A Proposed Factory Layout and Improved Process Time Using Lean Tools for FITCO Detergent Factory in Qatar

Maryam Mohdsaeed Abdulla
Petroleum Engineer
QatarEnergy
Engineering Management Masters Student
College of Engineering
Qatar University
Doha, Qatar
ma1305262@qu.edu.qa

Shaima Almuslimani
Health Facilities Licensing and Accreditation Engineer
Ministry of Public Health
Engineering Management Masters Student
College of Engineering
Qatar University
Doha, Qatar
sm2000146@qu.edu.qa

Zahra Al-Ansari
Production Planning Engineer
Qatar Airways
Engineering Management Masters Student
College of Engineering
Qatar University
Doha, Qatar
za1507112@qu.edu.qa

Aisha Al-Nabet
Planning Engineer
ASTAD Project Management
Engineering Management Masters Student
College of Engineering
Qatar University
Doha, Qatar
sm2000146@qu.edu.qa

Afaf H. Abunada
E-learning Coordinator
Ministry of Education and Higher Education
Doha, Qatar
199351582@qu.edu.qa

Abstract

Many factories tend to prioritize and focus on the production process that it goes through. The production process is heavily monitored in order to ensure that the output is set to the maximum. Factories can become more efficient when it comes to their productivity output through the elimination of wastes, the reduction in the total production cost, and increasing the quality of the products. It is quite often that factories face the issue of having to fulfill supply to production in a full time, full quantity, and quality target. Hence, the production process must become the focus of the factories and ensure that it is being properly carried out. In this research, the production process of FITCO Detergent Factory, a Qatari company that supplies the market with various detergent products will be studied. The company's process involves going through six stages in order to transform the raw material into the final product, liquid soap. In this paper, this process will be studied per the current state of the factory and its layout. Through the application of lean thinking, gaps will be determined and addressed accordingly to remove wastes, increase production rate at low cost, and reduce both the process and the lead times, as Lean thinking is a concept that when applied removes all kinds of redundancies or wastes in order to increase the efficiency to the required standard. Some of the tools that this method uses are: value stream mapping and the 5S tool.

Keywords
Lean, value stream mapping, 5S system, factory layout, lead time, process time

1. Introduction
Organizing the processes in a factory can be done through using lean. Lean also enhances the production rate in the factory while maintaining the product's quality, through the application of different tools such as the value stream mapping (VSM) and utilizing the 5S System. Both lean tools will be detailed in Section 3 of this paper.

This paper studies the FITCO Detergent Factory in Qatar which is specialized in producing diverse detergent types since 1985. Moreover, the company is internationally certified to distribute its products (Branding 2020). The scope of this paper is studying the factory layout of FITCO Detergent Factory as well as analyzing the process of producing a batch of one-liter bottles of hand washing soap with rose scent. Note that one batch consists of six bottles. The six steps below reflect the main processes in FITCO to produce the soap as an end product.
1. Manufacturing of plastic bottles
2. Sourcing the raw materials
3. Filling the plastic bottles
4. Warehousing and inventory tracking
5. Order management
6. Delivering to the client

1.1 Objectives
The reason for studying such a process is due to several objectives as listed below. Note that these objectives are addressed in detail in later sections of this paper.
1. Identify and eliminate non-value adding activities in the process by analyzing the performance of the six stages mentioned above. For example, bottle-necks will be identified to improve the efficiency of the stages in the production line as well as increasing the production rate. This objective is addressed by drawing a process map and utilizing VSM.
2. Simplify the process of soaps production to reduce both the lead time and process time. This is tackled using VSM.
3. Organize the facility as improving the work environment can enhance the productivity of FITCO's employees (Kovács 2020). For this objective, the 5S System is utilized.

2. Literature Review
This section focuses on literature review about lean application and its tools, which are applied on FITCO Detergent Factory in Section 5 of this paper.

2.1 Lean Thinking
Lean thinking is a technique to identify and eliminate wastes as a part of continuous improvement. The meaning of waste is non-value adding activities Lean is used in vast sectors, for example health, hospitality, oil and gas, manufacturing, and other businesses ((Rauch et al. 2016), (Aslam et al. 2021)) to improve the processes because lean

is a critical tool to enhance the productivity (Palange and Dhatrak 2021). To elaborate in the construction sector, new management ideas have been adopted to address issues in construction projects (Varajão 2016). As per (Shaqour 2022), lean construction is a unique new method that will positively develop the construction sector compared to the standard construction management approaches, as there are benefits of adopting lean on time savings, increased safety, risk prediction, quality, higher productivity, and rework reductions. Lean philosophy emphasizes that small changes over time can create long-term sustainable growth, mainly to maximize the value for the customer by eliminating wastes such as wastes related to motion, transport, overproduction, over-processing, and errors (Witt, Sandoe and Dunlap 2018). This is approached by engaging employees of different departments, functions, and levels to collaborate to enhance the organizational working environment through applying lean tools (Emiliani 2006).

2.2 VSM

Value Stream Mapping (VSM) is a lean visualization tool that draws how the request is made by the customer until the end product is delivered (Emiliani 2006). It enables waste reduction to improve material flow as well as minimize lead and process times (Barkokebas, et al. 2021). Since VSM is a visual tool, symbols are used to indicate the flow tasks from one to the next as shown in Figure 1 below. As a result, the resources in the process and their flow can be understood, and bottlenecks can be identified. This is useful in creating a holistic view of the process.

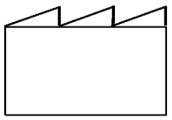
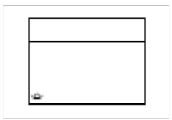
Symbol					
Meaning	Customer / supplier	Process block	Data block	Manual flow	Improvements

Figure 1. VSM symbols.

2.3 The 5S System

The 5S system is another lean thinking tool that utilizes five activities to be applied on a process or a system, aiming to increase its efficiency (Hawkins and Bonney 2019). The 5S tool goes beyond the regular change in a system. It creates a systematic change that leads to the standardization of the processes within a system to be followed by everyone (Witt, Sandoe and Dunlap 2018). Applying this tool boosts productivity, increases safety levels as well as ensures that the workplace is clean and tidy. As the name suggests, it consists of five steps that all start with the letter "S", as listed below (Flores et al. 2021).

1. Sort
2. Straighten
3. Shine
4. Standardize
5. Sustain.

The first step in applying the 5S system is sorting. It requires the removal of all activities that deem to be unnecessary in the system. It is then followed by the second step which is straighten or set in order, to organize the workplace to increase the employee's productivity by providing easy access for the work items. After that comes shine to ensure the tidiness of the workplace. Then comes the fourth step which is standardize. This step insists that a specific routine is implemented to make sure that all employees in the organization follow the same practice. The last step is sustain to ensure that all of the previous "S"s are being followed and adhered in a continuous manner (Hawkins and Bonney 2019). It is important to note that the 5S tool was eventually improved and a sixth "S" was added for safety (Fernández, et al. 2021).

Lean thinking and its applications such as the 5S system require the organization to foster a culture of employee empowerment to effectively identify and solve the problems because using Lean reflects positively on the organization and its employees (Emiliani 2006). Moreover, when the top management implement lean in the organization, the employees automatically mimic the leaders. As a result, the overall community at the workplace has a positive attitude, which enhances the productivity by further reducing the gaps (Latif and Vang 2021).

3. Methods

Data was collected by visiting FITCO Detergent Factory shop floor to identify the wastes in the current conditions. It is important to mention that FITCO Detergent Factory was the only enterprise which agreed to be interviewed as well

allowed for their name to be used for the case study. The team head was interviewed to gather information about the laborers daily tasks to understand how the facility layout and the work environment in general affect them (Al-bouainain 2022). Furthermore, the production line including the equipment were observed to understand how the soaps are produced. It was deduced that due to laborers' movement from one machine to another, issues can arise including order delays, larger waiting time or wait in progress (WIP), and lower laborer's productivity due to fatigue. Therefore, this paper aims to identify the wastes to suggest recommendations for improvements.

This paper studies the process of producing a batch of one-liter bottles of hand soap to satisfy the customer's demand of 600 bottles. In other words, 100 batch is required to fulfill the customer's order per 8-hour shift in a day. Therefore, the literature review is focused on lean topics that support the enhancements provided later in this paper. The published journals are mainly obtained from Taylor and Francis, Wiley Online, Scopus, Google Scholar, and ScienceDirect. Furthermore, the following keywords were used to search for the relevant literatures: lean tools, value stream mapping, 5S System, and factory layout. The published articles were chosen in English language, from years 2000 to 2022. Moreover, some literatures were screened out due to their irrelevance to the content of this paper, hence only 15 literatures were used.

FITCO Detergent Factory is considered as the case study, and is addressed in detail in Section 4 by presenting its current situation, which is approached through a simplified process map. Moreover, the wastes are identified by using the VSM. Also, the current factory layout is presented. On the other hand, Section 5 in this paper proposes changes to improve the process in FITCO Detergent Factory by eliminating wastes. This is achieved using the improved VSM to present the future state. Furthermore, the 5S System is implemented to propose enhancements to the factory layout. As a result, Section 6 measures the applied improvements by comparing both the lead time and process time before and after implementing lean. Towards the end of this paper, main conclusions from the case study are drawn and recommendations in the lead and process times along with facility layout have been proposed. Figure 2 summarizes this paper's methodology.

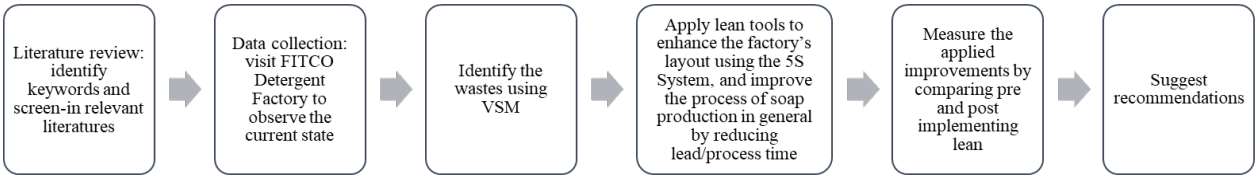


Figure 2. The methodology of this paper

4. Data Collection

This section presents the current situation of FITCO Detergent Factory by showing a simplified process map to manufacture a demand of 600 bottles from the one-liter soap bottle per day. This section also shows the current VSM along with the current factory layout.

4.1 Process Map

After FITCO Detergent Factory receives an order from the customer on the one-liter soap, the first step in the process is sending the request form to the supplier's inventory to release the raw materials. Usually, the customer demand is 600 bottles of the one-liter soap bottle with rose scent. Then, semi-automation machines mix the raw materials in a 2500 L container. After that, the mixed liquid soap moves into the production pipeline to the filling machines. In this step, the laborers put six bottles of the one-liter plastic bottles as one batch on the filling machine to be filled and sealed. Later, the laborers manually stick the label containing the brand name on the plastic bottles. The last step is to ship the one-liter soap bottles to the customer. Figure 3 summarizes the process map in FITCO Detergent Factory starting from receiving a request till the one-liter soap bottles are shipped.

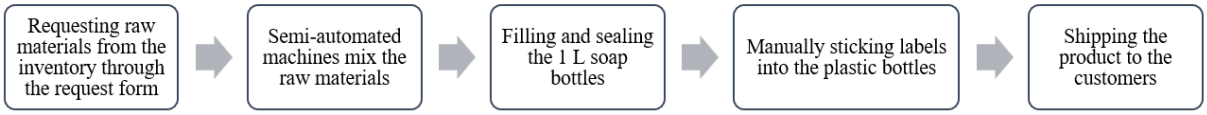


Figure 3. FITCO Detergent Factory process map diagram for producing the one-liter soap.

4.1 Current VSM

The figure 4 represents the current VSM of FITCO Detergent Factory.

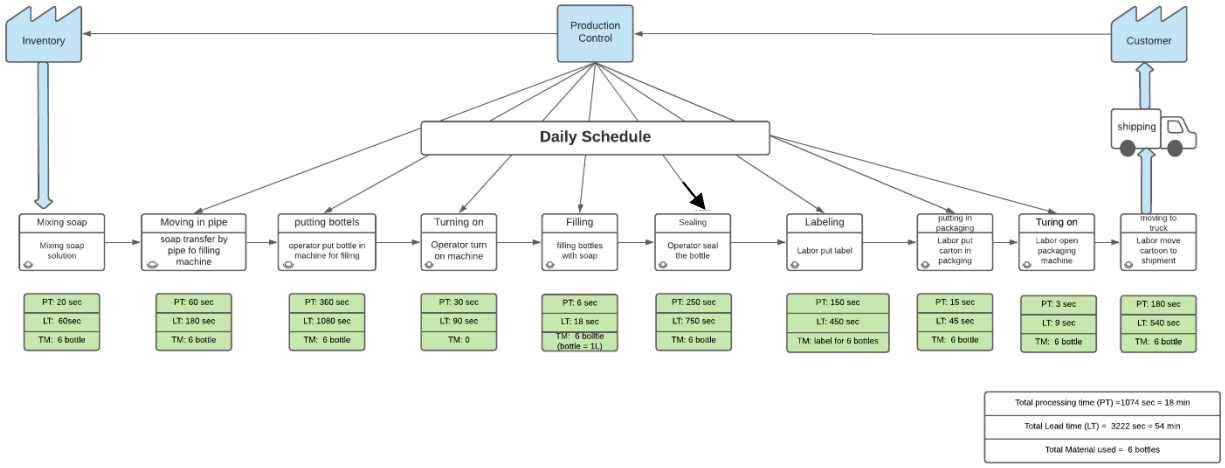


Figure 4. Current VSM of FITCO Detergent Factory

The VSM starts with the customer sending the demand information to FITCO Detergent Factory, so that the raw materials are obtained from the inventory. After that, semi-automation machines mix the raw materials in a 2500 L container, so that the mixed liquid soap moves into the production pipeline to the filling machines which takes 60 seconds as the cycle time or process time (PT). Note that the process time in this context means the time needed to complete one process block. Then, the laborer puts six bottles of the one-liter plastic bottles in the filling machine. The operator turns on the machine signaling the start of the bottle filling process. As shown in the VSM, then next step is the laborer sealing the six bottles using a sealing machine. This activity has the lead time (LT) of 450 seconds. Note that the lead time in this context means the maximum time a process block may take to be completed including the personal time, fatigue, and delays (PFD allowance). After that, the laborers manually stick the label containing the brand name on the plastic bottle to then put them into one box. Note that one box fits six bottles, hence a package is needed to pack several boxes with a packaging machine. Later, the laborers manually put all the packages into the truck signaling the readies of the product to be shipped to the customer.

The daily shift is 8 hours with PFD allowance of 15%. Therefore, the total available working time is 6.8 hr which is 408 min. Usually the step-up time to switch from a container to the other is 60 min. Therefore, the following equation is used to calculate the run time to manufacture the demand of soap.

Eq. (1)

$$Run\ time = Operation\ time - Setup\ time$$

As a result, the run time is 348 min. It can be deduced from the VSM that the PT is 18 min per batch. Hence, the current throughput rate is about 0.06 batch/min. This also can be translated as 114 bottles per day or 19 batches. Because the run time is only 348 min per day, it takes 1800 min to fulfill the customers demand of 600 soap bottles. In other words, FITCO Detergent Factory needs to work 30 hr or 3.75 shifts (4 days) to generate 100 batches as per the customer's demand.

4.2 Factory Layout

When visiting FITCO Detergent Factory, the current layout including the machines, stations, and laborers distribution across the factory were observed. The factory has a length of 90 m, width of 40 m, and a height of 8 m. As shown from Figure 5, the Labeling Store is at the right of the entrance, where the bottle labels are stored. Note that the red arrows indicate the entrances and safety exits in case of evacuations. Following the Labeling Stores are three Bottle Making Stations as FITCO Detergent Factory also manufactures and sells two plastic bottle types. However, as mentioned in Section 1, not all of FITCO Detergent Factory's activities are discussed in this paper.

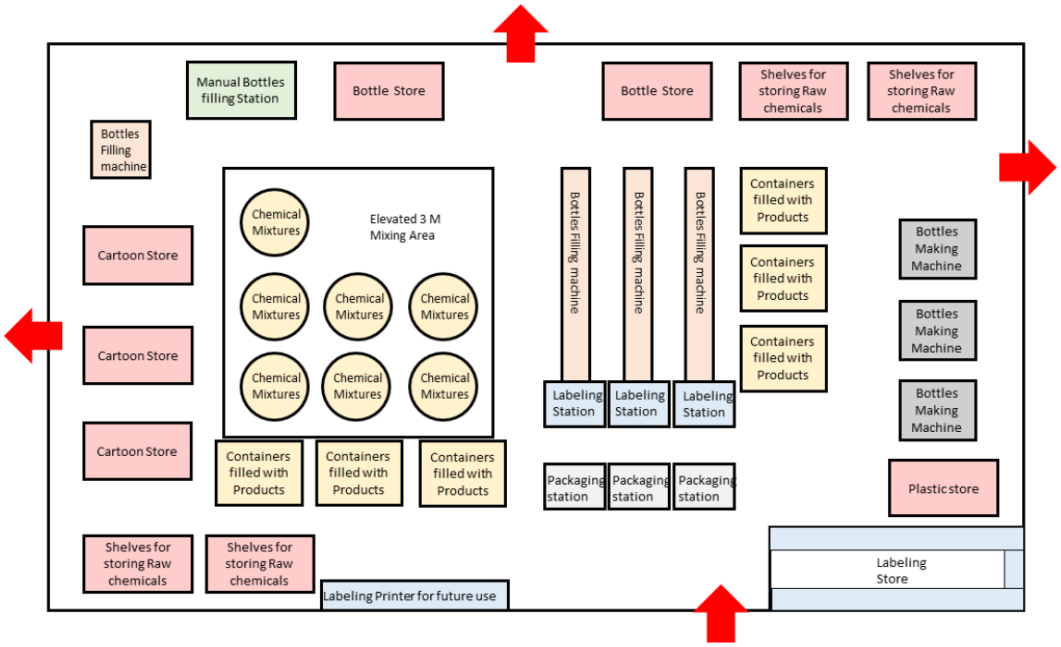


Figure 5. Current FITCO Detergent Factory layout.

After the bottles are made, they are either used directly in the Bottle Filling Machine or stored in the Bottle Store as shown in Figure 5. It was observed that when the laborers store the bottles in the Bottle Store, they need to bend down to reach the boxes on the floor that contain the bottle caps, which is considered against the ergonomic guidelines.

Regarding the raw materials, they are arranged and stored in shelves in the Raw Chemicals sections. The reason for arranging them in shelves is to ease selecting them prior to the mixing process. Note that the mixing of raw materials takes place in seven 2500 L containers in the Mixing Area, where some of the product is then stored in 1000 L containers to be used when needed. After that are the three Labeling Stations where the laborers manually stick the labels on the bottles after picking the labels from the Labeling Store as mentioned above. Next to the Labeling Stations are also three Packaging Stations to ensure that every six bottles of the one-liter soap are in one box ready for shipment. It is important to mention that unused boxes are stored in the three Cartoon Stores. It was observed that some of the boxes were not stored in an organized way which can restrict the laborers movement when picking up some boxes. Also, the Cartoon Stores were approximately 20 m away from the Packaging Stations. This consumed the laborers' time when moving back and forth to get the boxes. Moreover, there is a Manual Bottle Filling Station which is only used to train new laborers to ensure that they don't damage the Bottle Filling Machines

5. Results and Discussion

This section discussed the integration of lean thinking and discussed the proposed changes for FITCO Detergent Factory.

5.1 Numerical Results: Proposed VSM

After the analysis was done on the current VSM from Figure 5, some gaps are identified according to the lean thinking method. For example, the large LT can be noticed. Therefore, the proposed VSM in Figure 6 suggests reducing the throughput time to about 3 minutes through the elimination of five non-value adding activities. As a result, the company can satisfy the customer's demand by producing 116 batches per day which is equivalent to 696 bottles.

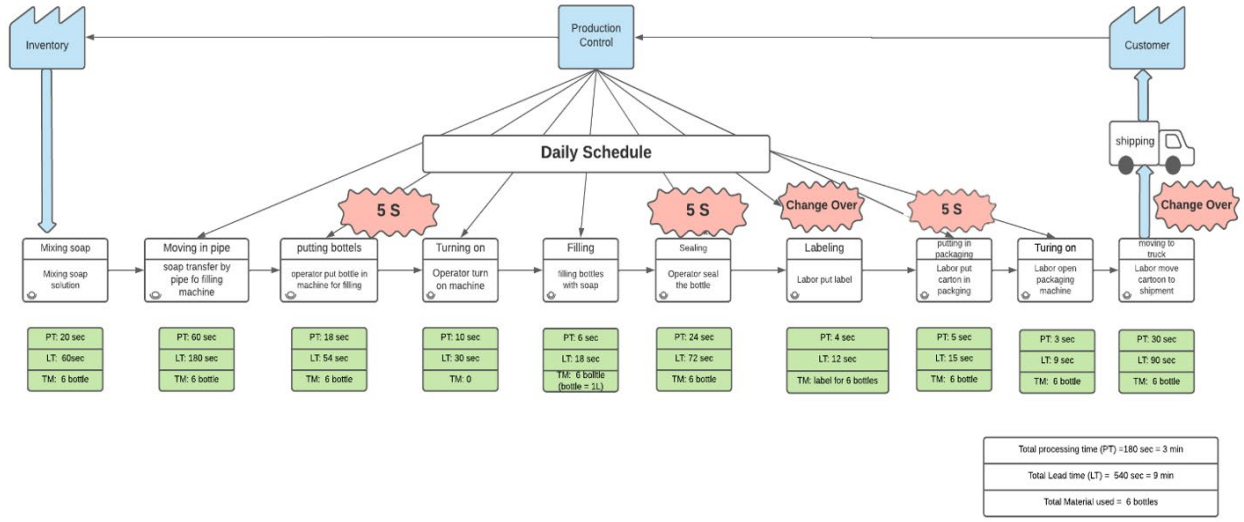


Figure 6. The proposed VSM.

The aim of this study is to raise knowledge of the Lean tool and its potential for use in many industries. There are a variety of studies on the market in the body of literature that focuses on adopting Lean tools in various industries. By adding technology into the production process, it will be possible to make lean manufacturing a successful strategy and reduce its limitations and improve the approach. Because technology and man will operate together, businesses may be able to win by employing a combination of techniques. Communication, information technology, and big data analytics skills are becoming increasingly vital for Lean Manufacturing employees.

The Lean Thinking concept emphasizes small improvements over time to produce long-term sustainable growth, Due to the implementation of the above measure of lean manufacturing by applying the VSM and 5S the process is improved in FITCO factory, Ergonomics and operational safety have both been improved as well as reducing the process and lead time in the factory and the results are tabulated below.

From the above case study VSM implementation has suggested industrial layout adjustments to eliminate non-value-adding operations, as well as their benefits. Furthermore, 5S method applied on workspaces to reduce wastes, modifications were concluded from the analysis using the 5S tool in the proposed factory layout.

By comparing the current state with the improved future state, the total processing time noticed to be reduced from 18 minutes to 3 minutes with an improvement of 83.3%. In addition, the same 83.3% improvement for Lead time from 54 minutes to 9 minutes is obtained by applying lean tools to the factory. Therefore, the table 1 summarized the numerical results.

Table 1. Comparison between current and future results

	PT (sec)	PT (min)	LT (sec)	LT (min)
Current Conditions	1074	18	3222	54
Improved Conditions	180	3	540	9

Furthermore, improvement of the time is calculated by using the equation below.

$$\text{Time Improvement \%} = \frac{(Old\ PT - New\ PT)}{old\ OT}\ x\ 100 \qquad \text{Eq. (2)}$$

As a results, the improvement in PT is 83.3%. Similarly, the improvement in LT is 83.3%.

5.2 Graphical Results

The proposed changes are given in Figure 7.

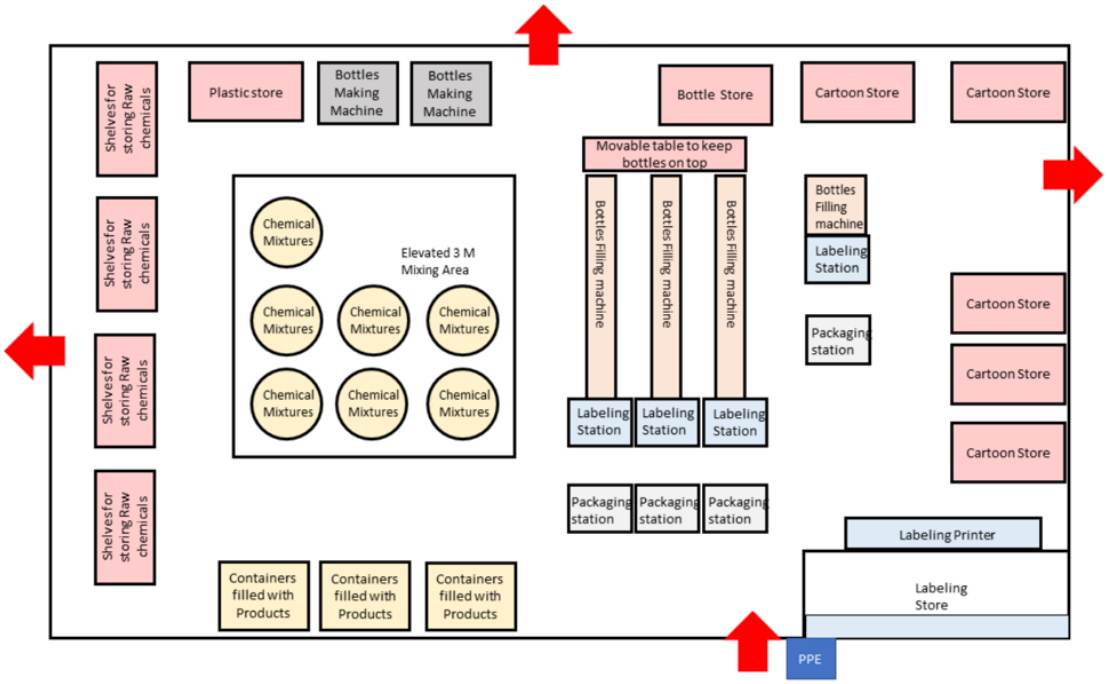


Figure 7. The proposed factor layout.

5.3 Proposed Factory Layout

Listed below are five proposed changes in the FITCO Detergent Factory layout and working environment in general to reduce non-value adding activities. Factory floor will be optimized by removing constraints and will make the process flow more efficient. This change will not alter the capital cost since all the equipment already exist. It will reduce the floor's congestion and will lead to a smoother flow between the different processing areas. Other advantages are also given below.

1. Change: Utilizing a wheeled table for packaging process to move the bottles from one point to another.
   Advantage: Will reduce transportation time of items. Will also help in reducing the amount of labor that is needed for transportation purposes through the increase of the carriage load limit per individual.
2. Change: Introducing automation for labeling at a rate of 100-300 bottles per minute.
   Advantage: This change will lead to reduction of the labeling time which is currently manually done.
3. Change: Use the labeling printer available at the factory to print the label locally instead of relying on outside sources.
   Advantage: By taking on this initiative, label storage will be reduced. In addition, since some labels are printed in bulk, some money might be saved.
4. Change: Ensure workers are wearing proper personal protective equipment (PPE) by providing a station containing PPE prior the factory's entrance.
   Advantage: Reduce risk and increase safety which will reflect positively on the production rate.
5. Change: Train workers.
   Advantage: Workers become more familiar with the available machinery and will be able to operate them in the proper manner to depend on the machines. Hence, this will lead to higher production rate and has less erroneous output.

Furthermore, as discussed earlier, 5S is a tool that can be applied on workspaces to reduce wastes through the elimination of non-value adding activities. According to Figure 7 the proposed factory layout, some of the changes were deduced based on the analysis deduced from the 5S tool. These are explained as follows:

The first two "S's in the method are "sort" and "set in order". This was done by clearing the workstations from unnecessary items in them. It was noticed that the tools and materials containers storage was located in an area that made it inefficient for workers to get. Hence, we proposed the relocation of the storage containers next to the packaging station. It was also noticed that chemical raw materials would be better places next to the chemical mixers instead of far from them. The changes can be seen in next figure 8.

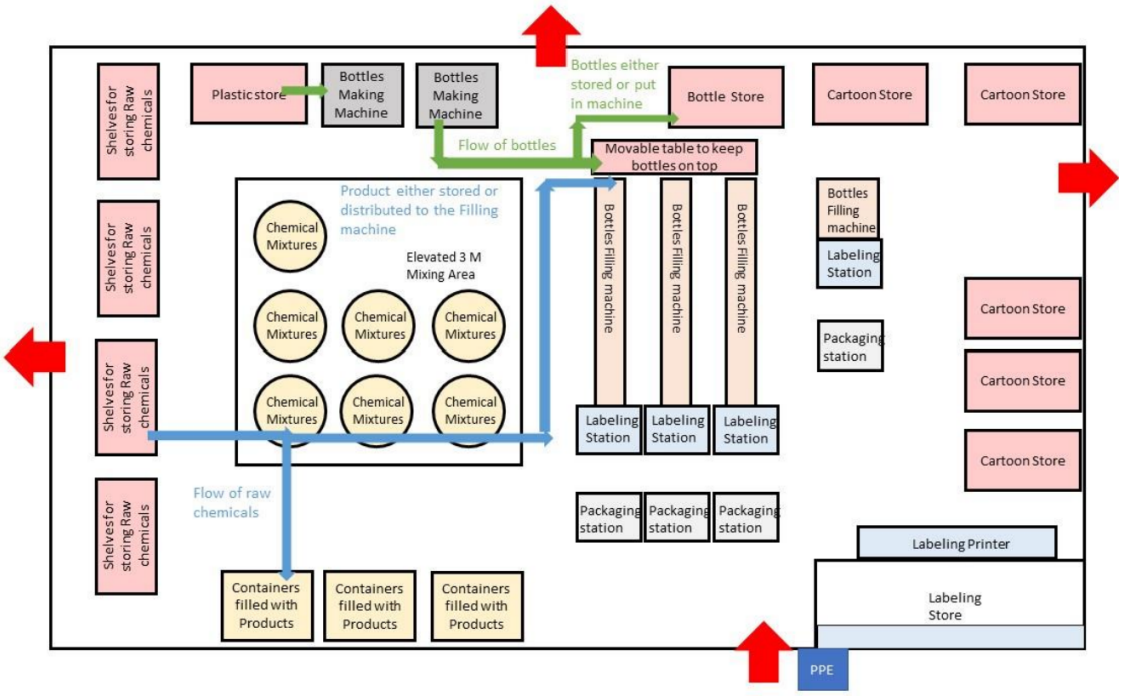


Figure 8. Proposed changes as part of the 5S tool.

After the first two steps, it was also noticed that moving the bottles making machines towards the back of the factory will reduce the distance to the filling machine station, which is the succeeding activity in the process. This saves a lot of time in terms of transportation of items between the stations. It was also proposed by the team that the amount of stored inventory of produced products is reduced. The current size of the container is 1000-liter cubes which takes a huge space and sometimes ends up going to waste due to passing the date of expiry.

In addition to the aforementioned changes, floor display signs can be used in order to ensure that everyone is aware of the system and what the flow of the process is like. This will make the workers become familiar with the workspaces even faster and will help in increasing the performance. The boundaries can be placed such that the boundaries of the workstations are clearly marked. This will ensure that everyone knows which areas to access and which areas not to get into. This will help in terms of safety and risk mitigation in the factory.

After the first two "S"s come the third one which is to shine, this can be maintained by instructing the workers to keep their workstations neat and clean while removing all unnecessary items from them. Following that is the fourth "S" which is standardization, which can be done by informing everyone about the changes made and making sure that everyone is aware of them and follows them. Finally, the fifth "S" which is sustain. This can be the responsibility of the management and the supervisors by ensuring that all of the steps addressed above are continuously adhered to and maintain the current system without deviations.

5.4 Validation
The results are validated with FITCO Detergent Factory by proving them a report of all the proposed improvements. The factory accepted the suggestions as future work for them to implement.

6. Conclusions and Recommendations
Lean thinking is applied in several industries, including the manufacturing industry due to its advantages in eliminating wastes to reduce process and lead times, increase productivity, reduce cost, and enhance the working environment. This is approached through utilizing the lean manufacturing tools such as the VSM and the 5S system as discussed in this paper.

This paper analyzed FITCO Detergent Factory as the case study to implement lean manufacturing tools on. Precisely, the process of manufacturing one liter of the hand wash bottles was studied starting from receiving the customer's order, raw materials sourcing and mixing, filling and labeling the bottles, and lastly packaging them prior to shipping them.

It was observed that the current process time for one batch containing six bottles consumed 18 min, hence the customer's demand of 600 bottles cannot be satisfied in one day. Therefore, by applying lean tools, the process time is recommended to be reduced to 3 min to fulfill the demand in one day.

Furthermore, it was observed that the factory layout forces the laborers to move for long distances and bend to reach out caps. Also, the laborers' safety is not considered in the Cartoon Stores due to clustered boxes. Therefore, it is recommended to move some stations in such a way where not a lot of transportation will be required between one step in the process and the one following it. For instance, the cartons should be moved and better placed next to the packaging station, the chemical raw materials should be moved next to the chemical mixers, and moving the bottle making machines towards the back of the factory to reduce the distance between it and the filling machine station.
It is important to note that lean thinking is a continuous process that all employees in FITCO Detergent Factory need to constantly improve. This can be addressed through building an internal collaborative culture that accepts changes.

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Biographies

Maryam Mohdsaeed Abdulla is a Qatari engineer. She is a chemical engineer by degree and a petroleum engineer by profession. While studying at Texas A&M University, she was sponsored by Maersk Oil where she got her summer internship. During the internship and rotating in different departments, the love of leadership had spiked. She graduated from Texas A&M University in chemical engineering in 2016 with a GPA of 3.42, while having a plan of leadership career at the back of her mind. Right after graduating, she worked at Occidental Petroleum at a petroleum engineer for three years. After that, she moved to work for QatarEnergy, where she got recognized for being a hard worker, and hence received awards. Her two top projects at QatarEnergy are reinjecting flared gas into the reservoir and a campaign of acid stimulation in sandstone reservoir. Currently, she is pursuing her graduate studies as Engineering Management Masters Student in the college of engineering at Qatar University. This degree will help her in shifting from the technical career to the managerial path, where she aims to be a leader in the oil and gas industry. Outside the working environment, she is enthusiastic in physical fitness, traveling, reading, and learning new languages.

Shaima Almuslimani Is a Qatari architect who graduated from the University of Bahrain College of Engineering. Currently working as health facilities licensing and accreditation Engineer at the Ministry of Public Health, she is responsible for ensuring health facilities in Qatar are compliant with local standards and regulations and meeting the Engineering and health requirements through layouts and documents. This position requires an understanding of Qatari regulations and skills in construction and stakeholder management. Her big achievements are involvement in updating Qatari health facility standards, her involvement with several of the largest health facilities, including Alahli and Turkish hospitals, and licensing new future facilities such as The View and Tenbek Hospitals. She has also represented Qatar and the MOPH international conferences such as ASHRAE and was sponsored by the MOPH to complete the Engineering Management Masters course at Qatar University. The main aim of pursuing an Engineering Management Master's course is to understand engineering management principles better to support the Licensing and Accreditation department in MOPH and obtain a leadership position to uplift the health sector management in Qatar.

Zahra Al-Ansari is a graduate student at Qatar University in the discipline of Engineering Management. This choice was done to further broaden her perspective in the engineering sector as well as the management sector by gaining more knowledge in both fields simultaneously. She has received her undergraduate degree from Texas A&M University at Qatar in Electrical Engineering. She is very curious and likes to be faced with tough challenges. She aspires to become a future leader to manage people to accomplish some of the achievements that she believes are going to positively reflect on her country, Qatar. She is currently working in the Heavy Maintenance department as a Production Planning Engineer in Qatar Airways. Her job requires an employee to have and nourish skills which are heavily related to the degree that she is pursuing which include: planning, scheduling, conducting meetings with multiple stakeholders, managing and directing a large number of people to complete the projects that are carried successfully and in a timely manner. By acquiring this degree all of the skills that she desires to master are going to be greatly enhanced as the focus of the program that she has enrolled in is on these specific skills.

Aisha Al-Nabet became member of Europe Research, achieved project “Find the optimal schedule for airport” and present it at conference in Italy. She participated as project manager (Trainee) to achieve collect data for security purpose in Ooredoo In 2015, she did her research to improve the productivity of Qatalum by optimize the facility layout “Simulation Modeling and Analysis of the Relining Facility at Qatalum”. Regarding her educational background, she got bachelor’s degree of Industrial and System Engineering, at Qatar University, Doha, Qatar. From 2015 until now she is working as planning engineer at ASTAD Project Management to complete number of projects, the most challenge she faces it is to handle the Education City Stadium project which is consider critical for whole world not only in Qatar.

Afaf H. Abunada is currently working as an E-Learning coordinator in the Ministry of Education and Higher Education, Qatar. She earned her MSc. in Engineering Management from the University of Qatar in 2022. The preparation for Eng. Abunada's career included a bachelor’s degree at Qatar University in computer science. She has

work experience in several ministries in Qatar of supervising technical Projects. Her work is split between developing and training for IT Projects and research focused on improving users' adoption and enhancing developed IT projects. Her Major research interests include E-government, E-Learning, user adoption, Lean management, and other areas in Management Information systems like IT project management, Encryption, and ERP systems.