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INVESTIGATIONS OF THE IMPROVEMENT IN PRODUCTIVITY BY APPLYING EFFECTIVE MAPPING FRAME WORK IN A MECHANICAL INDUSTRY WITH THE HELP OF FUZZY QFD

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Abstract

The present research work focuses on the application of value stream mapping (VSM) and fuzzy quality function deployment (FQFD) techniques for investigating the parameters necessary for productivity enhancement in garment manufacturing industry. During the research work, different tools, namely, 5S, logistic system improvement, Kaizan and Kanban were used for the purpose of performance enhancement, and with the help of VSM and FQFD, their rankings were obtained, and necessary changes were suggested to the targeted industry personnel.

Keywords: Productivity, Value stream mapping (VSM), Fuzzy quality function deployment (FQFD), Kaizan, Kanban, 5S, Logistic system improvement.

1. INTRODUCTION

Accoring to Soltani et al. (2023), the growth as well as great competitions among the manufacturing industries a great pressure on the industries for developing innovative strategies for their sustainability, and due to this reason, today, more and more firms are adopting strategies of cost reduction, waste reduction and similar techniques to remain competitive in the present era. Authors further added that in order to remain competitive, the concept of lean manufacturing is considered as one of the best alternatives. Bhamu and Sangwan (2014) added that there are many tools provided by lean manufacturing which focus on waste reduction, in order to remain competitive. Considering these facts, the present research work is devoted to the application of lean manufacturing concepts for the development of garment industry, and focuses on Investigations of the Improvement in Productivity by Applying Effective Mapping Frame work in a Mechanical Industry with the help of Fuzzy Quality Function Deployment (FQFD). For the purse of mapping, a well known technique, value stream mapping (VSM) is also used in the research paper.

1.1 Objectives of the Research

Following are the objectives of the present research work:

a. Development of integrated VSM-Fuzzy QFD framework for garment industry;

b. Investigations on the rankings of different parameters necessary for productivity improvement; and

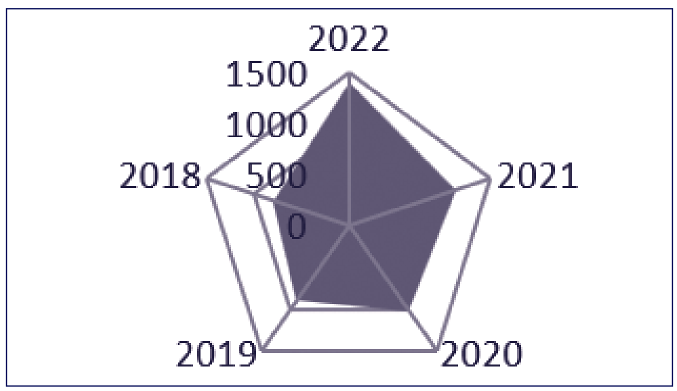
c. Rankings of important productivity parameters.

2. LITERATURE REVIEW

Present section deals with different aspects of the research work and presents scenario of research in the field of productivity, value stream mapping and fully QFD, and concludes with the gaps in the research, the details of which are presented in upcoming sub-sections.

2.1 Scenario of Research in the field of Productivity, Value Stream Mapping and Fuzzy QFD: Figure 2.1 represents the radar graph drawn on the basis of research publications in last five years using the search terms, productivity, value stream mapping and fuzzy QFD, from www.scholar.google.com.

Figure 2.1: Radar Graph based on search terms productivity, value stream mapping and Fuzzy QFD



2.2 Contributions of Researchers in the Field of VSM and QFD: The research work of Horsthofer-Rauch et al. (2022) focuses on different scientific approaches for digitalized value stream maps in the field of manufacturing, where as the Ferreira et al. (2022) studied this concept in assisting Industry 4.0 for analyzing the changes in materials, processes, equipment and the flow of information. In the similar manner, Rathore et al. (2022) developed a tool which was successful integrating lean concepts and ergonomics for the purpose of improving the issues of workers health along with the operational performance, and the research paper of Sangwa and Sangwa (2022) successfully integrated VSM for a complicated assembly line. Salwin et al. (2021) suggested that VSM is a successful technique to reduce company's waste. The study of Wang et al. (2020) aims at how VSM can be applied for improving operational training performances via immersive virtual reality based personalized training schedules, whereas the objective of the study carried out by Murali et al. (2020) was to improve the productivity of a manufacturing company. The research work of Rose et al. (2020) also focuses on enhancing the productivity of a firm using VSM concepts. Similarly, the results of the research work carried out by Ocampo et al. (2020) also advocated four phases of product development for a manufacturing industry. The research work of De Oliveira et al. (2020) highlighted the integration of QFD and analytical hierarchy process for manufacturing applications, whereas Yu-Che et al. (2019) stressed on marketing aspects of the firm using QFD. Talapratra and Shefa (2019) and Hatsey and Sileyew (2019) focused on furniture industry as well as Ethiopian industry sector, respectively. Similarly Huang et al. (2019) presented QFD applications in fashion industry, while Ahmed et al. (2019) focused on garment industry. Proceeding in the similar manner, the research work of Kapuria and Rahman (2018) was focused on T-shirt manufacturing firm using the same research tools.

2.3 Gaps in the Research: On the basis of the survey of available literature, the following research gaps were investigated:

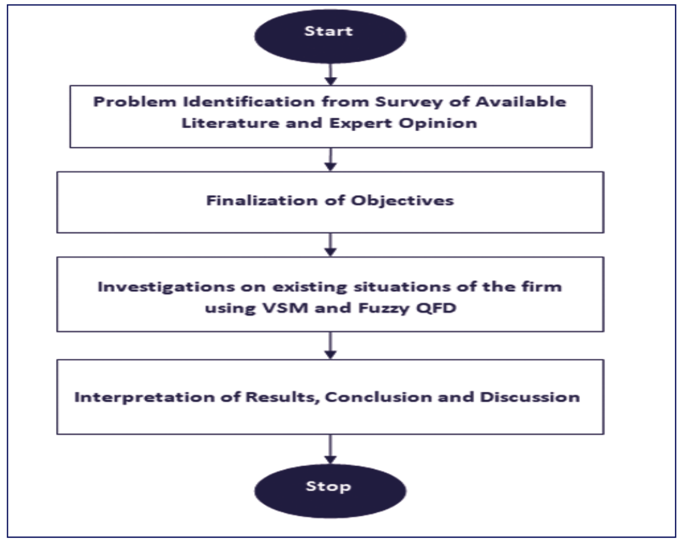
a. There is very limited research available which focuses on the integration of QFD and VSM for manufacturing industries; and

b. There is very limited research available which focuses on the integration of QFD and VSM for garment manufacturing.

3. SOLUTION METHODOLOGY

Figure 3.1 presents the flow chart of research methodology used to solve the research problem.

Figure 3.1: Research Methodology used to solve the Research Problem



Details of different techniques used in solving the research problem are presented as follows:

3.1. Value Stream Mapping (VSM): Value Stream Mapping (VSM) is a tool which is used for analyzing the material flow, information flow necessary in delivering a product to the customer. The advantage of using this method allows anybody to *see* both process flow and communications flow within the process or value stream (Nash and Poling, 2008). VSM includes five basic steps:

Figure 3.2: Steps of VSM

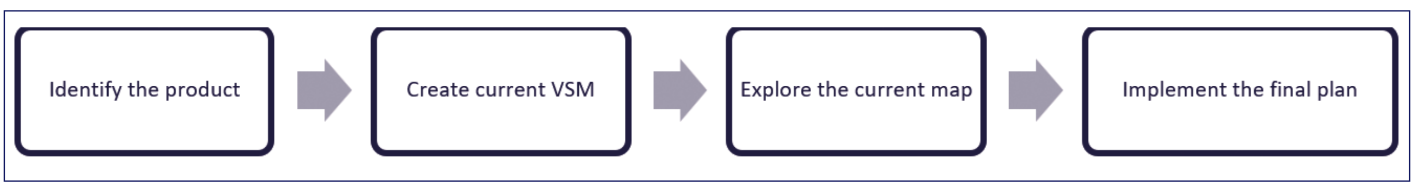


Figure 3.3 shows different VSM symbols.

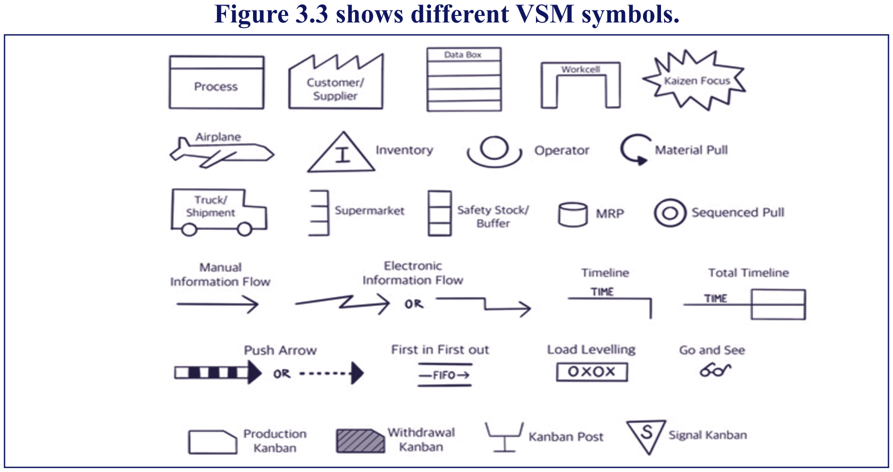
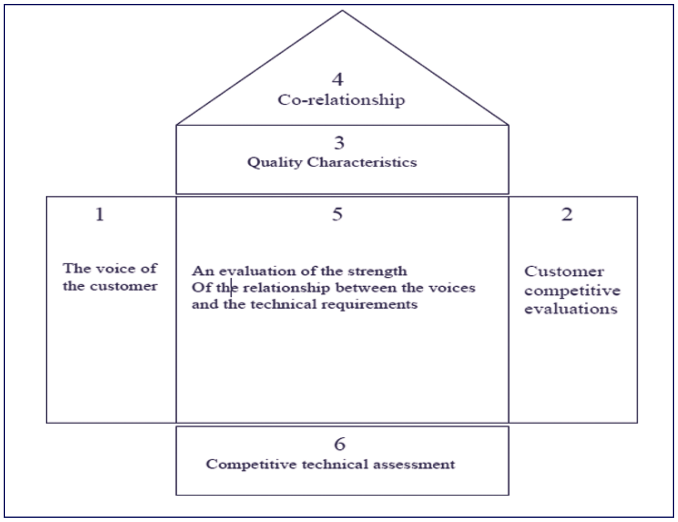


Figure 3.3: Different VSM Symbols (www.sixsigmadsi.com.com)

3.2 Fuzzy Quality Function Deployment (FQFD): According to Abu-Assab (2012), Quality Function Deployment (QFD) was developed in Japan in 1966 as a result of extensive efforts to reach product. The method was introduced as part of the total quality control (TQC) concept, as a method for new product development There is no single or unique definition for QFD, but a general basic concept of this method tells that QFD is a system with the aim of translating and planning the voice of the customer into the quality characteristics of products, processes and services in order to reach customer satisfaction. Figure 3.4 shows house of quality. Details of stages of QFD procedure are as follows (Kioumars et al. 2010):

Figure 3.4: House of Quality (Kioumars et al. 2010**)**



1. Determination of customer demands, expectations and complains;
2. Assessment of business from customers' comparative evaluation;
3. Determination of technical requirements for the products, by converting customers requirements into product specifications;
4. Determining interrelationships between technical requirements;
5. Creation of How-Whats matrix, and calculations of weights for technical requirements by multiplying the relationships with the importance;
6. Assessing the importance of individual technical requirement.

According to the principle of incompatibility (Zadeh, 1973), when facing a complex decision, human beings have difficulty in making a precise decision. As an effect, the data of human subjective judgment are usually fuzzy and imprecise in nature (Lin et al., 2006). Fuzzy data can be expressed using linguistic terms or in fuzzy numbers (Chen et al., 1992). Thus, the value of fuzzy measures as a linguistic value and then linguistic terms need to be converted to fuzzy numbers (Shyamal and Pal, 2007). There are many forms of fuzzy numbers to represent vague cases, but the most important is to use triangular fuzzy numbers. The various operations in fuzzy logic are addition, subtraction and multiplication. These operations are explained as follows:

Fuzzy-number addition: $(a_1, a_2, a_3) \oplus (b_1, b_2, b_3) = (a_1+b_1, a_2+b_2, a_3+b_3)$;

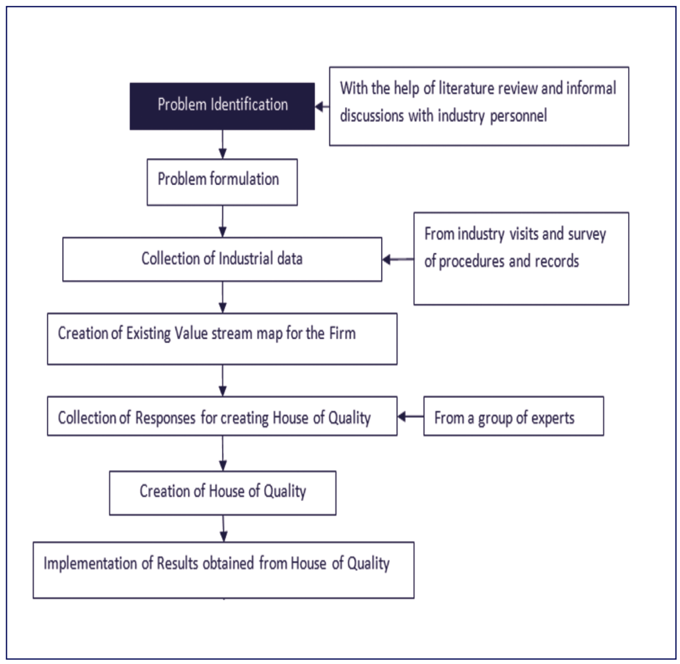
Fuzzy-number subtraction: $(a_1, a_2, a_3) \ominus (b_1, b_2, b_3) = (a_1-b_1, a_2-b_2, a_3-b_3)$;

Fuzzy-number multiplication: $(a_1, a_2, a_3) \otimes (b_1, b_2, b_3) = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3)$ (Klir and Yuan, 1995; Bowles and Pelaez, 1995; Lin et al., 2006).

4. CASE STUDY

Present chapter tells about the details of case study and tells about problem formulation and its solution, the details of which are presented in subsequent sub sections. Figure 4.1 tells about the overview of case study.

Figure 4.1: Overview of Case Study

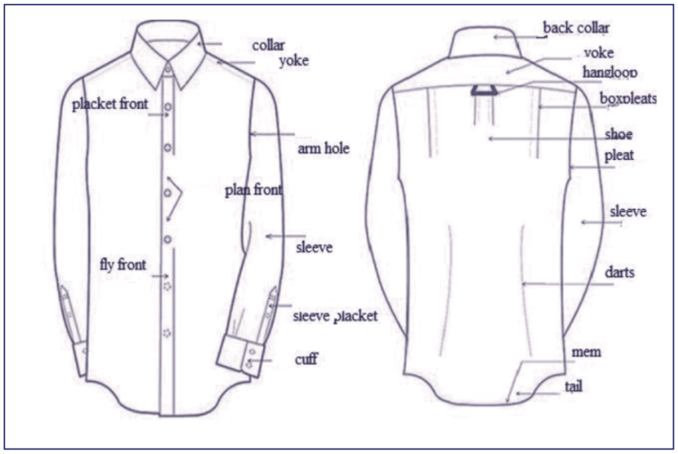


4.1 Problem Formulation: With the help of survey of available literature and discussions with the experts it was found that garment industry is one of the basic industries of the country and leads to the employment of over 4.5 Crore people. Domestic textiles and apparel industry contributes around 2 percent to GDP, 7 percent of industry output in value terms and 12 percent to country's export earnings. Considering above mentioned facts, garment industry was focused, and considering the complexity of product, a ready-made collar shirt manufacturing unit was targeted.

4.2 Problem Solution: Problem solution phase of the research problem consisting of following stages:

Analysis of collar shirt anatomy from research point of view: In the first stage of problem solution, analysis of collar shirt anatomy was made. Figure 4.3 shows the basic anatomy of a collar shirt.

Figure 4.2: Anatomy of a Collar Shirt (Sudarshan and Rao, 2013)



It was found that the anatomy was quite unsuitable from research point of view. This is because of patterns of drawing different parts together on a same machine. Due to this fact, anatomy of collar shirt was analyzed from manufacturing point of view and it was found that collar shirt are manufactured in *four* stages, as follows:

a. Preparational operations;
b. Back preparations;
c. Front preparations; and
d. Assembly.

Creation of Existing Value Stream Map: In the next stage of research work, creation of existing value stream map was accomplished. For this purpose, all the processes needed to create a collar shirt were analyzed and their interdependencies were investigated. For this purpose first of all, an outline flow chart of the process was created, as shown below:

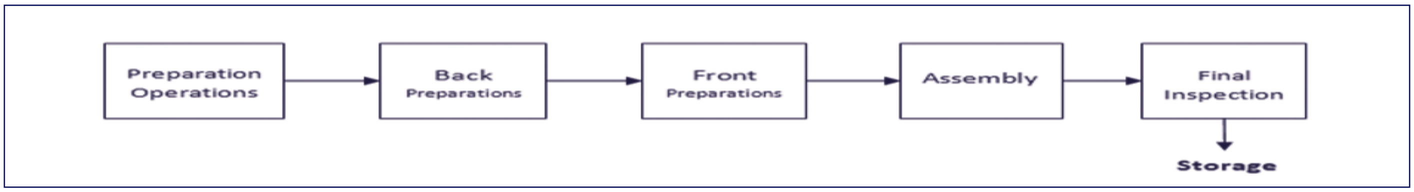


Figure 4.3: Outline Process chart for Collar Shirt Manufacturing

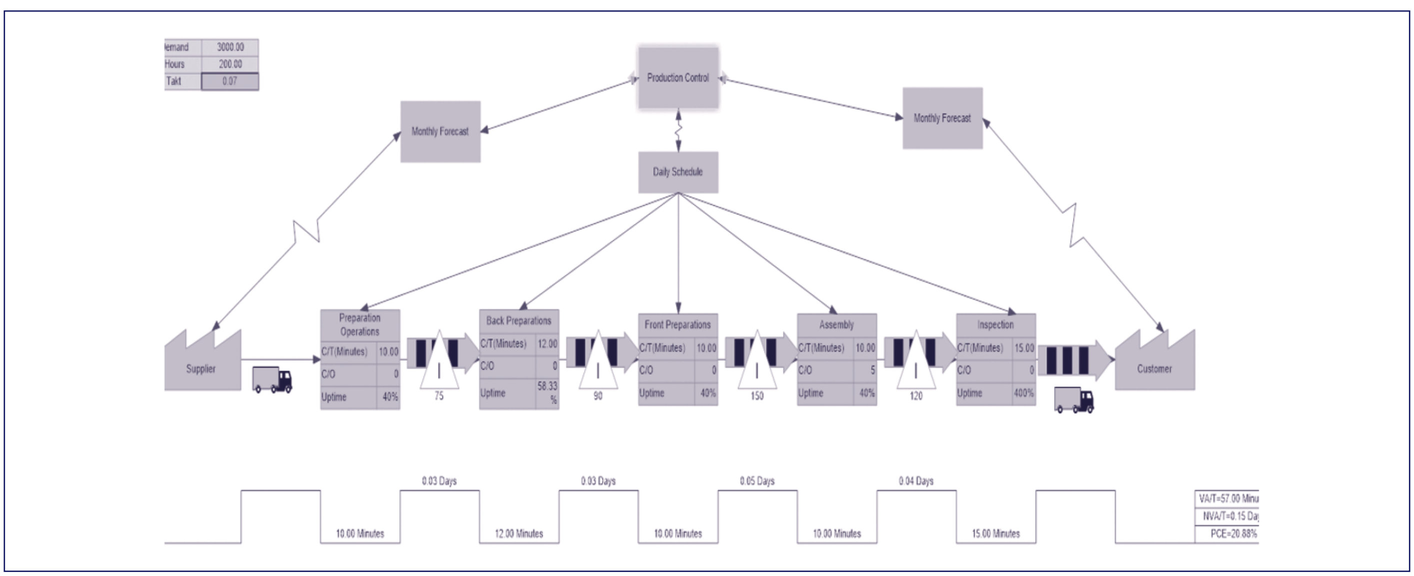
Considering above figure, calculations for different production parameters were made, as follows.

Table 4.1: Calculations of Times for different operations

S.No	Operation	Production Rate (numbers/hour/machine)	Cycle Time	Up time	Number of Operators
1.	Preparation Operations	6	10	40	1
2.	Back Preparations	5	12	58.33333	1
3.	Front Preparations	6	10	40	1
4.	Assembling	6	10	40	1
5.	Inspection	4	15	73.33333	1

With the help of above calculations, existing value stream map was created, as follows.

Figure 4.4: Value stream map for Existing Layout



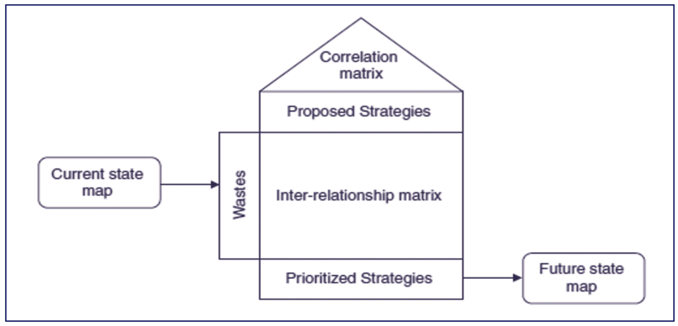
From above VSM, valuable and non valuable times were investigated, as follows:

Table 4.2: Investigated times from Value Stream Model

S. No	Operation	Valuable Time	Non-valuable Time
1	Preparational Operation	10 minutes	0.03 days
2	Back preparation	12 minutes	0.33 days
3	Front preparation	10 minutes	0.05 days
4	Assembly	10 minutes	0.04 days
5	Inspection	15 minutes	-

From above results, it was found that the valuable times were very less as compared to the non valuable times. Due to this reason, investigations were made in the search of reduction of non valuable times. For this purpose, quality function deployment (QFD) was conceptualized for the case problem. In the domain of QFD, house of quality (HOQ) is conceptualized which is used in converting customer expectations into product specifications, and it, therefore, it is used in prioritizing the customer needs which can be ultimately converted into product specifications. In the research work, fuzzy QFD is conceptualized, for easeful responses. Following model was targeted for HOD construction.

Figure. 4.5: Integrated VSM and FQFD (Mohanraj et al., 2015)



During the development of house of quality, in inter-relationship matrix, following degree of relationships were used:

Table 4.3: Degree of Relationships used in Inter-relationship Matrix

S. No	Name	Symbol	Fuzzy Number	Significance
1	Strong	●	(0.7, 1, 1)	Strong relationship between customer expectations and product specifications
2	Medium	○	(0.3, 0.5, 0.7)	Medium relationship between customer expectations and product specifications
3	Weak	∇	(0, 0, 0.3)	Weak relationship between customer expectations and product specifications

Table 4.4 shows the Linguistic variables used for accessing importance weight and their corresponding fuzzy numbers, which were used in accessing weights of customer expectations.

Table 4.4: Linguistic variables and associated Fuzzy Numbers

S. No	Weight of Importance	Fuzzy Numbers	Significance
1	Very high	(0.7, 1, 1)	Very high priority w.r.t. others
2	High	(0.5, 0.7, 1)	High priority w.r.t. others
3	Low	(0, 0.3, 0.5)	Low priority w.r.t. others
4	Very low	(0, 0, 0.3)	Very low priority w.r.t. others

In correlation matrix, following symbols were used.

Table 4.5: Symbols used in Correlation Matrix

S. No	Name	Symbol	Significance
1	Strong positive	++	Shows strong positive correlation of one product specification with other
2	Positive	+	Shows positive correlation of one product specification with other
3	Negative	-	Shows negative correlation of one product specification with other
3	Strong negative	--	Shows strong negative correlation of one product specification with other

From literature survey of QFD, following functional requirements were selected for the case problem.

Table 4.6: Functional Requirements for the Case Problem

S. No	Name of Functional Requirement	Description and Purpose
1	Logistic System Improvement (LSI)	It was used using online as well as offline modes. In online mode, more detailed designs were called from designers and in offline mode, better material handling systems and transportation systems (conveyers) were suggested.
2	5S	With the help of this tool, work cubical was organized in better manner.
3	Kanban	Kanban is a signaling tool to show over production of items which can be transferred to next station immediately.
4	Kaizan	It is a tool which advocates continuous improvement. Kaizan can be applied at every stage of process.

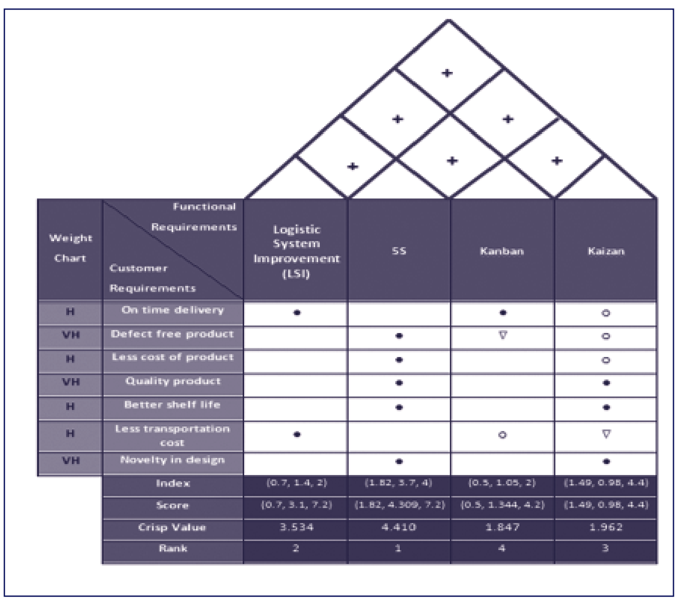
For investigations of customer requirements, interviews of customers and experts were organized, along with the backbone of literature survey, which yield following results.

Table 4.7: Customer Requirements for the Research Problem

S. No	Customer Requirements	Remarks
1	On time delivery	Both end user and outlet manager
2	Defect free product	Both end user and outlet manager
3	Less cost of product	Both end user and outlet manager
4	Quality product	Both end user and outlet manager
5	Better shelf life	Outlet manager
7	Less transportation cost	Outlet manager
8	Novelty in design	Both end user and outlet manager

Using above data and information, house of quality was created as shown in Figure 4.6.

Figure 4.6: House of Quality



5. RESULTS AND DISCUSSION

Present section is devoted to results made from and the discussion made about the research work, the details of which are presented in upcoming sub-sections.

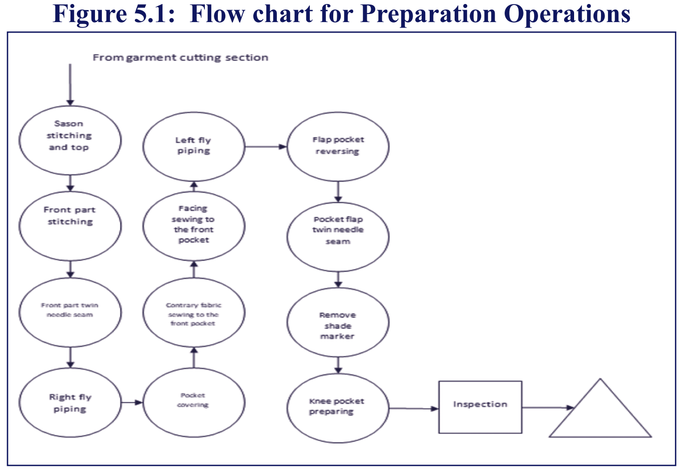
Results: Table 5.1 represents the ranking of different functional requirements.

Table 5.1: Ranking of Different Functional Requirements

S. No	Name of Functional Requirement	Ranking
1	Logistic System Improvement (LSI)	2
2	5S	1
3	Kanban	4
4	Kaizan	3

5.2 Discussion: In last chapter ranking of different quality indicators were obtained, which showed the direction in which changes in the existing system should be made. For this purpose, each main station in the system was deeply analyzed and corrections were made, as per the ranking of different indicators. In this series, first of all, flow process chart for preparation operations was created, as shown in figure 5.1.

Figure 5.1: Flow chart for Preparation Operations



On analyzing above diagram, it was found that there were many loop holes due to which productivity of the system was getting disturbed. For this station, following problems were found and solved using different approaches.

a) Non systematic placement of raw materials

First of all it was found that the items are not their designated places, due to which smooth and continuous flow of materials throughout the firm was getting hindered. In order to overcome this problem, big bins at important points plus small bins at every substation were placed. With 5S approach, focus on systematic placement of raw materials and inventory was made.

b) Smoothening the communication with suppliers:

It was found that there were many mis communications with the suppliers, due to which either there were mismatches in the type of procured items or in the quantity of items, due to which productivity of the system was failing. Under this process, number of conversations with suppliers were increased, due to which regularity in procurement practices was increased.

c) Lack of trained Staff:

During the research, it was also found that the there was a lack of trained staff due to which there was a lot of rejections, delays, etc. Considering these problems, a training program was started and successfully accomplished for the staff members plus store in charge.

d) Lack of signs at stations and sub stations:

Due to large number of small items present, many times workers got confused, due to which unnecessary time was spent in searching of items. In order to overcome this problem, proper signboards were placed at main stations and sub stations, due to which this problem reduced a lot. Flow process chart of second station is presented in figure 5.2. On this station following problems were investigated and solved.

a) Unstructured layout:

On this station, layout was found very old and unstructured due to which workers were facing problems in doing their tasks effectively. This problem was solved by taking consultancy from an expert, due to which ease in operations increased.

b) Maintenance of machines:

Maintenance of machines was accomplished due to which delay time as well as defective outputs were reduced.

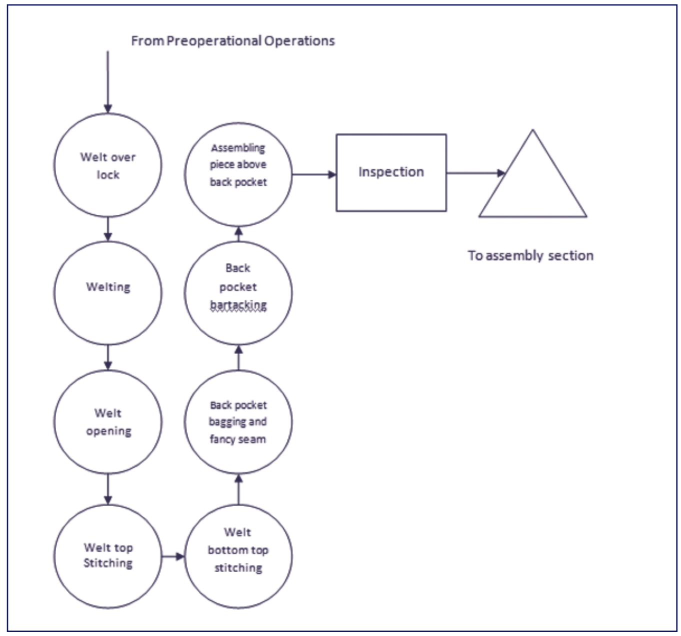
c) Lack of employees:

At this station, there was lack of an employee which was fulfilled by providing a trained, new employee.

d) Solving disputes among employees:

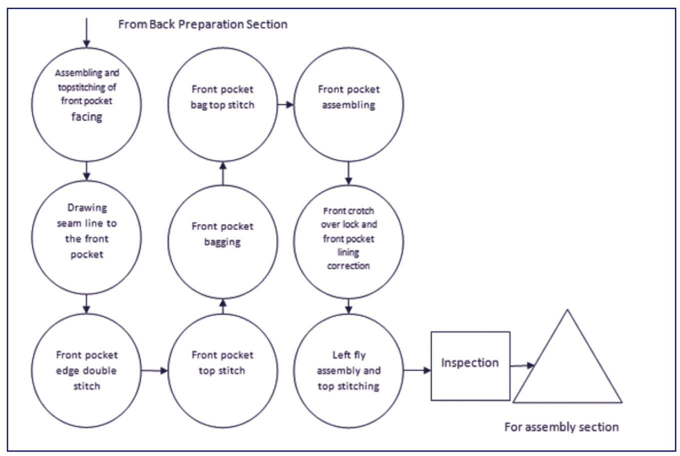
There were disputes among the employees of this station and previous station, which were solved in the presence of management team members.

Figure 5.2: Flow chart for Back Preparations



On creating flow process chart for front end operations, figure 5.3 was obtained.

Figure 5.3: Flow chart for Front Preparations



Following problems were found and solved at this station.

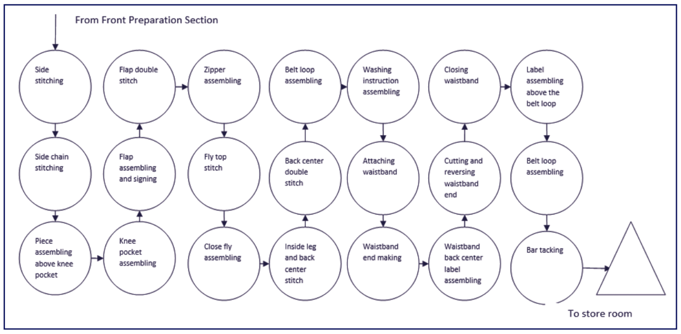
a) Lack of employee satisfaction: As a result of informal discussions with the employees, it was found that there were no increments to them since last three years, due to which employee turnover was greatest at this station as compared to the other ones, due to which this station was facing a lot or employee related problems. In order to solve this problem, it was requested to the management team members to grant increment to the employees of this station, and they consented.

b) Lack of supervisor: It was also found that at this station there was lack of a supervisor, which was also fulfilled.

c) Lack of training to the employees: Due to large turnover of employees, quality products were not obtained from this station, which was a big problem. So therefore, in order to solve this problem, a training session was organized for the employees, due to which, their work patterns changed.

The last station was the assembly station. It was a bigger station plus very important one considering quality, delivery and overall image of the firm. Figure 5.4 shows the flow process chart for the station assembly.

Figure 5.4: Flow chart for Assembly



At this station, following problems were observed and solved.

a) Lesser quality products: During initial stages of inspection, it was found that quality of products coming out of the station was not as per the standards, due to which there were heavier rejections, plus customer complains. Following problems were found behind this flaw.

a. Lack of training;

b. Lack of skilled supervisor; and

c. Revision of standards.

After investigations, above mentioned points were discussed with management team members and solved.

b) Older machines: During the training of employees, it was found that some machines were older and therefore not competent, which were replaced by new ones.

Mismatched team members: With advanced consent, some team members were replaced or reshuffled.

Table 5.1 shows the summary of different problems found and their solutions made, at different stations.

Table 5.1: Different Problems and Solutions at different Stations

S. No	Station	Problem	Solution
1.	Preparational Operations	Non systematic placement of raw materials	Provisions of bins
2.		Smoothening the communication with suppliers	Number of conversations increased
3.		Lack of trained Staff	Training provided
4.		Lack of signs at stations and sub stations	Signs provided
5.	Back Preparation	Unstructured layout	Layout changed
6.		Maintenance of machines	Maintenance provided
7.		Lack of employees	Employees appointed
8.		Solving dispute among employees	Dispute solved
9.	Front preparation	Lack of employee satisfaction	Problem solved by giving increments
10.		Lack of supervisor	Supervisor appointed
11.		Lack of training to the employees	Training provided
12.	Assembly	Lesser quality products	Training provided, supervisor's training arranged, standards revised
13		Older machines	Machines replaced by new ones
14.		Mismatched team members	Matched team members put in same teams

6. CONCLUSION, LIMITATIONS AND FUTURE SCOPE OF THE RESEARCH WORK

Present research work focuses on the performance enhancement of a manufacturing firm, with the help of value stream mapping and quality function deployment. In the research work, a garment manufacturing firm is targeted and its performance enhancement is accomplished using different tools, namely, 5S, logistic system improvement, Kaizan and Kanban. For this purpose, first of all existing parameters were investigated with the help of value stream map, followed by the creation of house of quality, which ultimately yielded the rankings of functional requirements. Following points represent the conclusion of present research work:

a. Implementation of performance enhancement tools considerably enhance the performance of a firm;

b. 5S implementation is the most important parameter for a firm; and

c. Lead time plays very important role in increasing the performance of the firm.

6.1 Limitations and Future Scope of the Research

Following points represent the limitations of the research work:

a. The research work is limited to a particular type of industry;

b. The research work is limited to a particular set of fuzzy numbers; and

c. The research work is limited to a particular set of performance enhancement parameters.

Following points represent the future scope of the research work:

a. An extensive research considering a broader set of industries can be initiated;

b. A broad research involving a broader sets of fuzzy numbers may be expected; and

c. An extensive research involving a broader set of performance enhancement parameters can be initiated.

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