objectives are:

1. To study the importance of India Post service considering sustainability initiatives in their strategic plan for the years 2021–2025
2. To understand the role of the managers and employees, ensuring that service quality enhancement is successfully achieved through applying QFD tool.

8.4 Literature Review

In this research, QFD used to find the factors (end-user queries) to develop a House of Quality Sustainable Design (HOQSD) model. This model highlights and bolsters the sustainability principles and performs the integration of customer priorities, information, and knowledge.

8.4.1 QFD Applied in Service Industries

QFD has been applied almost in all service industries such as marketing, shipping, healthcare, financial, education, and hotel, etc. For example, Dat et al. (2015) proposed a new methodology to integrate fuzzy QFD to maintain the market segment selection and assessment process. Lam and Lai (2015) developed a decision-support model for shipping companies to manage environmental issues in their operations. Ramı´rez et al. (2017) developed a technology assessment called the HOQ matrix for dissolved air flotation (DAF) system, which is used for water pre-treatment for RO desalination systems. Wood et al. (2016) proposed QFD for green hospital construction from the end-users perspective in healthcare services, both private and public hospitals in

Malaysia. Pyon et al. (2011) proposed a web-based Decision Support System (DSS) for the customer complaints called the Voice of the Customer (VOC) to improve the service quality. The system studied a major credit card company, in South Korea. Besides, Andronikidis et al. (2009) implemented QFD along with AHP and ANP to rank the customers' bank selection with the help of HOQ design.

Table 8.1: QFD Tool Applied in Service Industries

S.No	Author	Applied Industries	Description of the literature
1.	Miyoung Jeong, Haemoon Oh,1998	Hotel industry	Based on the framework of QFD, this study guidelines both external and internal service management issues. Besides, this study develops an application for the lodging industry to analyze the strategies.
2.	H. Brian Hwarng, Cynthia Teo, 2000	Education sector	Service-based quality function deployment (QFD) exemplified in higher education institutions to translate the Voices of Customers (VOC) into operations requirements. The survey occurred at the National University of Singapore business school.
3.	Sangeeta Sahney D.K. Banwet S. Karunes,2004	Education sector	In this study, initially, the SERVQUAL methodology was applied to find the gap between customer requirements and the demands of the actual service received in India. Then, QFD applied to find the set of least design quality factors that met student needs and parents' needs in the educational system.
4.	Andronikidis.A, et al. 2009	Banking sector	Implemented QFD along with AHP and ANP to rank the customers' bank selection with the help of HOQ.
5.	Kioumars Paryani, Ali Masoudi & Elizabeth A. Cudney,2010	Hotel industry	A case study was developed concentrating on a five-star hotel to exemplify the application of the QFD process. This study used a planning process to connect customer requests and service features in the hospitality industry.

6.	Chong Un Pyon, Ji Young Woob, Sang Chan Park, 2011	Financial service industry	Proposed a web-based DSS for the customer complaints called the Voice of the Customer (VOC) to improve the service quality. The proposed system is studied on a major credit card company in South Korea.
7.	Luu Quoc Dat,2015	Market segment	Proposed a new integrated fuzzy QFD to bolster the market segment selection and assessment process.
8.	Jasmine Siu Lee Lam & Kee-hung Lai, 2015	Shipping industry	Developed a decision-support model for shipping companies to manage environmental sustainability in their operations. An integrated ANP with QFD is recommended to serve this purpose.
9.	Wood LC. et al.2016	Healthcare services	Proposed QFD for green hospital construction from end-user perspectives.
10.	Yendery Ramírez et al, 2017	Process industry – seawater treatment	Technology assessment HOQ matrix developed for dissolved air flotation (DAF) system, which is used as water pre-treatment for RO desalination systems.
11.	Wu, W. Y., Qomariyah, A et al.2018	Hospitality industry	This study adopted the QFD and Analytic Network Process (ANP) method to identify the five major groups of service failure in hotels.
12.	Bulut, E., Duru, O., & Huang, S. T. (2018)	Airport service quality, Kansai International airport, Japan.	This study deals with a multilayer QFD model to concession the requirements of both airline companies and passengers to ensure sustainable service quality incorporation.
13.	Haber, N., Fargnoli, M., & Sakao, T. (2018).	Medical service	The QFD for Product-Service Systems (PSS) method was improved employing the Kano model to filter the customers' needs and convert the attractive ones into Receiver State Parameters (RSPs). Then, to properly assess these parameters and their inherent uncertainty, the Fuzzy Analytical Hierarchy Process (FAHP) method was used.
14.	Chen, K. J., Yeh, T. M., et al. (2018)	Fast-Food Chain Restaurants	The authors combined a refined Kano model QFD model. The refined Kano model used to measure the customers'

			service attributes based on DINESERV measurements. Then QFD employed, to describe the relationships among the service attributes and matching improvements as well as to find the priority for these improvements.
15.	Yan, H. B., Meng, X. S., Ma, T., & Huynh, V. N. (2019).	Bank window service	The study proposed an empirical case study of window service design based on service standardization in the Shanghai Branch of Bank JT. The results showed that the bank should pay more attention to "Service specifications", "Service providing specifications", and "Service evaluation and improvement standards.
16.	Yazdani, M., Kahraman, C., (2019).	French association of supply chain and logistics (ASLOG)	The paper provides the integration of QFD and GRA in representing main supply chain drivers under fuzzy environment.
17.	Cetinkaya, C., Kenger, O. N. et al.(2019).	Educational service	The QFD approach is applied to the educational curriculum in Gaziantep Industrial Engineering Department.
18.	Beheshtinia, M. A., & Farzaneh Azad, M. (2019)	Hotel industry	The authors used a hybrid model using the House of Quality (HOQ), SERVQUAL, and Kano models. The model implemented at Iran hotel. Initially, they identified 31 customer needs, then they ranked using SERVQUAL and Kano approaches.

Service-based QFD exemplified in a higher education institution to translate the Voices of Customers (VOC) into operations requirements. The survey occurred in Business School at the National University of Singapore (Brian Hwarng and Teo 2001). Similarly, in India, the SERVQUAL method was applied to find the gap between customer requirements and the expectation of service quality demands. For example, QFD used to find the set of least design quality factors that meet students' and parents' needs in the educational system (Sahney et al. 2004). Jeong and Oh (1998) and Paryani et al. (2010), applied QFD in the hotel industry to improve service quality. Paryani et al. (2010) used QFD to improve hospitality as a planning process to connect the customer expectations and service features provisions. Refer Table 8.1 for more detailed literature support on QFD applied in service industries.

8.4.2 Theoretical Background Support for the QFD Framework

The QFD framework considered two different theories (Universal theory, socio-technical system theory), and OSHA standards. The Universal Theory (UT) infers a direct relationship between a dependent (e.g. customer satisfaction) and independent variables (e.g., SQ dimensions/items). The socio-technical system theory implies that the technical and social sides are likely to positively interact, leading to better performance in operations as well as finance (Dabhilkar and Ahlstrom, 2013). The OSHA standards suggest better workplace environment conditions for the postal employees.

8.4.3 Research Gaps Related to QFD Method

The research gaps identified through the literature survey are:

• Much research has been done on sustainable product design and parts in manufacturing industries. But a few focuses have been given to the systematic implementation from customer perspectives, and none of them have tried for postal sustainable service design.

• None have applied the QFD method in the postal service design context for the improvement of service quality. For example, Shi and Xie (2009) and Bas (2014)

applied QFD in the construction industry. Whereas, Kasaei et al. (2014) and Wu and Ho (2015) used QFD for the selection of engineering material selection and mobile phone design.

• Similarly, none of the papers emphasized the significance of the sustainable postal service design to enhance the service quality from the end-users demands.

8.5 Research Method

A questionnaire study was used for this research method, and a random sampling target group of respondents was used (Figure 8.1). The questionnaire was circulated to postal employees and visitors to the postal office (customers). The statistical analysis supports to determine the demographical and postal service design factors which lead to the development of House of Quality Sustainable Design (HOQSD).

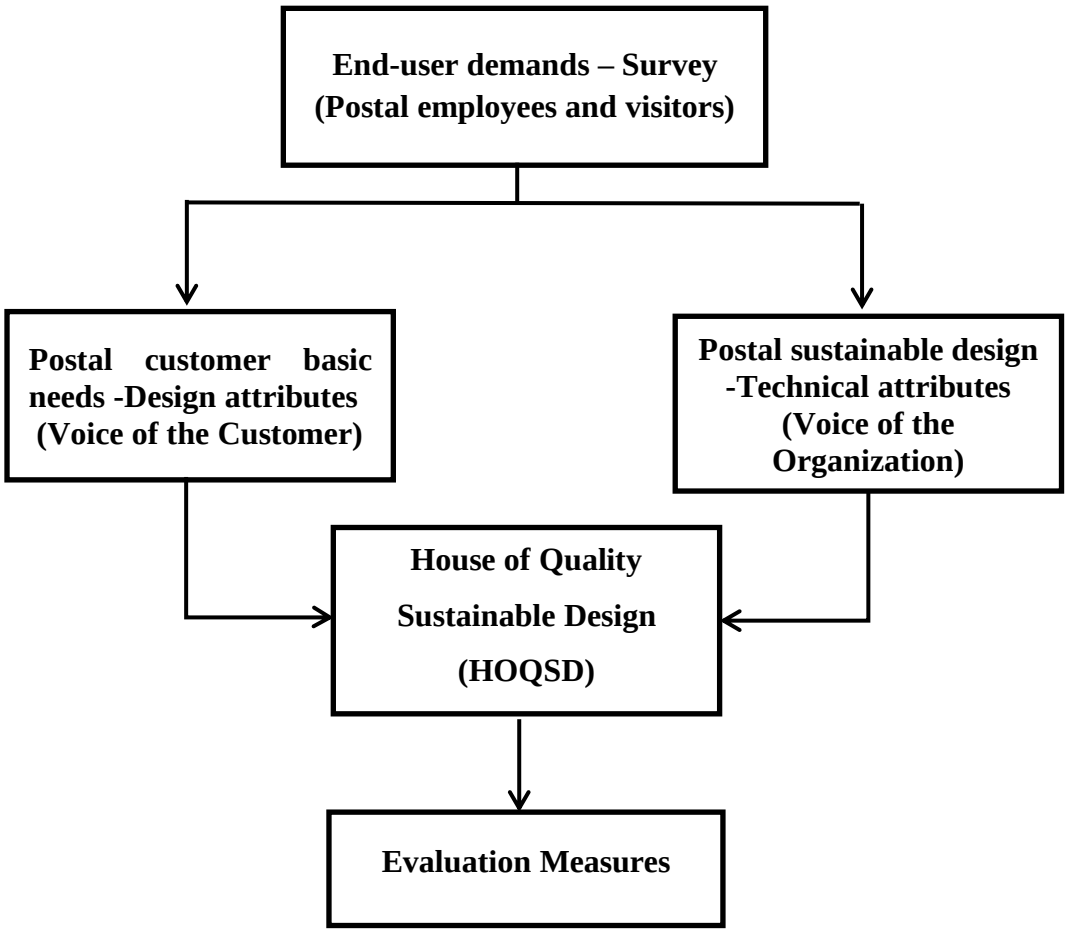


Figure 8.1: Methodological Flow of the Study

The demand quality of the postal service questionnaire survey was considered from Sureshchandar, G. S., Rajendran, C., & Anantharaman, R. N, (2002) from the banking service. Further, some questionnaire items were customized and revised to suit the postal service requirement — the SQ in five factors level, as shown in Tables 8.2 and 8.3.

Table 8.2: Demands for Service Quality Based on Five Categories

Sl. no	Critical factors	Explanation of the critical factors
1	Core service or service product	The service product is whatever features that are offered in a service
2	The human element of service delivery	All aspects such as reliability, assurance, empathy, truth, recovery, responsiveness that will fall under the domain of the human element in the service delivery
3	Systemization of service delivery: non-human element	The processes, procedures, systems, and technology that would make a service a seamless one.
4	Tangibles of service – servicescapes	The man-made physical environment, popularly known as the "servicescapes"
5	Social responsibility	It helps an organization to lead as a corporate citizen in encouraging ethical behavior in everything it does.

Source: Sureshchandar, G. S., Rajendran, C., & Anantharaman, R. N, (2002)

Table 8.3: Results of Core Service Quality in Terms of Five Factors

S.No	Service quality factors	Mean (μ)	Ranking	Standard deviation (σ)
1	Core service or service product	5.68	2	1.20
2	The human element of service delivery	5.74	1	1.21
3	Systemization of service delivery: non-human element	5.43	5	1.15
4	Tangibles of service – servicescapes	5.44	4	1.41
5	Social responsibility	5.66	3	1.07

Note: Likert scale value differs from 7 = Very good to 1 = Very poor.

Similarly, the sustainable/technical elements required for postal service design have been adopted (Wood L.C et al. 2016) as given in Table 8.4.

Table 8.4: Items Related to Quality Elements to Establish and Enforce Green Postal Service Design

Sl. No	**Quality element**	**Items**
1	Innovative design	Service innovation
		Comfortable working layout
		Green construction
		Product innovation
2	Sustainability	Energy efficiency
		Indoor environmental quality
		Workplace environment
		Green purchasing
		Effective utilization of water resource
3	Authority	Technology adoption
		Standardization
		Strict reinforcement
		Periodic quality assurance check

Source: Wood, L. C., Wang, C., Abdul-Rahman, H., & Abdul-Nasir, N. S. J. (2016)

In QFD, the HOQSD model is crucial for seeking end-users' responses based on their experience and India Post need this survey against the growing competition on other postal industries such as DHL, and TNT, etc.

8.6 Data Collection - NSH, Mangalore

200 questionnaires were distributed, among them, 116 returns were received. The overall response was received from 59 postal employees (50.8%) and 57 postal customers/visitors (49.1%). Statistical analysis was performed using SPSS 23.0 software.

Table 8.5: Demographic details of Respondents

Profile of respondents	Public Postal Service		Customers (Visitors)		
	Frequency (n=59)	Percent		Frequency (n=57)	Percent
Gender			**Gender**		
Female	27	45.8	Female	23	40.4
Male	32	54.2	Male	34	59.6
Age			**Age**		
Under 20	15	25.4	Under 20	1	1.8
21-35	20	33.9	21-35	33	57.9
36-50	20	33.9	36-50	14	24.6
Above 51	4	6.8	Above 51	9	15.8
Education level			**Education level**		
No formal education	1	1.7	No formal education	1	1.8
Primary education	11	18.6	Primary education	7	12.3
Secondary education	16	27.1	Secondary education	10	17.5
College/University	31	52.6	College/University	39	68.4
Work experience			**Frequency of visit**		

Less than 3 years	6	10.2	Every day	1	1.8
4-14	16	27.1	Once a week	6	10.5
15-25	17	28.8	Once every 2 weeks	28	49.1
More than 25 years	20	33.9	Once in a month or less	21	36.8
Position in postal service			Others	1	1.8
Manager	1	1.7			
ASP	1	1.7			
Postal assistant	20	33.9			
MTS	9	15.2			
GDS	7	11.9			
LRPA	7	11.9			
LSGRA	3	5.1			
Postman	7	11.9			
Postwoman	4	6.7			

The questionnaire study consists of two parts, such as Part A and Part B. Part A covers the demographics and background details of the respondents' as shown in Table 8.5. (e.g. gender, age, education level, work experience, and frequent visits to the postal service). Part B evaluated the importance of customer satisfaction on the present postal SQ. Internal reliability tested by Cronbach alpha, which was 0.971. Hence, it was acceptable for internal reliability factors (Nunnally J.C, 1978). It shows that the questionnaire linking with SQ and Sustainability were internally consistent. Hence, these factors were included in this analysis. This data was necessary for the postal department considering both postal employees and visitors, combined to explore the crucial elements of postal sustainable service design.

8.7 Results and Findings

8.7.1 Development of House of Quality Sustainable Design (HOQSD)

HOQ model visual appearances are like a house that defines the relationship between SQ elements and sustainable design elements placed on the column and upper row side Figure 8.2. HOQ translates the voice of the customer as SQ requirements and matches against how the postal departments will satisfy these requirements into technical aspects. It requires a set of end-user queries (SQ elements) and a set of sustainable design (technical elements). Initially, the SQ elements are not well matched against technical elements, and then it was transformed into distinct elements by subject matter experts comprising postmaster general, postal managers, researchers, and engineers. Based on the importance of each SQ, elements were grouped as first, second, third, fourth, and fifth groups. Then, technical elements are grouped as first, second, and third groups. The end-users' input becomes the customer needs or the SQ elements, and organization input becomes the technical requirements to satisfy customer expectations. A matrix was developed to include all the relationships and find the significant importance of sustainable service quality design. Each column is rated based on the computed total score at the bottom. The maximum rating gains more priority for further enhancement of customer satisfaction.

Based on a questionnaire survey from the end-users, 25 SQ elements were translated into technical elements or structure for the sustainable design. After that, a HOQSD model was developed for the public based on customer priorities from the questionnaire study. The first-stage variables are placed in the first column of Figure 8.3. The second-stage variables are then placed on the upper side of the first row in the same Figure 8.3 diagram. From the relationship, SQ elements matrix and sustainable design elements matrix were combined to establish a sustainable postal design system. Three symbols used for the relationship between SQ elements and technical elements in the relationship matrix. The symbol (■) indicates a strong correlation (priority rate 9); the symbol (▲) indicates medium correlation (priority rate 3); the symbol (●) indicates to possible correlation (priority rate 1), and no symbol used for no correlation.

For example, in core service factors there are five items adopted such as diversity and range of service, intensity, and depth of service, digital and physical security,

service availability and convenient operating time, etc. In this study, 7 points Likert scale has been employed to represent the possible core service construct. Among them, 1 represents 'Very Poor, and 7 represent ‘Very Good’ — the average values, are as shown in Figure 8.2.

Calculation of core service customer requirements into service innovation technical perspectives: (6.08 X 9) + (5.81 X 9) + (5.74 X 9) + (5.63 X 3) + (5.81 X 3) + (5.18 X 9) = 293.6

Similarly, comfortable working place: (5.83 X 9) + (5.93 X 9) + (5.86 X 9) + (5.50 X 9) + (5.69 X 9) + (5.25 X 9) + (5.44 X 9) + (5.63 X 9) + (5.69 X 9) + (5.57 X 9) + (5.69 X 9) + (5.43 X 9) + (5.79 X 9) + (5.66 X 9) = 710.6

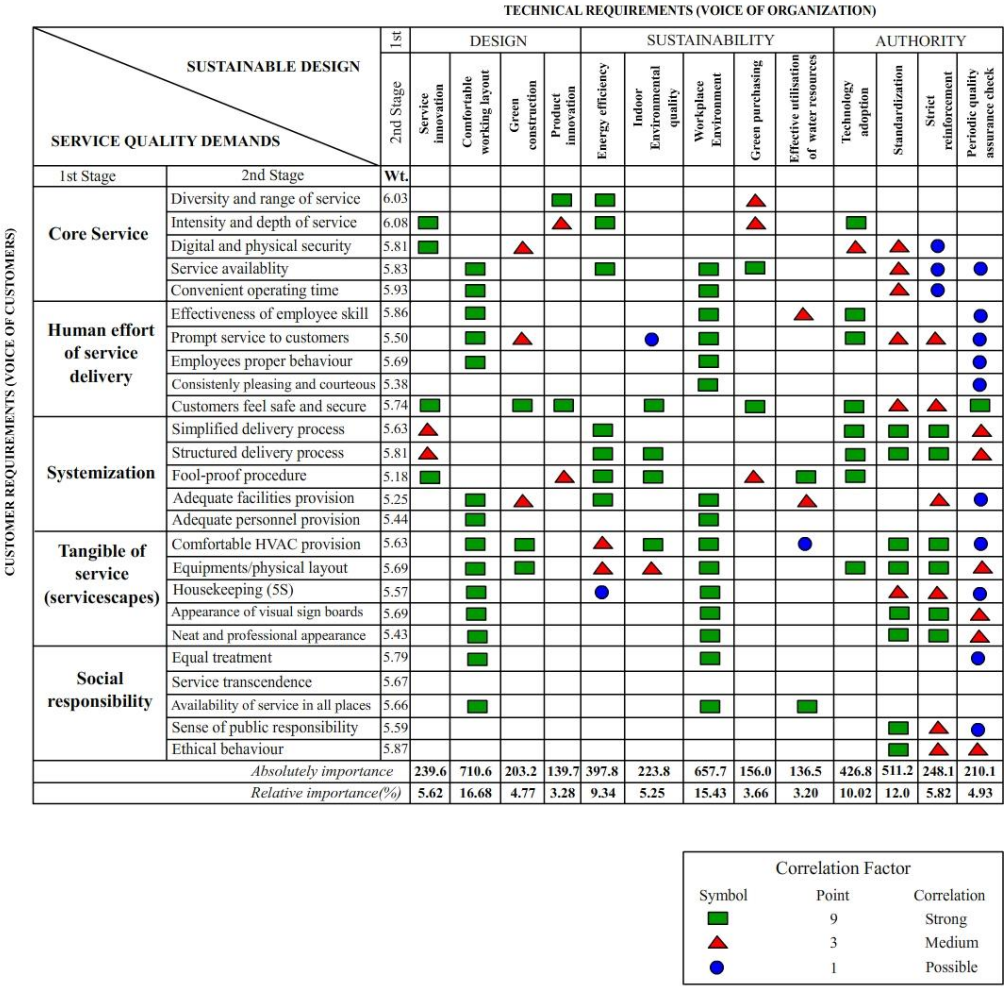
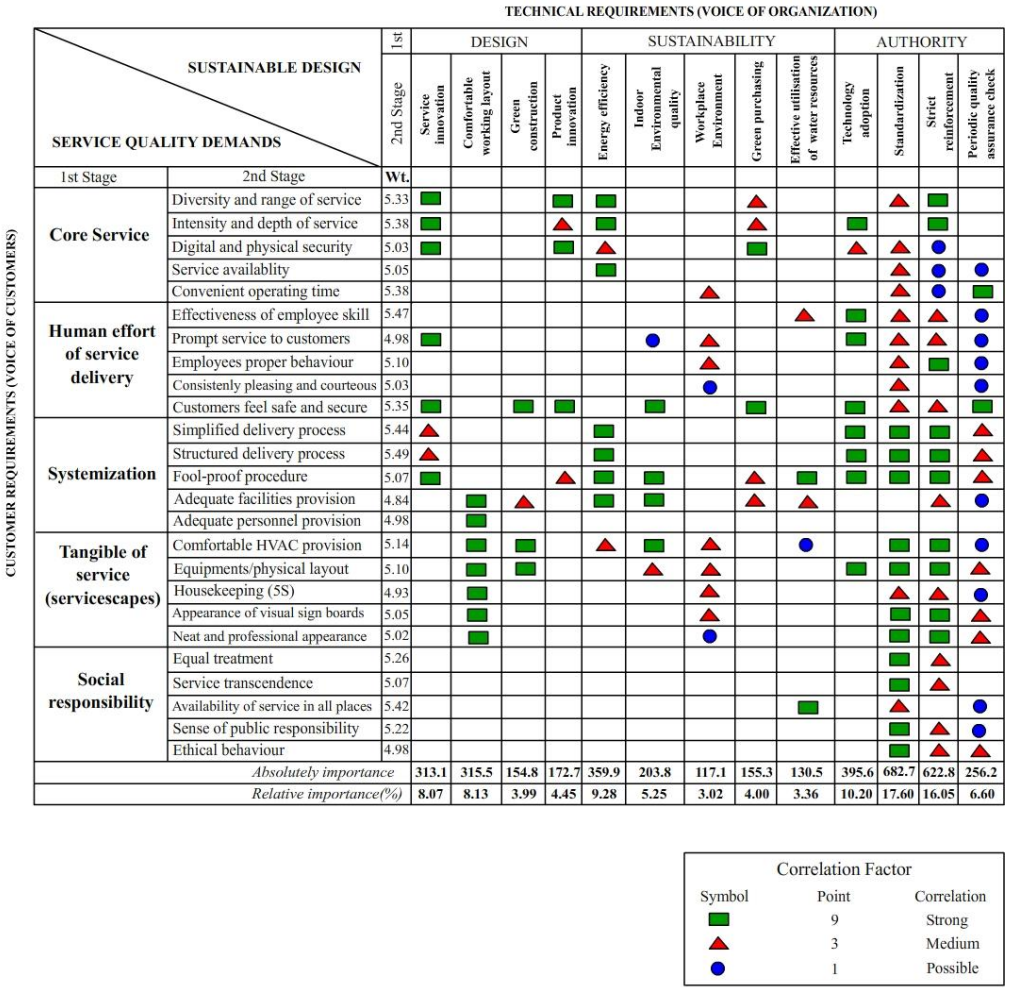


Figure 8.2: House of Quality Sustainable Service Design for Postal Employees



1st Stage	2nd Stage	Wt.	Service innovation	Comfortable working layout	Green construction	Product innovation	Energy efficiency	Indoor Environmental quality	Workplace Environment	Green purchasing	Effective utilisation of water resources	Technology adoption	Standardization	Strict reinforcement	Periodic quality assurance check
Core Service	Diversity and range of service	5.33	9			9	9			3			3	9	
	Intensity and depth of service	5.38	9			3	9			3		9		9	
	Digital and physical security	5.03	9			9	3			9		3	3	1	
	Service availablity	5.05					9						3	1	1
	Convenient operating time	5.38							3				3	1	9
Human effort of service delivery	Effectiveness of employee skill	5.47									3	9	3	3	1
	Prompt service to customers	4.98	9					1	3			9	3	3	1
	Employees proper behaviour	5.10							3				3	9	1
	Consistenly pleasing and courteous	5.03							1				3		1
	Customers feel safe and secure	5.35	9		9	9		9		9		9	3	3	9
Systemization	Simplified delivery process	5.44	3				9					9	9	9	3
	Structured delivery process	5.49	3				9					9	9	9	3
	Fool-proof procedure	5.07	9			3	9	9		3	9	9	9	9	3
	Adequate facilities provision	4.84		9	3		9	9		3	3			3	1
	Adequate personnel provision	4.98		9											
Tangible of service (servicescapes)	Comfortable HVAC provision	5.14		9	9		3	9	3		1		9	9	1
	Equipments/physical layout	5.10		9	9			3	3			9	9	9	3
	Housekeeping (5S)	4.93		9					3				3	3	1
	Appearance of visual sign boards	5.05		9					3				9	9	3
	Neat and professional appearance	5.02		9					1				9	9	3
Social responsibility	Equal treatment	5.26											9	3	
	Service transcendence	5.07											9	3	
	Availability of service in all places	5.42									9		3		1
	Sense of public responsibility	5.22											9	3	1
	Ethical behaviour	4.98											9	3	3
Absolutely importance			**313.1**	**315.5**	**154.8**	**172.7**	**359.9**	**203.8**	**117.1**	**155.3**	**130.5**	**395.6**	**682.7**	**622.8**	**256.2**
Relative importance(%)			**8.07**	**8.13**	**3.99**	**4.45**	**9.28**	**5.25**	**3.02**	**4.00**	**3.36**	**10.20**	**17.60**	**16.05**	**6.60**

Figure 8.3: House of Quality Sustainable Service Design for Postal Customers

Table 8.6: Calculation of Absolute Importance and Relative Importance

S.No	Absolute Importance	Relative Importance (%)
1	239.6	5.62
2	710.6	16.68
3	203.2	4.77
4	139.7	3.28
5	397.8	9.34
6	223.8	5.25
7	657.7	15.43
8	156	3.66
9	136.5	3.20
10	426.8	10.02
11	511.2	12.00
12	248.1	5.82
13	210.1	4.93
Tot.	4261.1	100.000

The above Figures 8.2 and 8.3 explicitly show the magnitude values of the most significant weighting factors in the design phase. The detailed information about the HOQSD model calculation is as shown in Table 8.6.

8.7.2 House of Quality Sustainable Design (HOQSD) – Postal Employees Feedback

From the findings of HOQSD of the postal employees (Figure 8.2), their comfortable working layout and workplace environment are the most significant important factors. Comparatively, the other elements factors are decreasing such as, 'standardization', 'technology adoption', 'energy efficiency', 'strict reinforcement', 'service innovation', 'indoor environmental quality', 'periodic quality assurance check', 'green construction', 'green purchasing', 'product innovation', and 'effective utilization of water resources'. Hence, postal employees strongly emphasize a comfortable working layout and workplace environment for prolonged working hours.

8.7.3 House of Quality Sustainable Design (HOQSD) – Postal Visitors' Feedback

From the findings of HOQSD of the postal visitors (Figure 8.3), standardization and strict reinforcement are the most significant factors. Reasonably, the other elements factors are declining such as, 'technology adoption', 'energy efficiency', 'comfortable working layout', 'service innovation', 'periodic quality assurance check', 'indoor environmental quality', 'product innovation', 'green purchasing', 'green construction', 'effective utilization of water resources', and 'workplace environment'. Thus, end-users' expectations should be standardization and strict reinforcement, which will bring and upright the postal business as a profitable one.

8.7.4 Redesign of NSH Post Office

From the implications of QFD principles, the NSH Post office has modified the existing facility layout based on lean service, workplace environment, and ergonomics criteria using MCDM methods. Here, postal management was looking for the enhancement of production, the betterment of employees working conditions with proper human working design principles.

8.7.5 Sustainability Principles Incorporated in NSH for Postal Employees

QFD is a strategic tool, which will be reinforcing the design principles in postal service industries. Sustainable design principles in postal service must be well-defined before implementation and to confirm that customers are delighted with the service provision. The sustainable design exemplifies some features such as improving ventilation, reducing energy use, improves air-conditioning, considering the life-cycle analysis, utilizing water resources effectively. Here in NSH, a ventilation facility has been provided by creating ceilings in the adjacent walls. Saving and utilizing the water properly is done by changing the whole pipeline connection system. Reuse the postal bags when it's empty — the lighting facilities are provided to the postal employees for the ease of sorting process. Exploiting natural lighting used during the day can decrease

energy costs and improve the atmosphere in post office layout. Likewise, the following areas, such as scanning, sorting, packaging, sealing sections were improved while initiating the HOQSD model in NSH in April 2018.

8.7.6 Sustainability Principles Incorporated in NSH for Postal Customers/Visitors

The QFD tool can make a gradually competitive from failure to successful firms (Azam Haron N et al. 2015). Also, the proper execution of QFD will lead to an increase in productivity, quality, and improvement in engineering knowledge and can decrease costs, service lead time, and reducing setup time (Stevenson W J et al. 2007). In terms of postal customers convenient, NSH has increased vehicle parking facility, modified post office infrastructure, an extension of working hours in the evening, a new green plantation in front of the post office, availability of drinking water, provision of feedback form, etc. The aforementioned total cost spent is around INR 2.0 Lakhs to improve the postal service quality and to enhance the postal ambiance.

8.8 Conclusion

8.8.1 Managerial Implications

Initially, inadequate and lack of customer requirements were faced and these were obtained by end-users before the sustainable design and facility planning began. All the customers' expectations for the initiative of the sustainable postal design were noted from the postal employees and the visitors of the postal departments. Then QFD tools were developed to provide the importance based on the weight to define the customers' expectations to get more clarity. The magnitude value in interpreting the end-user SQ requirements is converted into technical specifications and by showing the relative priority factors.

It is exemplified that QFD was applied to the postal service industry based on end-user queries. For that, a focus group (expert panel) was concentrated comprising of postmaster general, postal managers, researchers, and engineers to develop a HOQSD model for postal service enhancement. This focus group not only finds the relationship between SQ elements and technical elements but also enables them to work in the postal

departments. Finally, this HOQSD model creates better end-user fulfillment. Now, postal administrations can evaluate the cost-effective analysis by implementing postal service design to compete and sustain in the market.

This research intends to apply the QFD in postal service design to determine the customer needs. Further, these customers' needs have been translated into technical requirements for the suitability of operational planning at a different level. Hence, this research provides the guidelines of the QFD for the postal sustainable service designs known as the HOQSD model considering both postal employees and customers' views. The sustainable development initiates the light and ventilation facilities, improves the workplace environment as per the employee's convenience. Also, suitable equipment was provided for the scanning section to increase the net speed and sorting section for colour codes provision to improve the visual ergonomics. The postal delivery articles 10% increased from 8620 articles per day. Utilization of water resources, and there is a decrease in the energy costs by exploiting natural lighting during the day and improve the postal atmosphere, which promotes green building construction. In this way, this NSH post office is a benchmarking for all other Indian Post offices for adopting sustainable principles.

QFD is not a new concept that integrates customers' requirements into the final product or service. However, in real-time, it is difficult to achieve. With the help of quality metrics, QFD guides a structured, well-organized, and systematic way to attain the integration of end-user requirements. The quality matrix infers the quality demand to produce the SQ elements and technical specifications. From this study, it is understood that the QFD concept and technique could be used to define postal end-users' expectations, through planning, operation, and proper execution.

8.8.2 Limitations of the Research

Initially, this case study was conducted only in NSH, Mangalore, South Karnataka, the southern part of India. Secondly, the survey method was adopted in this research methodology. Thirdly, the sample size is less.

8.8.3 Further Research Recommendations

Firstly, this study can provide guidelines for another strategic goal to enhance the postal service quality in urban postal areas. Secondly, the fuzzy QFD is a better choice, if values are imprecise and vague to analyze for the same.

8.9 Summary

This research intends to apply the QFD in postal service design to determine the customer needs. Further, these customers' needs have translated into technical requirements for the suitability of operational planning at a different level. Hence, this research provides the guidelines of the QFD for the postal sustainable service designs known as the HOQSD model considering both postal employees and customers views.

CHAPTER 9

CONCLUSION

9.0 Introduction

This chapter includes the conclusion, limitations of this research, and directions for further research. The lean service in NSH Mangalore has been implemented without disturbing the daily routine of the postal departmental work.

9.1 Optimal Facility Layout Selection using MCDM Methods

A case study of the Indian Postal mailing service was adopted for empirical testing. Empirical results exhibited that the recommended methods are feasible in solving the practical layout design problem using AHP, TOPSIS, fuzzy TOPSIS and GRA. TOPSIS is a practical method for the recommended problem and is appropriate for precise performance ratings. When the performance ratings are imprecise and vague, then the fuzzy TOPSIS,GRA are the preferred methods. The FLD problem is an important decision-making problem to reduce the material (mail) handling distance and operational cost. The MCDM methods help for solving this kind of issue. Hence, this study has come up with MCDM methods to select the feasible layout among the alternatives to enhance production.

9.2 Implementation of Lean Service Tools and Techniques and its Assessment

Suitable lean service tools were implemented in NSH to reduce wastes and improve the production, environmental, and housekeeping concepts. To study the relationship and impact of Lean Service System (LSS) on operational performance in mail service operations in India. Measuring operational performance in mail service operations is a big challenge in the postal service industry. Hence, a cross-sectional survey was conducted and measured to find the relationship and impact of Lean Service Practices (LSP), Lean Workplace Environment Practices (LWEP), and Lean Social Practices (LSoP) on Operational Performance in India Post service industry. Pearson correlation

coefficient results indicated that there was a strong correlation between LSP (r = 0.728), LWEP (r = 0.722), and LSoP (r = 0.654) and operational performance. Significant impact on LSP (β = 0.484) on operational performance, then LWEP (β = 0.387) and followed by LSoP (β = 0.182) on operational performance. The practical effect of the findings of the LSS is successfully implemented to enhance the postal business operational performance. This study addresses to find the appropriate empirical model to test a LSS in India Post service industry, which is scant in the existing literature. Moreover, this study helps lean practitioners to design and develop the required lean tools and techniques to implement in different service sectors.

9.3 Development of VSM-Simulation Models and Taguchi Methods

A practical case has been analyzed and the study has proposed a suitable methodology of current and future state of VSM simulation models with Taguchi methods. VSM was used to identify and eliminate the NVA. Simulation models are used for imitating the real production system and improves the future state of VSM production metrics by carefully analyzing the models. Taguchi methods are used to optimize the operational performance parameters of the India Post service industry. From the VSM mapping, it is found that there are significant parameters called as control factors such as takt time, process ratio, inventory level, value-added time, production lead time. It is found that there is a 11.36 percent enhancement in delivering articles per person. The empirical results are promising and help in a decrease in inventory, cycle time, space utilization, workforce, etc. Thus, the VSM – Simulation and Taguchi models readily can be applied to any service or manufacturing industries. In particular, to the best of the author's knowledge, this study precisely studies the LS design problem for the postal service industry that none of them have attempted before. In the future, the case organization can implement operations management topics such as cycle time reduction, layout design, forecasting demand and scheduling for superior competitive advantage to its competitors and this can be the future research opportunities.

9.4 Postal Sustainable Design using QFD Technique

The QFD is applied in postal sustainable design to determine the customer needs. Further, these customers' needs are translated into technical requirements for the suitability of operational planning at a different level. Hence, this research provides the guidelines of the QFD for the postal sustainable service designs known as the HOQSD model considering both postal employees and customers' views. The sustainable development initiates the lighting and ventilation facilities, improves the workplace environment as per the employee's convenience. Also, suitable equipment was provided for the scanning section to increasing net speed and sorting section for color codes provision to improve the visual ergonomics. Hence, postal delivery articles 10% have increased from 8620 articles per day. Utilization of water resources and thereby decrease in the energy costs by utilizing natural lighting during the day and improving the postal atmosphere, which promotes green building construction. In this way, this NSH post office is a benchmarking for all other Indian Post offices for adopting sustainable principles.

9.5 Limitations of the Study

The lean service concept has been newly implemented in the postal service sector. So, this is purely based on the case study and has only been explored in the mail services. Only the MCDM technique was used for finding a feasible layout design for the Indian postal service. There are many other tools and techniques available which have not been exploited. The lean service assessment has been done by 150 employees of the postal organization. This is a small sample size. The results are specific to the conclusion.

9.6 Future Research Directions

In the future, with the addition of six sigma (i.e.), Lean – 6 Sigma (DMAIC Method) can be implemented in the postal service sector to reduce process variation in the production system. The entire process can be analyzed through a lean supply chain link to enhance the overall efficiency of the postal system. This lean service implementation can be done in Railway Mail Services (RMS) and other head sorting centers by carefully analyzing the tools and techniques with postal management support. This postal service sector sorting process can be implemented with automation or semi-automation to improve the operational performance and short time to deliver the articles to the addressee.

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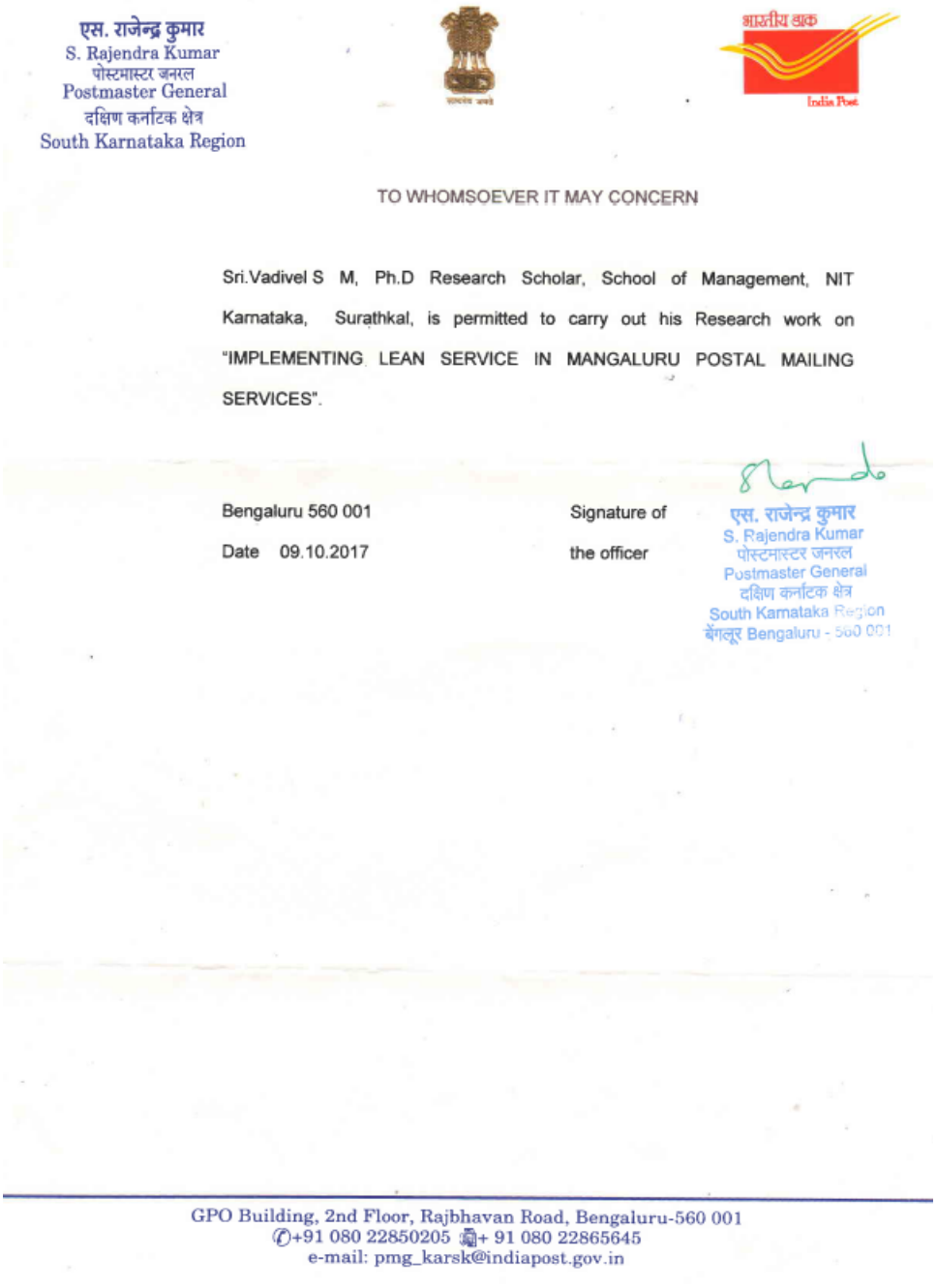
Appendices

I. Permission Letter from South Karnataka PMG



एस. राजेन्द्र कुमार
S. Rajendra Kumar
पोस्टमास्टर जनरल
Postmaster General
दक्षिण कर्नाटक क्षेत्र
South Karnataka Region

भारतीय डाक
India Post

TO WHOMSOEVER IT MAY CONCERN

Sri.Vadivel S M, Ph.D Research Scholar, School of Management, NIT Karnataka, Surathkal, is permitted to carry out his Research work on "IMPLEMENTING LEAN SERVICE IN MANGALURU POSTAL MAILING SERVICES".

Bengaluru 560 001

Date 09.10.2017

Signature of the officer

एस. राजेन्द्र कुमार
S. Rajendra Kumar
पोस्टमास्टर जनरल
Postmaster General
दक्षिण कर्नाटक क्षेत्र
South Karnataka Region
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II. Questionnaire of the study

1.Selection of best layout using Analytical Hierarchy Process (AHP)

Dear Sir/Madam,

Good day! I am Vadivel S M, Research Scholar, School of Management, NIT Karnataka, Surathkal. I am doing my research work on implementing lean service in India post mail services. This survey is part of my research work to find the appropriate layout in order to improve the productivity. In this regards, I request you to fill the questionnaire form. Your answers will be helpful to select the suitable layout from the alternatives.

INSTRUCTIONS:

1. Please tick (√) mark in the given pairwise comparisons in the row at a time.

2. This survey will be helpful to select the best layout as your needs, so answer as accurately as possible.

3. There are seven alternative layout drawings are given, observe and do the tick (√) mark.

AHP - QUESTIONAIRE FORM

Saaty (1 – 9) Scale

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2, 4, 6, 8	For compromises between the above
Reciprocals of above	In comparing elements X and Y - if X is 3 compared to Y - then Y is 1/3 compared to X

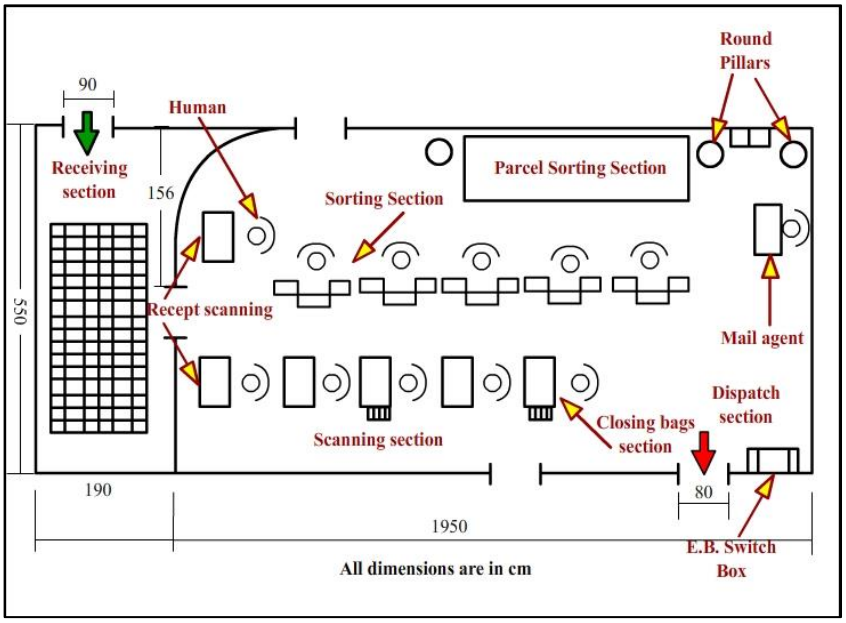

Figure 1 Alternative layout 1

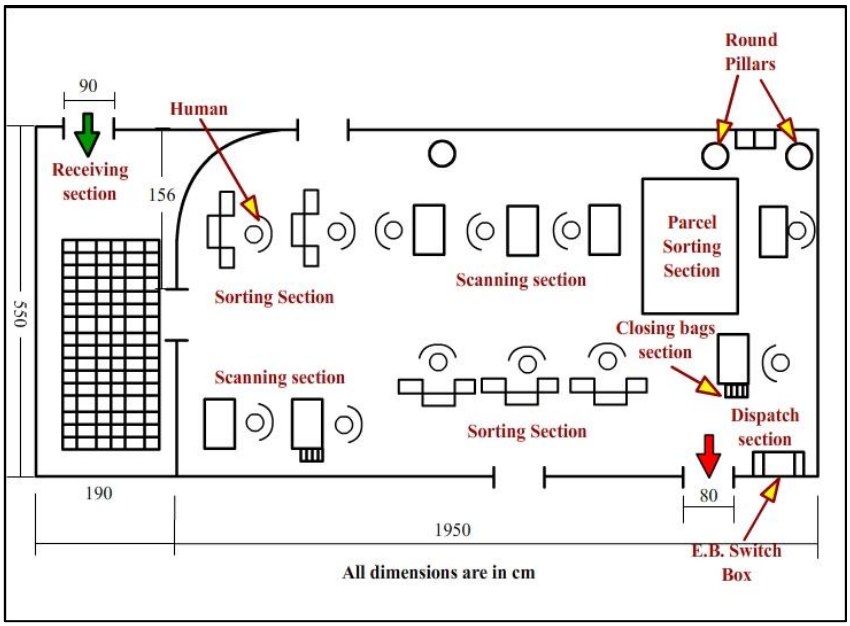

Figure 2 Alternative layout 2

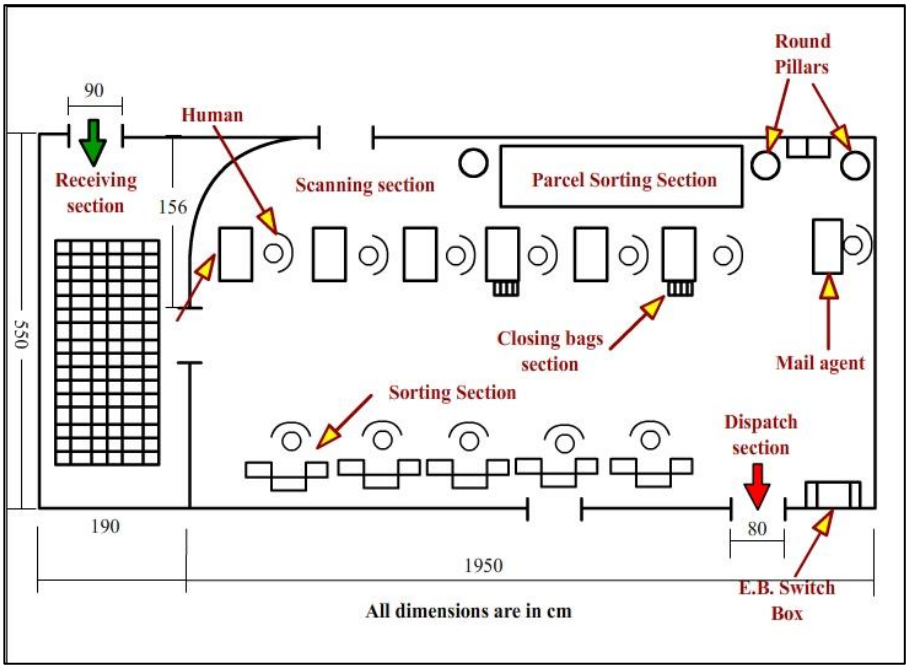

Figure 3 Alternative layout 3

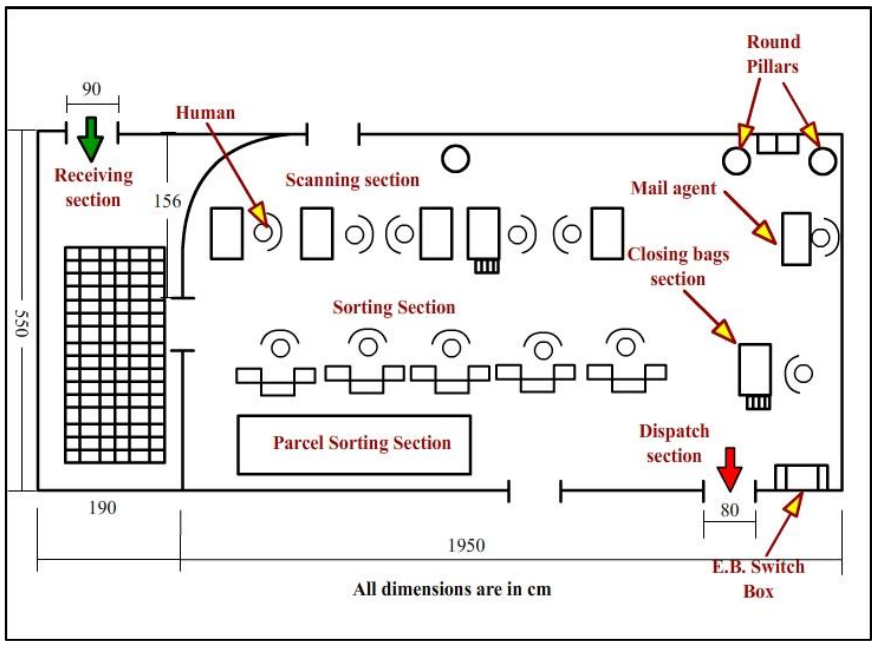

Figure 4 Alternative layout 4

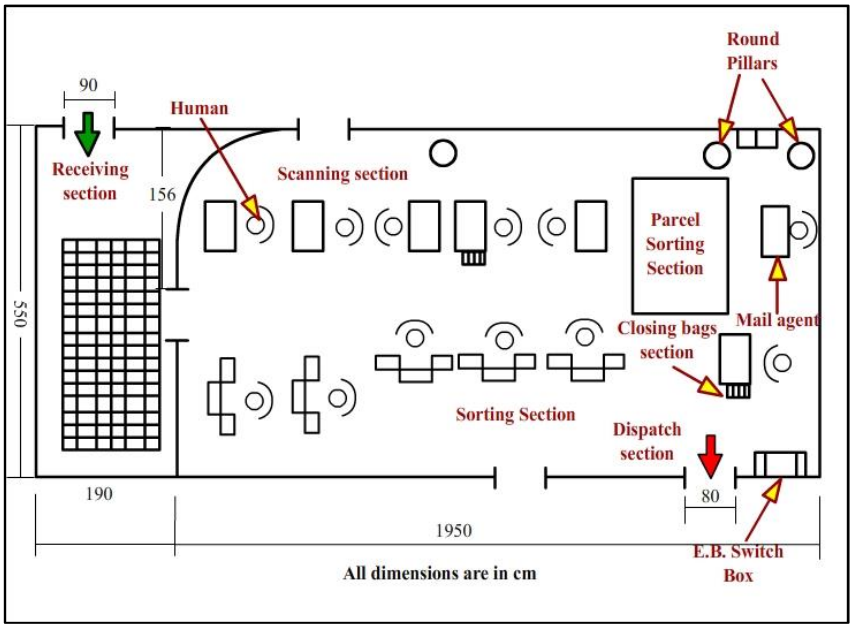

Figure 5 Alternative layout 5

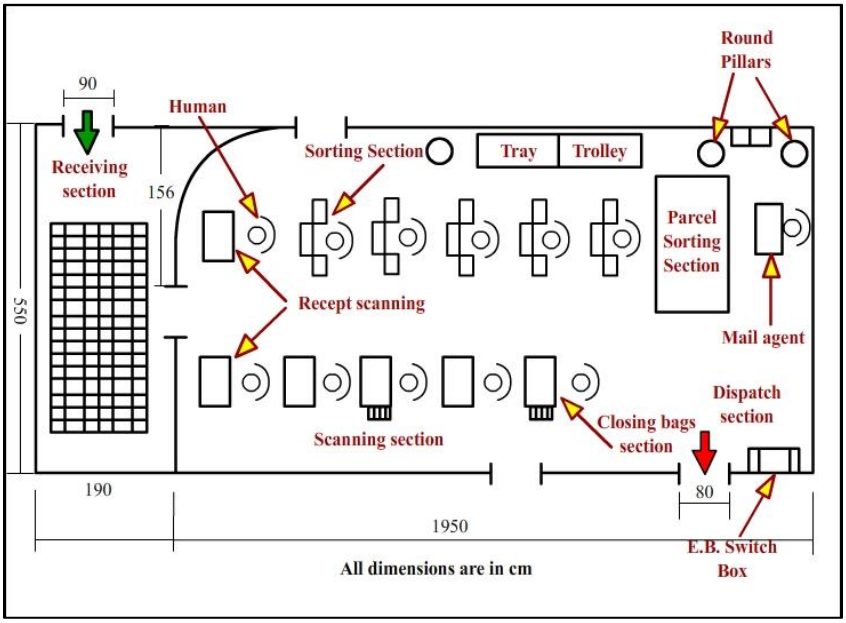

Figure 6 Alternative layout 6

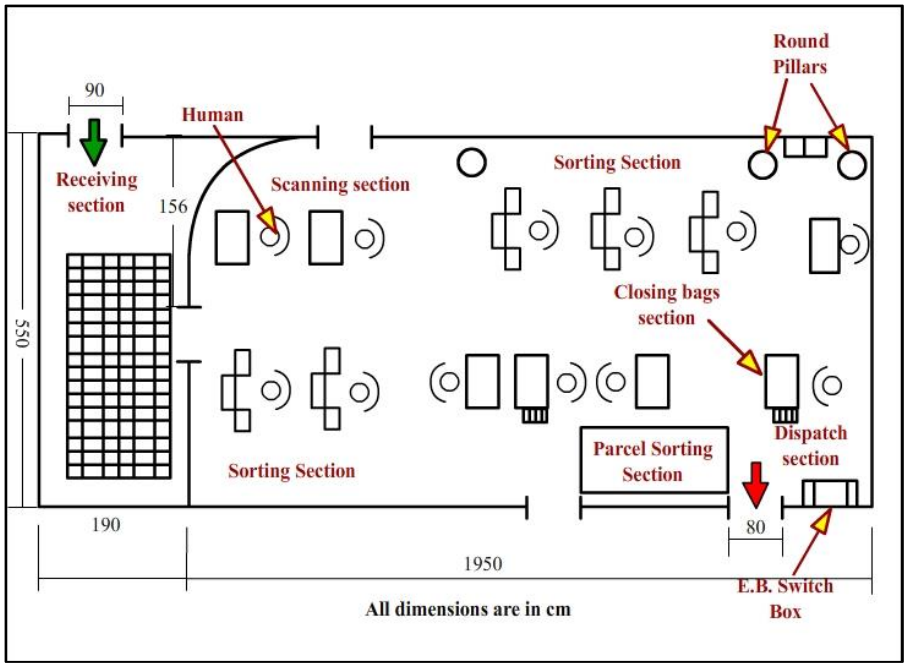

Figure 7 Alternative layout 7

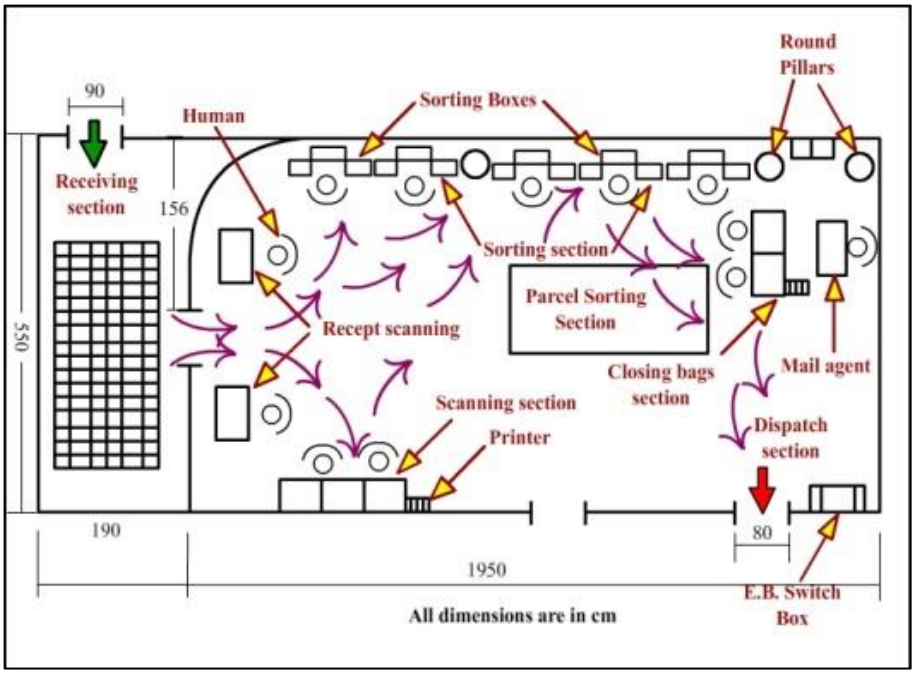

Figure 8 Alternative layout 8 (Existing Layout)

Example:

Table.1 Questionnaire for Criteria

Automobile	Relative Importance																	Automobile
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Hyundai			√															Toyota
Hyundai													√					Maruthi Suzuki
Toyota									√									Maruthi Suzuki

<u>Explanation about tick marks:</u>

- First tick mark represents Hyundai car Very Strongly preferred (7) than Toyota
- Second tick mark represents Hyundai reciprocally strongly preferred (1/5) than Maruthi Suzuki **(or)**
  Second tick mark represents Maruthi Suzuki is strongly preferred (5) than Hyundai
- Third tick mark represents Maruthi Suzuki is equally preferred with Toyota

Criteria vs Criteria Table.1 Questionnaire for criteria

Attribute 1	Relative Importance																	Attribute 2
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Lean service approach																		Working environment conditions
Lean service approach																		Ergonomics approach
Working environment conditions																		Ergonomics approach

Table.2 Questionnaire for Criteria and Sub-criteria

Lean service approach	Relative Importance																	Lean service approach
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Efficient movement of mail																		Efficient movement of personnel
Efficient movement of mail																		Throughput time
Efficient movement of mail																		Material handling time
Efficient movement of mail																		Efficient space utilization
Efficient movement of mail																		Efficient process flow
Efficient movement of mail																		Flexiblity
Efficient movement of mail																		Inventory reduction
Efficient movement of personnel																		Throughput time
Efficient movement of personnel																		Material handling time
Efficient movement of personnel																		Efficient space utilization
Efficient movement of personnel																		Efficient process flow
Efficient movement of personnel																		Flexiblity

Efficient movement of personnel																		Inventory reduction
Throughput time																		Material handling time
Throughput time																		Efficient space utilization
Throughput time																		Efficient process flow
Throughput time																		Flexiblity
Throughput time																		Inventory reduction
Material handling time																		Efficient space utilization
Material handling time																		Efficient process flow
Material handling time																		Flexiblity
Material handling time																		Inventory reduction
Efficient space utilization																		Efficient process flow
Efficient space utilization																		Flexiblity
Efficient space utilization																		Inventory reduction
Efficient process flow																		Flexiblity
Efficient process flow																		Inventory reduction
Flexiblity																		Inventory reduction

Table.3 Questionnaire for Criteria and Sub-criteria

Working environment conditions	Relative Importance																	Working environment conditions
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Light facilities																		Ventilation facilities
Light facilities																		Noise control
Light facilities																		Pollution control
Light facilities																		Aesthetics
Light facilities																		Safety
Light facilities																		Equipment availability
Ventilation facilities																		Noise control
Ventilation facilities																		Pollution level
Ventilation facilities																		Aesthetics
Ventilation facilities																		Safety
Ventilation facilities																		Equipment availability
Noise control																		Pollution control
Noise control																		Aesthetics
Noise control																		Safety
Noise control																		Equipment availability
Pollution control																		Aesthetics
Pollution control																		Safety
Pollution control																		Equipment availability
Aesthetics																		Safety
Aesthetics																		Equipment availability
Safety																		Equipment availability

Table.4 Questionnaire for Criteria and Sub-criteria

Ergonomics approach	Relative Importance																	Ergonomics approach
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Emergency exit																		Security
Emergency exit																		Ease of supervision
Emergency exit																		Work Posture
Emergency exit																		Comforts
Emergency exit																		Facilities
Emergency exit																		Ease of accessibility
Emergency exit																		Ease of maintenance
Security																		Ease of supervision
Security																		Work Posture
Security																		Comforts
Security																		Facilities
Security																		Ease of accessibility
Security																		Ease of maintenance
Ease of supervision																		Work Posture
Ease of supervision																		Comforts
Ease of supervision																		Facilities
Ease of supervision																		Ease of accessibility
Ease of supervision																		Ease of maintenance
Work Posture																		Comforts
Work Posture																		Facilities

Work Posture																		Ease of accessibility
Work Posture																		Ease of maintenance
Comforts																		Facilities
Comforts																		Ease of accessibility
Comforts																		Ease of maintenance
Facilities																		Ease of accessibility
Ease of accessibility																		Ease of maintenance

Table.5 Questionnaire for alternatives - lean service approach subcriteria

Efficient movement of mail	Relative Importance																	Efficient movement of mail
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
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Layout 4																	Layout 6
Layout 4																	Layout 7
Layout 5																	Layout 6
Layout 5																	Layout 7
Layout 6																	Layout 7

Table.6 Questionnaire for alternatives - lean service approach subcriteria

Efficient movement of personnel	Relative Importance																Efficient movement of personnel
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 5																		Layout 7
Layout 6																		Layout 7

Table.7 Questionnaire for alternatives - lean service approach subcriteria

Througput time	Relative Importance																	Throughput time
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 5																		Layout 7
Layout 6																		Layout 7

Table.8 Questionnaire for alternatives - lean service approach subcriteria

Mail handling time	Relative Importance																	Mail handlng time
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
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Layout 4																		Layout 7
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Layout 5																		Layout 7
Layout 6																		Layout 7

Table.9 Questionnaire for alternatives - lean service approach subcriteria

Efficient space utilization	Relative Importance																	Efficient space utilization
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 6																		Layout 7

Table.10 Questionnaire for alternatives - lean service approach subcriteria

Efficient process flow	Relative Importance																	Efficient process flow
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 6																		Layout 7

Table.11 Questionnaire for alternatives - lean service approach subcriteria

Flexiblity	Relative Importance																	Flexibilty
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 6																		Layout 7

Table.12 Questionnaire for alternatives - lean service approach subcriteria

Inventroy reduction	Relative Importance																	Inventory reduction
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 6																		Layout 7

Table.13 Questionnaire for alternatives – work environment condition subcriteria

Light facilties	Relative Importance																	Light facilities
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Layout 6																		Layout 7

Table.14 Questionnaire for alternatives – work environment condition subcriteria

Ventilation facilties	Relative Importance																	Ventilation facilities
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
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Table.15 Questionnaire for alternatives – work environment condition subcriteria

Noise control	Relative Importance																	Noise control
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.16 Questionnaire for alternatives – work environment condition subcriteria

Pollution control	Relative Importance																	Pollution control
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.17 Questionnaire for alternatives – work environment condition subcriteria

Aesthetics	Relative Importance																	Aesthetics
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.18 Questionnaire for alternatives – work environment condition subcriteria

Safety	Relative Importance																	Safety
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.19 Questionnaire for alternatives – work environment condition subcriteria

Equipments availability	Relative Importance																	Equipments availability
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.20 Questionnaire for alternatives – ergonomics subcriteria

Emergency exit	Relative Importance																	Emergency exit
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.21 Questionnaire for alternatives – ergonomics subcriteria

Security	Relative Importance																	Security
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.22 Questionnaire for alternatives – ergonomics subcriteria

Ease of supervision	Relative Importance																	Ease of supervision
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.23 Questionnaire for alternatives – ergonomics subcriteria

Work posture	Relative Importance																	Work posture
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.24 Questionnaire for alternatives – ergonomics subcriteria

Comforts	Relative Importance																	Comfors
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.25 Questionnaire for alternatives – ergonomics subcriteria

Facilities	Relative Importance																	Facilities
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.26 Questionnaire for alternatives – ergonomics subcriteria

Ease of accessibility	Relative Importance																	Ease of accessibility
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

Table.27 Questionnaire for alternatives – ergonomics subcriteria

Ease of maintenance	Relative Importance																	Ease of maintenance
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Layout 1																		Layout 2
Layout 1																		Layout 3
Layout 1																		Layout 4
Layout 1																		Layout 5
Layout 1																		Layout 6
Layout 1																		Layout 7
Layout 2																		Layout 3
Layout 2																		Layout 4
Layout 2																		Layout 5
Layout 2																		Layout 6
Layout 2																		Layout 7
Layout 3																		Layout 4
Layout 3																		Layout 5
Layout 3																		Layout 6
Layout 3																		Layout 7
Layout 4																		Layout 5
Layout 4																		Layout 6
Layout 4																		Layout 7
Layout 5																		Layout 6
Layout 5																		Layout 7
Layout 6																		Layout 7

2. Assessment of Lean Service Implementation in Indian Postal Mailing Service

Dear Sir/Madam,

Good day! I am Vadivel S M, Ph.D. Research Scholar from School of Management, National Institute of Technology Karnataka (NITK), Surathkal. This is part of my research work in Indian Postal Mail Service. This research work is to assess the lean service implementation in National Speed post Hub (NSH) Mangalore and necessary approval has been obtained from competitive authority. I request you to fill the questionnaire given below. Your answers will be helpful in understanding the critical success factors of implementing lean service in NSH Mangalore. Your responses will be used only for academic purpose and your information will be kept confidential.

INSTRUCTIONS:

1. Your identity will be kept anonymous**.**

2. Please answer the questions as per given instructions.

3. If you find some questions are not relevant to you, kindly do not answer.

4. This survey will be helpful in understanding lean service implementation in Indian postal service, answer as accurately as possible.

5. After answering all the questions, kindly submit the questionnaire.

6.Filled in questionnaire shall be collected by me.

Part A

1. Gender: ☐Male ☐ Female ☐ Other
2. Age : ☐ Under 20 years ☐ 21 - 35 years ☐ 35 – 50 years ☐ Over 50 years
3. Education level: ☐ SSLC ☐ Higher Secondary ☐U.G ☐P.G ☐Others
4. Work Experience
   ☐Less than 3 year ☐ 4 - 14 years ☐15 - 25 years ☐More than 25 years
5. Nature of employment : ☐Permanent ☐Temporary (Contract basis)

Part B

i. Indicate the extent to which postal services are implemented the following lean service practices: (Tick any **one** option on the scale).

Scale: (1) Not implemented (2) Under consideration (3) Beginning (4) Partially implemented (5) Fully implemented

	Not Implemented				Fully Implemented
1. Value stream mapping	1	2	3	4	5
2. Continuous improvement	1	2	3	4	5
3. 5S	1	2	3	4	5
4. Improving facility layout	1	2	3	4	5
5. Standard operating procedure	1	2	3	4	5
6. Kanban	1	2	3	4	5
7. Cellular layout	1	2	3	4	5
8. Root cause analysis	1	2	3	4	5
9. Single piece flow	1	2	3	4	5
10. Visual control	1	2	3	4	5
11. Improve productivity	1	2	3	4	5
12. Work load balancing	1	2	3	4	5
13. Mistake proofing	1	2	3	4	5
14. Quick set up time	1	2	3	4	5
15. Takt time	1	2	3	4	5
16. Process redesign	1	2	3	4	5
17. Reduce cycle time	1	2	3	4	5
18. Reduce lead time	1	2	3	4	5
19. Improve flexibility	1	2	3	4	5

ii. Indicate your level of agreement /disagreement as a direct consequence of lean service implementation on social practices (Tick any **one** option on the scale).

Scale: (1) Strongly Disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly Agree

	Strongly Disagree				Strongly Agree
1. Effective communication system	1	2	3	4	5
2. Employee empowerment	1	2	3	4	5
3. Employee commitment	1	2	3	4	5
4. Employee involvement	1	2	3	4	5
5. Having multifunctional employees	1	2	3	4	5
6. Leadership	1	2	3	4	5
7. Obtaining management support	1	2	3	4	5
8. Performance measurement system	1	2	3	4	5
9. Training	1	2	3	4	5

iii. Indicate your level of satisfaction/dissatisfaction as a direct consequence of lean service implementation on workplace environmental practices (Tick any one option on the scale).

Scale: (1) Not Satisfied (2) Satisfied (3) Moderately Satisfied (4) Very Satisfied (5) Extremely Satisfied

	Not Satisfied				Extremely Satisfied
1. Lighting facilities	1	2	3	4	5
2. Ventilation	1	2	3	4	5
3. Visual Identification	1	2	3	4	5
4. Noise control	1	2	3	4	5
5. Temperature	1	2	3	4	5
6. Cleanliness	1	2	3	4	5
7. Workspace	1	2	3	4	5
8. Ergonomics	1	2	3	4	5
9. Floors and traffic routes	1	2	3	4	5
10. Drinking water facilities	1	2	3	4	5
11. Equipment availability	1	2	3	4	5

iv. Indicate your level of agreement/disagreement on improving operational performance as a direct consequence of the implementation of lean service practices (Tick any one option on the scale).

Scale: (1) Strongly Disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly Agree

	Strongly Disagree				Strongly Agree
1. Identification and elimination of waste	1	2	3	4	5
2. Improvement in space utilisation	1	2	3	4	5
3. Improvement in customer perception of service quality	1	2	3	4	5
4. Improvement in employees performance	1	2	3	4	5
5. Improvement in employees understanding the process	1	2	3	4	5
6. Improvement in productivity	1	2	3	4	5
7. Improvement in flow speed	1	2	3	4	5
8. Improvement in line efficiency	1	2	3	4	5
9. Improvement in lighting facilities	1	2	3	4	5
10. Improvement in ventilation facilities	1	2	3	4	5
11. Improvement in housekeeping	1	2	3	4	5
12. Reduction in cycle time	1	2	3	4	5
13. Reduction in number of human errors	1	2	3	4	5

NATIONAL INSTITUTE OF TECHNOLOGY
KARNATAKA, SURATHKAL

List of Publications based on PhD Research Work

[to be filled-in by the Research Scholar and to be enclosed with Synopsis submission Form]

Sl. No.	Title of the paper	Authors	Name of the Journal/ Conference/ Symposium, Vol., No., Pages	Month & Year of Publication	Category *
1	Sustainable postal service design: Integrating quality function deployment from the customers perspective	Vadivel S.M., Sequeria A. H., Sunil Kumar Jauhar, Vimal Kumar	International Journal of System Assurance Engineering and Management, 11(2),261-273, Springer publishers. pp.1-12, DOI: https://doi.org/10.1007/s13198-019-00906-6	April 2020	1
2	Enhancing the Operational Performance of Mail Processing Facility Layout selection using AHP	Vadivel S.M., Sequeria A. H., Deeksha Sanjay Shetty, and Sunil Kumar Jauhar	International Journal of System Assurance Engineering and Management, 11(2),494-505, Springer publishers. pp.1-13, DOI: https://doi.org/10.1007/s13198-019-00854-1	April 2020	1
3	A hybrid method for the selection of facility layout using experimental design and grey relational analysis: A case study	Vadivel S.M., Sequeria A. H.	International Journal of Hybrid Intelligent Systems (IJHIS), IOS Press publishers, Vol.15, pp.101-110, DOI: 10.3233/HIS-190264.	June 2019	1
4	Enhancing the Operational Performance of Mail Processing Facility Layout selection using Multi - Criteria Decision Making Methods	Vadivel S.M., Sequeria A. H.	International Journal of Service and Operations Management, Inderscience publishers. DOI: 10.1504/IJSOM.2020.10018620.	July 2018	1
5	Lean service application towards operational performance in Indian Postal Mailing Service – A Conceptual Model	Vadivel S.M., Sequeria A. H.	International Journal of Engineering Technology Science and Research, Vol.4,No.10,pp 24 – 28.	October 2017	1

6	A Novel Approach for Operational Performance Mail Processing Facility Layout selection using Grey Relational Analysis: A Case on India Speed Post Service Industry	Vadivel S.M., Sequeria A. H.	Advances in Intelligent Systems and Computing, Springer publishers, Vol.940, pp.1123-1132, A Book Chapter, DOI: https://doi.org/10.1007/978-3-030-16657-1_105.	December 2019	3
7	Metaheuristic for Optimize the India Speed Post Facility Layout Design and Operational Performance Based Sorting Layout Selection Using DEA Method	Vadivel S.M., Sequeria A. H, Sunil Kumar Jauhar.	Advances in Intelligent Systems and Computing, Springer publishers, vol.941, pp.1035-1044, A Book Chapter, DOI: https://doi.org/10.1007/978-3-030-16660-1_101.	December 2019	3
8	Lean Ergonomics Evaluation of Indian postal Manual sorting facility layouts – a Empirical study,	Vadivel S.M., and Sunil D.Souza,	COSMAR16,IISc.Bangalore, pg.no.17.	November 2016	4
9	An operational performance of Indian Postal Service using Lean manufacturing approach A conceptual framework	Vadivel S.M., and Sequeira A.H	International conference on Strategies in volatile and uncertain environment for emerging markets, Department of Management Studies, IIT Delhi, 14-15, Pg.no.20.	July 2017	4
10	Indian postal service operational performance by lean sustainability approach,	Vadivel S.M., and Sequeira A.H	ATHENAEUM 18, 8th International conference on Contemporary Management Research, Bharathidasan Institute of Management (BIM), IIT Madras, 9th and 10th Feb. 2018, Pg.no.4	February 2018	4
11	Indian postal manual sorting facilities layout selection using AHP methodology	Vadivel S.M., and Sequeira A.H	RCOSCM 18, Research conference on Operations and Supply Chain Management, Symbiosis Institute of Operations Management, Nashik, 17th February 2018. Pg.no.35-47.	February 2018	3
12	Green Postal Service Design: Integrating quality function deployment from customer's	Vadivel S.M., and Sequeira A.H	2nd International Conference on Innovative Research in Science, Technology and Management	September 2018	3

	perspectives		(ICIRSTM 18), National university of Singapore (NUS), Singapore, 29-30, September 2018. Pg.no.31		
13	Evaluating and Ranking the operational performance Mail Processing Facilities layout using Grey Relational Analysis	Vadivel S.M., and Sequeira A.H	12th Annual International Conference of the Society of Operations Management, IIM Kozhikode, 20-22, December 2018. Pg.no.16.	December 2018	4
14	Implementing lean service tools and techniques in India speed post service – A case study	Vadivel S.M., and Sequeira A.H	12 Annual International Conference of the Society of Operations Management, IIM Kozhikode, 20-22, December 2018. Pg.no.17	December 2018	4
15	Value Stream Mapping Simulation (VSM-Sim): methodology to design the lean service systems in India Post Service Industry – A case study	Vadivel S.M., and Sequeira A.H	8th International Engineering Symposium (IES2019) at Kumamoto University, Japan, March 13-15, 2019.pp-640-645.	March 2019	3
16	The impact of lean service practices, workplace environment practices, and social practices on the operational performance in India Post service industry	Vadivel S.M., and Sequeira A.H	7th International Business Analytics and Intelligence Conference (DCAL2019) at IIM Bangalore, India, December 05-07, 2019.Track 21.	December 2019	4

* Category: 1: Journal paper, full paper reviewed
2: Journal paper, Abstract reviewed
3: Conference/Symposium paper, full paper reviewed
4: Conference/Symposium paper, abstract reviewed
5: Others (including papers in Workshops, NITK Research Bulletins, Short notes etc.)

(If the paper has been accepted for publication but yet to be published, the supporting documents must be attached.)

UNDER REVIEW - 3

1. Vadivel S.M and Sequeria A. H., Robert Rajkumar, "The impact of lean service, lean workplace environment, lean social practices on operational performance of Indian postal service,", **Annals of Operations Research**, Springer publishers. (ABDC - A indexed), Paper id: ANOR - D - 19-01256.
2. Vadivel S.M., Sequeria A. H., Sunil Kumar Jauhar, "Applying simulation and Taguchi methods to design the lean system in India post service", **Annals of Operations Research,** Springer publishers. (ABDC - A indexed), Paper id: ANOR – D - 20 - 00470.
3. Vadivel S.M and Sequeria A. H. "Systematic literature review on lean service and future directions to sustainability model for service industries" **International Journal of Lean Six Sigma**, Emerald publishers., Paper id: IJLSS-12-2019-0121.

UNDER PREPARATION - 2

1. Vadivel S.M and Sequeria A. H. 'A lean system and Taguchi method for the enrichment of operational performance in mail processing operations – A case study'.
2. Vadivel S.M., Sequeria A.H. 'Analyzing critical success factors of lean implementation in mailing service industry using Graph theory and DEMATEL approach'.

CANDIDATE BIO- DATA

Currently working as an Assistant Professor in Industrial and Production Engineering Department, National Institute of Engineering (NIE), Mysuru – 570008.

EDUCATION DETAILS

Program	Institution	%/CGPA	Year of completion
Ph.D. in Operations Management	National Institute of Technology, Karnataka **(NIT-K)**	9.15/10	2020*
M.S. in Operations Management	Indian Institute of Technology Madras, Chennai **(IIT-M)**	8.33/10	2015
M.E in Manufacturing Engineering	Government College of Technology,Coimbatore **(GCT-CBE)**	8.92/10	2011
B. E in Industrial Engineering	College of Engineering, Anna University, Guindy, Chennai **(CEG-ANNA UNIVERSITY)**	76%	2009
Diploma in Mechanical Engineering	Sri Ramakrishna Mission Technical Institute, Chennai (**SRMTI**).	90.25%	2003
SSLC	Sri Ramakrishna Mission Residential High School, Chennai.	84.25%	2000

INTERNATIONAL PUBLICATIONS - 5

1. Vadivel S.M and Sequeria A. H., Deeksha Sanjay Shetty, Sunil Kumar Jauhar (2019) "Enhancing the Operational Performance of Mail Processing Facility Layout selection using AHP" International Journal of System Assurance Engineering and Management, Springer publishers. pp.1-13,DOI: https://doi.org/10.1007/s13198-019-00854-1 (Scopus Indexed).
2. Accepted: Vadivel S.M., Sequeria A. H., Sunil Kumar Jauhar, Vimal Kumar (2019) "Sustainable postal service design: Integrating quality function deployment from the customers perspective" International Journal of System Assurance Engineering and Management, Springer publishers. (Scopus Indexed).
3. Accepted: Vadivel S.M and Sequeria A. H. (Jan. - 2020) "Enhancing the Operational Performance of Mail Processing Facility Layout selection using Multi - Criteria Decision Making Methods" International Journal of Service and Operations Management, Inderscience publishers. (Scopus Indexed). DOI: 10.1504/IJSOM.2020.10018620.
4. Vadivel S.M., and Sequeria A. H. (2019) "A hybrid method for the selection of facility layout using experimental design and grey relational analysis: A case study", International Journal of Hybrid Intelligent Systems (IJHIS), IOS Press publishers, pp.1-10, DOI: 10.3233/HIS-190264.

5. Vadivel S.M and Sequeria A. H. (2017) "Lean service application towards operational performance in Indian Postal Mailing Service – A Conceptual Model, International Journal of Engineering Technology Science and Research, Vol.4, No.10, pp 24 – 28.

BOOK CHAPTERS – 4 (SCOPUS INDEXED)

1. Vadivel S.M., and Sequeria A. H. (2019) "A Novel Approach for Operational Performance Mail Processing Facility Layout selection using Grey Relational Analysis: A Case on India Speed Post Service Industry", Advances in Intelligent Systems and Computing, Springer publishers, vol.940, pp.1123-1132, DOI: https://doi.org/10.1007/978-3-030-16657-1_105.
2. Vadivel S.M., Sequeria A. H, Sunil Kumar Jauhar. (2019) "Metaheuristic for Optimize the India Speed Post Facility Layout Design and Operational Performance Based Sorting Layout Selection Using DEA Method", Advances in Intelligent Systems and Computing, Springer publishers, vol.941, pp.1035-1044, DOI: https://doi.org/10.1007/978-3-030-16660-1_101.
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INTERNSHIP - 1

1. Vadivel S M successfully completed the JASSO Scholarship program: Spring Intenship Proggram 2019, (March 12-19,2019) at Graduate School of Science and Technology, Kumamoto University, Japan.

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1. Journal of cleaner production, Elsevier Publications. 2019
2. International Journal of System Assurance Engineering and Management, Springer Publications,2019
3. International journal of lean six sigma, Emerald Publications, 2018 & 2019.

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