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Improving Utilization of Space and Productivity of Kitchen-Cabinets Door at GM Profile Company Using Lean Six Sigma Methodology

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Declaration

I declare that I have developed and written this Master thesis completely, and it has been generated by me as a result of my own original thesis, and has not been submitted elsewhere for any other degree or qualification. Moreover, I have not used sources or means without declaring them in the text, otherwise they are referenced.

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Abstract

This study examines the impact of Lean Six Sigma methodology implementation in the industrial companies in the wood sector. It illustrates the use of this methodology in helping wood products manufacturers in effectively utilizing their resources and organizing work environment to become more productive and create an environment of continuous improvement.

The importance of this study stems from the need of improving the utilization of space and productivity of kitchen-cabinets door production process at GM Profile Company in Al-Bireh (Palestine) by eliminating waste and reducing variation and waste in order to better control production processes and be able to offer competitive prices.

DMAIC (Define, Measure, Analyze, Improve, and Control) improvement methodology of Lean Six Sigma was implemented in five phases to achieve the desired objectives. The problem and the critical to quality metrics were identified in the define phase using a set of tools such as SIPOC (Supplier, Input, Process, Output, and Customer), PCD (Problem Context Diagram), project charter, and critical to quality tree. Current performance was measured in the measure phase using flow chart, VSM (Value Stream Mapping), eight wastes, and quick wins. Root causes of the problems were identified using cause and effect diagram and interrelationship diagraph. The layout and the productivity of kitchen-cabinets door production process were improved using the first three phases of 5S, flow chart, and value stream mapping. The achieved results were sustained using the last two phases of 5S, flow chart, work forms, and check lists.

At the end of the improvement efforts, the productivity of the kitchen-cabinets door production process and the layout were improved resulting in the reduction of lead time to produce kitchen-cabinets doors from 428.4 minutes to 138.2 minutes while the improvements in the utilization of space resulted in organizing the work environment, reducing number of accidents by 50% (from 4 to 2), and improving the layout of the following processes: kitchen-cabinets door production process, wooden door production process, wooden profiles stapling process, and wooden mesh production process through the utilization of 16% of company’s area. Moreover inventory management was also improved through controlling raw materials purchase and storage, improving final products delivery and storage, and introducing new products.

This study contributes to introducing lean Six Sigma methodology implementation in small and medium size enterprises in Palestinian industry and confirms the importance of this methodology in improving quality through eliminating wastes and reducing variation which plays a huge role in survival in the Palestinian economy that is facing many challenges.

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List of Abbreviations

- LSS: Lean Six Sigma
- DMAIC: Define, Measure, Analyze, Improve, and Control
- ABC: Activity Based Costing
- CI: Continuous Improvement
- SPC: Statistical Process Control
- SME: Small and Medium Enterprises
- R.P.M: Revolution Per Minute
- FMEA: Failure Mode Effect Analysis
- VSM: Value Stream Mapping
- CTQ: Critical to Quality
- CSF: Critical Success Factors
- 5S: Sort, Set in order, Shine, Standardize, and Sustain
- VA: Cycle Time
- DT: Delay time
- LT: Lead Time
- SIPOC: Supplier, Input, Process, Output, and Customer
- SOP: Standard Operating Procedures
- PCD: Problem Context Diagram
- WIP: Work in Progress
- ID: Interrelationship Diagram.
- NIS: New Israeli Shekel.

Chapter 1
Introduction

1.1 Overview

By improving process efficiency, productivity is implicitly improved and in the current rapidly evolving world there is always an opportunity for improvement that has to be exploited. This objective can be reached through Lean Six Sigma methodology (LSS) which is one of the contemporary improvement methodologies that emerged from the combination of Lean manufacturing and Six Sigma.

This research is the first one in Palestine that examines the effectiveness of implementing Lean Six Sigma methodology in improving productivity and utilization of space in a wood products manufacturing organization with make-to-order production strategy. Other researchers examined 5S lean methodology effectiveness in industrial organizations and LSS effectiveness in service industry.

LSS methodology was adopted as a preference of the other improvement methodologies such as PDCA (Plan, Do, Check, and Act), Kaizen, and Business Process Management (Analyze, Redesign, Execute, Monitor, and Optimize) due to the nature of the business of GM Profile Company and the need to eliminate waste and organize work environment which can be achieved through the implementation of LSS tools.

Antony et al. (2017) confirmed that Lean and Six Sigma integration is important as lean focuses on improving the flow of information and materials between the steps in the process and Six Sigma works to improve the value-adding transformations which occur with in the process steps.

The DMAIC cycle of Six Sigma (Define, Measure, Analyze, Improve, and Control) is considered the phases of the study where Lean and Six Sigma tools are used for the purpose of the identification and elimination of wastes and root causes of variation.

LSS is an effective way to increase quality, productivity, and corporate profitability in wood industry. (Guerrero et al., 2017)

Due to the high competition and rapid technological development, organizations have to strive to continuously improve in order to meet and exceed customer expectations in terms of quality, speed and cost and thus gain customer satisfaction which is the key to improving profitability.

The implementation of LSS methodology as an improvement methodology includes determination of the scope through the define phase, collecting data for the purpose of understanding the current situation through the measure phase, analyzing collected data for the purpose of identifying the root causes of variation and waste and ultimately identification of opportunities for improvement in the analyze phase, proposing, implementing and testing solutions through the improve phase, and finally sustaining the gains and communicating lessons learned in the control phase.

A key to the success of LSS implementation is the commitment of top management which includes resource allocation and capacity building in addition to employee's involvement which is vital since LSS tools help to identify opportunities for improvement and the employees will improve the processes.

The research statement is “exploring LSS implementation in medium sized Palestinian manufacturing plants through investigating utilization of space and productivity of Kitchen-Cabinets door production line at GM Profile Company using Lean Six Sigma methodology ".

The outcomes of this research include better understanding of reduced cycle time, better utilization of space, better employee's involvement, standard operating procedures, inventory management system, and ultimately improving productivity.

1.2 Company Profile

GM Profile Company is one of its kinds in Palestine and was established in 1999 in the industrial zone of Ramallah city. The company is specialized in producing the following wooden products: wooden frames, wooden corniche, wooden kitchen-cabinet doors, wooden doors frames, wooden decorative frames, and wooden doors.

Due to the high increase on the demand of its products, the company moved in 2008 to a new location in the industrial zone of Al-Bireh city. The total area of the new location is 1100 square meters which is almost double the area of the old location. The company has twenty-two employees including management, finance, sales agents, skilled workers, and laborers.

The company has two main production lines with more than twenty machines, the first one is the wooden profiles production line and the second one is the kitchen-cabinets doors production line. The company frequently adds new products according to customer’s demand which are wooden doors, wooden mesh for gardens and decoration, wooden door frame, and wooden door-frame casement. All products of kitchen-cabinets door production line and majority of other products are based on make-to-order production strategy.

The company has the ability to produce customized products according to customer demand. It produces high quality products due to the accumulation of experience over twenty years, good experience in purchasing and inspecting raw materials, and high professionalism of its staff.

The company sells its products in the Palestinian and Israel territories. The company used to have an Arabic partner who lives in the Israeli territories, the partnership ended in 2018. The owners of GM Profile Company have three wood-retail companies and are considered as major customers of GM profile. The company targets carpenters, decoration companies, wood supplies companies, and construction contractors.

1.3 Problem Statement

GM Profile Company has a limited space for storing raw materials, products, and production residues; it has low control on these items which resulted in high waste, crowded workplace, unorganized environment, and unsafe workplace.

The company has low supervision over staff daily duties and lack of production schedule for the kitchen-cabinets door production line which resulted in low productivity, delays to customers, and cancelled completed products that cannot be sold to other customers as these products were made according to customers' specifications and design.

1.4 Importance of the Study

Wood products manufacturers in Palestine have to improve their productivity and eliminate waste and variation in their processes to face the high competition in price and quality from wood products importers. This research will be a reference for achieving these goals for small and medium manufacturing organizations in Palestine.

GM Profile Company is facing the following problems:

1- Unutilized space.

2- Lack of inventory management system.

3- Low productivity in the kitchen-cabinets production line.

4- Estimated prices.

5- Lack of follow up of production scheduling.

6- Long lead time.

7- Overproduction in wooden profiles production line.

GM Profile Company has two main production lines, the first one is wooden profiles production line and the second one is kitchen-cabinets doors production line. The major concern in the first line is overproduction due to long changeover time and the major concern in the second line is low productivity. The company has low space which is used to storing raw materials, products, and production residues.

Due to high competition in local market and the new view of customers to quality and price, GM Profile Company has to provide new products, improve their productivity and offer competitive prices through cost cutting which can be achieved by better utilization of space, reduced cycle time, building inventory management system to reduce waste and be able to track raw material to reach an accurate pricing, better allocation of resources, follow up of production schedule, follow up of worker's daily duties, and ultimately improving profitability to be able to survive.

These goals can be achieved through the implementation of LSS methodology which provides the staff with the required experience of using Leans Six Sigma tools.

1.5 Research Objectives

This research aimed to examine the effectiveness of LSS methodology in improving productivity and space utilization in small and medium wood manufacturing organizations in Palestine.

Other industrial organizations can also benefit from this research in improving their productivity and/or space utilization.

LSS methodology was applied at GM Profile Company to:

1- Improve utilization of space.

2- Improve lead time.

3- Improve productivity of Kitchen-cabinets production line

4- Improve inventory management system.

5- Improve production scheduling.

6- Improve profitability through ABC costing.

Chapter 2
Literature Review

2.1 Overview

This chapter summarizes some of the published articles regarding the adopted methodology and implemented tools in addition to other related topics. It includes continuous improvement, LSS integration, LSS implementation, success factors/hurdles to LSS implementation, improving productivity, inventory management, ABC (Activity Based Costing), facility layout utilization, Lean management, production scheduling, an overview of VSM (Value Stream Mapping) and 5S (Sort, Set-in order, Shine, Standardize, and Sustain), and previous studies on the implementation of LSS methodology. This will help in gaining enough knowledge to help in improving the utilization of space and the productivity of kitchen-cabinets door production line at GM Profile Company.

This chapter is divided into three sections, the first one presents the theoretical background about the above-mentioned methodology and tools, the second one presents previous studies on LSS implementation, and the third one presents success factors/hurdles to LSS implementation.

2.2 Theoretical Background

This section presents the theoretical background including the definitions and the evolvement of the adopted methodology and tools in this study from different point of views.

2.2.1 Continuous Improvement (CI)

Bessat and Caffyn (1997) confirmed that the late twentieth century environment possesses many challenges to all kinds of organizations; organizations therefore need to respond by reconfiguring and reinventing their processes and structure, and to continue to doing so over time.

Bessant and Francis (1999) defined continuous improvement as an organization-wide process of incremental innovation which represents an important element in such dynamic capability since it offers mechanisms whereby a high proportion of the organization can become involved in its innovation and learning processes. While Anand et al. (2009) defined CI as a systematic effort to seek out and apply new ways of doing work. CI initiatives such as Lean production and Six Sigma have increased among service and manufacturing organizations. Due to an increasing pace and complexity of business environments, organizations compete on processes and the ability to continuously improve their processes.

Another definition of CI according to Martocchio et al. (2000) is an organizational ethic encouraging employees' initiative for learning to improve performance. It often includes the notion of pay for knowledge, which rewards employees for attaining competence that can be applied in the workplace and includes a network of training courses that an organization makes accessible to employees. Continuous improvement focuses on developing skills, abilities, and job-related knowledge of each employee.

Improvement can be either small incremental change (kaizen) or innovative step change (process re-engineering). The two are complementing each other. Kaizen is characterized by workers on the shop floor identifying problems and suggesting solutions. Tuning system on a low scale is likely to need a low cost generated from an intimate knowledge of a small part of the system (Bond, 1999).

CI can take place at three different levels within the organization: at the management level, group level, and individual level. At the management level, the implications of CI are on the strategy of the organization. Group level CI includes problem-solving tasks at a wider level, while individual level CI deals with improvement on day-to-day tasks. In order to gain maximum benefits from a CI program, CI must be implements at all of these levels (Bhuiyan and Baghel, 2005).

2.2.2 Lean Six Sigma Evolution and Definition

The evolution of Lean Six Sigma improvement methodology (LSS) had started in the 2000s, researchers have used the term Lean sigma to describe a system that combines both Lean and Six Sigma (Salah et al., 2010).

Pepper and Spedding (2010) have noticed that the Lean thinking philosophy of business improvement and the more scientific improvement methodology of Six Sigma have experienced success in a wide range of industries. The two methodologies are influential motivators of change as stand-alone methods, but more provokingly, if merged together, can potentially represent an exceptionally powerful tool.

Salah et al. (2010) defined LSS as a methodology that targets elimination of waste and variation, following the DMAIC structure, to achieve customer satisfaction with regards to cost, delivery and quality. It focuses on achieving better financial results for the business, improving processes, and satisfying customers.

Arnheiter and Maleyeff (2005) concluded that a LSS organization would capitalize on the strengths of both Lean management and Six Sigma. A LSS organization would include the following three primary principles of Lean management:

(1) Seeking maximization of the value-added content of all operations.

(2) Evaluating all incentive systems to ensure that they result in global optimization instead of local optimization.

(3) The decision-making process should base every decision on its relative impact on the customer.

A LSS organization would include the following three primary principles of Six Sigma:

(1) Changes are based on scientific studies by stressing data-driven methodologies in all decision making.

(2) It would promote methodologies that strive to minimize variation of quality characteristics.

(3) Designing and implementing a company-wide and highly structured education and training regimen.

According to Arnheiter and Maleyeff (2005), the DMAIC model refers to five interconnected phases (i.e. define, measure, analyze, improve and control) that systematically help organizations to solve problems and improve their processes. A brief definition of the DMAIC phases is as follows:

- **Define:** Defining the goals of selected projects, project scope and boundary, the team's role, and customer requirements and expectations.

- **Measure:** Providing a structure to evaluate performance and selecting the measurement factors to be improved as well as monitoring, comparing, and assessing subsequent improvements and their capability.
- **Analyze:** Identifying the root cause of problems (defects), understanding why defects have taken place as well as comparing and prioritizing opportunities for improvement.
- **Improve:** Reducing the amount of quality problems and/or defects by using experimentation and statistical techniques to generate possible improvements.
- **Control:** Ensures sustainment of improvements and that ongoing performance is monitored. Process improvements are also institutionalized and documented.

Lean and Six Sigma both emphasize process flow. Lean focuses on process flow by improving speed and increasing productivity with minimum waste. Six Sigma focuses on process flow by minimizing variation. Lean focuses on cost reduction through eliminating all sorts of waste and non-valued added activities. Six Sigma however focuses on cost reduction by systematically targeting cost of poor quality items in various processes. Lean uses JIT, visual management, value stream mapping, work flow standardization etc. Six Sigma on the other hand uses statistical and non-statistical tools for variation reduction such as Statistical Process Control (SPC), cause effect analysis, design of experiments, histograms, Analysis of Variance (ANOVA), multi-variance charts, etc.(Jiju, 2011).

2.2.3 Improving Productivity

There are many means for improving productivity; one of these means is the effective time management. Managers should identify and correct time-wasting behaviors, use their time effectively, and improve their overall time management skills.

They will become more organized, able to spend more time with staff on the important elements of employees' jobs, thus helping to improve performance (Arnold and Pulich, 2004).

Another two means of improving productivity are the cellular manufacturing where machines serving the same product are grouped together; this system integrates various functional activities with the production system, and the third one is the integration of research and development with the rest of the company (Gunasekaran et al., 1994).

Researchers confirmed the role of LSS in improving productivity, Ray et al. (2006) concluded that a successful Lean manufacturing program results in improving productivity, lowering cost, and improving quality. Ultimately, manufacturers who follow Lean manufacturing principals will grow, inspiring new manufacturers to adopt this discipline. Lean manufacturing can translate into a sharp reduction in rework and a 20% improvement in productivity, which can easily double profit.

Moreover, Desai (2012) concluded that Six Sigma is one of the most effective breakthrough improvement strategies having direct impact on operational excellence of an organization. It addresses effectiveness and efficiency of the industry thus simultaneously improving productivity and quality.

2.2.4 Inventory Management

Too much inventory creates financial burden, increase possibility of damage, spoilage and loss, and consumes physical space. Further, excessive inventory frequently compensates for poor forecasting, haphazard scheduling, sloppy and inefficient management, and inadequate attention to procedures and process. On the other hand, too little inventory often increases the likelihood of poor customer service and disrupts manufacturing operations. In many cases good customers may switch supplier if the desired product is not immediately available (Koumanakos, 2008).

Firms can meet demand growth in the future and delay the purchase of additional capacity through adopting the longer-term capacity acquisition perspective which suggests building additional inventory with the excess capacity. Based on the data obtained from the firm under study, a new production line in this firm costs over $10 million and delaying its purchase by even six months can save them over $500,000 while the cost of building up additional inventory is about $200,000 (Rajagopalan and Swaminathan, 2001).

Inventory management techniques must contribute to maximizing the owner's wealth. Inventory management decisions are complex. Inventory ties excess cash and burdens the enterprise with high costs of inventory service and opportunity costs. By contrast, higher inventory stock helps increase income from sales because customers have greater flexibility in making purchasing decisions and the firm decrease risk of unplanned break of production (Michalski, 2013).

2.2.5 Activity Based Costing (ABC)

Many service and manufacturing organizations are now adopting ABC. ABC takes place at two-stage approach where cost drivers at various levels of activity are the basis for allocating indirect costs to product units. In the first stage, resource costs are assigned to cost pools according to the various types of performed activities. Each type of activity is individually costed out based on the total costs of resources consumed divided by the volume of activity performed. In the second stage, activity costs are assigned to the services, customers, and products that benefit from or create the demand for the activities. While in traditional cost models, the proxy cost drivers are volume or volume-related measures (Ra and Elnathan, 1999).

Turney (2010) confirmed that Activity Based Costing (ABC) has evolved greatly over more than two decades; it faced criticism and lowered visibility at the beginning of life cycle. Nowadays, it has reached maturity and acceptance in the market place for management ideas and methods. ABC emerged as a tool for profit improvement.

ABC provides better understanding of cost structure which helped many manufacturing and service organizations improve their competitiveness by enabling them to make better decisions. Through ABC it is possible to cost out the products more accurately and completely by classifies indirect (overhead) costs and allocate them to customer-required products or services, based on the activities needed to produce these products (Ra and Elnathan, 1999).

According to Eden and Ronen (2002):

1. ABC costing creates reliable data for decision making and performance evaluation.
2. ABC appears to be a necessary condition for effective management since it reveals the cost of complexity arising from composition of operating costs and the range of products and variations in the structure.
3. ABC deals with non-production costs such as those associated with marketing and distribution which are ignored by traditional costing because are they are not considered as a part of the product cost according to accounting principles.

Krishnan (2006) concluded from their case study of improving the costing system of a Malaysian university that the ABC system enables the university managers to calculate the ‘true’ cost of a product i.e. cost per students and provides more accurate cost management. ABC team must be released from normal duties for an effective implementation of the system. The ABC system enables the department heads to analyze and see things, through the lens of costs and work activities.

Moreover, Waters et al. (2001) concluded that the effectiveness and financial impact of quality improvement programs can be measured and compared against their costs through ABC. ABC can determine corresponding unit costs and track services performed both correctly and incorrectly.

2.2.6 Facility Layout Utilization

Aleisa and Lin (2005) defined facility layout as the arrangement of spaces, features, and activities according to the relationship that exists between them. Facility or plant layout is a part of facilities design, which includes material handling, building design, plant location, etc. Plant layout analysis includes a study of relationship diagrams between different departments in the facility and the cost of material movement, material flow diagrams, processing times, product routings, and the production line process flow charts.

According to Kim & Kim (2000), layout design significantly affects work-in progress inventory and system efficiency. New manufacturing systems, e.g. cellular manufacturing systems and flexible manufacturing systems have been implemented in many manufacturing firms to meet customer demand, meet market demand, and enhance system flexibility and efficiency.

In order to improve the design of waste recycling centers, visitors' activities, and vehicle flows should be studied. Several achievements can be reached by applying Lean production principles, such as cleaner waste fractions and shorter visiting times.

Efficiency lead time, flexibility, peak flows, capacity, bottlenecks, and queues were also influenced (Sundin et al., 2011).

2.2.7 Production Scheduling

Maccarthy and Liu (1993) defined scheduling as the allocation of resources over time to perform tasks. The importance of good scheduling strategies cannot be overstressed in production environments in today's competitive markets. The need for efficient plant running and quick response to market demand gives rise to complex scheduling problems in all but the simplest production environments.

The main objective of scheduling is to achieve efficient utilization of resources to satisfy marketing demands. At the same time, there must be sufficient flexibility to allow for contingency re-planning whilst retaining a high degree of overall stability. Production scheduling occurs at four levels in the planning process; precise sequencing of jobs on machines , end product completions, supporting component schedules, and aggregate (resource) scheduling (Buxey, 1989).

2.2.8 Value Stream Mapping

Value stream mapping (VSM) has emerged as the preferred way to implement Lean. VSM is a mapping tool for describing supply chain networks. It maps material flows and information flows that signal and control the material flows. This facilitates the process of implementing Lean by helping in identifying the value-added steps, and eliminating the non-value added steps/waste (muda) in a value stream (Lian and Van, 2002).

Venkataraman et al. (2014) defined VSM as a visual representation which helps in determining where the waste occurs. VSM are utilized for the purpose of assessing the current manufacturing processes and creating ideal and future state processes. VSM maps the process flow in order to identify various factors like:

- Value added time (time taken for producing the end product),
- Non Value-added time (time taken which does not contribute to the production of end product),
- Cycle time (time required to perform a process) and
- Changeover time (time required to change tool and programming etc.).

This helps in identifying and eliminating waste and ultimately implementing Lean principles.

Belokar et al.(2012) defined VSM as a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System). VSM helps in understanding and streamlining-g work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process, where waste is any activity that does not add value to the final product. VSM is developed at four major steps to identify material and information of current state:

1. Product
2. Drawing current state
3. Drawing future state
4. Developing a work plan for implementing the future state.

Lu et al. (2011) stated that VSM provides a picture of both current-state and future-state maps. The difference between both the two maps is helpful in visualizing what conditions would work when improvements are made. Current-state map is considered the basis for developing future-state maps, which helps in eliminating wasted steps and interfaces while pulling resources through the system and smoothing flow.

Lasa et al. (2008), concluded that VSM is a suitable tool for redesigning production systems. While the main weakness the lack of training in several Lean concepts on the part of company personnel.

VSM helps in visualizing the present level of wastes occurring in the organization such as inventory, defects, and transportation, and the future possibilities of reducing or eliminating them (Silva, 2012).

2.2.9 Waste Elimination through 5S

According to Deshpande et al. (2015), 5S was originated in the 1980's as one of the Japanese techniques which was introduced by Takashi Osada. They defined 5S as a workplace management methodology which helps for improving work environment, human capabilities, and thereby productivity.

Pasale and Bagi (2013) defined 5S as a strategy for obtaining workplace organization and cleanliness, and it will do more for morale, productivity, and quality than any other Lean manufacturing improvement tools. The philosophy of the 5S has its roots in Japan. Name 5S is the acronym of five Japanese words of the following meanings:

1. Seiri (Sort): sort out what is not needed.
2. Seiton (Set in order): a place for everything.
3. Seiso (Shine): cleanliness of workplace.

4. Seiketsu (Standardize): define standard method/way of doing the work.

5. Shitsuke (Sustain): maintain consistency in the method/way of doing the work.

Deshpande et al. (2015) have implemented 5S in Samsonite Group which is specialized in making all the products related to the journey. They obtained the following results from 5S implementation:

- Better use of working area through proper workplace management;
- Proper location and identification of tools and materials reduced searching time;
- Huge cost saving from waste and unwanted materials;
- And, enhancing work environment lead to increasing worker's morale.

After implementing 5S in a ceramic manufacturing company, Patel and Thakkar (2014) Concluded that implementing 5S and visual management system lead to improving the work environment, inventory system, safety of employees, space utilization, less scope of error, increased productivity, also increasing efficiency of machines, maintenance the cleanness of devices, maintenance the clean workplace, easy to check, quick informing about damages, and elimination of the causes of accidents in the company.

Al-Aomar (2011) has implemented 5S at Prefab Company in Amman for the purpose of increasing the effectiveness of their manufacturing and assembly operations through a better workflow and an enhanced layout of the workplace. The facility produces prefabricated structures such as portable buildings, homes, offices, and communication shelters. The implementation targeted 10 areas in the plant during 3 months to improve overall plant operations and clean up the process. A new layout is developed at each area and a thorough clan up process is started, and all 5S's are implemented using clear forms and procedures. Results showed tangible changes on the plant floor along with increased productivity and improved worker's morale. They also concluded that 5S approach can be adapted to other types of manufacturing processes as well as offices and service processes.

Pasale and Bagi (2013) have implemented 5S in Sunmill Industries which is specialized in manufacturing automotive parts. The obtained results are: 250 square feet space is available for use, fixture setting time is reduced by 28%, productivity is improved by reducing searching time through allocating space for tools, material, and components, and employees in the organization become self-disciplined.

2.3 Lean Six Sigma Previous Studies

LSS methodology was adopted in this study since it is as a widely used methodology which resulted in tangible improvements in many manufacturing industries worldwide. This section presents couple of case study on DMAIC methodology implementation.

According to Kaushik et al. (2008), the successful applications of Six Sigma in SMEs have been reported by very few studies. It is much easier to buy-in management commitment and support in small companies as there are more agile than large organizations. Small companies do not have the slack to free up talented people up engage in training followed by execution of Six Sigma projects. It is much easier for small companies to link compensation to Six Sigma implementation compared to a large company.

DMAIC methodology was applied to reduce defects in a rubber gloves manufacturing organization. Defects were reduced by determining the optimum oven's temperature and conveyor's speed, which were defined as 230°c and 650 R.P.M.

respectively. In terms of the Six Sigma level, the concept literally refers to reaching a Sigma level of Six, or in other words, 3.4 DPMO (Jirasukprasert et al., 2014).

Pimsakul et al. (2013) applied DMAIC methodology to improve the production process of a laser computer mouse. After implementing the DMAIC methodology, the yield of the functional test procedure increased from 96.2 to 98.6.

As a result of implementing DMAIC methodology in automobile part manufacturing company to reduce defects in the fine grinding process, the rejection level of distance pieces after the fine grinding process has been reduced from 16.6% to 1.19%. The project resulted in an estimated annual saving of about US$2.4 million. This encouraged management to implement the Six Sigma methodology for all improvement initiatives in the organization (Gijo et al., 2011).

DMAIC methodology has been applied at Belt Manufacturing Industry which is specialized in producing automotive belts and hoses to optimize cord wastage variables. The DPMO of cord wastage was improved from 549531to 14908, Sigma level was improved from 1.37 to 3.6 (Khekalei et al., 2010).

The implementation of LSS methodology at a pharmacy department of an Italian hospital resulted in reduction of safety risk, reduction of financial cost, six days reduction in lead time, and 60% less time for transportation and motion (Chiarini, 2012).

Junankar and Shende (2011) have used DMAIC methodology to minimize rework in a belt manufacturing industry. The Sigma level was improved from 2.7 to 3.2 and the organization achieved breakthrough in reducing fabric rework due to Six Sigma DMAIC Methodology.

Many benefits were reported from Lean implementation in an indian production industry with the help of VSM technique such as work in progress was reduced by 89.47 percent, finished goods inventory was reduced by 17.85 percent, processing time was reduced by 12.62 percent, lead time was reduced by 83.14 percent, required manpower was reduced 30 percent, and output per operator was increased by 42.86 percent (Singh et al., 2010).

Lessons learned from applying Lean principles and techniques at Timberline's is that it is effective for improving productivity and quality of software product development and that the quality is impacted by all sections of the company. Lean principles should be adapted to culture and circumstances of the organization which will accelerate organizational learning and continuous reduction in variation in process and product (Middleton et al., 2007).

Pickrell et al. (2005) have applied LSS methodology in two case studies in a worldwide manufacturer of military and automated industrial machinery. Results obtained in the first case study of military application are reduction in cost, cycle time, customer return, and inventory, and increasing production capacity. While in the second case study of automated document control system, customer rejections and manufacturing delays were reduced.

2.4 Success Factors/Hurdles to LSS Implementation

The most important critical success factors (CSFs) for LSS implementation identified in the literature were leadership style, organizational culture, management commitment, and Linking LSS to Business Strategy. Leadership styles was identified as one of the more important CSFs for the implementation of Lean Six Sigma (Laureani and Antony, 2012).

Kaushik et al.(2008) also stated some critical success factors for Six Sigma implementation such as:

- Implement Six Sigma at a pace where staff can digest the methodology and achieve benefits.
- The greatest barrier to Six Sigma implementation in SME's to date has been the way the major Six Sigma training providers have structured their offerings in regard to deployment guides, training materials, and price.

On the other hand Kwak and Anbari, (2006) reported other factors influencing successful Six Sigma projects such as cultural change, project management and control skills, organizational commitment and management involvement, and continuous training. Understanding the shortcomings, obstacles, and key features of Six Sigma provides opportunities for better implementation of Six Sigma projects.

Managers should support the LSS teams as their commitment and support is one of the top critical success factors for LSS projects. However, a lack of management support definitely leads the whole project to fail. It is clear that a lack of resources is a massive challenge for organizations, regardless of the size of the organization of the evolution of the country. Financial resources shortage is one of the main barriers to LSS success in a massive number of organizations (Albliwi et al., 2014).

Kumar (2007) also confirmed that management commitment and involvement is the most important factor in the successful implementation of Six Sigma. The two most important impeding factors are the lack of resources and poor training/coaching. Employees' empowerment is also essential as well as to be allowed to use tools/techniques in their job and provided requisite training to apply the knowledge in the right way. If any of the critical success factors is missing during the implementation stages of a Six Sigma, it would then be the difference between a successful implementation and a waste of efforts, tome, money, and resources.

Lack of adequate funding prevents SMEs from implementing good productivity improvement strategies such as Lean manufacturing. The leadership and funding deficiencies inhibit other productivity initiatives such as workforce training, denying SMEs the benefits of improvement in knowledge, skills and cultural awareness (Achanga et al., 2006).

There is a positive progress in adopting and practicing CSFs of LSS implementation to improve business operations and organizational performance in the Malaysian automotive industry. The two extremely important factors for LSS implementation and Malaysian automotive industry are customer focus and leadership (Habidin and Yusof, 2013).

Most top managers in their adoption of Lean management missed the opportunity of the application of the “respect for people” principle. The focus of the business was the continuous improvement, more specifically the methods used to achieve improvements in productivity and quality, reductions in defects and lead-time, cost savings, etc. while the creators of Lean management, people from Toyota, simultaneously focused on respect for people (Emiliani, 2006).

2.5 Summary

In this chapter, the adopted methodology and implemented tools were defined through reviewing previous studies. The previous studies on the implementation of LSS methodology and its tools confirm the effectiveness of this methodology in improving the productivity and the utilization of space in the industrial organizations. Finally, the critical success factors/hurdles were identified in order to be taken into consideration during the implementation of LSS methodology.

Chapter 3
Research Methodology

3.1 Introduction

This research targets improving utilization of space and productivity of Kitchen-cabinets doors production line at GM Profile Company in Albireh through the implementation of LSS methodology. The DMAIC phases (Define, Measure, analyze, Improve & Control) were followed to reach the targeted improvements. Quantitative methods such as cycle time, production scheduling and others were used to validate the results.

According to Espinoza et al. (2010) the DMAIC phases and goals of each phase are presented in figure 3-1:

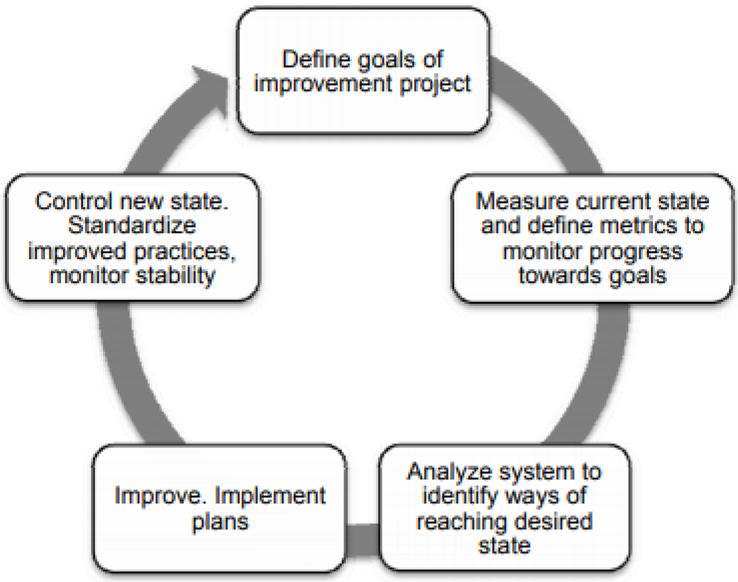


Figure 3-1 DMAIC Phases (Espinoza et al., 2010)

DMAIC methodology is used to improve already existing processes and had been proven to be successful in increasing profitability in all industries by raising customer satisfaction, improving cycle times, eliminating defects, and reducing costs (Prashar, 2014).

3.2 DMAIC Methodology Activities and Utilized Tools

Selvi and Majumdar (2014) stated that DMAIC methodology is a systematic method for analyzing & improving business processes. It is a data-driven quality strategy used to improve processes, it is an integral part of a Six Sigma initiative, and it can alone be implemented as quality improvement methodology or as part of other process improvement initiatives.

Data were collected in this quantitative study through interviews, brain storming sessions and onsite visualizations by the improvement team members. Data collection sheet, checklists, production form, and production progress follow up form were developed in addition to referring to historical data from accounting system during the implementation process of each phase of DMAIC.

The developed activities in the five phases of the DMAIC are:

Define Phase:

- Develop problem context diagram to identify the vital few processes that contribute to the problem under study and the vital few processes that are affected by the problem.
- Develop a project charter to identify the business case, problem statement, scope, and improvement team formation.
- Prepare SIPOC table to identify inputs, result measures, customer needs, and result concerns.

Measure Phase:

- Prepare drawing for the current layout and identify quality concerns.
- Develop flow chart to understand the current process.
- Develop data collection tools and collect data.
- Develop value stream mapping diagram for the current process to identify cycle times, lead time, process efficiency, material flow, and information flow.

Analyze:

- Evaluating each step of the process.
- Inspecting the collected data and transforming it into charts and graphs.
- Brainstorming the potential causes through cause and effect diagram (fishbone diagram).
- Identify root causes through interrelationship diagram.

Improve:

- Develop potential solution based on the root causes.
- Identify easiest solution to implement.
- Communicate the solution to be implemented.
- Implement 5S tool to design the new layout and organize the work environment
- Prepare flow chart for the proposed solution.
- Prepare new work forms to standardize work procedures.
- Implement the proposed solution.
- Determine benefits and impacts through value stream mapping of the new status.

Control:

- Develop metrics to help monitoring, documenting, and sustaining gained improvements.

Chapter 4
Define Phase

4.1 Introduction

The define phase is the first phase of DMAIC methodology with the objective of understanding the current situation and the desired situation through historical data analysis and onsite tour to identify the improvement opportunity and the scope of the improvement effort (Ganguly, 2012).

This chapter includes identifying problem statement, forming the improvement team, preparing the project charter, preparing SIPOC diagram, preparing problem context diagram, and finally identifying critical to quality measures.

After identifying the problem statement the improvement team is formed. A problem context diagram is then prepared to gain better understanding of the current situation, identify processes that contribute most to the problem, and identify the processes that are affected by the problem.

The next step is to prepare the project charter to identify the business case, key players, barriers and support estimate. Then a high level process map is prepared using the SIPOC diagram to identify the scope of the improvement efforts, current performance, goal performance, output measures, result concerns, and customer needs. The final step in the define phase is to identify the critical to quality measures for customer needs using critical to quality tree diagram.

Implementing these steps and tools helped the improvement team to gain better understanding of the current performance, quality concerns, and the objectives of the improvement efforts. The improvement team was formed by the chairman of GM profile Dr. Ashraf Almimi. The team members are:

- Sponsor: Dr. Ashraf Almimi
- Team Leader: Baha Awad
- Members: Plant manager, accountant, two workers at Kitchen Cabinets doors production line, one worker from the wooden profiles production line.

4.2 Problem Definition

After conducting several interviews and meetings with the sponsor, the plant manager, and the accountant to discuss the current status of the work environment and possible improvement opportunities, the improvement team agreed that the priorities for improvement are the utilization of space at GM Profile Company and the improvement of kitchen-cabinets doors production line.

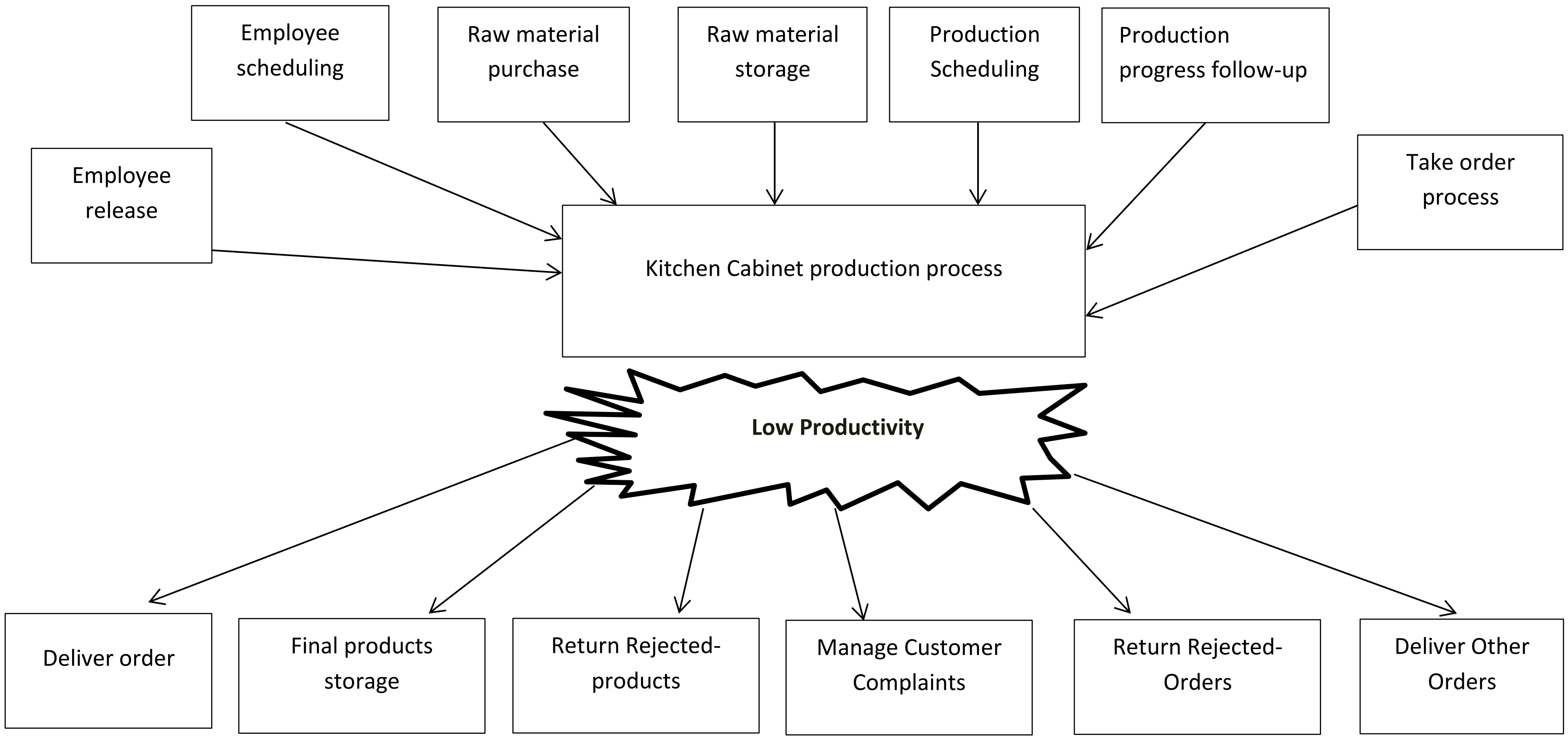
Due to limited space at the factory it was noticed that the raw materials are not organized in specific areas; the production residues are also accumulated around the machines, on the walls and around the working tables; the final products are not labeled or stored in appropriate locations according to product category; work in process (WIP) is not organized nor visible to staff to monitor work progress; and lack of inventory management policy. This mandates the intervention of improving utilization of space through appropriate tools. On the other hand, the kitchen cabinets doors production line does not allow smooth flow, inability to follow up production progress, lack of production scheduling, lack of workers supervision, and ultimately delayed delivery to external customer due to long lead time.

After identifying the targeted areas, the improvement team prepared the problem context diagram presented in figure 4-1 to gain better understanding of the problems, to identify the contributing processes to the problem, and the affected processes by the problem. After this step the project charter and the SIPOC were prepared where the aim of using these two tools is explained in the following sections.

4.3 Problem Context Diagram

Problem context diagram tool is used to help the improvement team in identifying the scope of the problem. PCD has three levels, the problem under investigation is presented in the middle of the diagram with the related process, the upper level of the diagram presents the processes/steps that contribute to the problem, and the lower level of the diagram presents the steps/processes affected by the problem. The PCD diagram for kitchen cabinets doors process is presented in figure 4-1 below:

Upstream processes that affect this process



Downstream processes affected by the process

Figure 4-1 Problem Context Diagram for Kitchen-Cabinet Door Production Process

After preparing the PCD, the improvement team was able to identify the following:

- The few 20% of upstream processes that contribute most of the 80% to late delivery to customer are:
  a- Production Scheduling Process:
    - There is no production scheduling
    - Delivery time is roughly estimated
    - Urgent orders are placed in production directly and will delay delivery of other orders
  b- Production Progress Follow-up:
    - No production-progress follow-up forms are adopted therefore no data is available about orders status or daily productivity.
    - Unassigned responsibility for production progress follow-up accordingly worker's time is not utilized according to demand.
    - No measures of cycle times are present therefore bottleneck is not identified
- The few 20% of downstream processes are most impacted by the late order delivery are:
  a- Final Product Storage:
    - Unassigned area for final product storage where it is stored on floor without being isolated from production area and without labelling which may lead to product damage and lack of ability of follow-up of undelivered orders.
    - Some customers are not contacted to collect their order so final product remains on floor for a long period and could be damaged or rejected later.

- Rejected orders by customer remain on floor and cannot be sold to other customers since all products are customized upon customer demand which will cause financial loss to the company.

b- Manage Customer Complaint Process:

- Delayed delivery results in lost sales opportunities for the customer and thus customer dissatisfaction which will result in more complaint to be managed.
- Delayed delivery results in losing customers and company reputation which will negatively affect customer retention.

Benefits to the business if the problem was solved:

a- Hard benefits:

- Improving productivity

b- Soft benefits:

- Increase customer satisfaction and thus improve customer retention and gain new customer.
- Improve employee's satisfaction.
- Improve company's reputation and thus increase market share.

Regarding the current layout status, the improvement team agreed to prepare the current layout drawing in the measure phase to gain better understanding of the problems In the layout, contributing processes/step and affected processes/steps.

4.4 Project Charter

Project charter helps in managing expectations of the improvement efforts. This charter is considered as an agreement on roles, contributions and importance of cooperation from all team members.

The prepared project charter presented in table 4-1 presents the following elements:

- Problem definition and study purpose: problem, purpose, improvement measures, present performance, and goal performance
- Business case: impact on the business, employees, customers, other processes, work environment, key deliverables, and other benefits.
- Scope: the scope is from customer give order for producing kitchen cabinet doors until order delivery to the customer. It also includes inventory from issuing purchase order and until sorting final products. Out of scope is the wooden profile production line.
- Enablers: Workers free time or ability of overtime by 4 hours per week, workers training, and financial resources
- Barriers: Workers resistance to change, work overload, financial resources, workers literacy, and top management commitment
- Support Estimate: Outside workers for work place organization, wood sawdust machine, storage shelves and labels, and three trollies for WIP flow.

Table 4-1 Project Charter for Improving Utilization of Space and Productivity of Kitchen Cabinets Doors Production Line at GM Profile

Project Sponsor	Ashraf Almimi
Team Leader	Baha Awad
Project Title	Improving Utilization of Space and Productivity of Kitchen Cabinets doors Production Line at GM Profile Company in Albireh
Date	7-7-2018
Issue	2018.1

1. Problem Definition and Purpose

Problems:

- The work environment is not organized where the inventory, production residues and final products are stored within the same area and not separated from the production area.
- Kitchen cabinets doors products pricing is roughly estimated.
- Lack of production scheduling.

Project Purpose: Improving utilization of space & productivity of Kitchen Cabinets doors production line

Improvement measures:

- Cycle time and lead time
- Daily productivity of Kitchen cabinets doors
- Production sorting and labelling introduced
- Standard operating procedures introduced
- New lay out design
- Newly introduced products
- Sales report

Present Performance:

- Long lead time and unorganized work environment.

Goal Performance:

- Reduced lead time and organized work environment.

Completion Time:

- Project should be completed by the end of August, 2019

2. Business Case (Issues to be addressed/process to be improved)

Problems:

1- Customer:
- Delivery delay
- Lost opportunities

2- Kitchen Cabinets doors production line:
- Low productivity
- Wastes (defects, waiting, motion, excess processing)

3- Wooden profiles production line:
- Wastes (defects, overproduction, waiting, inventory, transportation)

4- Business:
- Losing customers
- Lost opportunities
- Low sales
- Non utilized space

5- Work environment:
- Stagnant products
- Unorganized work place

6- Employees:
- Hampering movement
- Overburdened
- Work accidents and injuries

Why is this a priority:

The survival of the company depends on the improvement of productivity and the utilization of space since wastes should be reduced or eliminated to reduce the cost and ultimately the profit of the company.

Key Deliverables:

- New layout design
- Production management system
- Inventory management system

Other Benefits:

- Maintaining current customers and gaining new customers
- New products release
- More satisfied employees

Key Players		Scope
Sponsor	Ashraf Almimi	In scope: work place area and kitchen cabinets doors production line.
Team Leader	Baha Awad	
Team Members	Maher, Musa, Mohammad, Issa, Ibrahim, and Nidal	Out of scope: External customers, wooden profile production line.
Other Key People	Imad, Fayez	
Enablers/Risk Mitigation		**Barriers/Risks**
- Workers free time or ability of overtime by 4 hours per week. - Workers training - Financial resources		- Workers resistance to change - Work overload - Financial resources - Workers literacy - Top management commitment
Support Estimates		
- Outside workers for work place organization - Wood sawdust machine - Storage shelves and labels - Three trollies for production flow		

4.5 SIPOC

SIPOC stands for Suppliers, Inputs, Process, Outputs, and Clients. SIPOC analysis is a methodology for process improvement employing analysis based on diagrammatic representation of key elements of a process namely, Suppliers, Inputs of the process, Process itself, Outputs of the process and Customers (the recipients of the process). This analytical tool is used mainly to understand and further improve an individual process within a business. SIPOC is a continuous improvement tool (Parkash and Kaushik, 2011).

The improvement team prepared SIPOC as presented in table 4-2:

Table 4-2 SIPOC for Kitchen-Cabinets Door Production Process

Key Business Process Name: Produce Kitchen-Cabinet Doors				
Suppliers	**Input**	**Process**	**Output**	**Customers**
- Customer - Sales person	1- Machines 2- Raw Materials 3- Workers 4- Production form 5- Production manager	**Process Purpose:** Produce kitchen cabinet doors to customers on time. **Process Owner:** Production Manager	1- Kitchen-cabinet doors 2- Invoice hand over	- carpenters - retailers and wholesalers of wood and its accessories - construction contractors

Process Steps (High Level)	Prepare productio n order →	Prepare raw material →	Cut frame pieces →	Carving filling's track →	Cutting filling pieces →	Cabinet door assembly (frame and filling) →	Final product sanding	**Results Measures** Number of invoices issued	**Customer Needs** On time delivery Right product Right specifications
Process Measures	No	No	Production form check list	No	Production form check list	No	No		
Present Data	Production order forms	No	Production form check list	No	Production form check list	No	Issued invoices		
Goal Performance	100% accurate dimensions of pieces to be prepared	100% accurate selection of wood type	100% of pieces are produced according to production form specifications	100% of track are carved with same width and depth	100% of pieces are produced according to production form specifications	100% of assembled doors are according to customer's dimensions	100% of produced door are finished to be delivered on time	**Results Concerns** Productivity of eight square meters per day does not meet customer demand	**Date** 20-7-2018
Sources of Variation & Waste	Workers experience.	Raw material source, machines, workers experience, and measuring tools	Workers experience, Saw blade quality, And Measuring tool accuracy.	Carving machine, raw material quality, and workers experience.	Workers experience, Saw blade quality, And Measuring tool accuracy.	Workers experience, glue quality, assembly vise quality, and work place cLeanliness.	Sanding paper quality, workers experience, sanding machine quality.		**Version** 2018.1
Impact on Performance	No	Delay raw material preparation	Delay cutting, Produce wrong dimensions	Delay carving And lead to assembly problems	Delay cutting and Produce wrong dimensions	Delay assembly and produce in accurate dimensions.	Delay finish and rework.		

Through preparing the SIPOC table the improvement team agreed on the following customer needs, result measures and result concerns:

- Customer needs: On time delivery, right product, right specifications, and right quantity since orders are customized.
- Result measures: Number of issued invoices.
- Result concerns: Productivity of eight square meters of kitchen-cabinets doors per day does not meet customer demand.
-

4.6 Critical to Quality

The last step of the define phase is preparing critical to quality tree based on customer needs with the aim of identifying measures related to those needs. Berty (2011) in his master thesis project stated that a CTQ tree will translate customer requirements to numerical requirements for the product or service. In other words, it will help us view which metrics should we attack during the project.

CTQ tree have three parts, the first one is the customer needs, the second one is the drivers of the customer needs, and the third one is the critical to quality metrics of those drivers.

Customer needs identified in the SIPOC are right specifications, right product, and on time delivery. Since this study aims to improve productivity of kitchen cabinets doors production line, the focus is on three drivers of the customer needs. The first one is the accuracy of customer order specifications and design that confirms that the right product is produced, the second one is the production scheduling that confirms if customer order is scheduled on agreed time, and the third one is the production progress follow up to confirm that order production is not delayed.

The improvement team prepared the CTQ tree presented in figure 4-2 below and was able to gain better understanding of the required metrics in the measure phase.

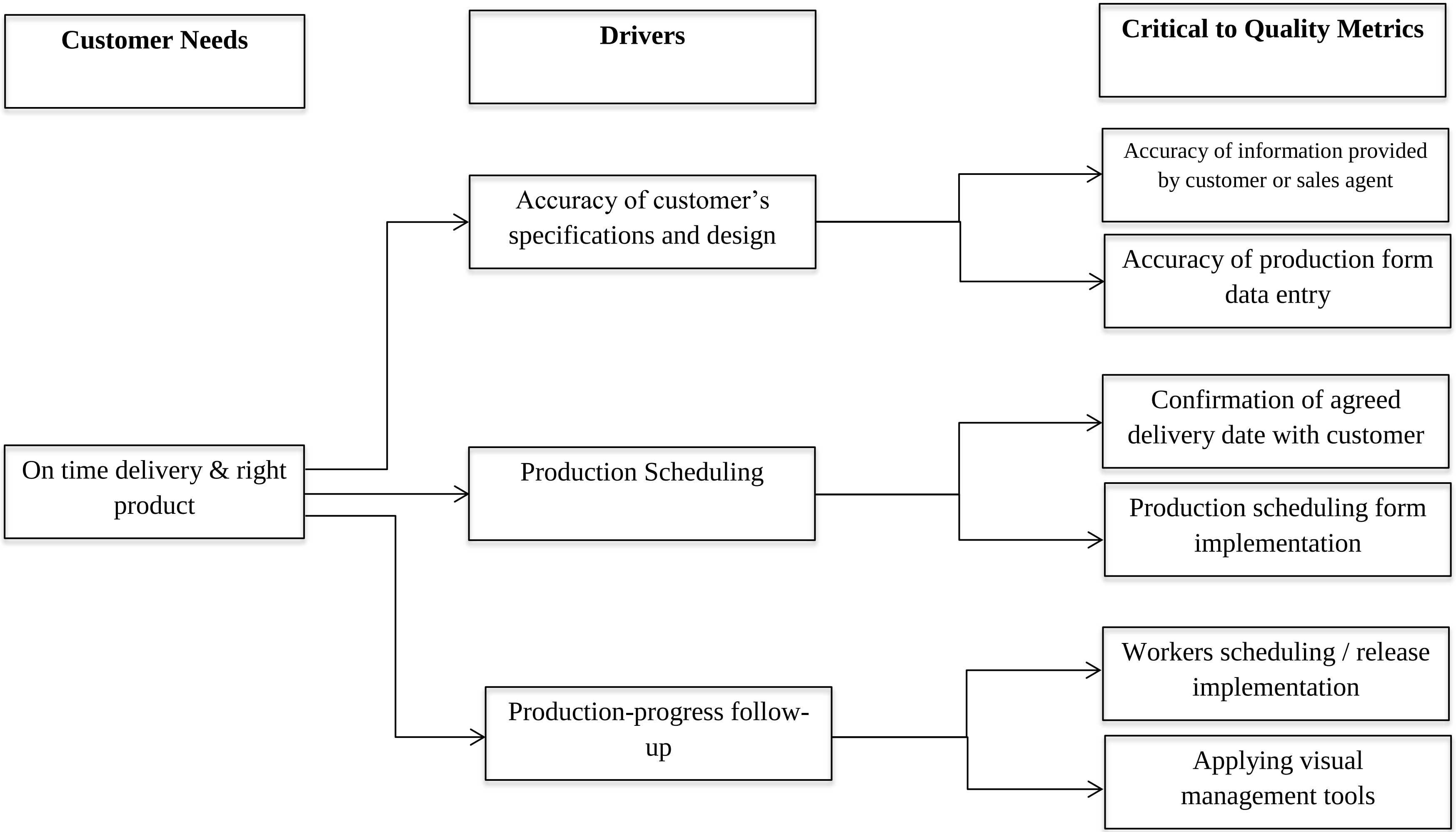


Figure 4-2 Critical to Quality Tree for Kitchen-Cabinets Door Production Process

Chapter 5
Measure Phase

5.1 Introduction

The second phase of the DMAIC methodology is the measure phase. The measure phase involves data collection and data evaluation processes to find the factors that identify the impact on performance (Srinivasan et al., 2014).

In order to gain better understanding of the process of producing kitchen cabinet door, the improvement team agreed to prepare flow chart for this process, collect data for each step including cycle time and delay time, prepare value stream mapping for this process to understand material and information flow and process efficiency, and finally possible quick wins through identifying eight wastes in the process using DOWNTIME (defects, overproduction, waiting, non-utilized talents, transportation, inventory, motion, and excess processing).

The following step is drawing the current status layout of GM profile to allocate machines, spare parts, tools, raw materials, final products, and production residues. Microsoft VISIO software was used for this purpose. The improvement team viewed the current situation to identify areas with problems, possible quick wins, and the utilized space.

5.2 Flow Chart

The improvement team prepared the flow chart for the kitchen-cabinet door process as presented in figure 5-1:

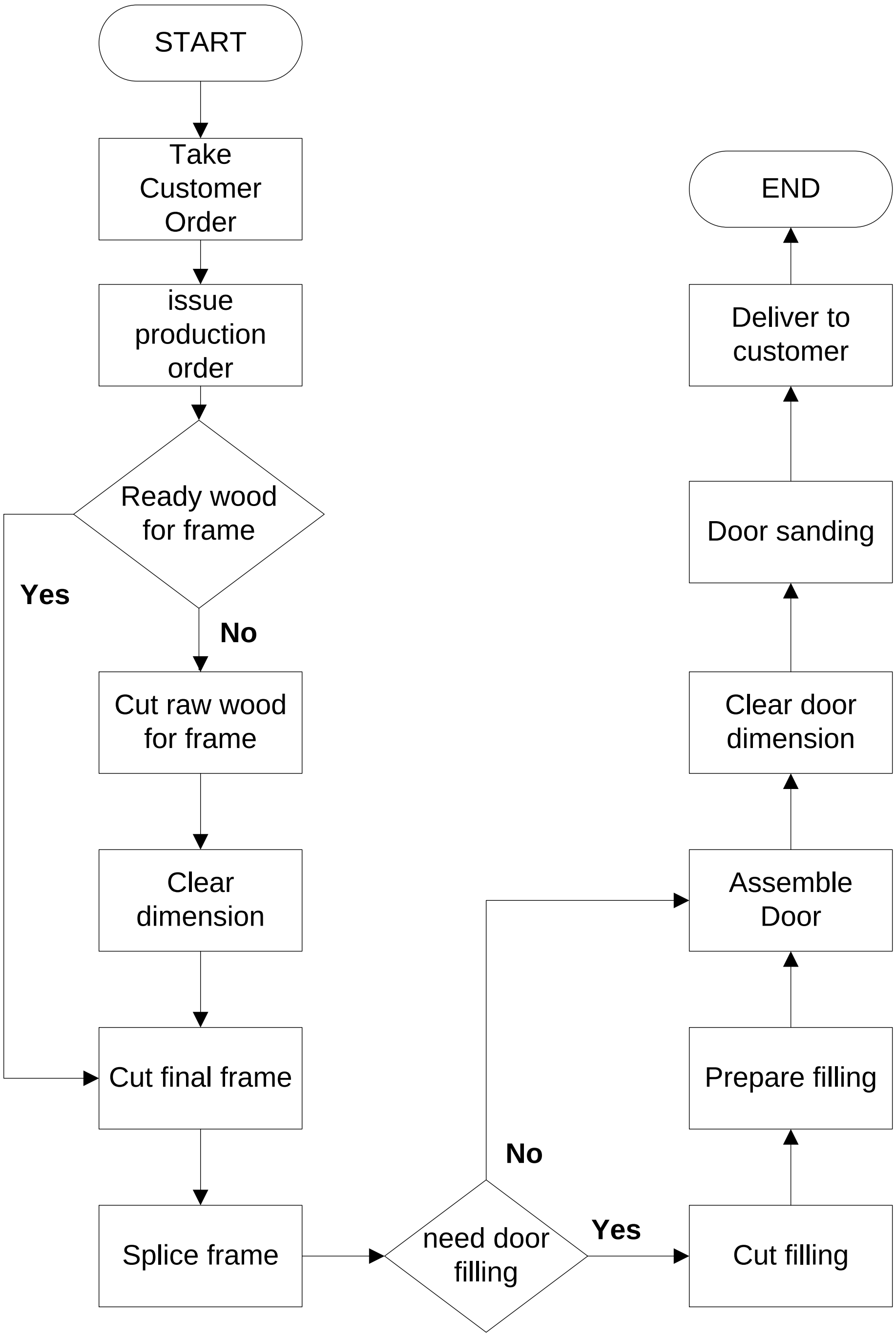


Figure 5-1 Flow Chart for Kitchen-Cabinets Door Process

The process of producing kitchen cabinet door consists of the following steps:

- Take customer order verbally, by phone, or in writing.
- Issue production order.
- The production steps can be divided into three stages:
  - a- Preparing door frame.
  - b- Prepare door filling.
  - c- Assembly.
- **Stage a**: According to customer's order, if the frame of the door is to be made of produced wooden profiles, then the frame preparation stage includes cutting the frame and splicing the frame only, but if the frame of the door is to be made from unprocessed wood, then the frame preparation stage includes cutting raw wood, clearing dimensions, cutting final frame, and splicing frame.
- **Stage b**: according to customer's order, if the door filling is to be made from pure glass, then there is no need for wooden filling and production process moves to stage c where the customer is responsible for installing the glass filling after receiving his order, but if the door is to be made of wooden filling, then the filling preparation stage starts with cutting door filling, and preparing door filling that may include additional steps depending on customer's order.

Figure 5-2 presents kitchen cabinet door sample photo:

Figure 5-2 Kitchen Cabinet Door Sample Photo

- **Stage c**: the prepared frame and filling is assembled, the final dimensions of the door are cleared, and the sanding of the produced door is the last step of the production process.

The produced order of kitchen cabinet doors are then sorted in random places according to available space (between machines, on the walls, in walkways, near raw materials, …etc.) without any labeling, no isolation from ground to avoid humidity, subject to being damaged, and subject to obsolescence. The last step is to deliver the final product to the customer, the company calls the customer to come and pick his order, send the order with driver, or transport it with other orders.

There are 5 assigned workers for this production line, four of them are able to produce the kitchen-cabinets door from a to z, and one can handle sanding only.

5.3 Eight Wastes

Lean manufacturing targets eliminating wastes that ties capital and consumes resources.

Douglas et al. (2015) stated that Lean movement has identified eight categories of waste:

- Motion – unnecessary movement of people or equipment to perform the process
- Transportation – unrequired material movement to perform the processing;
- Non-utilized people – not utilizing the full abilities of staff;
- Inventory – work in progress (WIP), all parts, and finished goods not being processed;
- Defects – all work associated with identifying and correcting defects;
- Over production – producing more than demand;
- Waiting – time wasted in waiting for the delivery of the previous process step;
- Excess processing – doing things that add no value for the customer.

After gaining a clear definition of the eight wastes, the improvement team prepared the eight wastes table for producing kitchen cabinet door process as presented in table 5-1:

Table 5-1 Eight Wastes of Kitchen-Cabinets-Door Process

Process		**DOWNTIME**							
Step #	**Process Step**	**Defects**	**Overproduction**	**Waiting**	**Non-utilized Talent**	**Transportation**	**Inventory**	**Motion**	**Excess processing**
1	Take customer order	✔							
2	Issue production order	✔		✔			✔		
3	Cut raw wood for frame	✔		✔		✔	✔	✔	
4	Clear frame dimension						✔	✔	
5	Cut final frame						✔	✔	
6	Splice frame						✔	✔	
7	Cut filling						✔	✔	
8	Prepare filling						✔	✔	
9	Assemble door						✔	✔	
10	Clear door dimension						✔	✔	
11	Door sanding						✔	✔	✔
12	Deliver to customer	✔		✔			✔		

According to the eight wastes table, it can be concluded that the following wastes in each step:

- Take customer order: defects occur in specifications, required raw material, and design due to taking customer order verbally without revision with customer after writing them down.
- Issue production order: Defects occur in specifications or design during inserting data in the production form. Inventory and delay occur since issued production orders accumulate at the manager office without being scheduled or released to workers to start production.
- Cut raw wood for frame: some defects occur due to accumulation of prepared raw wood on floor beside unprepared raw wood for a long period without being separated or transferred to next work station, and other defects occur due to cutting error due to wrong specifications or wrong measurement. Inventory occurs due to cutting many orders at the same time while being transferred to next work station one by one. Waiting occurs due to long time needed to prepare raw wood for this step because inventory is not managed. High transportation in moving raw wood due to vertical and horizontal accumulation of pallets of wood which required moving many raw wood pallets a side with the fork lift, bringing the required raw wood to cutting station, and then returning unneeded raw wood to its place.
- Inventory and motion: Inventory and unnecessary motion occurs at all production steps due to improper layout of the production line, unmanaged inventory, and unorganized work environment for sorting work in progress or raw materials residues.
- Door sanding: Excess processing due to unnecessary repetition of sanding for the same product.

- Deliver to customer: Defects occur due to improper storage of final products on random places floor. Waiting occurs due to lack of follow up of order delivery to customer and lack of labelling of final product.

Potential quick wins: the frame preparation stage (step 3 to step 6) can be conducted in parallel with the filling preparation stage (Step 7 and step 8). In case of having more than one order of same raw wood and for the purpose of the utilization of raw wood, the frame cutting step is performed before the filling cutting step. The company needs an additional sliding table panel saw. Performing the two stages simultaneously lead to reducing lead time.

5.4 Data Collection

The improvement team collected process data through live observations of producing kitchen cabinet doors. Cycle time and delay time were collected using data collection sheet attached in appendix A. The cycle time of each process step represents the time spent from the beginning until the end of the process step, while delay time of each process step represents the wasted time from the end of the previous step until the beginning of the next step. The collected data is summarized in table 5-2, where CT= cycle time, DT= delay time, LT= Lead time which is the sum of cycle time and delay time (LT=CT+DT), and %VA= percentage value added of the process which measures process efficiency.

Table 5-2 Process Efficiency Data for Current Status of Kitchen-Cabinet Door Process

Process step	**AVGCT(minute per square meter)**	**AVGDT(minute per square meter)**	**AVGLT(minute per square meter)**	**%VA = CT/LT %**
Cut raw wood for frame	14.8	11.1	25.9	57
Clear dimension	24.0	16.9	40.8	59
Cut final frame	14.4	20.9	35.2	41
Splice frame	5.9	20.0	25.9	23
Cut filling	17.5	18.3	35.8	49
Prepare filling	30.7	41.1	71.8	43
Assemble door	44.4	70.1	114.5	39
Clear door dimension	13.1	9.2	22.3	59
Door sanding	27.5	28.7	56.2	49

Data were collected for five orders of same raw wood and same design, total processed in the five orders is 36.73 square meters. Average cycle time (AVG CT), average delay time (AVG DT), and average lead time (AVG LT) of each order were calculated per square meter through dividing each time by total square meters produced in each order, and the final average is then calculated for the five orders. The %VA column represents the percentage of value added time spent on producing the unit and gives a clear view of the efficiency of each process step. This data will be visualized in the value stream map in the next section to identify process efficiency.

5.5 Value Stream Mapping

Value stream refers to those specifics of the firm that add value to the product or service under consideration. It usually starts with customer delivery and work its way back through the entire process documenting the process graphically and collecting data along the way.

A very important part of the VSM process is documenting the relationships between the manufacturing processes and the controls used to manage these processes, such as production scheduling and production information. Majority of process mapping techniques often only document the basic product flow, while VSM also documents the flow of information within the system. Where the materials are stored (raw materials and WIP) and what triggers the movement of material from one process to the next are key pieces of information. VSM is about eliminating waste wherever it is (Singh and Sharma, 2009).

Based on data collected in table 5-2; the improvement team prepared value stream map presented in figure5-3.

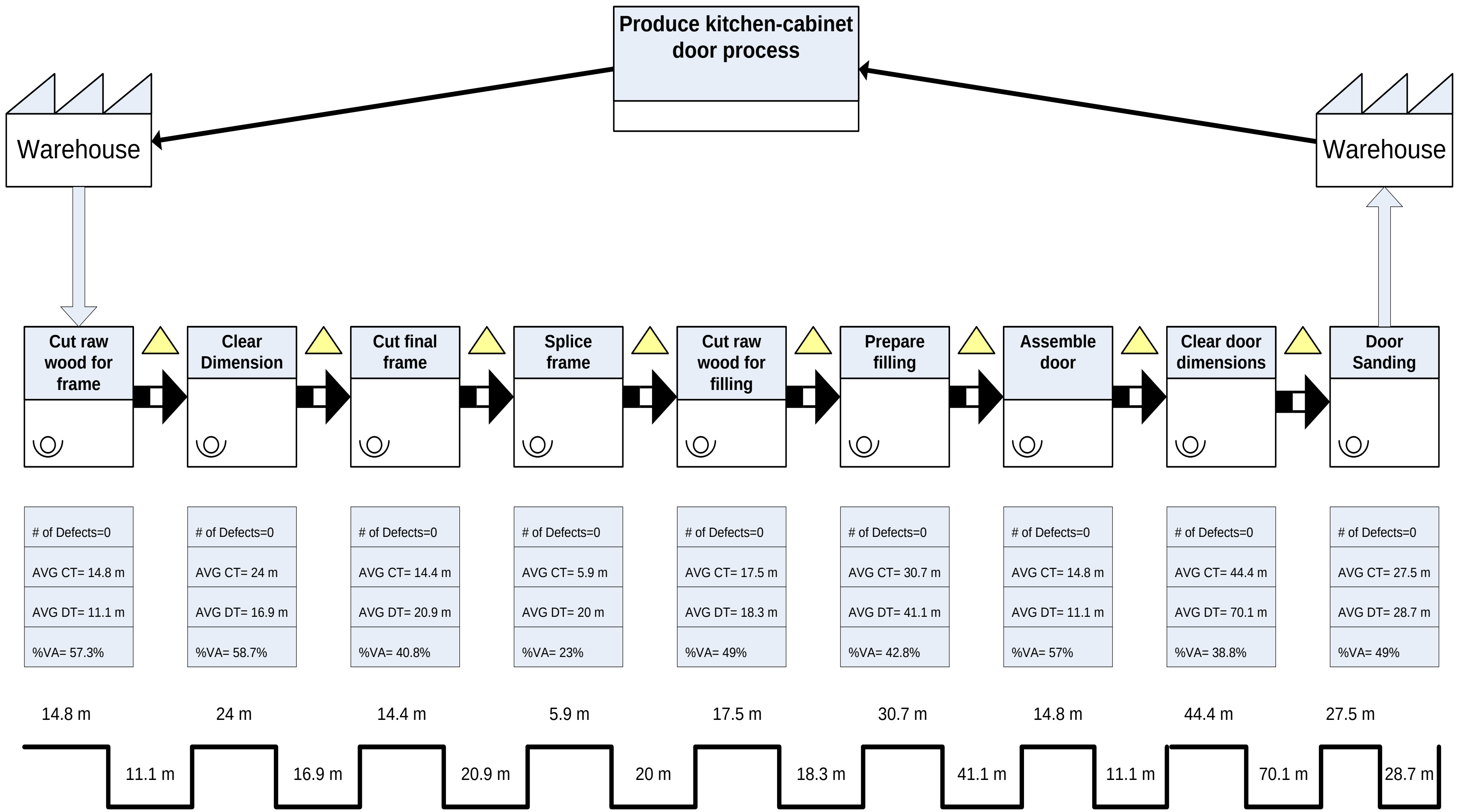


Figure 5-3 Value Stream Map for Kitchen-Cabinet Door Process

Process efficiency is calculated by dividing summation of cycle time by total lead time, where total lead time equals the summation of all cycle times and delay times. While %VA of each process step is calculated by dividing step's CT by its LD.

Process Efficiency = %VA of Produce Kitchen-Cabinet Door Process = **∑CT's/∑LT**

= (192.4 / 428.4)
= 45%

Long waiting took place at clear door dimension step due to waiting for the used glue to become dry and also at splice frame step where low percentage value added can be noticed for these two steps.

5.6 Facility Layout

The improvement team agreed to prepare the drawing of the current layout of GM profile and allocate all machines, spare parts storage, raw materials storage, final products storage, production residues storage, admin office, and other production tools or aids.

In order to gain better understanding of the advantages/disadvantages of the current layout, the improvement team agreed that the drawing should include number of workers on each machine, flow of raw materials from the start of the production line and until it is stored / delivered to customers, and work in progress.

In order to identify quality concerns and present problems in each area, the improvement team agreed on numbering each machine, each storage area, and to examine each production line separately.

The drawing of the existing layout is presented in figure 5-4:

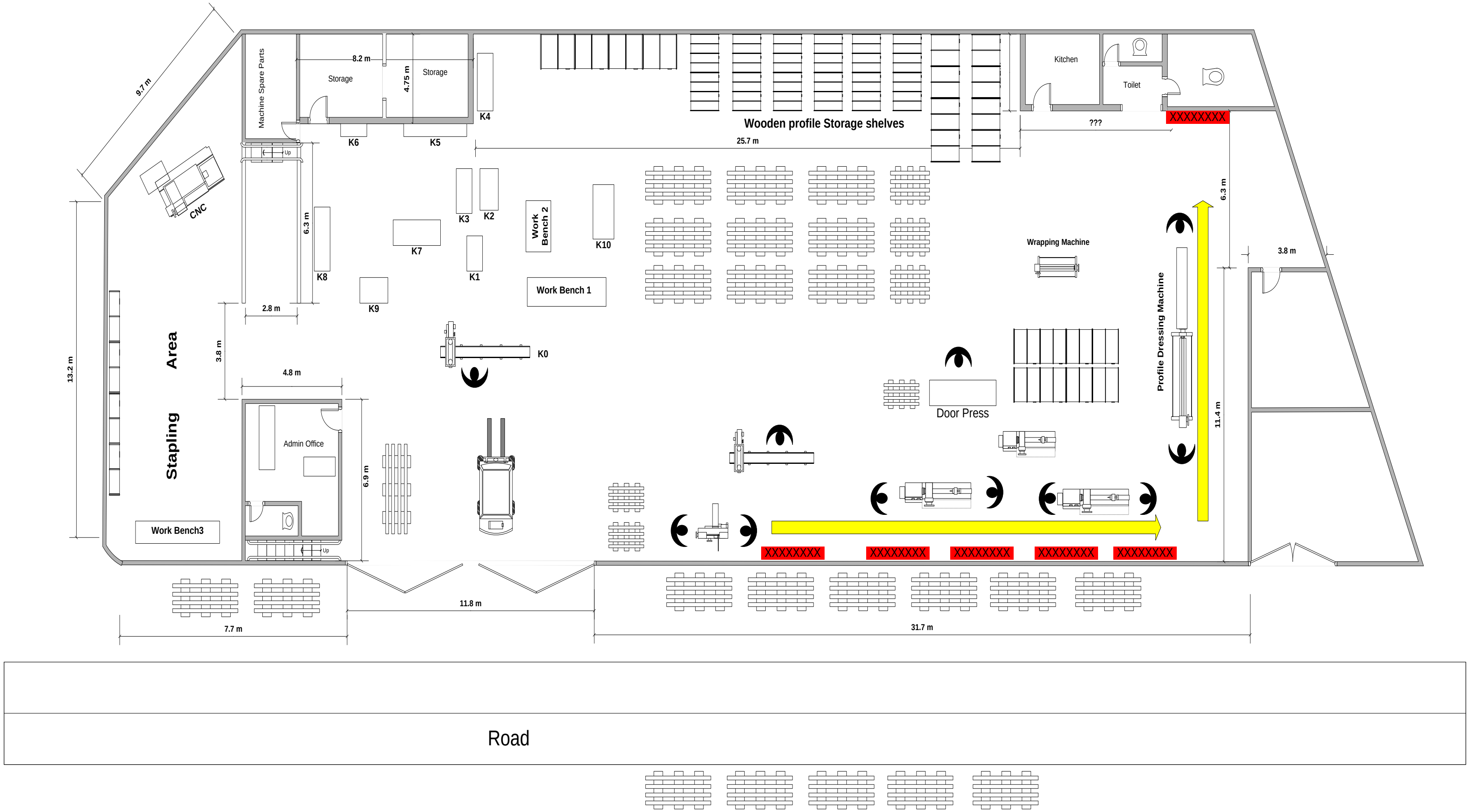


Figure 5-4 Layout of GM Profile before Improvement

The improvement team agreed on dividing the layout into areas in order to provide better and clearer presentation of the use of each area, current performance, and quality concerns. According to the current layout, the layout was divided into the following areas:

1- Wooden profiles production line layout.
2- Wooden profiles storage area.
3- Kitchen-Cabinet door production line layout.
4- Raw materials storage area.
5- Wood CNC and wooden profiles stapling area.
6- Unutilized areas.
7- Wooden doors production area.

5.6.1 Wooden Profiles Production Line Layout

The wooden profile production line is the major production line at the company since its establishment. It produces wide variety of wooden profiles with wide range of designs, specifications, raw material, and ability of customized profiles.

The machines in this production line are arranged in series and the workflow is represented by yellow arrows. Each machine has two or three workers, one for the entry of the raw wood, one for handling the output of the machine, and the third one for pouring a liquid that facilitate the flow of the raw wood. The layout of this line is presented in figure 5-5.

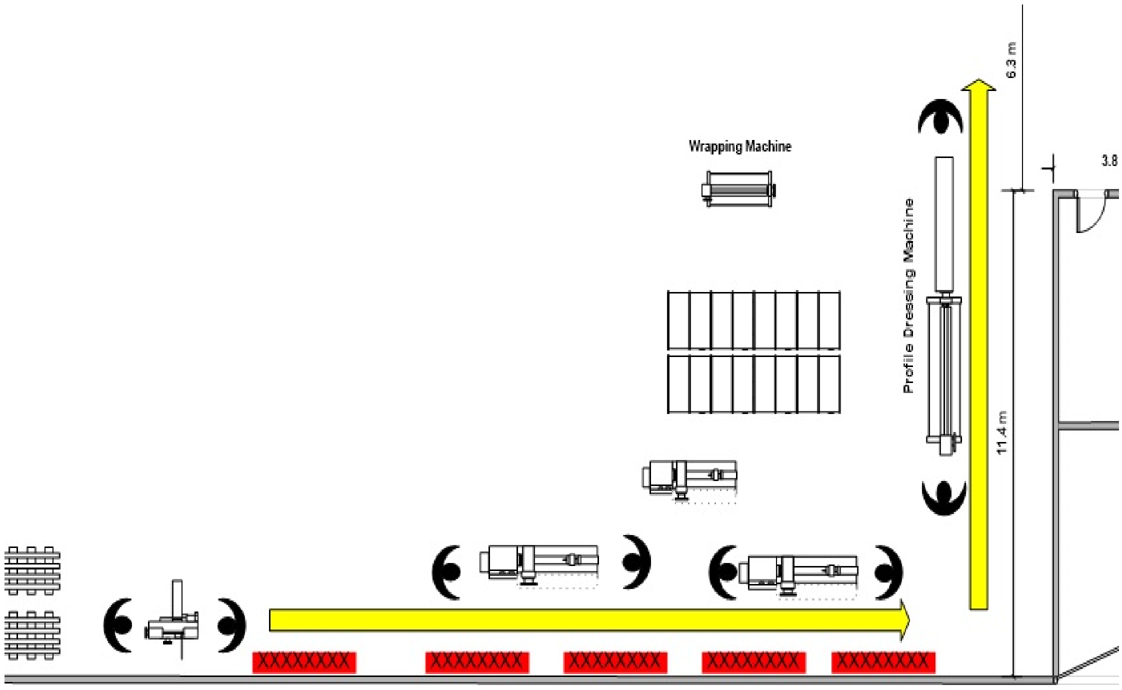


Figure 5-5 Wooden Profile Production Line Layout

There are four machines at this line, the first one is for slicing the raw material, the second one is for dimension clearance, the third one is for the formation of the shape of the wooden profile, and the last one is for dressing of the wooden profile.

The current layout is considered as the optimum layout due to workflow and machines position in the best space optimization.

The current performance of the production line and the quality concerns are presented in table 5-3:

Table 5-3 Wooden Profile Production Line Current Performance

Process Step	Current Performance	Quality Concern	Supporting Photos
Issue production order	Production order is printed with specifications, customer information, profile specifications and design.	- Crowded and unorganized space at raw material entry which delays production start-up until area is cleared. - lack of follow up on produced quantity	
Dimension clearance	Sliced wood is sorted at the entry of the clearing machine	- Work residues and defected products are stacked beside machine and on the walls - Lack of follow up or measurement of defects and production residues.	

Wooden profile formulation	Cleared wood is sorted at the entry of the formulation machine	- Work residues and defected products are stacked beside machine and on the walls. - Lack of follow up or measurement of defects and production residues. - Long setup time.	
Wooden profile dressing	Formulated profile is sorted at the entry of dressing machine	- Work residues and defected products are stacked beside machine and on the walls. - Lack of follow up or measurement of defects and production residues. - Long setup time. - Unsorted raw material. - no labelling for final product - Unorganized storage of final product.	

Quality concerns in the above table can be summarized as follows:

1- Lack of production scheduling.
2- Lack of control of produced quantities (overproduction).
3- Defective products and production residues are neither measured nor sorted out; it is accumulated near the machines and on the walls. (red X's in the figure represents defective and production residues on the walls).
4- Long setup time for profile formulation machine and profile dressing machine.
5- No labeling for final products.
6- Unorganized sorting of final product.
7- The company produces additional quantity of profiles according to workers memory of high turnover instead of sales reports.

5.6.2 Wooden Profiles Storage

The company produces more than 12 different designs of wooden profiles; each design is produced from different raw material and different wrapping which leads to large number of different final products. These products are sorted vertically in shelves with a total area of more than 95 square meters and some profiles are sorted on top of shelves. The majority of the shelves are located in one area, some shelves are located in other areas, and due to unorganized workplace some profiles are sorted on pallets near raw material and in any available space. None of the produced profiles are labelled or separated according to design, raw material produced from, or dressing color.

Current status in storing locations is presented in table 5-4 with supporting images.

Table 5-4 Wooden Profile Storage Areas

Storage area	Supporting image
Assigned Shelves area	
Random Sorting in an unassigned areas	
	
	

Due to unmonitored overproduction, lack of labelling, lack of follow up on storage; the following concerns are identified:

1- Unsorted wooden profiles according to design, raw material, or wrapping.

2- Uncounted wooden profile stock.

3- Obsolescence of some of the wooden profiles.

4- Sorting in random places.

5- Customer order is identified according to memory and experience.

6- Lack of follow up on undelivered orders.

7- Stagnant profiles in many areas.

8- Producing profiles that are available in stock due to lack of information.

9- Large number of defected profiles due to current sorting.

5.6.3 Kitchen-Cabinet Door Production Line Layout

The second main production line at GM Profile Company is kitchen-cabinets doors production line. It produces customized products according to customer demand which includes specifications about quantity in square meter, dimensions, design, and wood type. Five employees are available in this production line on average with the possibility of release of one or two according to work load in other areas or worker's absenteeism.

The current layout of the machines in this production line is presented in figure 5-6.

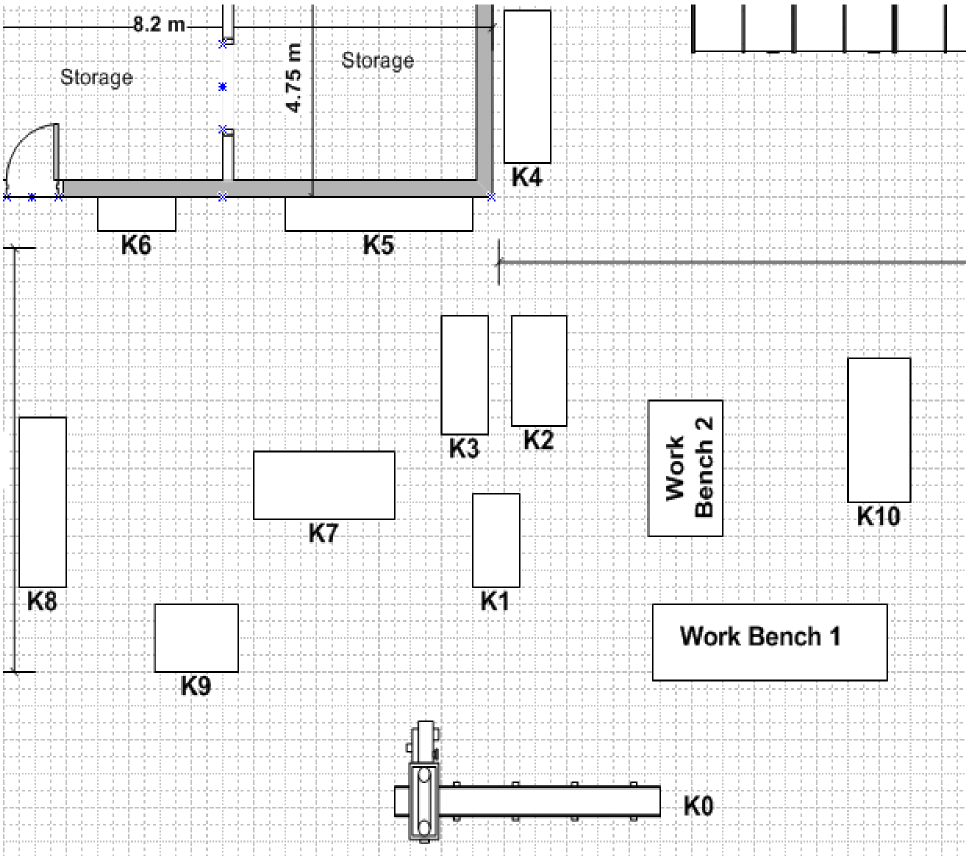


Figure 5-6 Kitchen-Cabinets Door Production Line Layout

The available machines in this line are named with the letter K and a number in order to present work flow sequence in an easy way. The total area of this line exceeds 200 square meters. Figure 5-7 gives better visualization of the production line.

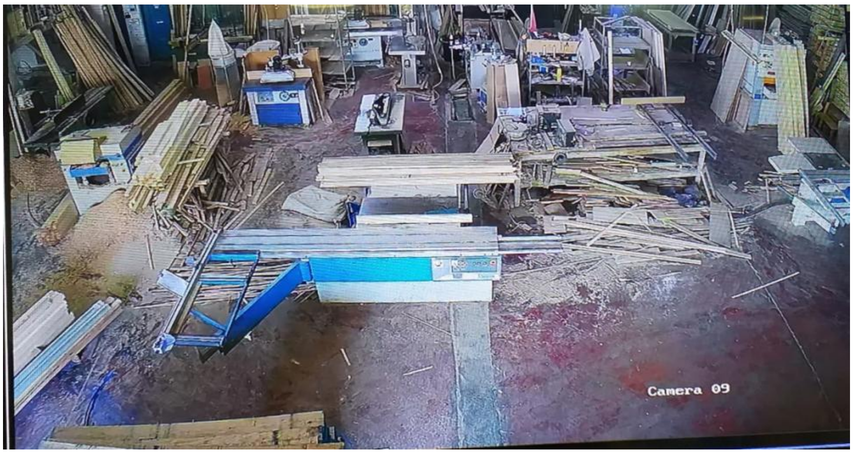


Figure 5-7 Kitchen-Cabinets Door Production Line

The names of the machines and their assigned codes are presented in table 5-5:

Table 5-5 Machines of Kitchen-Cabinets Door Production Line

Machine Code	**Machine Name English**
K0	Sliding Table Panel Saw
K1	Spindle Moulder Machine
K2	Drilling Machine
K3	Rope Saw
K4	45 Degrees Saw Machine
K5	Wood Milling Machine
K6	Wood Milling Machine
K7	Wood Milling Machine
K8	Side Planner machine
K9	Surface Planner Machine
K10	Automatic Sanding Machine (Contact 2000)

While the work flow for this line is presented in table 5-6:

Table 5-6 Work Flow Sequence of Kitchen-Cabinets-Door Production Line

Step #	Process step in sequence	Machine used in process step
1	Cut raw wood for frame	K0
2	Clear dimension	K8 + K9
3	Cut final frame	K0 OR K0+ K4
4	Splice frame	K6 OR K2 OR K5
5	Cut filling	K0
6	Prepare filling	K8 + K7
7	Assemble door	workbench 1
8	Clear door dimension	K0
9	Door sanding	manual on workbench 2 or K10+manual on workbench 2

The layout is not organized according to workflow sequence which resulted in high motion, low traceability of work in progress, high interaction between workers during work time and lots of side chatting, and crowded work area with machines and workers which lead to work accidents, inability to apply visual management, inability to utilize work trollies, and workers are unable to identify orders priority for production. Spindle molder machine and rope saw machine are utilized for some specific steps according to some work designs and these machines can be located in other places instead of being placed in the middle of the production area.

Figure 5-8 and figure 5-9 present the work flow sequence for kitchen-cabinets doors production line to illustrate the randomness in machines distribution in the current layout. The production process was divided into two stages to avoid high interaction between arrows.

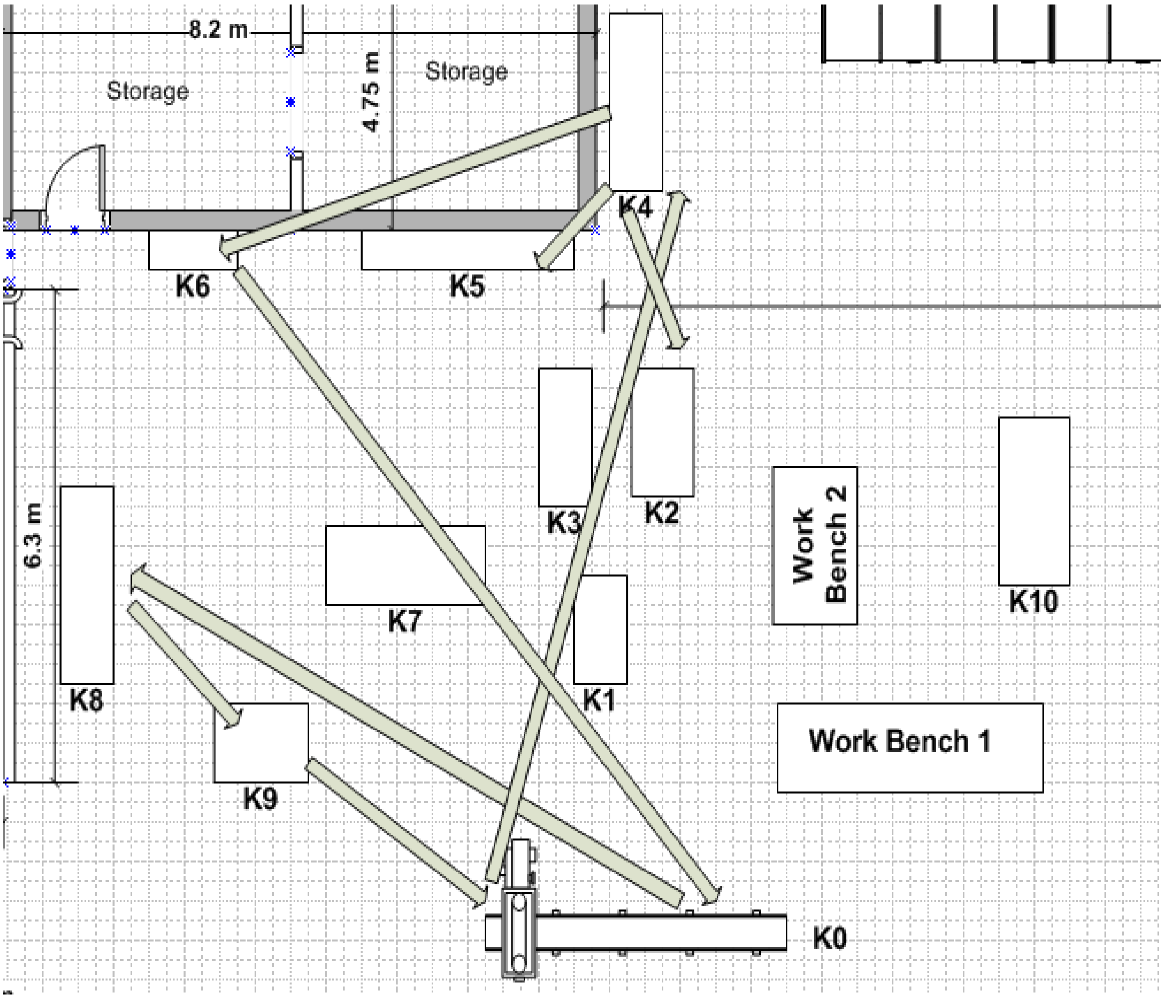


Figure 5-8 Work Flow of Frame Preparation Stage

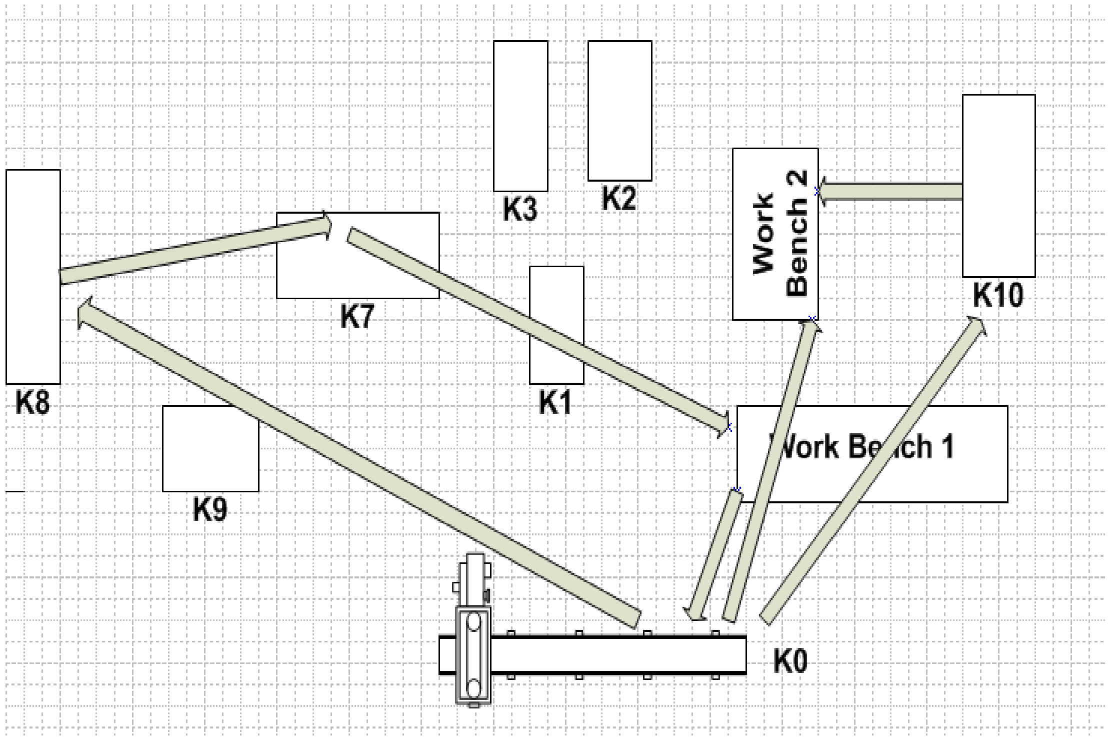


Figure -5-9 Work Flows of Filling Preparation, Door Assembly, and Sanding

Taking into consideration that the door frame preparation stage (from steps 1 to 4) can be performed in parallel with door filling preparation stage (from step 5 to 6), which indicates the overlapping in work steps at same machines that results in delaying some steps.

Table 5-7 presents the current status of the unorganized and highly crowded area of the kitchen-cabinet door production line, stacked raw materials residues, unorganized work in progress, unclean area, unsafe area for workers movement, and final products are randomly sorted in many places without any labelling or assigned storage place.

Table 5-7 Current Status of the Area of Kitchen-Cabinets Door Production Line

5.6.4 Raw Material Storage Area

The assigned area of raw material storage is in the middle of the factory due to the current layout design. Due to utilized space; the current status of raw material storage is presented by pallets shape in the prepared layout drawing.

Table 5-8 presents current status of raw material, quality concerns and supporting images.

Table 5-8 Current Status of Raw Material Storage

Storage Area	Quality Concerns	Supporting Photos
Assigned area in the middle of the factory	Large amount of raw material is stacked beside and above each other in an unorganized manner, obsolescence of raw material, defective material due to large weight of stacked above, and a long time is wasted to draw raw material in current stacking and return it back which means high rework.	
Random storage areas of raw material	Raw material is stored in random places such as in front of admin office, at the entry door, at the road sides outside the factory, and in the walkways. Some of these temporary storing areas are becoming permanent due to utilized space. Due to lack of raw material separation; some of these materials becomes obsolete and others get defected by time.	

	Outside factory sorted material are subject to being damaged due to weather condition or subject to theft. Production residues are stacked between machines, cleared in long intervals, no assigned area, useful residues for production are stacked with un-useful ones and are subject to disposal.	
	Wooden saw dust is not cleared on regular basis. The accumulation of raw material, production residues and final products in random areas causes crowded, unorganized and unsafe work environment.	

5.6.5 Wood CNC and Wooden Profiles Stapling Area

The company has a wood CNC machine that is not in use since two years due to malfunction. The allocated area for this machine is around 45 square meters. It was agreed that the company will fix this machine and try to sell it due to inability of running this machine by the current staff in addition to high running cost.

Beside this machine lies the wooden profile stapling area, this area is dedicated to stapling wooden profiles with wooden bars according to customer demand. The reserved area is around 65 meters.

The assigned area for the CNC machine and stapling is presented in figure 5-10:

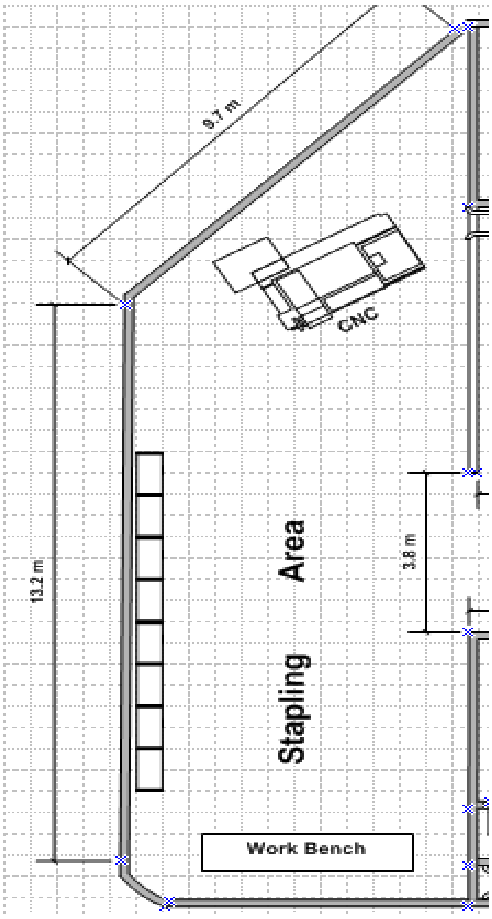


Figure 5-10 CNC Machine and Profile Stapling Area

The improvement team agreed that the CNC machine should be sold due to malfunction in the machine and inability of any of the current staff member to run this machine or make the necessary maintenance. The company contacted the manufacturer of the CNC machine with the help of external industrial engineer, through live conference the manufacturer guided the engineer and the machine was fixed and tested. The company is facing high challenge in finding a buyer to this machine due to the large space needed to run this machine and also the high price of this machine. The company has two options of moving this machine outside the factory, the first one is to disassemble the machine, move it to another location, and reassemble it; which will put it at risk of new malfunction during the disassembly and/or reassembly, the other option is to disassemble the machine and move it to another location and keep it unassembled which is also very risky since buyers would like to test the machine which will require assembly again. The final option is to sell as stock for any buyer to save the booked space for future utilization.

Regarding the profile stapling area, the stapled profiles are produced at the profiles production line, transported in pallets to the stapling area from the far east to the far west of the factory. The profiles are sorted in shelves, stapled, and then sorted on floor or in shelves.

Table 5-9 below presents current performance of the stapling area, quality concerns and supporting images.

Table 5-9 Profile Stapling Area Quality Concerns and Supporting Images

Process Step	Quality Concerns	Supporting Photos
Receive incoming profiles	Received profiles are sorted in shelves unorganised or separated, stacked over each other, large quantity is accumulating which leads to defects and obsolescence, and unnecessary transportation.	
Staple profiles	Profiles are stabled on workbench 3, unorganised withdrawal of profiles for stapling lead to defected profiles and accumulation on floor, and defected profiles are not separated from good ones.	

Sort stapled profiles on pallets or on walls	No labelling for stapled profiles, some stapled profiles are sorted on pallets, and some profiles are sorted on walls and stacked above each other's which lead to defects and obsolescence, overproduction of stapled profiles due to lack of produced quantity follow up, and unorganised work area.	

5.6.6 Unutilized Areas

In the current layout there are some unutilized areas due to disorder in storing raw materials, final products, and production residues.

The first area is presented in figure 5-11:

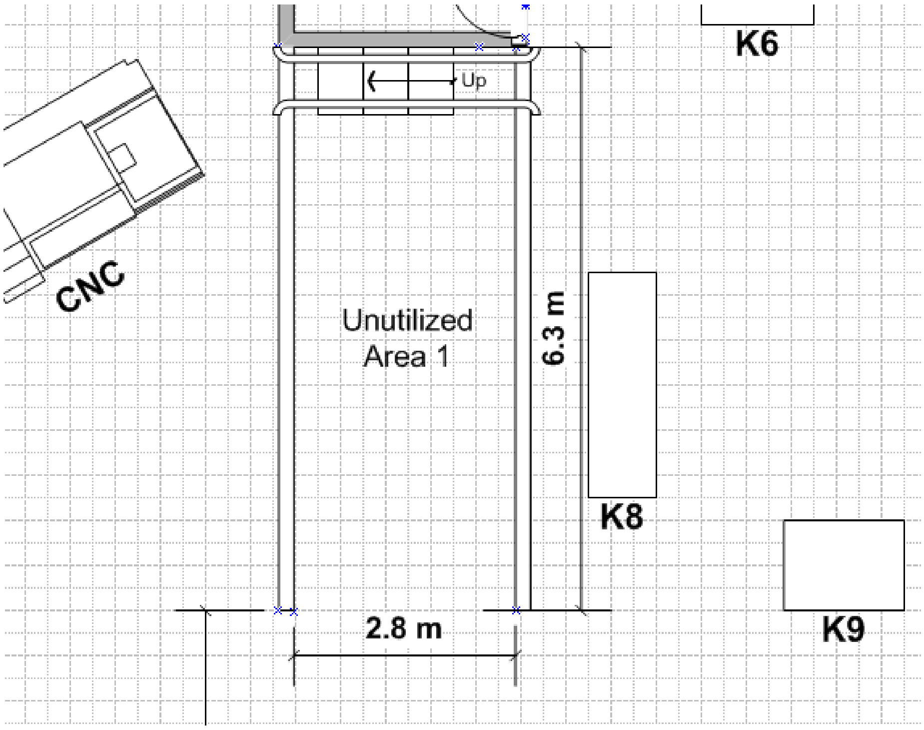


Figure 5-11 Unutilized Area One

This area lies between the CNC machine area and kitchen-cabinet door production area, the total area is 17.64 square meter, and the roof of this area is also unutilized with 17.64 square meter.

This area is currently full with wooden profiles, unsorted, unseparated, and unlabeled. The area is getting stacked with profiles as presented in figure 5-12:

Figure 5-12 Unutilized Area One

The second area is presented in figure 5-13:

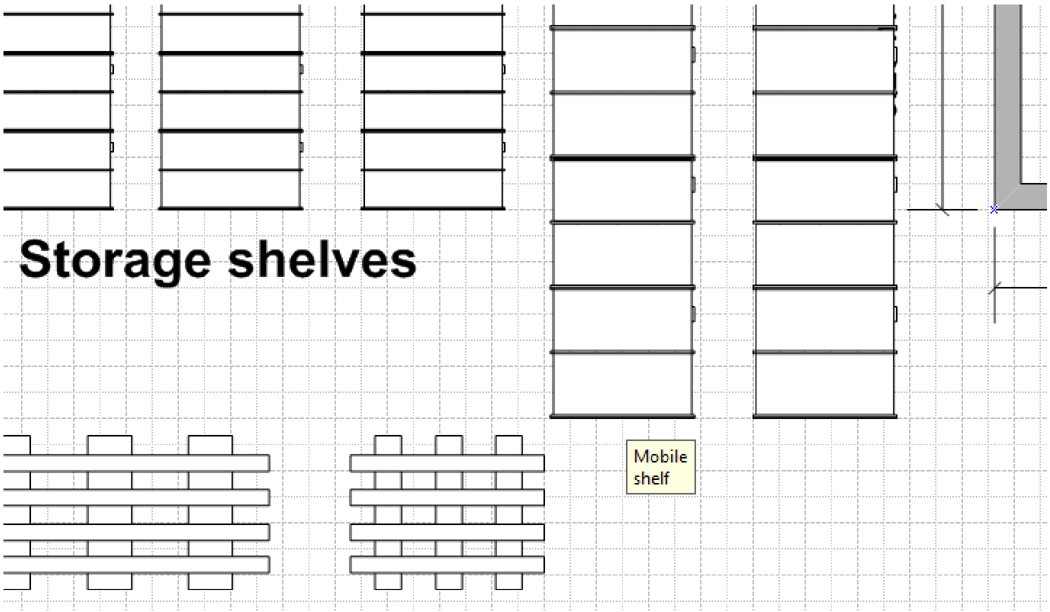


Figure 5-13 Unutilized Area Two

This area is occupied by the extended two shelves of profile storage as presented above. The total area is 24 square meters, the sorted profile can be moved to other shelves.

The third area is presented in figure 5-14:

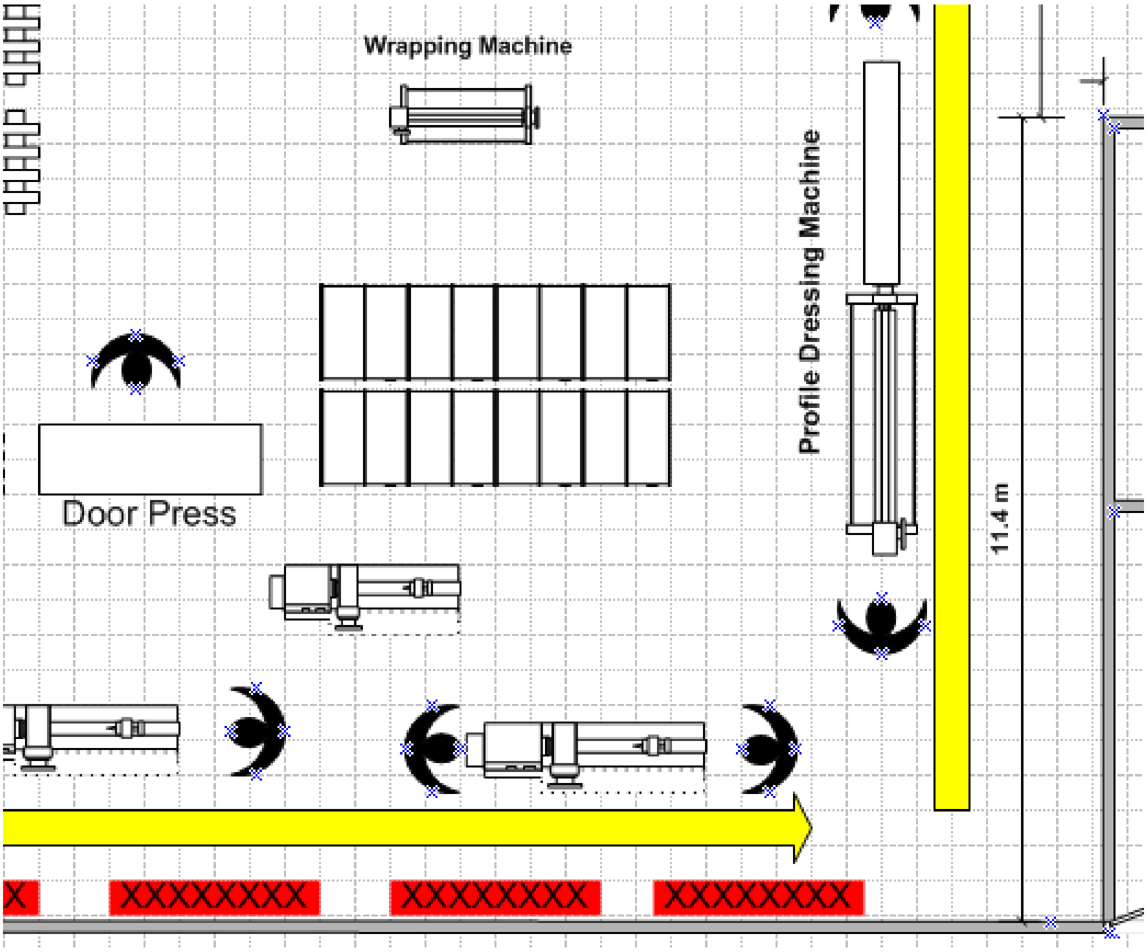


Figure 5-14 Unutilized Area Three

This area lies between door press machine, profile dressing machine, and wrapping machine with a total area of 27 square meter, the located shelves are stacked with profiles that can be moved to profiles storage area, and the produced profile can be sorted beside the wrapping machine, wrapped, and the moved to assigned shelves.

The current status of this area is presented in figure 5-15:

Figure 5-15 Unutilized Area Three Photo

This area is not organized and the stacked products, raw material and work residues hampers workers movement and profile wrapping process.

The fourth unutilized area is presented in figure 5-16 which consists of an office of total area of 39 square meter.

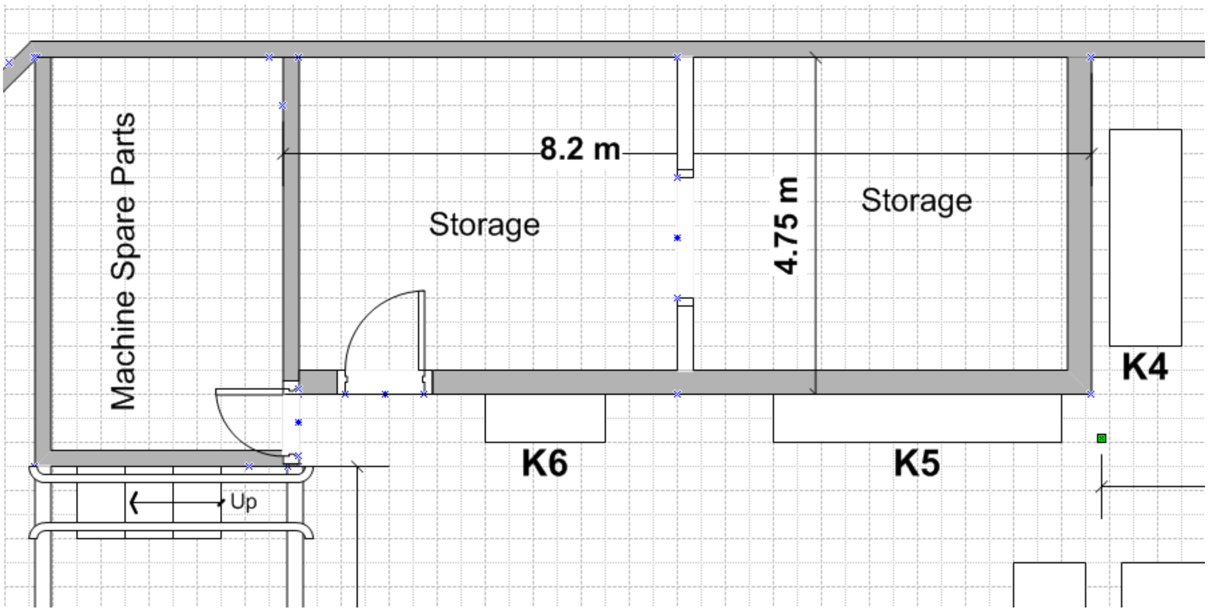


Figure 5-16 Unutilized Area Four

This area is used to store wooden profiles and raw materials in an unorganized manner as presented in figure 5-17:

Figure 5-17 Unutilized Area 4 Photo

This area is internally divided into two sections by wooden decoration as presented above.

The fifth area is utilized but not well organized which is the machine spare parts room presented in same figure 5-16 of area four.

The current status of this room utilization is presented in table 5-10:

Table 5-10 Current Status of Utilization of Machine’s Spare Parts Room

The current status lacks of order, separation of parts according to machine name, cleanliness, and labeling.

5.6.7 Wooden Door Production Area

The wooden door production area is presented in figure 5-18:

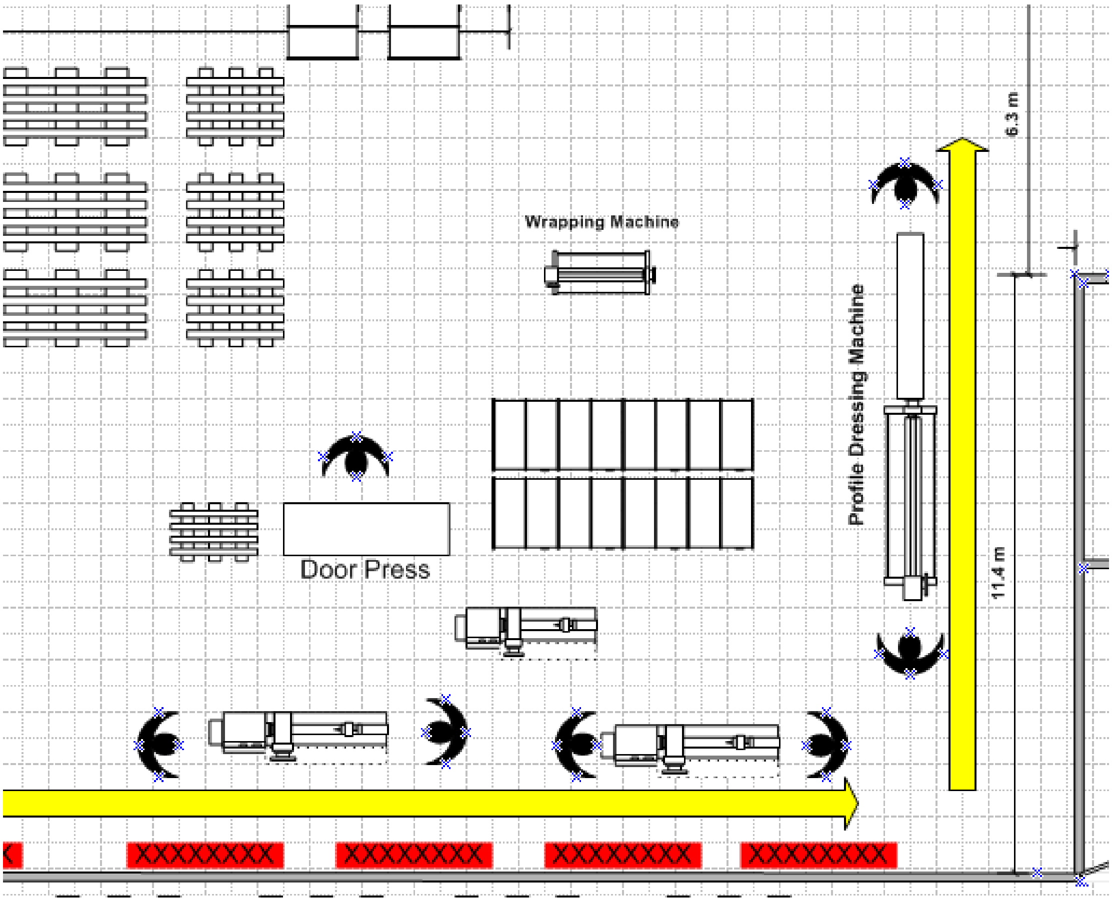


Figure 5-18 Wooden Door Production Area

The door press machine is utilized to pressing wood panels only. It is located in crowded area with shelves, raw materials pallets, near wooden profile production line, low space for work table for gluing the wood panels which is not drawn on the figure because it is mobile table according available space for this work. There is no place to store raw materials for pressing wood panels and also there is no space for storing final product which causes additional crowding during work on door pressing machine, hampering worker's movement, and delaying utilization of forklift in moving produced profiles for order delivery at the entry of the factory.

5.6.8 Order Delivery Process

Some orders are delivered to customers through external driver with an arrangement from company accountant or manager and some orders are picked up by customer from company. In case of order delivery with a driver, the workers load orders to the truck and the company send an invoice to each customer with the driver who confirms order delivery by the end of the day and informs the company in case of any problem in delivery to be followed by the accountant or manager. In most cases of customer picking his order, the customer enters the company, walks directly towards workers in their work station, start talking to them about his order, walk in the factory to take a look at his order, and then workers start preparing order for loading and inform accountant or manager about delivering the order to the customer. The same occurs with customers who come to the factory to purchase ready products. After order is prepared to be loaded to customer vehicle, the accountant issues invoice to the customer and dues are collected in cash payment, bank check, or delayed.

There are no assigned workers for order's delivery, no standard procedure for this process, no supervision from manager or accountant on loading order to check the delivered quantity in comparison with customer's order.

The company assigned a worker to sell wood residues and sawdust after being packed in plastic bags, the filled bags are not stored in separate area, no assigned price for sale, and no available data about the stock of these two products. The assigned worker sells these products to unknown customers after factory closure and deliver collected dues to the accountant beginning of next day without using any form or issuing invoices to customers.

Customer complaints about delivering less quantity cannot be traced due to lack of data about available stock. For the same reason higher loaded quantities cannot be traced.

5.7 Findings and Summary

The findings from the studying status of the current layout of GM Profile can be summarized as follows:

- Improper placement of door wrapping machine and profile stapling work bench.
- Unassigned areas for raw material storage.
- Unorganized work environment due to improper storage of raw materials, work residues, and final products which can be considered as bad utilization of space.
- Improper layout of kitchen-cabinets door production line.
- Low process efficiency of kitchen-cabinets door production line.
- Unutilized areas in the factory due to stacked products and raw materials.
- No assigned worker or agreed procedures for order delivery.

At the end of this phase the improvement team gained a better understanding of the current performance in the current layout regarding storage of raw materials, final products, work residues, layout of production lines, process efficiency of kitchen-cabinets door production line, utilized spaces, order delivery status, and work environment. This helped the improvement team to identify the quality concerns in these processes and areas.

Chapter 6
Analyze Phase

6.1 Introduction

The analyze phase is the third phase of the DMAIC methodology and it aims to examine the data collected in the measure phase in order to prepare a list of sources of variation and waste. These potential causes will be studied and analyzed to identify the root causes.

The key tool to be used in this phase is the fishbone which is known as the cause and effect diagram. According to (Bose, 2012), the fishbone is a tool for analyzing the business process and its effectiveness. It is also known as "Ishikawa Diagram" because it was invented and incorporated by Mr. Kaoru Ishikawa, a Japanese quality control statistician. It is defined as a fishbone due to its structural outlook and appearance.

6.2 Cause & Effect Diagram

The fishbone diagram and analysis typically assist to uncover all the symptoms of any business problem by evaluating the causes and sub-causes of one particular problem. It is also termed as "Cause-Effect analysis" for that particular reason. In a typical fishbone diagram the targeted problem has been put on the head of the diagram and the causes are put as the bones and then smaller bones are created as the resemblances of the sub-causes. Ultimately after completion of the diagram it is a comprehensive evaluation of the causes of the main problems and also reveals the root causes as well. There are six classic categories of a fishbone diagram which are categorized as the main causes of any problems of business process. Those are people, equipment, materials, environment, management and process. The analysis of these six variables reveals the reasons of a problem regardless of its type or severity (Bose, 2012).

During the measure phase the improvement team agreed on organizing some areas for sorting raw materials, final products, and work residues to be able to collect data for these items and avoid additional stacking. The improvement team started with organizing the storage area of wooden profiles and storage area of stapling profiles. The company hired external workers who performed this duty with the supervision of the team leader and the help of two members of the improvement team Mr. Issa and Mr. Fayez.

Top management commitment to sustaining the outcomes of the organization efforts was crucial for the success of the improvement effort. This process took five consecutive days and the team was able to organize these areas as desired.

The plant management was not able to sustain the achieved results in the above mentioned areas; on the contrary, these areas became stacked with other products and need to be reorganized again.

The improvement teams agreed with the sponsor to set targets for the factory management that are crucial for the success of the improvement efforts. These targets are assigning storage areas for final products, labelling all final products according to customer's name, scheduling the production of customer's orders, and monitor production progress to control overproduction and avoid additional stacking. The factory manager could not fulfil the agreed targets and chose to resign by the end of October, 2018.

It was noticed that the instability in factory management had played a huge role in the current status of unorganized work environment in general and the present quality concerns in specific. The chairman of the organization and the sponsor of the improvement team hired a new qualified manager by November, 2011 taking into consideration the required skills in communication, production management, and inventory management.

As soon as the new plant manager was hired, a meeting was arranged with the presence of the improvement team, the sponsor, and the new manager who was provided with an overview of the improvement efforts taking place at the factory, has shown a high enthusiasm and willingness to play an effective role of this team.

The improvement team proceeded with the analyze phase and conducted several brain-storming sessions and was able to identify the potential causes of the improper layout of the factory which are presented in the cause and effect diagram shown in figure 6-1.

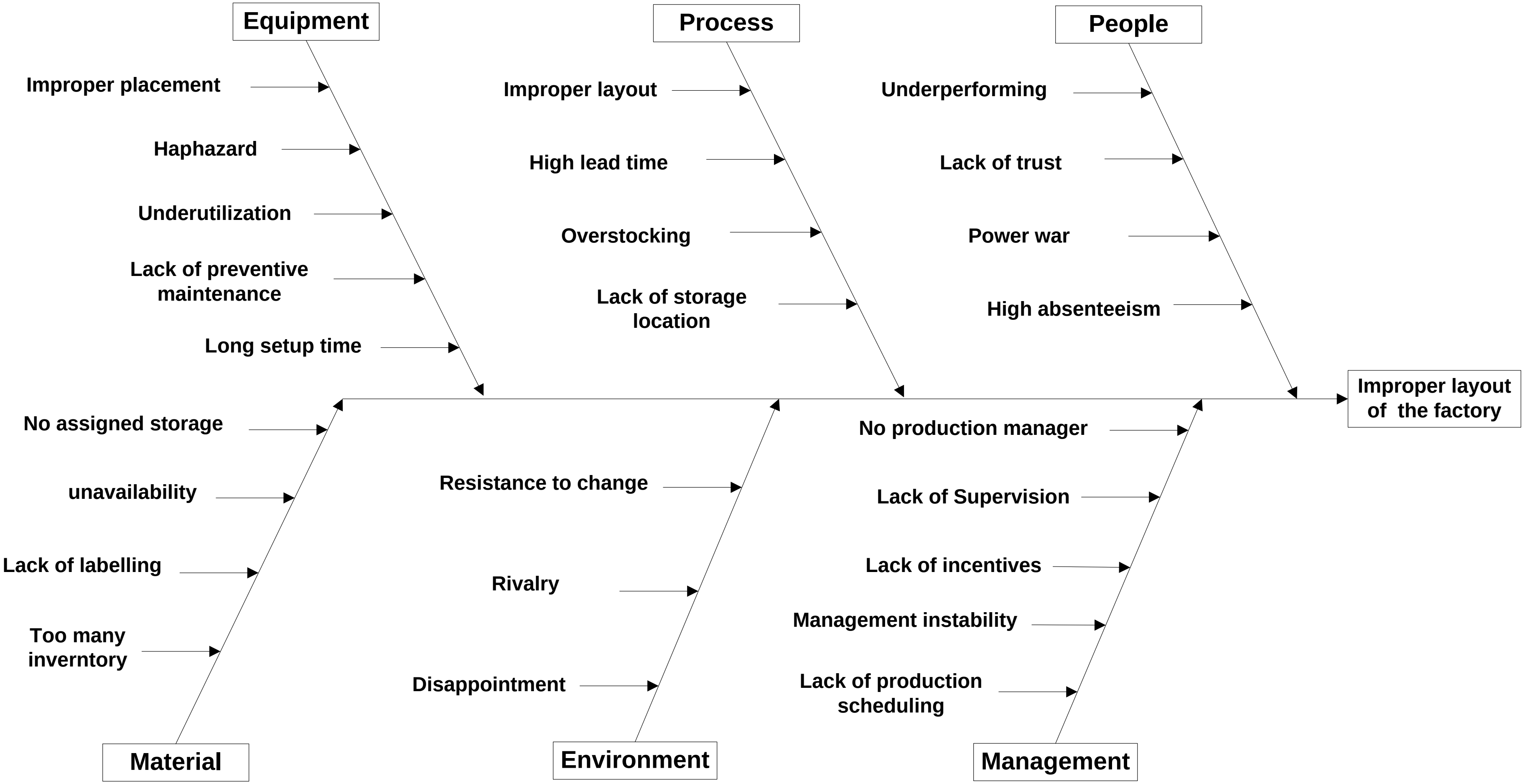


Figure 6-1 Cause and Effect Diagram (Fishbone Diagram)

After identifying the potential causes in the cause and effect diagram, the team identified the root causes of the problem under investigation using an interrelationship diagram. According to Dogget (2006), interrelationship diagram (ID) helps in identifying root causes by identifying, analyzing, and classifying the cause-and-effect relationships that exist among all critical issues so that key factors can be part of an effective solution. The ID uses arrows to show cause-and-effect relationships among a number of potential problem factors. Arrows drawn between the factors represent a relationship. As a rule, the arrow points from the cause to the effect.

The improvement team prepared the interrelationship diagraph shown in figure 6-2 based on cause and effect diagram, the arrows were drawn between potential causes in order to identify root causes and the potential solutions.

Outgoing arrows represent a causal relationship and incoming arrows represent an effect relationship, both arrows are counted for each potential cause (factor), the higher number of arrows for each factor indicates if it is an effect or a cause. If the number of outgoing arrows is higher than incoming ones then the factor is considered as a cause, and if the number of incoming arrows is higher than the outgoing ones then the factor is considered as an effect.

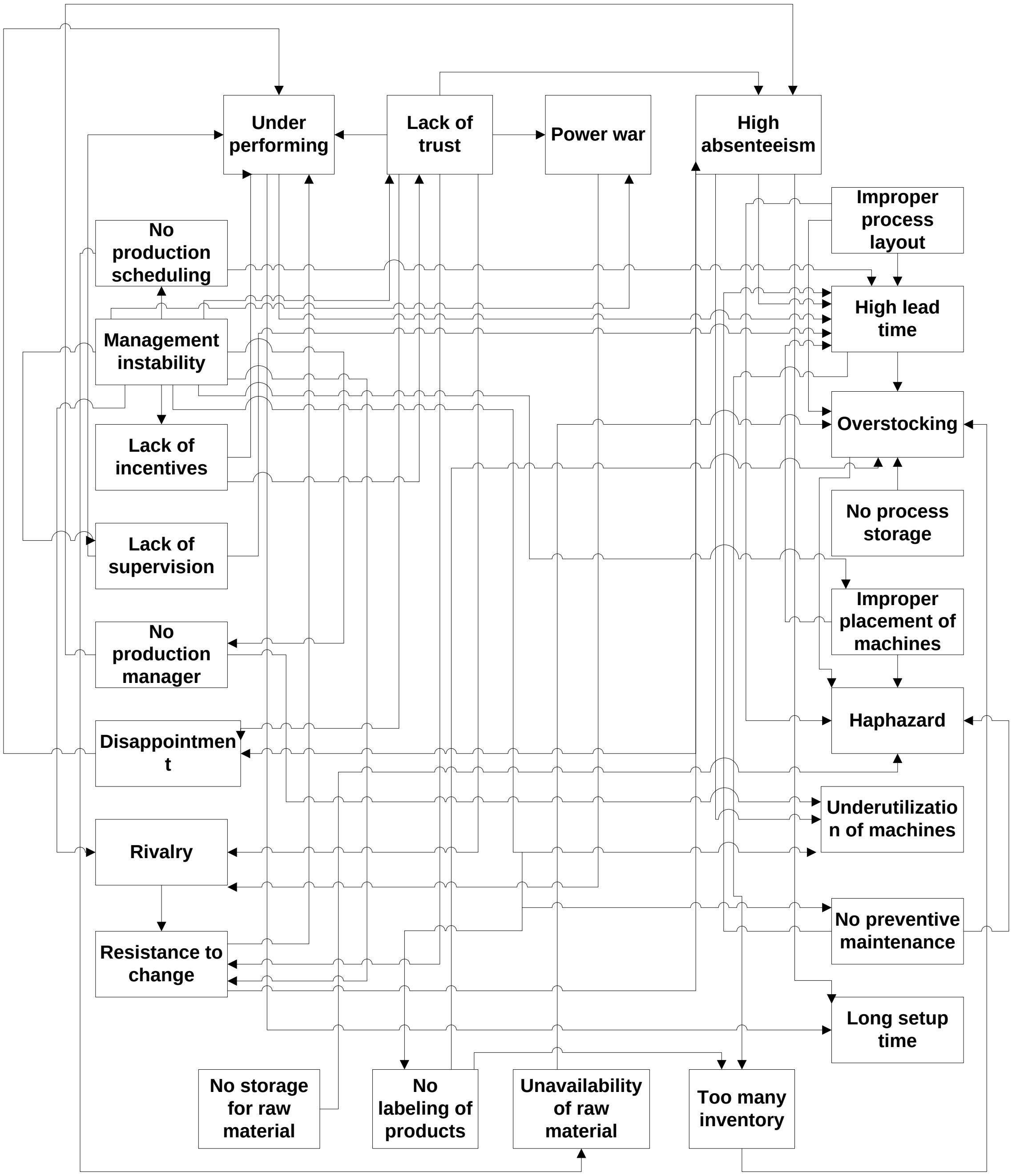


Figure 6-2 Interrelationship Diagraph

According to the interrelationship diagraph, table 6-1 presents the number of incoming arrows, number of outgoing arrows, and factory classification as a cause or effect.

Table 6-1 Interrelationship Diagraph Analysis

Factor	# of outgoing arrows	# of incoming arrows	Factor classification
Under performing	2	6	Effect
Lack of trust	6	2	Cause
Power war	1	2	Effect
High absenteeism	4	3	Cause
Improper process layout	3	0	Cause
High lead time	2	7	Effect
Overstocking	1	5	Effect
No process storage	1	0	Cause
Improper placement of machines	2	1	Cause
Haphazard	0	5	Effect
Underutilization of machines	0	3	Effect
Lack of preventive maintenance	2	1	Cause
Long setup time	0	2	Effect
Too many inventory	0	2	Effect
Unavailability if raw material	1	1	Effect
Lack of product labelling	2	1	Cause
No assigned storage of raw material	1	0	Effect
Resistance to change	2	3	Effect
Rivalry	0	4	Effect
Disappointment	1	2	Effect
No production manager	2	1	Cause
Lack of supervision	2	1	Cause
Lack of incentives	2	1	Cause
Management instability	12	0	Cause
Lack of production scheduling	2	0	Cause

After identifying the causes of the improper layout of the factory and low productivity of the kitchen-cabinets door production line, the improvement team proposed the following solutions for each cause as shown in table 6-2.

Table 6-2 Proposed Solutions for the Root Causes Identified in the Measure Phase

Factor	Proposed Solutions
Lack of trust	Arrange a meeting with staff to clarify the aim of the improvement efforts
High absenteeism	Study each case of absenteeism separately and take action regarding unjustified ones.
Improper process layout	Design new layout of the factory according to measure phase findings
No process storage	Assign storage area for each process
Improper placement of machines	Design new layout of the factory according to measure phase findings
Lack of preventive maintenance	Sign a contract with an industrial engineer to handle the preventive maintenance
Lack of product labelling	Prepare labels for all products according to customer name
No production manager	Hire production manager or assign his duties to one of the qualified employees
Lack of supervision	Prepare production progress form to follow work progress
Lack of incentives	Set target for employees and tie it with incentives
Management instability	Empower the current manager by providing him with the authority and required resources
Lack of production scheduling	Prepare production scheduling form using Gant chart

6.3 Summary

The improvement team identified the root causes of the problems in the current layout and the low process efficiency of the kitchen-cabinets door production line using cause and effect diagram and interrelationship diagraph. According to the identified root causes the improvement team was able to propose solutions for these problems to be implemented in the improve phase.

Chapter 7
Improve Phase

7.1 Introduction

At the fourth stage of the improvement initiative lies the improvement phase. The Improve phase focuses on identifying expected solutions, suggesting a set of alternative solutions to enhance performance, and implement some of these solutions according to the available budget and the expected cost for each alternative.

The improvement team studied the annual sales and spotted the fluctuation of demand for wooden profiles products in addition to high competition from wooden profiles importers. The improvement team proposed hiring two sales agents for the aim of reaching current customers in Israeli and Palestinian territories to take orders, collect dues, search for new customers, and market new products. Through verbal feedback from customers the improvement team proposed adding new products of wooden door frames and casement, wooden doors production line using wooden panel pressing machine, and to reproduce wooden mesh which can be produced from production residues.

According to the causes identified in the analyze phase and proposed solutions, the improvement team agreed on dividing the improvement phase into three stages:

1- Organize the work environment using 5S Lean tool to be able to design the new layout of the factory in order to improve placement of machines, improve layout of kitchen-cabinets door production line to allow visual management, better allocation of wooden panel pressing machine, better allocation of wooden profile stapling bench work, and assign storage locations for raw materials and final products.

2- Prepare new flow chart for kitchen-cabinets door production line, collect data for the new process, and prepare new status value stream mapping for this process.

3- Prepare work forms for production scheduling, raw material purchase, and labelling of final products to be able to monitor and control production process and manage inventory in the control phase

4-

7.2 5S Implementation

5S is a Lean method and a system for process improvement to clean workplace, reduce waste, and improve labor productivity. 5S helps maintaining an orderly workplace and utilizes visual cues to achieve more consistent operational results (Al-Aomar, 2011).

5S is implemented in five phases; the sort phase aims to sorting out unnecessary items, the set in order phase aims to assigning a place for everything, the shine phase aims to the cleanliness of the work environment, the standardize phase aims to documenting the work method, and the sustain phase aims to sustaining the gains from 5S implementation. The first three phases were implemented in the improve phase and the last two phases (standardize& sustain) were implemented in the control phase.

The improvement team agreed on creating an item card for each product before the start of sorting phase to be able to track each product and insert data in the accounting system.

7.2.1 Sort Phase

The sorting phase focused on sorting out excess stock of wooden profiles, work residues, and defected raw material. The major concern in the current status of crowded work environment is the wooden profiles that are stored in many places such as assigned shelves, between and above assigned shelves, in front of administration office, on the walls, between machines, and inside the office located beside kitchen-cabinets door production line with a total area of 39 square meters. Table 7-1 shows current status of wooden profile storage.

Table 7-1 Wooden Profile Random Storage

Since there are no data available regarding the number of available wooden profiles and which ones are obsolete or with low demand, the improvement team studied the sales report of the first six months of the year 2018 and sorted out defective and stagnant profiles and concentrated these efforts on two areas. The first one is the shelves of the wooden profiles and the second one is the shelves and walls beside the wooden profile stapling work bench to free space for randomly stored wooden profiles as show in table 7-2.

Table 7-2 Current Status of Wooden Profile Storage

Current status of wooden profiles storage


14 pallets of stagnant and obsolete wooden profiles were sorted out from the two areas and were sent outside the factory to a storage location in Beitonia that belongs to factory owners.

The improvement team then sorted out all wooden profiles inside the office of 39 square meter area due to the obsolescence of these profiles and lack of any sales for these profiles since more than seven months. These profiles are presented in figure 7-1. This step helped in freeing the whole space of the office. After sorting out these profiles, the company offered special discount on these profiles and were able to sell some of them for 12000 NIS. The company also contacted many firms for the utilization of the sorted out profiles in producing wood products and offered high discount on the price of these profiles.

Figure 7-1 Current Status of Office Utilization

After that the company sorted out all defected raw materials and unnecessary work residues to a nearby store that belongs to the plant owners.

The final step was sorting out the unnecessary parts and materials from the spare parts storage room shown in figure 7-2.

Figure 7-2 Current Status of Spare Parts Storage Room

7.2.2 Set-in Order and Shine Phases

The set-in order phase included the design of the new layout to improve machines placement and assign areas for raw materials and final products storage. After the end of the sort phase, the improvement team studied the current layout, available spaces, work flow, and workers movement in all of the production lines and areas, the team agreed on the following design of the new layout of the factory as shown in figure7-3.

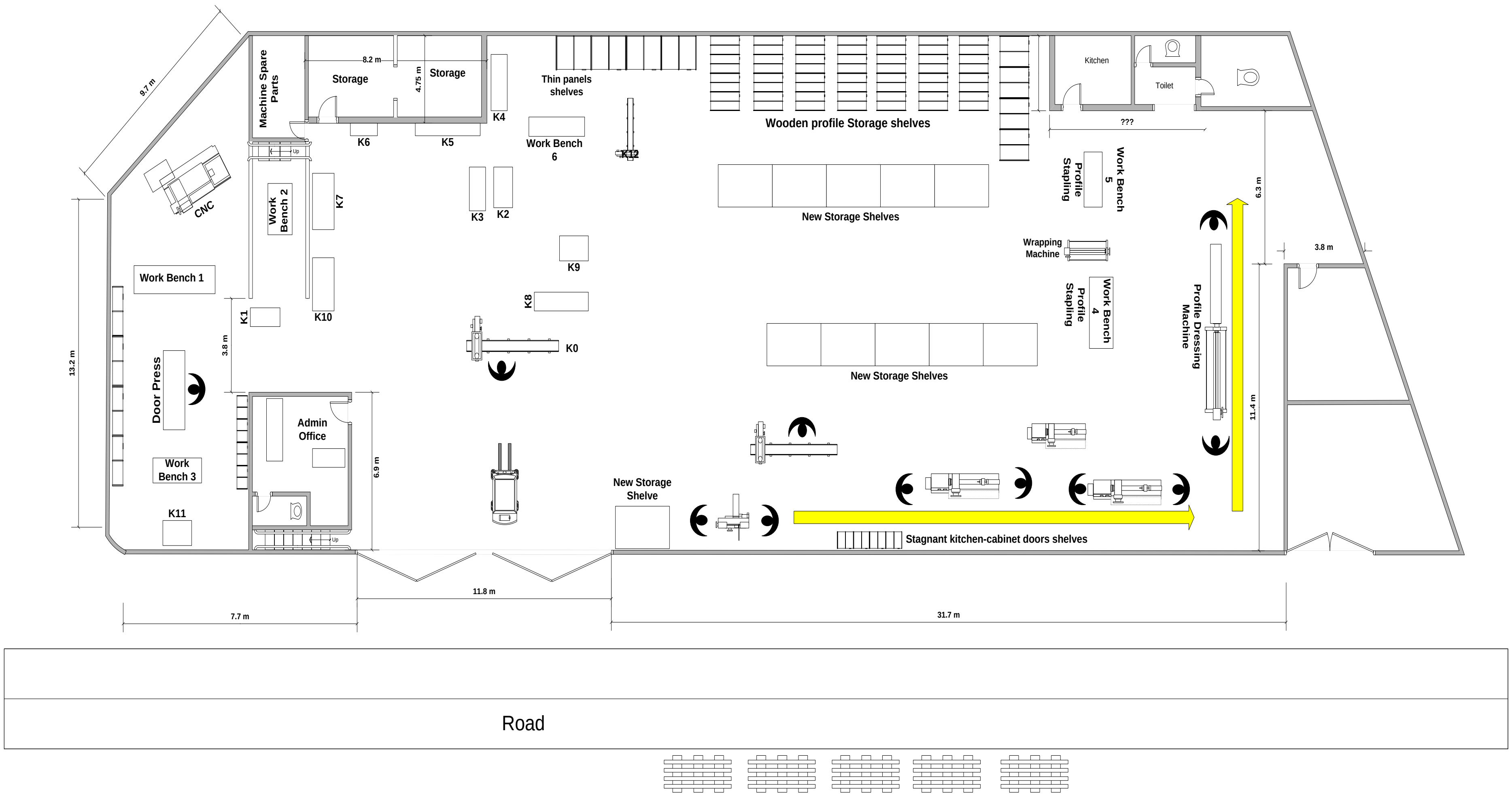


Figure 7-3 GM Profile New Plant Layout

The new layout design was implemented and the achieved results are presented in separate sections according to targeted areas and processes. The shine phase was implemented in parallel with the set in order phase to achieve the cleanliness of each area after the set in order is finished.

7.2.2.1 Wooden Profiles Storage New Status

After sorting out stagnant and obsolete profiles the team started organizing the available profiles according to design and wrapping color. The stock of each profile was counted and the collected data was stored in the accounting system for the first time since the establishment of the factory. The accountant created a card for each profile design to be able to track the stock, control the production of each profile to avoid overproduction of low demand profiles, and identify stagnant profiles.

The company added twelve stands for storing raw material and final products including wooden profiles, each stand consists of 3 shelves, and the roof of the last shelf is supported by bars to support the raw material from dropping behind the stand since there is not separation between the roofs of the stands which are placed beside each other to allow storing wood panels of length higher than 2.5 meters.

This design allows the forklift to move the wood pallets beside the work station without and need of moving other pallets since each layer holds only one pallets and nothing is stacked above it which helped in eliminating the rework in the old status of the storage and the wasted time in moving the unwanted pallets. The new status is supported with figures as show in table 7-3.

Table 7-3 New Status of Wooden Profiles Storage

Before sorting out	**After sorting out**
	
	
	

7.2.2.2 Raw Materials Storage

To avoid stacking raw materials above each other and reduce the unnecessary transportation and rework in moving these materials to the production areas, the company added 12 stands for storing the raw materials and finals products with a design as show in figure 7-4.

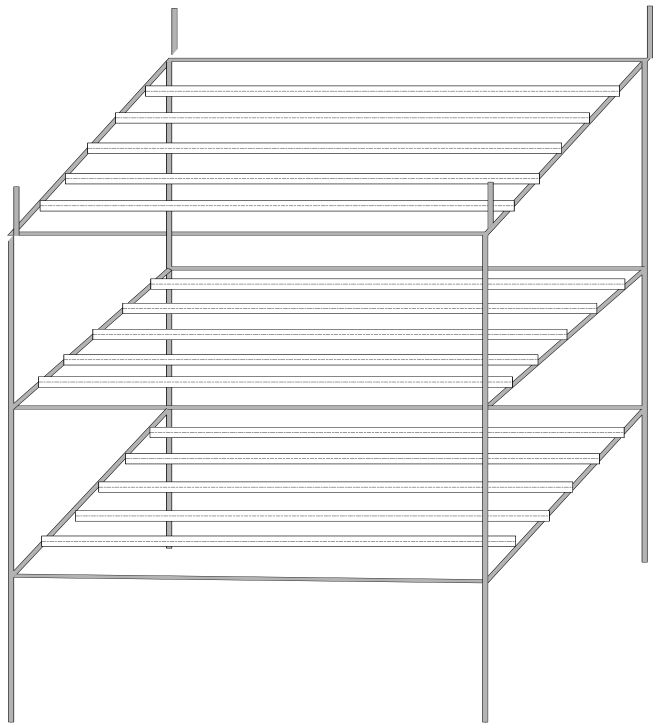


Figure 7-4 Design of New Stand for Raw Materials and Final Products Storage

The dimensions of the stands are 300 cm wide, 115 cm height, and 125 cm depth. These stands were designed according to the dimensions of the majority of raw materials and the remaining raw ones with higher dimension will be stored on top of the shelves which are supported with bars from the back to prevent raw material from falling behind the stands to guarantee staff safety and protect raw materials from possible damage. The stands are not fixed to ground which allows flexibility in moving these stands using the forklift for the best space utilization when needed.

These stands provided enough space for raw materials and unsorted final products. The new status of the raw materials storage is presented in supporting images show in table 7-4.

Table 7-4 New Status of Storage Stands

Old status of raw material storage	**New status of raw material storage**
	
	
	All of raw materials are sorted in stands

After sorting all final products and raw materials the company conducted stock check for final products as a higher priority and the collected data were recorded in the accounting system for the first time since the establishment of the new plant. Stock of raw materials will be checked later due to the high workload on the improvement team members.

7.2.2.3 Wooden Profiles Stapling Area

The stapling area was moved from the far side of the factory and reallocated at the end of wooden profile production line to avoid high transportation of wooden profiles, stacking unstapled profiles on walls and shelves, and stacking final products on walls and ground. The new location also allows sorting unstapled profiles in the assigned shelves with low transportation since it is located three meters away from these shelves, this will keep excess profiles sorted in place while the stapled profiles will be sorted on pallets to be loaded directly to trucks and transported to customer or stored in the raw materials shelves.

The new status of wooden profile stapling area is presented in table 7-5 with supporting images.

Table 7-5 New Status of Wooden Profile's Stapling Area

Old status of wooden profiles stapling area	New status of wooden profiles stapling area
	

7.2.2.4 Wooden Door Production Line

The wooden door production machine was located in the middle of the factory in a very crowded place with raw materials and final products. The work bench is mobile and is placed near the machine when needed, there are no assigned places for storing raw materials and final products, and the old location of the machine also caused delay in production since the atmosphere is full of wood dust which will cause improper gluing for the doors.

The drilling machine used for opening holes for door locks was located between the machines of the kitchen-cabinets door production line. This area is considered a busy area with high motion of workers and high transportation of work in progress.

The door pressing machine, drilling machine, and work bench were moved to the freed area of wooden profiles stapling area. The raw materials are available near the machines and the final product is also stored near the machine. This area is almost free of wood dust which will not affect or delay doors gluing. The machines and work bench are located near each other which guarantees low motion and low transportation.

The new status of the wooden doors production line is show in table 7-6 with supporting images.

Table 7-6 New Status of Wooden Door Production Line

Old status of wooden doors production line	New status of wooden doors production line
	

7.2.2.5 Wooden Mesh stapling Area

The company used to produce wooden mesh long time ago, the mesh is used to be produced on a mobile table placed in any free space which does not allow smooth flow of the production process and cause high interaction between workers and materials movement. The improvement team agreed to utilize the space available in the roof of the new location of kitchen-cabinets door sanding area. The total area is around 18 square meters which was utilized to place the raw materials, work bench and store final products. This area is presented in figure 7-5.

Figure 7-5 Wooden Mesh Production Area

The new location provided separate area that guarantees safe work location free of interaction with anything or anyone, improved productivity of wooden mesh due to availability of assigned location and provided visual management of the production process.

7.2.2.6 Spare Parts Storage Room

The spare parts and work files were sorted in the spare parts storage room according to spare part category which provided faster access to spare parts and files and easy check of spare parts or files which supports future efforts in preparing preventive maintenance system for the machines. The new status of this room is presented in table 7-7.

Table 7-7 New Status of Spare Parts Storage Room

Old status of spare parts storage	New status of spare parts storage
	
	
	

7.2.2.7 New Layout of Kitchen-Cabinets Door Production line

The new layout was designed for kitchen-cabinets door production line to achieve continuous flow, reduce high motion of workers. The new layout is shown in figure7-6.

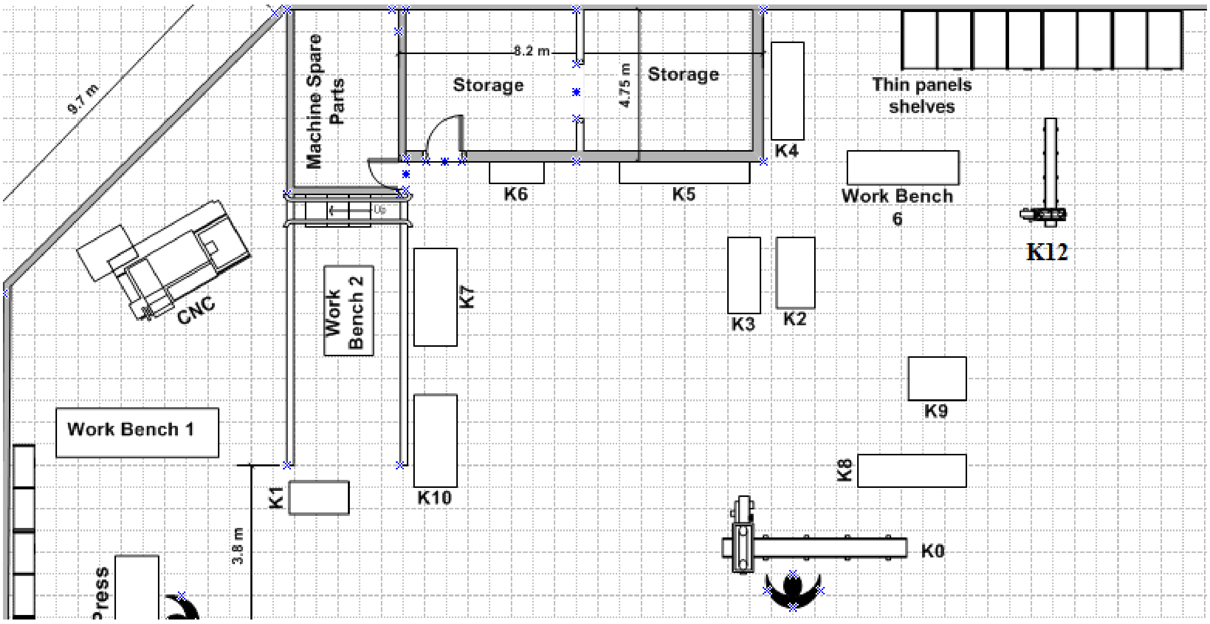


Figure 7-6 New Layout of Kitchen-Cabinets Door Production Line

The new layout included reallocation of machines K1, K7, K8, K9 AND K10. A new sliding panel table saw (K12) was purchased and installed due to the high workload on the existing one which delays some orders and ultimately increase lead time.

Work bench 1 for assembly was moved beside the CNC machine, work bench 2 for final product sanding was moved to an unutilized area of 18 square meters, and work bench 6 was added for assembly to allow assembling more than one order at a time to improve productivity and reduce lead time. The new layout is supported with images shows in table 7-8.

Table 7-8 Supporting Images of New Status of Kitchen-Cabinets Production Line New Layout

Old status supporting images	New status supporting images
	
	

The new layout allowed utilization of work trolley and provided visual management of workflow. Visual management helped in reducing interaction between workers, reducing wasted time in side chatting, and work progress can be identified easily since each trolley is labeled with production order form which also reduced time needed to update customers about the status of their orders.

The new layout implementation was accompanied with work environment cleaning from work residues and unneeded tools or shelves. The storage shelves of thin wood panels were placed horizontally which caused stacking of wood panels above each other where the lower ones remain in place unutilized. These shelves were flipped vertically to give workers the ability of pulling any panel. Table 7-9, table 7-10, and table 7-11 present supporting images of the new layout in comparison with the old one.

Table 7-9 Supporting Images of Thin Wood panel's Storage

Horizontal storage in old status	Vertical storage in new status
	

Table 7-10 Supporting Images of Assembly Work Bench

Old status of assembly work bench	New status of assembly work bench
	

Table 7-11 Supporting Images of Final Product Sanding Work Bench

New status of sanding work bench	Old status of sanding work bench
	

The new layout took a U shape to achieve continuous workflow, the workflow in the new layout is shown below, figure 7-7 shows work flow for frame preparation stage and figure 7-8 shows work flow of filling preparation stage, assembly, and sanding.

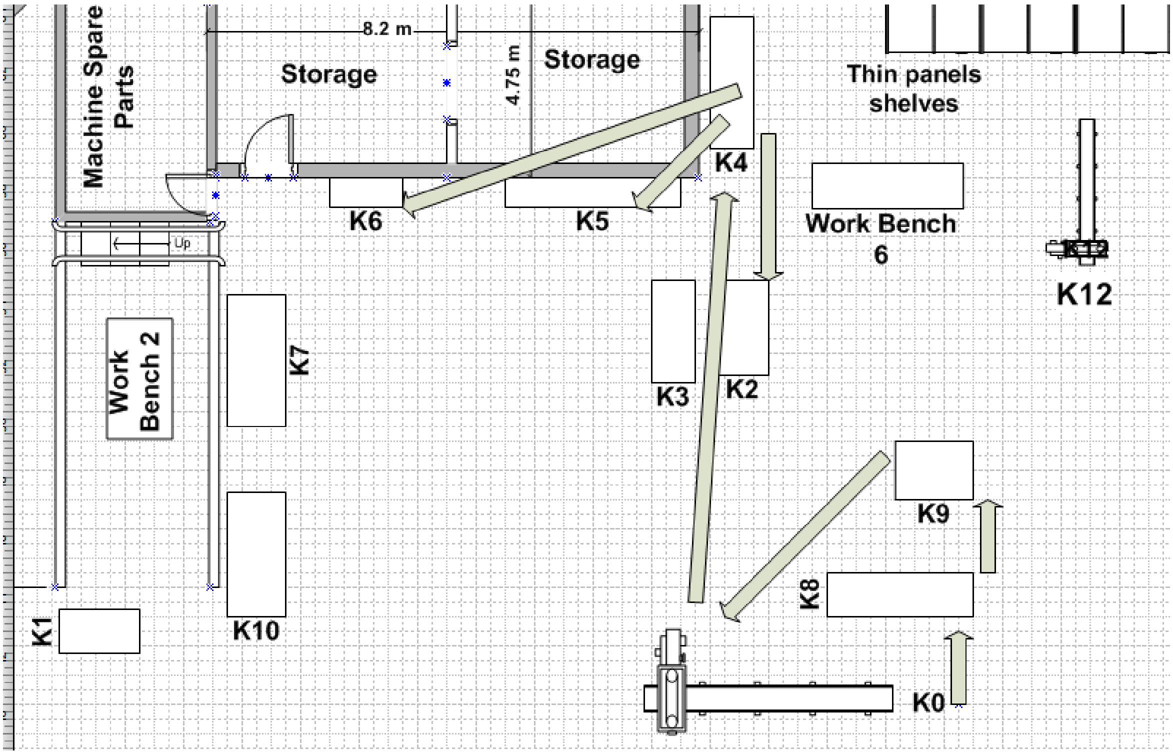


Figure 7-7 Work Flow of Frame Preparation Stage in the New Layout

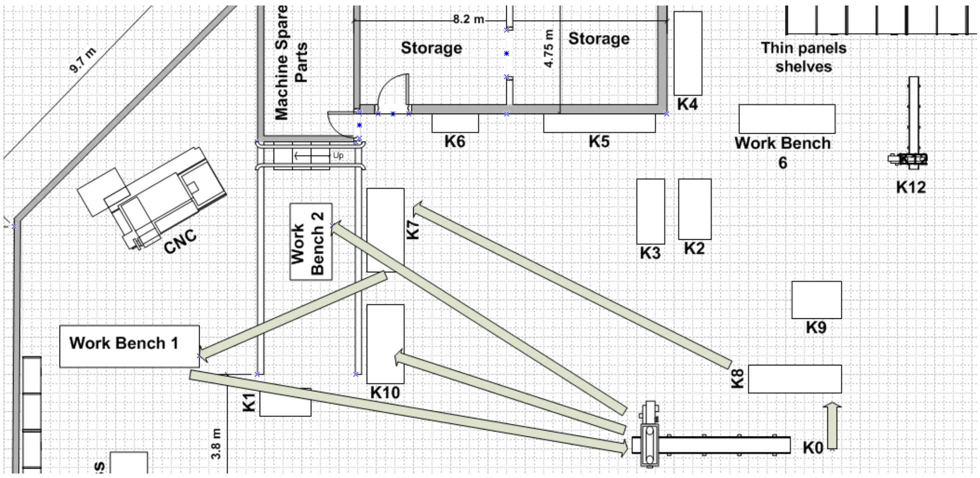


Figure 7-8 Work Flow of Frame Preparation Stage, Assembly, and Sanding in the New Layout

The workflow sequence of the frame preparation stage is K0, K8, K9, K0, K4 or K5 or K6, and finally to the assembly work bench 1. While the workflow sequence of the filling preparation stage, assembly and sanding of final product is K0, K8, K7, assembly work bench 1, K0, sanding work bench 2, or K10 then to sanding work bench 2. In case of producing multiple orders and/or working on frame preparation and filling preparation simultaneously then the new sliding table saw machine (K12) and assembly work bench 6 is utilized.

By placing both figures above each other as shown in figure 7-9, it will be clear that there is minimum interaction between the two stages which facilitates working on the two stages simultaneously with minimum motion of workers and work progress and minimum interaction which ultimately will reduce lead time.

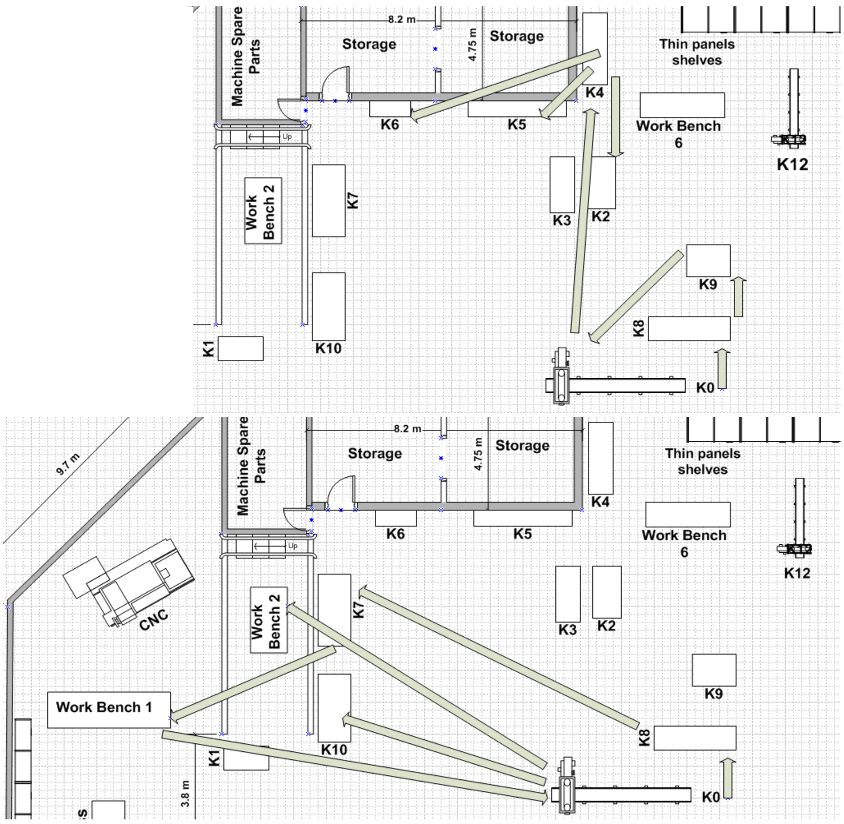


Figure 7-9 Work Flow of Kitchen-Cabinets Door Production Process

The contributions from the improvements to the layout are presented as follows:

- Improved storage of raw materials using the new storage stands located beside wooden profile storage shelves and reducing storage area from 34 square meters to 19 square meters. The raw materials are stored in stands and can be withdrawn with the forklift without any obstacles which speeds the step of moving raw materials to the production area, prevents stacking and obsolescence of raw materials, and allows easy inventory check.
- Reducing storage area of raw materials at the entry door from 24 square meters to 7.5 square meters using the new stands. The free space will be utilized for order delivery preparation in winter.
- Free space of 12 square meters in front of administration office is now available which can be used for order delivery preparation during winter and inspection of incoming raw materials.
- Free space of 39 square meters is now available in the room located near spare parts room which can be utilized as a show room for final products, storing kitchen-cabinets door products, or others purposes.
- Free space of 18 square meters is now available and utilized for the sanding of kitchen-cabinets doors.
- Free space of 43.2 square meters is now available near CNC machine after moving wooden profiles stapling work bench and was utilized for the wooden doors production line and storage of raw materials and final products of this process.
- Sorting spare parts of machines and documentation files allowed faster stock check and easier access. Wooden profile stapling work bench was occupying a space of 3

square meters, the available stands was kept to store raw materials for door production and final products.

- Utilizing an area of 18 square meters for producing wooden mesh which is located at the roof of the new sanding area of kitchen-cabinets doors.
- Free space of 10 square meters is now available at the end of wooden profiles production line and was utilized for wooden profiles stapling work bench.
- Free space of 19 square meters in the middle of the factory is now available by moving wooden door production process to the new location and was utilized for placing 5 storage stands for raw materials and final products. The wooden door production machine booked a space of 2 square meters only.
- Reduced number of accidents by 50% for the first six months of the year 2019 in comparison with the same period of 2018.
- The current layout allows parking truck beside the storage stands for order delivery in winter.
- The current layout reduced transportation in delivering raw materials to the work stations and reduced worker’s motion to pick raw materials.

Financial contributions from the achieved improvements and newly introduced products:

- An income of 12,000 NIS was generated from selling stagnant profiles during sort phase of 5S through the sponsor of the improvement initiatives.
- An income of around 6400 NIS was generated through selling stagnant profiles by factory management after set in order phase and these profiles were sorted in the assigned places.

- 160 MDF sheets of total value of 16,200 NIS that were stagnant since more than three years will be utilized in production and/or sold to customers.
- Three pallets of mahogany raw wood with total value of around 45,000 NIS that were stagnant for more than two years will be utilized in production and/or sold to customers.
- The contributions to sales of the two sales agents for the period from 1-8-2018 to 31-7-2019 are 883,594 NIS with a proportion of 29% of total sales during this period.
- The contributions to sales of the new released products are 158,811 NIS from door frame product, and 131,768 NIS from wooden doors.

7.3 Improving Productivity of Kitchen-Cabinets Door Production Line

The first step for improving the productivity of this production line was improving the layout which was implemented in the set in order phase of 5S. The placement of the machines in the new layout provided smooth flow and freed spaces that allow better and safer workers movement and WIP flow. It is possible now to utilize the work trolleys in the new layout and to monitor work progress visually.

The improvement team prepared the new flow chart of Kitchen-Cabinets Door Production process shown in figure 7-10. The new flow chart aims to preparing the first two stages of the process in parallel which are frame preparation and filling preparation which are easier to follow in the new layout due to the lower interaction between workers and better placement of machines in U shape form.

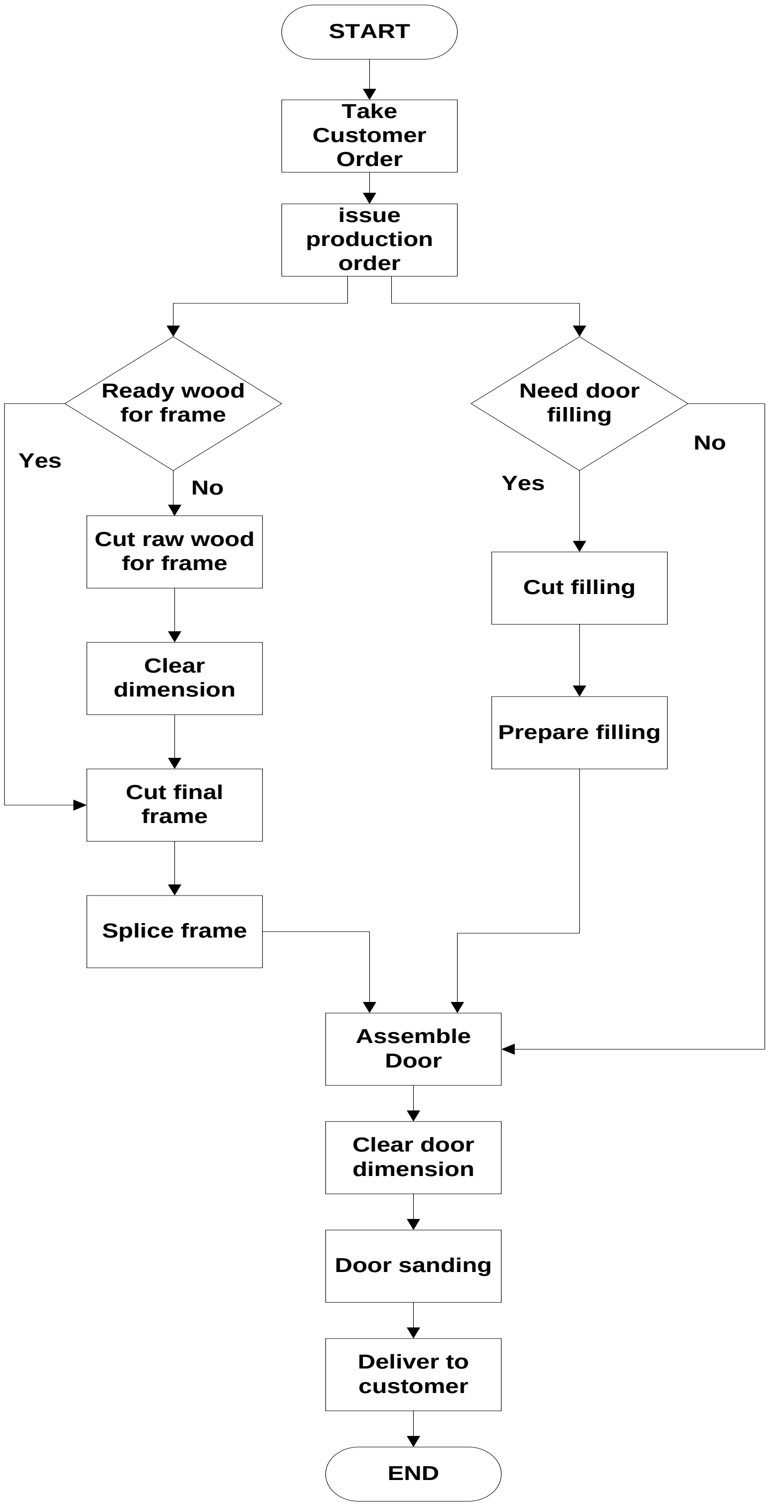


Figure 7-10 Flow Chart of New Status of Kitchen-Cabinets Door Production Process

After implementing the new flow chart, the improvement team collected data for the new process as shows in table 7-12.

Table 7-12 Process Efficiency Data for New Status of Kitchen-Cabinet Door Process

Process step	**AVG CT (minute per square meter)**	**AVG DT (minute per square meter)**	**AVG LT (minute per square meter)**	**%VA = CT/LT %**
Cut raw wood for frame	9.7	1.5	11.2	87
Clear dimension	10.8	5.6	16.4	66
Cut final frame	11.8	3.3	15.1	78
Splice frame	5.3	3.2	8.5	62
Cut filling	7.9	1.9	9.8	81
Prepare filling	11.4	5.9	17.3	66
Assemble door	22.0	8.5	30.5	72
Clear door dimension	7.8	13.4	21.2	37
Door sanding	26.2	9.1	35.3	74

Data were collected for three orders of same raw wood and same design, total processed in the three orders is 32.73 square meters.

7-4 Value Stream Mapping for New Status of Kitchen-Cabinets Door Production Process

Based on data collected in table 7-12; the improvement team prepared the value stream map for the new process as presented in figure 7-11.

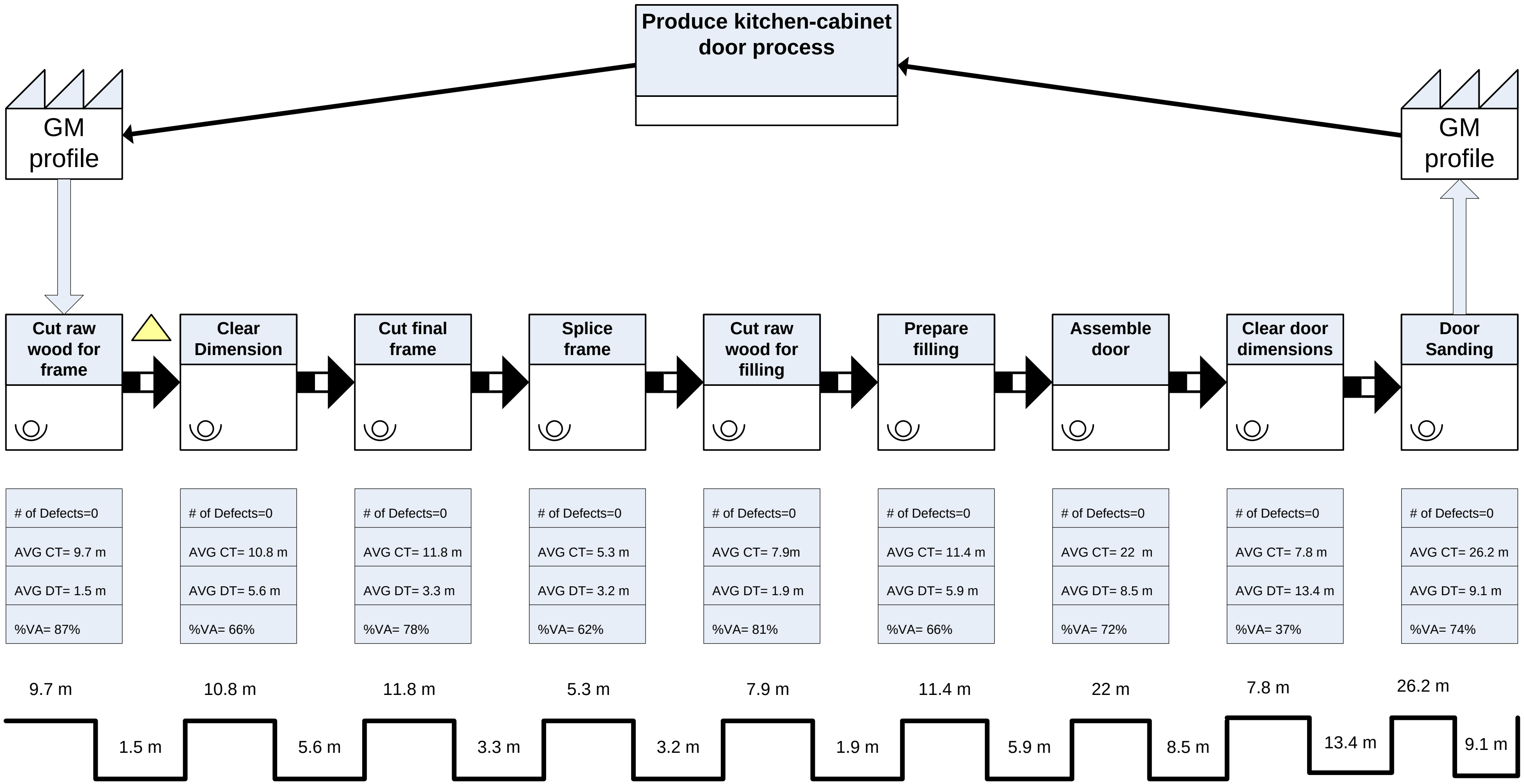


Figure 7-11 Value Stream Map of New Status of Kitchen-Cabinet Door Production Process

Since the new process included preparing door frame stage in parallel with preparing door filling stage, the highest lead time of the two stages is used for calculate process efficiency while the lowest will is excluded from calculations.

Lead time for prepare door frame stage = 11.2+16.4+15.1+8.5 = 51.2 minutes

Lead time for prepare door filling stage = 9.8+17.3 = 27.1 minutes

Lead time of prepare door frame stage is added to the times of the following steps in the process which are assemble door, clear door dimension, and door sanding.

Total lead time = 51.2+30.5+21.2+35.3 = 138.2 minutes

Total cycle times = 9.7+10.8+11.8+5.3+22+7.8+26.2 = 93.6 minutes

Process efficiency of new process = %VA of kitchen-cabinets door production process

$= \sum CT's / \sum LT = 93.6 / 138.2$

$= 68\%$

According to the collected data, the contributions from the improvements to the process through the new flow chart and new layout of the processes and the plant are as follows:

- Process efficiency has increased from 45% to 68%
- Lead time was reduced from 428.4 minutes to 138.2 minutes per square meter. Accordingly the company reduced order delivery duration promise to customers from 30 days to 10-15 days depending on work load.
- Improving productivity of kitchen-cabinets production process through reducing cycle time and delay (reducing lead time).
- The new layout of the process helped in reducing motion and speeding work flow, while the introduced visual management reduced the underperforming of the workers

which lead to reducing cycle times, reducing delay, and reducing side-chatting of the staff.

- Cycle time of door assembly step has increased due to the variation in workers experience and skills and the company should assign competent staff to this step.
- High delay still exists at clear door dimension step due to waiting of the glue to dry.
- Cycle time of door sanding step can be reduced through assigning two workers for this step in the next orders when possible.
- The delay in pulling raw materials for door frame and for door filling stages was highly reduced due to the new sorting of raw materials in the new storage shelves that are located near the process which allows workers to pull raw materials freely and the ability of utilizing the forklift to pull the whole pallet to the production line within a short period of time.

7.5 People Involvement

The improvement team formation targeted staff members from all departments and all processes to guarantee high involvement of people which is critical to the success of LSS implementation. The improvement team members were trained on using LSS tools at each phase and were involved in all activities with the support and supervision of the team leader. All other staff members were also consulted, informed about the aim of this study, and assigned with tasks that contribute to improving utilization of space or productivity of kitchen-cabinets door production. The new plant manager offered monetary incentives upon achievements to encourage staff involvement and confirm their role in reaching the targeted goals and sustaining the improvements, at the end of the improvement efforts five staff members were offered monetary incentives of 500

NIS for each one and the plant manager confirmed that it will be an ongoing incentive. Sales agents were also informed with the achieved results and assigned to inform the customers with improvements in lead time reduction, the ability to deliver kitchen-cabinet door orders within 10-15 days, and to inform them about the new released products and ability to produce other customized products on demand.

7.6 Activity Based Costing (ABC)

The improvement team was not able to introduce Activity Based Costing for kitchen-cabinets door due to the following reasons:

1- Another improvement study has started at the same time of this study but has been postponed due to due unforeseen circumstances. The study is supposed to introduce new organizational structure, total productive maintenance for all of the machines at the factory, and pricing of wooden profiles products which are used in producing kitchen-cabinets doors and its pricing is considered as a prerequisite for ABC of some designs of kitchen-cabinets doors.

2- Lack of production manager who will follow and control raw material delivery to work stations, consumed raw material, work residues, worker’s time at each activity and each machine, administrative staff working time of each activity, and other related data. The current staff and high load on the factory manager did not allow collecting these data.

3- High absenteeism of some of the workers who play a critical role in this regard which lead to repetitive release of workers to other work stations or duties.

4- Lack of pricing of raw materials per wooden bar.

5- The workload and the huge efforts that have been made for this study did not allow free time for the improvement team to conduct the required training and prepare the required tools to collect data and introduce ABC for kitchen-cabinets doors.

7.7 Summary

The improvement team implemented the 5S lean tool and succeeded in improving the current layout including storage of raw materials and final products, layout of production lines, spare parts storage room, and utilizing 16% of the plant area. While the productivity of kitchen-cabinets door production line was improved through developing and implementing new flow chart for this process and the improved process efficiency was presented in the new VSM.

Chapter 8
Control Phase

8.1 Introduction

This is last phase within the DMAIC process which ensures sustaining the improvements, monitoring the ongoing performance, documenting, and institutionalizing the process improvements (Jirasukprasert et al., 2014)

The 5S standardize and sustain phases were implemented simultaneously to sustain the gained improvements. The improvement team agreed to divide this phase into two stages:

1- Monitoring and controlling raw materials and final products storage and delivery.

2- Monitoring and controlling production progress in kitchen-cabinets door production line.

8.2 Monitoring and Controlling Raw Materials Storage and Final Products Storage and Delivery

In order to manage and control inventory of raw materials and final products the improvement team agreed on assigning a staff member for each task with an alternative member in case of absence of the assigned one. The factory manager will follow up fulfilling these tasks on daily basis.

A purchase order form was prepared to monitor and control raw materials inventory and avoid excess inventory or shortage in raw materials. The form is show in table 8-1. The Arabic form is presented in appendix B.

Table 8-1 Purchase Order Form

Purchase order form for raw materials /spare parts / tools	
Date:	
Ordering Part	
Item Name	
Specifications	
Available Quantity	
Needed Quantity	
Supplier Name	
Applicant signature	
Manager Signature	
Receiving Part	
Reception Date	
Received Quantity	
Conformity to Specifications	
Notes:	
Storage Location	
Recipient Signature:	

The purchase order form is divided into two sections, ordering section and receiving section. The ordering part of the form will be filled and signed by the applicant; it includes date of application, item name, item specifications, available quantity, needed quantity, and potential supplier name which will be filled by the applicant and confirmed or amended by the accountant. The factory manager will sign the form to confirm approval of purchase. Then the accountant will check, contact suppliers, and confirm supplier name. The assigned receiver of the purchase process will fill the receiving part that includes date, received quantity, matching specifications, any notes including less or extra quantity, change in item specifications, defects, returns to suppler, …etc. Finally he will sign the form and deliver it to the factory manager. In case of different specifications and/or quantity, the receiver will directly inform the factory manager who will inform the applicant of the order to confirm receiving or rejecting the order partially or fully. The received items will be stored in place as written in the purchase form. Finally the form is returned to the accountant who will insert the data in the accounting system and arrange filing in assigned folders.

This form helps in managing and controlling purchased items. Any missing step is easily detected by the factory manager or the accountant and the assigned staff member will be informed directly to avoid future mistakes. The factory manager will follow that the purchased item is stored in the assigned location.

Regarding managing and controlling final products storage and delivery, the improvement team agreed on labelling all final products that will be delivered to customers using an A4 paper with customers' name. The accountant will print this paper after being informed of production completion and will directly contact customer for order delivery arrangements.

Authorized excess production are stored in assigned locations where it was agreed that wooden profiles are stored in the assigned stands near same design, or on pallets to be stored in the new storage stands, door frame and casement are sorted on pallets and stored in the new stands, and wooden mesh are sorted on pallets and stored in the new stands. There is no excess production of kitchen-cabinets doors since they are customized products which are stored in the sanding area and inside the freed space in the offices beside spare parts room, this room can be also utilized as a show room for all products.

Regarding order delivery process, the improvement team prepared flow chart for this process including assigned resources for each process step as presented in figure 8-1.

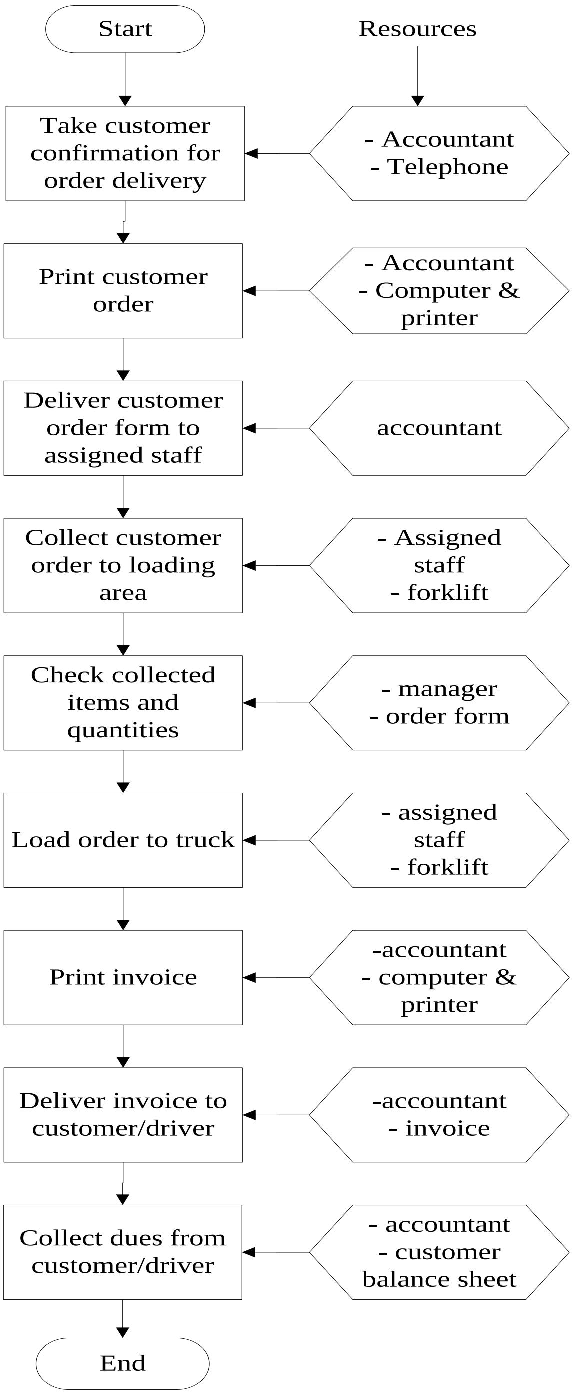


Figure 8-1 Deliver Customer Order Flow Chart

This flow chart is the standard reference for order delivery process. Any deviation from this flow chart is spotted and the responsible staff is identified. The role of the manager in checking collected quantities and items according to customer order helps preventing loading of more/less quantities and loading wrong items.

To control and sustain improvements in order delivery process, the improvement team prepared the following check list presented in table 8-2 to prevent any missing steps or deviation in the process. The Arabic check list is presented in Appendix C.

Table 8-2 Order Delivery Check List

Order Delivery Check List		
Process Step	Check in the ☐	Name &Signature of Assigned Staff
Take customer confirmation for order delivery	☐	
Print customer order form	☐	
Deliver customer order form to assigned staff	☐	
Collect customer order to loading area	☐	
Check collected items and quantities	☐	
Load order to truck	☐	
Print invoice	☐	
Deliver invoice to customer/driver	☐	
Collect dues from customer/driver	☐	

After implementing the new flow chart of order delivery process, the company was able to stop the manipulation of order delivery and succeeded in generating sales from selling wooden sawdust of 52,535 NIS for the first five months of the year 2019 while sales of this product for the same period were 15,740 NIS. The old price of this product was 5 NIS per bag and the new price is 10 NIS and the company was able to prepare a list of customers for this product to contact them when there is an available stock.

8.3 Monitoring and Controlling Production Progress of Kitchen-Cabinets Door Production Line

The improvement team prepared production form to monitor and control production progress of kitchen-cabinets door production line as show in table 8-3, the Arabic form is presented in Appendix A. This form accompanies each order on the work trolleys. There are five assigned staff members for this production line, four of them have the required skills to perform all the tasks to produce kitchen-cabinets door, the remaining one will handle final product sanding. The four staff members were divided into two teams, one member of each team handles door frame preparation and the other handles door filling preparation according to developed flow chart for this process. One of them is assigned for the assembly and the other is released to help the other team or start working on new order. The assembled product is sent to last work station of sanding. After sanding is completed the final product is labeled with customer name and the accountant is informed of production completion to contact customer for order delivery.

Table 8-3 Kitchen-Cabinets Door Production Form

Kitchen-Cabinets Door Production form				
Customer Name:		Order number:		Date:
Process Step	**Start Time**	**End Time**	**Name of Assigned staff**	**Consumed Materials**
Cut raw wood for Frame	Date: Time:	Date: Time:		
Clear Dimensions	Date: Time:	Date: Time:		
Cut final frame	Date: Time:	Date: Time:		
Splice frame	Date: Time:	Date: Time:		
Cut filling	Date: Time:	Date: Time:		
Prepare filling	Date: Time:	Date: Time:		
Assemble door	Date: Time:	Date: Time:		
Clear door dimensions	Date: Time:	Date: Time:		
Door sanding	Date: Time:	Date: Time:		

The improved layout allows visual management of production in this process where the manager can identify production progress through the location of work trolley. Also the prepared production form helps the manager in identifying delay at each step, step where defects occur, and responsible staff member to take the necessary action. Process data will also be available for future studies and analysis.

The company has a form for order specifications and design for each order. This form is attached to the production form of each order which accompanies the work trolley. Since kitchen-cabinets door is a customized product and cannot be sold to other customers, it was agreed with the accountant and manager to confirm order specifications and design with each customer after electronic recording of the data to avoid any false data during manual recording of order specifications and design by the customer, sales agent, or the accountant. This confirmation is taken verbally face to face with the customer or by phone.

In order to be able to have an update of the status of all kitchen-cabinets door orders and inform the customers about the status of their orders, the improvement team prepared the production progress follow up form presented in table 8-4. The Arabic form is presented in Appendix D.

Table 8-4 Production Progress Follow up Form for Kitchen-Cabinets Door Process

Production Progress Follow up Form for Kitchen-Cabinets Door Process									
Customer Name	**Cut wood for frame**	**Clear dimensions**	**Cut final frame**	**Splice frame**	**Cut filling**	**Prepare filling**	**Assemble door**	**Clear door dimensions**	**Door sanding**

8.4 Production Scheduling for Kitchen-Cabinets Door Production Line

Production scheduling aims to achieve efficient utilization of resources to satisfy customer demand. The improvement team conducted the required training for the concerned staff to be able to schedule customers' orders using Gantt chart. Wilson (2003) stated that Gantt charts were used to coordinate activities to achieve smooth flow of orders through the factory while keeping machines and staff busy.

Gantt chart allows presenting work orders or activities over time, the improvement team agreed on using the chart presented in table 8-5. The Arabic chart is presented in appendix (). This form can be adopted in other production processes. The scheduling is prepared on weekly basis and may be extended to a longer period depending on demand. The factory manager received the required training on using this form and is able to conduct training to other staff members when needed.

Table 8-5 Production Scheduling Form

#	**Customer Name**	**Start**	**Finish**	**Duration**	**Date:**					
					Day1	**Day2**	**Day3**	**Day3**	**Day5**	**Day6**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

8.5 Sustaining 5S Achievements

To sustain the achieved results of 5S initiatives, the improvement team prepared a check list presented in table 8-6. This check list guarantees conformance to standards and provide the required action in case of nonconformity. Staff member who repeats incompliance to the standards will be warned in writing. The Arabic check list of 5S is presented in appendix F.

Table 8-6 5S check List

Process / Step	**Check if conform**	**Action for nonconformity**
Maintaining cleanliness of work area	**Yes** ☐ **No** ☐	Clean work area at the end of the day
Maintaining cleanliness of machines, spare parts and tools	**Yes** ☐ **No** ☐	Clean machines, spare parts, and tools at the end of the day
Sorting raw materials in assigned places	**Yes** ☐ **No** ☐	Sort raw material in assigned place
Sorting final products in assigned places	**Yes** ☐ **No** ☐	Sort final products in assigned space
No stacking of WIP	**Yes** ☐ **No** ☐	- Separation of WIP according to production forms. - Compliance to production forms. - Check machine status - Assign task to other staff in case of absence of assigned one.
Sorting work residues and defects in assigned places	**Yes** ☐ **No** ☐	Sort work residues and defects in assigned places
Labelling of final products	**Yes** ☐ **No** ☐	Label final products
Compliance to production form	**Yes** ☐ **No** ☐	- correct error - identify responsible staff and take necessary action.
Sorting spare parts and tools in assigned places	**Yes** ☐ **No** ☐	Sort spare parts and tools in assigned places
Staff knowledge of work standards	**Yes** ☐ **No** ☐	Arrange training sessions

8.6 Documentation

It was agreed with the plant manager that all forms will be organized in separate files, and all files should be kept for at least two years duration. After this period the company is authorized with the disposal of the forms. The accountant/manager is responsible for filing and disposal of the work forms.

A visit was arranged to the plant after one month and it was assured that all forms were implemented, organized, and kept as agreed.

8.7 Summary

The improvement team was able to monitor and control raw materials storage and final products storage and delivery through introducing and implementing purchase order form, flow chart for order delivery process, and order delivery check list. The team monitored and controlled the production progress through introducing and implementing production order form, production progress follow up form, and production scheduling form. The team was able to sustain the improvements in the layout through introducing and implementing the 5S check list.

Chapter 9
Conclusions and Recommendations

9.1 Introduction

LSS implementation at GM Profile Company has proven that it is a powerful methodology for improving productivity of kitchen-cabinets door production line and improving space utilization.

The wide variety of LSS tools helped in reaching the desired state. SIPOC, project charter, PCD, and CTQ tree tools helped in identifying opportunities of improvement and critical to quality factors. Flow chart and VSM helped in measuring the current performance of the targeted process. While layout drawing and analysis helped in identifying quality concerns in the current layout. Cause and effect diagram and interrelationship diagram helped in identifying root causes of the problems under investigation. Flow chart and VSM helped in improving the lead time of targeted process. 5S helped in organizing work environment, improving utilization of space, and improving layout of kitchen-cabinets door production process, wooden door production process, and wooden profile stapling process. Finally, flow chart, 5S, and work forms helped in standardizing and sustaining the improvement.

9.2 Conclusions

The results of implementing LSS methodology at GM Profile Company to improve utilization of space and productivity of kitchen-cabinets door production line are presented as follows:

1- Contributions from improving productivity of kitchen-cabinets door production process:
   - Lead time of kitchen-cabinets door production process was reduced from 428.4 minutes to 138.2 minutes per square meter.
   - Process efficiency has increased from 45% to 68%.
   - Order delivery duration was reduced from 30 days to 10-15 days.
   - Introducing visual management and improving work flow of kitchen-cabinets door production process through improving the process layout.
   - Improved productivity of kitchen-cabinets door production process by reducing cycle times and delay.

2- Contributions from improving the layout:
   - Improved storage of raw materials using the new storage stands located beside wooden profile storage stands and reducing storage area from 34 square meters to 19 square meters. The raw materials are stored in stands and can be taken with the forklift without any obstacles which speeds the step of moving raw materials to the production area, prevents stacking and obsolescence of raw materials, and allows easy inventory check.
   - Reducing storage area of raw materials at the entry door from 12 square meters to 4 square meters using the new stands.

- Free space of 12 square meters in front of administration office is now available, which can be used for order delivery preparation during winter and inspection of incoming raw materials.
- Free space of 39 square meters is now available in the room located near spare parts room which can be utilized as a show room for final products, storing kitchen-cabinets door products, or other purposes.
- Free space of 18 square meters was made available and is utilized for the sanding of kitchen-cabinets doors.
- Free space of 43.2 square meters is now available near CNC machine after moving wooden profiles stapling work bench and was utilized for the wooden doors production line and storage of raw materials and final products of this process.
- Sorting spare parts of machines and documentation files allowed faster stock check and easier access.
- Utilizing an area of 18 square meters for producing wooden mesh which is located at the roof of the new sanding area of kitchen-cabinets doors.
- Free space of 10 square meters is now available at the end of wooden profiles production line and was utilized for wooden profiles stapling work bench.
- Free space of 19 square meters in the middle of the factory was made available by moving wooden door production process to the new location and was utilized for placing 5 storage shelves for raw materials and final products.
- Reducing number of accidents by 50%.

3- Financial contributions from achieved improvements and newly introduced products:

- Total area of freed space is 175.7 square meters which equals 16% of the factory area. According to the current rent of 120,000 NIS per year, the financial contribution of the freed space equals 19,167 NIS per year.
- 18,400 NIS sales were generated by selling stagnant profiles.
- The value of detected stagnant raw materials is 61,200 NIS which will be utilized in production or sales.
- 290,579 NIS was generated from sales of newly introduced products.
- 883,594 NIS was generated from the contributions of sales by the sales agents.
- Additional income of 36,795 NIS was generated from controlling order delivery process.
- Top management commitment and staff involvement are very important factors in the successful implementation of LSS.

9.3 Recommendations

To continuously improve the work environment, improve productivity, and accordingly improve profitability, it is recommended that GM Profile Company:

1. Establish a research and development unit and provide it with the required resources to study market opportunities for new products, improve skills of staff, import raw materials to be able to offer competitive prices, and measure customer satisfaction.
2. Establish quality unit to continuously improve quality of services and products.
3. Establish a measurement system for all processes to be to introduce ABC to all products.
4. Hire an industrial engineer as a production manager to allow general manager to carry out other duties and be able of sustaining the achieved improvement. The industrial engineer can also establish preventive maintenance for the machines to reduce setup time, reduce downtime, and decrease number of accidents.
5. Start searching for substitutes for some of its employees due to age factor and lack of self-development. Some of them will retire in the next few years.
6. The company should continuously grant monetary incentives due to the high impact of this factor on worker’s performance.
7. The company should train one of the workers to handle the setup of wooden profiles production machine in addition to the current one to arrange setup in the absence of any of them and avoid production delay.
8. The company should operate the CNC machine or sell it to be able to utilize the assigned space for this machine.
9. The company should seek to maintain management stability through incentives on annual sales and empowerment.

10. The company should purchase wood sawdust machine to help in the disposal of work residues which will also contribute to income generation and keep the work environment clean and safe.
11. The improvement team should implement 5S on frequent basis to maintain disciplined and safe work environment.
12. Establish a showroom to its products.

9.4 Future Researches

LSS can be implemented to all processes at GM profile Company to improve service quality by reducing variation and eliminating wastes in these processes. The proposed future researches include improving profitability of GM profile through ABC costing of all products, critical success factor of LSS implementation in small and medium enterprises, establishing total productive maintenance system using LSS methodology, and the role of research and development in gaining competitive advantage in small and medium enterprises.

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Appendices

Appendix A: Arabic Kitchen-Cabinets Door Production Form

نموذج انتاج دفات المطابخ				
اسم الزبون:			**رقم الطلبية:**	**تاريخ التسليم:** / /
مرحلة العمل	**اسم الشخص المكلف**	**وقت بدء العمل**	**وقت انتهاء العمل**	**مواد مستهلكة**
تشريح الاطار		التاريخ: الساعة:	التاريخ: الساعة:	
مسح على الرابوخ والفارة		التاريخ: الساعة:	التاريخ: الساعة:	
قص الاطار		التاريخ: الساعة:	التاريخ: الساعة:	
عمل مجاري مدخل الدفة		التاريخ: الساعة:	التاريخ: الساعة:	
قص الحشوات		التاريخ: الساعة:	التاريخ: الساعة:	
تحضير الحشوات		التاريخ: الساعة:	التاريخ: الساعة:	
جمع الدفات		التاريخ: الساعة:	التاريخ: الساعة:	
تربيع الدفات		التاريخ: الساعة:	التاريخ: الساعة:	
حف الدفات		التاريخ: الساعة:	التاريخ: الساعة:	

Appendix B: Arabic Purchase Order Form

نموذج شراء مواد خام / قطع غيار / عدد للآلات	
التاريخ:	
قسم الطلب	
اسم الصنف	
المواصفات	
الكمية المتوفرة	
الكمية المطلوبة	
الشركة المزودة	
توقيع مقدم الطلب	
توقيع المدير	
قسم الاستلام	
تاريخ الاستلام	
الكمية المستلمة	
مطابقة المواصفات	
ملاحظات	
مكان التخزين	
توقيع المستلم	

Appendix C: Arabic Order Delivery Check List

قائمة فحص تسليم طلبية الزبون		
خطوة العملية	ضع علامة في☐	اسم وتوقيع الشخص المخول
الحصول على تأكيد من الزبون باستلام الطلبية	☐	
طباعة طلبية الزبون	☐	
تسليم طلبية الزبون للشخص المخول بتحضيرها	☐	
احضار طلبية الزبون لمنطقة التحميل المخصصة	☐	
فحص عناصر الطلبية التي تم احضارها	☐	
تحميل الطلبية للسيارة	☐	
طباعة الفاتورة	☐	
تسليم الفاتورة للزبون / السائق	☐	
تحصيل الذمم من الزبون / السائق	☐	

Appendix D: Arabic Production Progress Follow up Form for Kitchen-Cabinets Door Process

نموذج متابعة تقدم انتاج قسم دفات المطابخ									
اسم الزبون	تشريح الاطار	مسح على الرابوخ والفارة	قص الاطار	عمل مجاري مدخل الدفة	قص الحشوات	تحضير الحشوات	جمع الدفات	تربيع الدفات	حف الدفات

Appendix E: Arabic Production Scheduling Form

رقم	اسم الزبون	بدء	نهاية	المدة	التاريخ:					
					يوم 1	يوم 2	يوم 3	يوم 4	يوم 5	يوم 6
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Appendix F: Arabic 5S Check List

العملية / الخطوة	ضع علامة بحسب التقيد	الاجراء الواجب اتخاذه في حال عدم التقيد
المحافظة على نظافة مكان العمل	Yes ☐ No ☐	تنظيف مكان العمل في نهاية يوم العمل
المحافظة على نظافة الآلات وقطع الغيار والعدد	Yes ☐ No ☐	تنظيف الآلات وقطع الغيار والعدد في نهاية يوم العمل
ترتيب المواد الخام في المكان الخصص	Yes ☐ No ☐	قم بترتيب المواد الخام في المكان المخصص
المنتجات في المكان المخصص	Yes ☐ No ☐	قم بترتيب المنتجات في المكان المخصص
تراكم مواد الانتاج بين العمليات	Yes ☐ No ☐	- فصل مواد الانتاج بحسب كل طلبية - الالتزام بنموج الانتاج - فحص صلاحية الآلات - في حال غياب الشخص المكلف بالعمل يتم تكليف شخص بديل
ترتيب بقايا الانتاج والمنتجات التالفة في المكان المخصص	Yes ☐ No ☐	قم بترتيب بقايا الانتاج والمنتجات التالفة في المكان المخصص
وجود ملصق باسم الزبون على المنتجات	Yes ☐ No ☐	قم بوضع ملصقات باسم الزبون على المنتجات
التقيد بنموذج الانتاج	Yes ☐ No ☐	- تصحيح الخطأ إن وجد - تحديد الشخص المسؤول عن عدم التقيد واتخاذ الاجراء اللازم بحقه
ترتيب القطع والأدوات في المكان المخصص	Yes ☐ No ☐	قم بترتيب القطع والأدوات في المكان المخصص
علم الموظفين بمعايير العمل	Yes ☐ No ☐	قم بترتيب جلسات تدريبية على المعايير

الملخص

تبحث هذه الدراسة في أثر تطبيق منهجية Lean Six Sigma على الشركات الصناعية في قطاع الأخشاب. يوضح دور استخدام هذه المنهجية في مساعدة منتجي المنتجات الخشبية في الاستخدام الفعال لمواردهم وتنظيم بيئة العمل لتصبح أكثر إنتاجية وتخلق بيئة للتحسين المستمر.

تنبع أهمية هذه الدراسة من الحاجة إلى تحسين استخدام المساحة والإنتاجية لعملية إنتاج أبواب خزائن المطبخ في شركة GM Profile في البيرة من خلال التخلص من الهدر وتقليل التباين في العمليات والذي يساعدها على البقاء في العالم سريع التطور.

تم تطبيق منهجية DMAIC لـ Lean Six Sigma على خمس مراحل لتحقيق الأهداف المرجوة. تم تحديد المشكلة والمقاييس المهمة للجودة في مرحلة التعريف باستخدام مجموعة من الأدوات مثل SIPOC، PCD ، Critical to quality tree، وميثاق المشروع. تم قياس الأداء الحالي في مرحلة القياس باستخدام flow chart ، VSM، 8 wastes ، وquick wins. تم تحديد الأسباب الجذرية للمشاكل باستخدام cause and effect diagram وinterrelationship diagram . تم تحسين تصميم المنشاة وإنتاجية خط إنتاج أبواب خزائن المطبخ باستخدام المراحل الثلاث الأولى من 5 S، flow chart، و VSM. تم الحفاظ على النتائج المحققة باستخدام المرحلتين الأخيرتين من 5 S، flow chart ، work forms ، و check lists .

في نهاية جهود التحسين ، تم تحسين إنتاجية خط إنتاج أبواب خزائن المطبخ وتصميم المنشأة مما أدى إلى تقليل وقت الانتاج إلى 138.2 دقيقة في حين أدت التحسينات في استخدام المساحة إلى تنظيم بيئة العمل ، تقليل عدد الحوادث بنسبة 50 ٪ ، وتحسين مخطط العمليات التالية: عملية إنتاج باب خزائن المطبخ ، عملية إنتاج الأبواب الخشبية ، عملية تدبيس البروفيلات الخشبية ، وعملية إنتاج الشبكات الخشبية من خلال الاستفادة من 16 ٪ من مساحة المنشأة. علاوة على ذلك ، تم تحسين إدارة المخزون من خلال ضبط عمليه شراء المواد الخام وتخزينها ، تحسين عملية تسليم المنتجات النهائية وتخزينها ، وإدخال منتجات جديدة.

تساهم هذه الدراسة في إدخال تطبيق منهجية LSS في المؤسسات الصغيرة والمتوسطة الحجم في الصناعة الفلسطينية وتؤكد أهمية هذه المنهجية في تحسين الجودة من خلال تقليل الهدر وتقليل التباين والذي يلعب دورًا كبيرًا في البقاء في الاقتصاد الفلسطيني الذي يواجه العديد من التحديات.