



UNIVERSITI PUTRA MALAYSIA

DESIGN OF A SMALL SCALE FACTORY FOR POMEGRANATE JUICE

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JUICE**

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ABSTRACT

Food factory system is a manufacturing system that transforms raw ingredients into food product that can be consumed or easily prepared by the consumers using physical, mechanical chemical and thermal process. In Malaysia, the food and beverage manufacturing are dominated by more than 97% of small and medium enterprises (SMEs). Most SMEs have problems related to low productivity and hygiene. Previous reports showed that the problems can be sourced back to the poor design of the food factory that overlook aspects related to production efficiency and hygienic design. This project was performed to solve the productivity and hygiene requirement through the design of the new factory owned by Company X, a Malaysian SME that ventures in pomegranate juice business. The new factory was designed using 9 design stages that integrates the Good Manufacturing Practice (GMP) aspects and considers the productivity requirement. The new factory has Production Program of 145,000 bottles per year, reserve capacity of 22.4 %, utilizes reconstitution and aseptic filling processes, optimizes machines capacity as well as has efficient spine layout, adequate number of facilities and utilities supplies. Simulation analysis with FlexSim software showed that the productivity of the new factory was increased by six times, while the lead time was reduced by 65 %. The improvement was due the designated continuous line, tangible Production Program, optimized machines capacity and layout arrangement. Meanwhile, the analysis with Hygienic Checklist Tool shows that the new design complied with majorities of hygiene requirement which is 97 % of score percentage. Thus, the factory is ready for implementing GMP once the operation is run. This include separation of low and high risk area, material and personnel flow, airflow, spatial design and building structures specification. In conclusion, an efficient and hygienic food factory system can be

achieved when the productivity and GMP requirement were addressed as early as at the design process.



ABSTRAK

Sistem kilang makanan ialah sistem pembuatan yang menghasilkan produk makanan daripada bahan mentah akan di makan dan di sediakan oleh pengguna dengan menggunakan proses fizikal, proses mekanikal, proses kimia dan proses haba. Di Malaysia, sektor pembuatan makanan dan minuman telah didominasi lebih daripada 97% usahawan industri kecil dan sederhana. Kebanyakan industri kecil dan sederhana mempunyai masalah produktiviti yang rendah dan masalah kebersihan. Laporan sebelum ini telah menunjukkan bahawa masalah telah terhasil daripada kelemahan reka bentuk kilang yang tidak menitik beratkan aspek yang berkaitan dengan kecekapan pengeluaran dan reka bentuk kilang yang bersih. Projek ini telah dihasilkan untuk menyelesaikan masalah pengeluaran dan keperluan bagi meningkatkan kebersihan kilang baru yang dimiliki oleh Syarikat X. Syarikat X ialah salah satu industri kecil yang menghasilkan dan menjual produk . Kilang baru telah direka menggunakan sembilan cara untuk mereka bentuk kilang yang selari dengan aspek Amalan Pengilangan yang Baik (GMP) dan menitik beratkan keperluan productiviti jus yang akan disediakan. Kilang baru mempunyai program pengeluaran produk sebanyak 145, 000 botol setahun dan mempunyai kapasiti simpanan sebanyak 22.4%. Kapasiti simpanan ini sangat penting bagi memudahkan proses pembotolan atau proses melarutkan pati jus delima sebelum dihantarkan ke kilang yang diupah. Kilang baru X telah berjaya menunjukkan kecekapan plan kilang, mempunyai pekerja yang cukup dan keperluan utiliti. Perisian FlexSim digunakan untuk menganalisis dan ia menunjukkan bahawa produktiviti kilang baru telah meningkat enam kali lebih tinggi dan masa telah menurun sebanyak 65% daripada masa yang digunakan untuk penghasilan jus. Penambahbaikan daripada segi reka bentuk telah dibuat dan menghasilkan proses yang berterusan, program pengeluaran yang sesuai,

penggunaan mesin yang optimum dan susun atur kilang yang efisien. Sementara itu, analisis dengan Alat Semak Kebersihan menunjukkan bahawa reka bentuk baru memenuhi keperluan kebersihan sebanyak 97%. Dengan itu, kilang X telah bersedia untuk melaksanakan GMP sebaik sahaja operasi dijalankan. Ini termasuk pemisahan kawasan risiko rendah dan tinggi, aliran bahan dan kakitangan yang berterusan, aliran udara yang bersih, reka bentuk ruang yang mencukupi dan spesifikasi struktur bangunan. Sebagai kesimpulan, sistem kilang makanan yang cekap dan bersih boleh dicapai apabila keperluan produktiviti dan GMP ditangani seawal proses reka bentuk.

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CHAPTER 1

INTRODUCTION

In this chapter, an overview of the project conducted which consist of the company background, project background, problem statement, scope of the project and the objectives was described.

1.1. Company Background

Company X is a local company producing pomegranate juice since 2012 in Malaysia. The premise is located at Jalan Gurney, Kuala Lumpur and it has about 63 of franchisers around Malaysia which in Kelantan, Pahang, Kuala Lumpur and Selangor. The product that been produced under the brand of Jus Minda.

From day by day, the demand for juice has increased due to the growing market of pomegranate juice. In order to meet the customer's demands, the company is planning to build up the small scale factory that can meet the required productivity as well as not compromising the good practise of food safety and hygiene. The missions of this company are to produce the quality juice products in sufficient quantity in the required time and to comply the food safety and hygiene standard. This company also has the visions to be one of the successful local food producers and expand their products at the international level. Currently, they have received invitation to collaborate with food companies from Thailand

and Singapore. Yet, due to the low productivity and failure to comply Good Manufacturing Practice (GMP), they are not able to grasp the opportunity.

1.2. Overview of Pomegranate Fruit

Pomegranate fruit is a long lived and drought tolerant plant that widely cultured in Iran, India and the Mediterranean countries such as Turkey, Egypt and Morocco (Ercisli et al., 2011). This fruits has been used as traditional medicine in Egypt and Turkey while also found to prevent the cancer and cardiovascular disease by improving the antioxidant level in the human body (Silva et al., 2013). Pomegranate fruit is a rich source of polyphenols, including ellagitannins, gallotannins, ellagic acids, gallagic acids, catechins, anthocyanins, ferulic acids, and quercetins (Zarfeshany et al., 2014). It is known as “super fruit” due to its high nutritional value and health benefits to the consumer. It has a high source of antioxidant due to high content of polyphenols like flavonoid and hydrolysable tannins (Hills, 2003). These polyphenols exhibit various biological activities, such as eliminating free radicals, inhibiting oxidation and microbial growth, and decreasing the risk of cardiovascular and cerebrovascular diseases and some type of cancers (Mena et al., 2011).

1.3. Malaysian SMEs in Juice Processing and Their Challenges

According to Rahim and Abdul Raman (2015), the demand for exotic fruit juices such as pomegranates has shown an increasing trend in Malaysia. Parallel to the increasing market potential, more juice production plants are established and they are mostly operated by small and medium enterprises (DOS, 2014; Rahim and Abdul Raman, 2015). Juice processing is based on UHT pasteurization, hot-filling, and aseptic packaging in tetra

packs and PET bottles of different pack sizes (Arshad et al., 2014). Juices are also packaged in tin containers.

Although the production system of juice is less complex than food products, Arshad et al. (2014) reports that SMEs juice processors also experience low productivity, quality and difficulties to practice hygiene in their food factories. The low productivity is attributed due to the lack of mechanization and automation, lack of formalization in the factory operation, poor infrastructure and low operator's productivity (Arshad et al., 2014; Rani et al., 2014). This is supported by Baker (2013), whereby most food factories are still operated in a home-kitchen style with traditional and uncontrolled processes.

According to Malaysia Gazette (2017), 15% from 1282 registered entrepreneurs of small and medium enterprise (SME) in the Ministry of Domestic Trade and Consumer Affairs Malaysia (KPNDKK) managed to enter the market of four biggest supermarket such as Tesco, Giant, Aeon and Aeon Big. Most of the products that managed to enter the market of the supermarket are foods and fruit juices made from SME business. Because of that, Ministry of Domestic Trade and Consumer Affairs Malaysia (KPNDKK) encouraged the entrepreneurs from SME to follow the requirement of the law such as Good Manufacturing Practice (GMP) to ensure the quality of the products are preserved and can be exported to the international level. Due to the encouragement, the numbers of registered SME's entrepreneurs increasing to 10, 342 on April 2014 and continually increasing from time to time (Zulhisham, 2015). The registered entrepreneurs are informed by the Deputy of Domestic Trade and Consumer Affairs Malaysia (KPNDKK) to improve their productivity to cater the international demands and to deal with a competitions between other entrepreneurs (Zulhisham, 2015).

As for food hygiene, the physical facilities for unloading, storage, and handling are mostly dilapidated with poor hygiene and sanitation. The practices for handling, washing, sorting, grading and cleaning do not comply GMP (Jali et al., 2016; HACCP). In the informal processing sector, even basic hygiene and sanitation is non-existent. There is no standard GMP procedure for employee personnel practices, cleaning and sanitation, receiving, handling and processing of raw material, and storage and distribution of finished products (Arshad et al., 2014). As a result, SMEs are not able to practice standard food hygiene and have difficulties in obliging the Food Hygiene Regulation 1985. There are cases where the local premises are closed by Health Officer due to being filthy, infiltrated with pest, poor ventilation and refrigeration system (Hasnan et al., 2014).

1.4. Food Factory Design and SMEs Challenges

A food processing factory is known as a manufacturing system that transform raw ingredients, by physical or chemical means into marketable food products that can be easily prepared and served by the consumer (Holah and Lelieveld, 2011). Most SME's in Malaysia have lack knowledge on food factory design (Jali et al., 2016). The design practice are usually trial and error, informal, unsystematic and based on contractor's suggestion (Rani et al., 2014; Hasnan et al., 2019). Consequently, the resulted factory are plagued with production inefficiencies such as inconsistent production volume and prolonged production time and also hygiene problems (Hasnan et al., 2014).

SME's in Malaysia are known to have many challenges during the design phase. Due to the lack of financial capability, they are not able to hire consultants (Zain et al., 2012). Hence, the factory is designed by themselves or architects and contractors with poor knowledge on food process. They also have lack of skilled and educated employees which

makes it difficult for them to acquire the systematic knowledge on food processing (Zain et al., 2012; Talib et al., 2013).

1.5. Problem Statement

Beginning 2009, Company X is one of the small and medium enterprise company that produced pomegranate juice. The demand for their pomegranate juice is increasing due to the growing awareness on its nutrients and benefits for the health of the consumers. Nevertheless, the current production output is not sufficient as the current processing method is not efficient and additionally, it does not comply the food safety aspect. The home-style kitchen production has a few weaknesses that lead to prolonged production time. Some of the inefficiencies are too many manual processes, disorganized production facilities and too long waiting time between processes. Moreover, the contracted beverage factory used for reconstitution and bottling process in Semenyih also had lack of hygiene practice and poor factory condition that can affect the quality of the juice produced. Those weaknesses showed that the company did not comply the Good Manufacturing Practice (GMP) to ensure the food safety which actually ensures the good quality of product. As a result, the production of juice fluctuates and the juice production didn't meet the customer demands.

The current production of pomegranate juice is 2400 - 5000 bottles per month and the real demand of the products can reach up to 10,000 bottles which is 2 to 3 times higher than the current capacity. In order to meet the increasing demand, Company X has decided to pursue a proper factory premise that must be designed to meet the increasing productivity requirement as well as meet the food hygiene aspects. The new factory premise must comply all the design aspect in Good Manufacturing Practice (GMP) to help the company

to expand their business with international countries nearby such as Thailand and Singapore. Against this problem statement, it becomes the aim of this final year project to propose an efficient and hygienic factory system design for Company X. The project is also in line with SME Master Plan (2012–2020) that aims to create dynamic and competitive SMEs through high productivity and formalization in the SME production system (Arshad et al., 2014).

1.6. Significance of Work

Upon completing this project work, a factory design and specification for the pomegranate juice is proposed. The design should be able to deliver a factory system that is production efficient and able to implement hygiene. In order to achieve this, a suitable manufacturing system and layout are presented, productivity improvement in new factory is compared to existing production and the hygienic design are evaluated. The outcome of this project shall prepare the factory certified with GMP which is important for meeting global food safety and quality standard.

In a bigger perspective, the study shall demonstrates the feasibility and method to set-up a competent food factory for the SME industries. This study is therefore in line with the current Eleventh Malaysia Plan, 2016-2020 and SME Masterplan 2012-202 that has their focus on boosting the productivity of SMEs and compliance to global food standard (SMECORP, 2018).

1.7. Research Objective

The general research goal of this study is to design a feasible and competent factory for the small-scale production of reconstituted pomegranate Juice. In order to achieve this, the followings are the specific objectives:-

1. To design an efficient and hygienic food factory system for the small-scale production of pomegranate juice.
2. To analyse the productivity improvement in the new factory compared to the existing juice production using simulation analysis (FlexSim Express).
3. To evaluate the compliance of the new factory to GMP design using Hygienic Design Checklist Tool software.

1.8. Structure of Thesis

This thesis consists of five chapters that explained the whole information about the study in details. It starts with a general introduction that explained the research problem and covers the thesis organization. Chapter 2 is the literature review which contains background information on the research problem. Chapter 3 is the methodology for this research which consists of the design steps involved and the software used throughout this research. Chapter 4 is the results obtained from the simulation and the stage design steps while Chapter 5 is the discussions based on the results obtained. The final chapter provides general conclusions on the research followed by acknowledgement.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the studies of food factory design and the current problems occurs related to the production efficiency (productivity) and hygiene as well as the issues and challenges to design a competent food factory for the SMEs. This chapter also include the market potential of the pomegranate juice produced which is produced by the case study company. The chapter ends with method to analyse the design namely simulation analysis and hygienic design checklist.

2.1. Pomegranate Juice

Pomegranate juice is made from the extracted edible parts of pomegranate fruits. There are a few types of juice in the market such as reconstitute juice, fresh juice and not from concentrate juice (NFC). Reconstituted juice is a juice made from a fruit juice concentrate (Welland, 2014). It differs slightly in taste to fresh juices, carrying a different texture and aroma. Juice produced from a juicing machine or pressed is known as fresh juice which the water is removed and reduce it to a concentrate. Then, the non from concentrate juice (NFC) is fresh juice extracted from the fruit and has not been concentrated (Grante, 2014). It is usually judged of higher quality than juice from concentrate and is slightly more expensive. NFC juice is the closest match to freshly squeezed juice (Welland, 2014).

The common method used in Malaysia producing pomegranate juice is by importing the concentrate from producing country such as Turkey (Siddiqui and Akbar, 2018). The concentrate received are chilled in 4 °C to will be reconstituted with water to produce ready to drink (RTD) pomegranate juice. Unfortunately, due to the lack of knowledge of the proper process of pomegranate juice, the local manufacturer will have a problem to reconstitute the concentrate into the juice (Amarra et. al, 2016). Because of that, the quality of the drinks produced is low compared to the original concentrate and cannot give a comparable nutrients to the consumers. The juice produced might lose its colour, aroma and nutrients. Furthermore, some manufacturers have added high percentage of sugar to increase the shelf life and provide sweetened taste (Loncaric et. al., 2018). The addition of the sugar can inhibit the microbial growth and can be stored at ambient temperature (Amarra et. al, 2016). The high amount of sugar in the juice can reduce the antioxidant mechanism in the juice because of the interaction of the sugar with the available polyphenols inside the pomegranate concentrate (Loncaric et. al., 2018).

Pomegranate fruit has been always known as a “superfruit” that contains high vitamin C, which is also known as good antioxidant that helps to fight cancer (Hills, 2003). Meanwhile, its juice contains high concentration of three types of polyphenols such as ellagitannins, gallotannins and ellagic acids which have been shown to help prevent cancer and heart disease (Mena et al., 2011). Pomegranate juice can help improve blood flow to the heart in people with certain types of heart disease and may help prevent the collection of plaque in the arteries. The U.S. Food and Drug Administration have approved the following nutrient content for pomegranate juice which it is cholesterol-free, high in fiber and high in vitamin C (Butler, 2016).

2.2. Market Potential of Pomegranate Juice in Malaysia

The market of pomegranate fruits in Asia has been growing, whereby greater consumption of pomegranate processed product can be observed such as juice due to its high nutritional value (Siddiqui and Akbar, 2018). In Malaysia, the market of pomegranate juice is quite good since it offers high nutritional benefits to the human body. The market share for pomegranate juice in Malaysia is found to increase starting from year 2013 until now according to World Pomegranate Market (2015).

2.3. SME Productivity Issue

Small medium enterprise (SME) in Malaysia are classified as small entrepreneurs that form a businesses that can maintain revenues, assets and employees that below certain threshold. Department of Statistics Malaysia state that there are 37 861 total of SME's in manufacturing sector and 6016 of them are involved in the processing and manufacturing of food and beverage products (DOSM, 2011). In Malaysia, food and beverage manufacturing sector is dominating about 96% establishment by SME (MIDA, 2013). Because of that, SME play important role in driving the Malaysian economic growth due to its high number of establishment and employment in food and beverage manufacturing sector (Zulkifli et al., 2011). Despite the high percent of establishment, there are a few issues occurred that related to Malaysian Small and Medium Enterprise (SME). Wang (2003) stated that SME had to face many challenges in this globalised environment such as lack of financing, low productivity, lack of managerial capabilities, poor access to management and technology, and heavy regulatory burdens, among others. Meanwhile, according to Hasnan et al. (2014), the two major issues faced by SME's operation are low

productivity and hygiene issues in SME factories. This two major issues are in many ways related to the poor factory design system.

Productivity is defined as the measurement of efficiency of the production (Anonymous, 2019). In other words, it measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output (Kenton, 2019). In Malaysia, majority of SME in food and beverages manufacturing sector had shown low productivity that causing the food import bill of the processed food to increase (DOSM, 2015). Consequently, the productivity index has been affected and become negative which implies the poor growth of food manufacturing sector in Malaysia (DOSM, 2015).

According to Shamsuddin et al. (2011), the low productivity of the SME can be caused by the low skill of workers and the technology used by the factory during productions. Moreover, the factory systems have been poorly designed with incorrect capacity, poor layout that not suitable for food factory, wrong material handling and overlook the production volume requirement (Amit et al., 2012). Next, the operator allocation in food factory is another one of factor that can affected the low productivity of the factory (Rani et al., 2014). This is because operators are responsible on performing the process during production and when they are inefficiently allocated, this can affect the output of production and cost. Moreover, it is reported that the poor layout of the small scale food processing had increase the possibilities of inefficient production flow which may lower the factory productivity (Saudah et al., 2015; Ojaghi et al., 2015). In a nutshell, food factory design problems may result in the low productivity as the production can become too long and the yield is however, too low (Hasnan et al., 2018).

2.4. SME Hygiene Problem

Hygiene is an important aspect in a food and beverages manufacturing sector. According to Food Hygiene Regulations 2009, it is compulsory to have a good hygiene system with safe and effective cleaning practises for all the food and beverage production in order to produce goods that safe to consume. It is found that most of SME's have a difficulties to produce a consistent product output and comply with food safety and hygiene standard required (PEMANDU, 2010). Good Manufacturing Practices (GMP) and Hazard Analysis Critical Control Point (HACCP) are food safety management system used worldwide including Malaysia to ensure the production of safe food product. Despite the effectiveness of the GMP and HACCP in ensuring food safety at the manufacturing level, the implementation is low and has not been compulsorily mandated in Malaysia.

In Malaysia, Ministry of Health (MOH) is responsible on the certification of GMP and HACCP. The standards are specified as below:

1. Malaysian Standard (MS) 1514: 2009 Good Manufacturing Practice (GMP)
2. Malaysian Standard (MS) 14: 2009 Hazard Analysis Critical Control Point (HACCP)

Good Manufacturing Practice (GMP) is guidelines that govern the operating conditions in a food premise to enable safe food production. It also a minimum requirements and prerequisite program for HACCP system for the food premise to have a safe food productions that followed Malaysian standards. This prerequisite programs is required to ensure that the manufacturer provide the necessary conditions to prevent cross-contamination and the potential of contamination in food processing. Because of some reasons, the number of food factories in Malaysia that been certified with GMP is still

low. It can be shown in December 2015, about 243 SME companies which is less than 4% of the total of food processing companies only managed to receive GMP certifications in Malaysia (FSQD, 2015). Meanwhile, HACCP is a food safety management system addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product (FQSD, 2015). To get a HACCP certification, the food premise must apply the GMP certification and comply with current legislation and standards. According to Food Safety and Quality Division (FSQD), Ministry of Health Malaysia (2019), this certification give many benefits to the manufacturer to attract the customers and also can increase the demand of the product at local and international level. Due to the low number of food factories that certified with GMP, Jali et al., (2016) discovered SME perceived the design according to GMP requirement are complex and subjected to many misunderstanding.

Food Safety and Quality Division Ministry of Health Malaysia (FQSD), 2015 had inspect a total of 124,254 food premises and about 2,422 which is 1.9% from total of food premises were closed due to insanitary food premises under Section 11, Food Act 1983. The hygiene problems can be related to the poor factory design. The incorrect ventilation system can cause the airborne contamination to the product during production because it can transfer the airborne particles to food (Graham, 2011). Factory layout is an important criteria of a hygienic factory and the improper layout can cause inefficient of work area location that increase the possibility of contamination (Lelieveld et al., 2014). Poor layout of factory design also leads to poor production that experienced the problems such as cross-contamination, pest infestation, inefficient material and operators flow and

excessive moving distance during the production (Ojaghi et al., 2015; Hasnan et al., 2018). Insufficient facilities such as changing room and hand wash station inside the food factory are also the factor that lead to poor hygienic design (Jali et al., 2016). This is because lack of facilities can cause the workers to have a low hygienic exposure and transmit the bacteria and pathogens during working. In brief, the poor factory design especially the neglect on sanitary design will provide poor environment to the food factory and causing quick food spoilage due to unhygienic condition (Jali et al., 2016).

2.5. SME Challenges to Design Food Factory

According to Manzini and Accorsi (2013), analysis, evaluation, design, planning, management and control activities are important to define the performance and problems related to food quality and safety, costs efficiency and environmental sustainability. A proper food factory design is an important aspect in producing a safe practices and food production. Food factory design is however unique as food is perishable items that have inconsistent quality and varied shelf life. Their quality and shelf life are influenced by many factors such as temperature, humidity, raw material and technology used to extend their shelf life (Manzini and Accorsi, 2013). Moreover, food is consumed by the humans and animals, so the food produced must be safe and clean from pathogens. Because of the reasons, food factory design which have a proper layout, an efficient process and hygienic aspects are important in food and beverages manufacturing sector (Hasnan et al., 2014). The design requirement have been guided in MS 1514 Good Manufacturing Practice for Food, and yet, its translation into physical factory design has been challenging and confusing for the SMEs due to limited capital, skill and food knowledge (Jali et al., 2016; Ab Rahman and Abdul Ghani, 2017; Hasnan et al., 2018).

Their constraints also impeded their capability to design an efficient factory. The design of food factory for high productivity has not been properly guided in the literatures, agency's guideline or standards (Addy, 2015). There have been certainly several researches that address certain design aspects as operators' allocation, information flow, layout, materials flow and equipment. Nevertheless, too often these 'inter-dependent' aspects are viewed separately. There is a lack of coordination to develop a highly efficient food factory system. Meanwhile, the literatures such as handbooks usually covered wide area, spreading across different type of processes in developed countries with multiple design alternatives and solutions (Baker, 2013; Lelieveld et al., 2014). They aim to provide a comprehensive solution on the certain design aspect, which results in a brilliant individual item but not the performance of the whole factory. Hence, an understanding on how the system design can affect the production efficiency remains unclear for the food SMEs who depend heavily on the information that can be obtained from agencies or published information, since they are not able to hire food specialist to design their factory.

2.5.1. Lack of Knowledge

According to Razdi et al., (2017), the lack of knowledge of the workers and inexperience business partners are the cause of the inefficient production. Inefficient production can cause the loss of market and customers when the manufacturer cannot fulfil customers demand. More than that, lack of training to the workers especially operators will be the challenges to the SME since the operator worked are from foreign country. Next, Hashim and Wafa, (2002) and Muhammad et al. (2010) identified that the main problems faced by SMEs in Malaysia are the lack of knowledge regarding marketing skills, branding, customer loyalty and also lack of good connection with local and international customers.

Social barriers on Malaysia's SME had become a problems for the manufacturers to compete with other manufacturers and most of them lose the chances to expand their business (Alam et al., 2011).

2.5.2. Lack of Finance

Financial problems is the one of SME challenges faces by the entrepreneurs in Malaysia (Hasnan et al., 2014). Most of the SME in Malaysia still cannot compete with international product due to the lack of finance source. Moreover, it is hard for SME to gain the capital during their first start up since they have to compete with large sector companies (Radzi et al., 2017). A high income or capital of the company help to produce a high quality products and meet the standards required by local and international level for the export purpose (Aris, 2006). It can be proved by the survey conducted by Zain et al., (2012) which stated financial problems and complicated loan procedure are the main problems facing by the respondents from food factory sector.

2.5.3. Informal and Unsystematic Design Method

Due to the financial problems, SME's in Malaysia are having a problems to hire the good skills workers and the professionals such as consultants and workers. This is because most of the skill workers and professionals cost is too high and the existing staff productivity is low which automatically causing the unsystematic factory design (Zain et al., 2012). Usually, with the help of professionals, manufacturers can proposed a proper food factory design with a several method used such as trial and error method before designing the factory. Informal and unsystematic design method had led to the increasing of the production problems and affected the manufacturers. As a result, the poor food factory

design cannot cope with the customer demands and had a poor hygienic system of factory (Ojaghi et al., 2015; Kingphadung and Choothian, 2016; Jali et al., 2016).

2.6. Design of Hygienic Food Factory

A food premise is a place where the process of making product starting from the receiving of raw materials until shipping process happened. In Malaysia, it is compulsory for the manufacturers especially the SME's to design food premise with a hygienic aspects and easy for cleaning and maintenance purpose according to Food Hygiene Regulations 2009 or known as Peraturan-Peraturan Kebersihan Makanan (PPKM 2009). But there is no specific guideline of this regulations and it just enforced by the law. The first guideline in designing hygienic food factory is produced in 2009 which known as Malaysian Standard (MS) 1514 Good Manufacturing Practice (GMP). The guideline is located in Section 4 of the standard and used as a guidance for the industries in Malaysia by providing the complete and detail requirements needed to design a hygienic food factory (SIRIM, 2009). The main objectives of hygienic design are to ensure that location, design and construction of food premises, equipment and facilities are capable to achieve (SIRIM, 2009):-

- 1) Minimization in contamination;
- 2) Design and layout allow appropriate maintenance, cleaning and disinfection and minimize air-borne contamination;
- 3) Surfaces and materials, especially food contact surfaces are toxic free in intended use, suitably durable and easy to maintain and clean;
- 4) Suitable facilities are available for temperature, humidity and other control;
- 5) Provide effective protection against pest access and harbourage.

The summary of the standard requirement for the GMP Design in MS1514 is given Table 2.6.1 below:

Table 2.6.1: Summary of GMP Design

Design Elements	Summary
Location	In particular, the establishment should be located away from areas subject to flooding, area prone to pest infestations, areas where wastes, either solid or liquid, cannot be removed effectively and areas which are environmentally polluted with industrial activities that can pose potential and serious threat of contaminating food.
Premises and room	<ul style="list-style-type: none"> • Layout: Should permit good food hygiene practices, including protection of foodstuffs against cross-contamination during and in between operations. • Internal structure and fitting: Should be soundly built of durable materials and be easy to maintain, clean and where appropriate, able to be disinfected.
Equipment	<p>General design: Should be made of materials with no toxic effect in intended use. Where necessary, equipment should be durable and moveable or be disassembled to allow for maintenance, cleaning, sanitisation and to facilitate inspection for pests.</p> <p>Design of control and monitoring equipment: Equipment used to cook, heat treat, cool, store or freeze food should be designed to achieve the required food temperatures as rapidly as necessary in the interests of food safety and suitability and maintain them effectively.</p>

Table 2.6.1 Continued

<p>Facilities</p>	<ol style="list-style-type: none">1) Water supply: An adequate supply of potable water with appropriate facilities for its storage, distribution and temperature control, shall be available to ensure the safety and suitability of food.2) Drainage and waste disposal: Drainage channels are fully or partially open, they are to be so designed as to ensure that waste does not flow from a contaminated area towards or into a clean area, in particular an area where foods likely to present a high risk to the final consumer, are handled.3) Cleaning facilities: Adequate facilities, suitably designated, shall be provided for cleaning food, utensils and equipment.4) Personal hygiene facilities: Include adequate means of hygienically washing and drying hands (wash basin and sanitizers), adequate number of toilets and not to open directly into rooms where food is handled and adequate changing facilities for personnel.5) Temperature control: Depending on the nature of the food operations undertaken, suitable facilities of sufficient capacity should be available to ensure safety and suitability of food.6) Ventilation system: Should be designed and constructed so that air does not flow from contaminated areas to clean areas and can be adequately maintained and cleaned.7) Lighting: Adequate natural or artificial lighting should be provided to enable the undertaking to operate in a hygienic manner.8) Storage: Adequate facilities for the storage of food, ingredients and non-food chemicals such as cleaning materials or lubricants should be provided.
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The specific hygienic design requirement which is the layout of the factory by standard of GMP in Figure 2.6.1 are shown but the technical methods to achieve the requirements are not explained well. It is one of the SME's challenges where the misunderstanding and the confusion of SME's entrepreneur will occur due to the lack knowledge in designing food factory (Jali et al., 2016).

According to Food Safety Magazine (2013), there are several organizations worldwide that involved in hygiene design and constructions of food premise. The organizations involved are European Hygienic Design Group (EHEDG), National Sanitation Foundation (NSF) International and 3A Sanitary Standards (3A SSI) (Schmidt, 2013). 3A Sanitary Standards (3A SSI) is the best equipment standards in dairy industries but nowadays, many food entrepreneur have recognize this standards and used it for equipment purchases.

According to Hygienic Design of Food Manufacturing Premises written by Holah (2014), hygienic food factory design must able to protect the factory from internal and external hazards. It also must compliance with the customers and give the best hygienic practice. In the hygienic design guideline, it also placed the importance on the design of the small food manufacturing facilities. The proposed new concept of hygienic factory design such as hazard management, wall and floor interfaces, drains and floor characteristics, entrances and hygiene steps and the suitable services required such as electricity and lighting needed as a guideline for the manufacturers to design a hygienic food factory. Moerman (2010) and Holah (2014) had discussed that the importance to design the barriers in the food factory to prevent the unwanted pathogens and hazards. The design of barriers are consisted about 4 level as below:

- Level 1 : Concerns about outer premise
- Level 2 : Concerns about factory buildings
- Level 3 : Zoning establishment within the plant where each of which have different hygienic requirements and restricted access
- Level 4 : Concerns about finished product enclosure

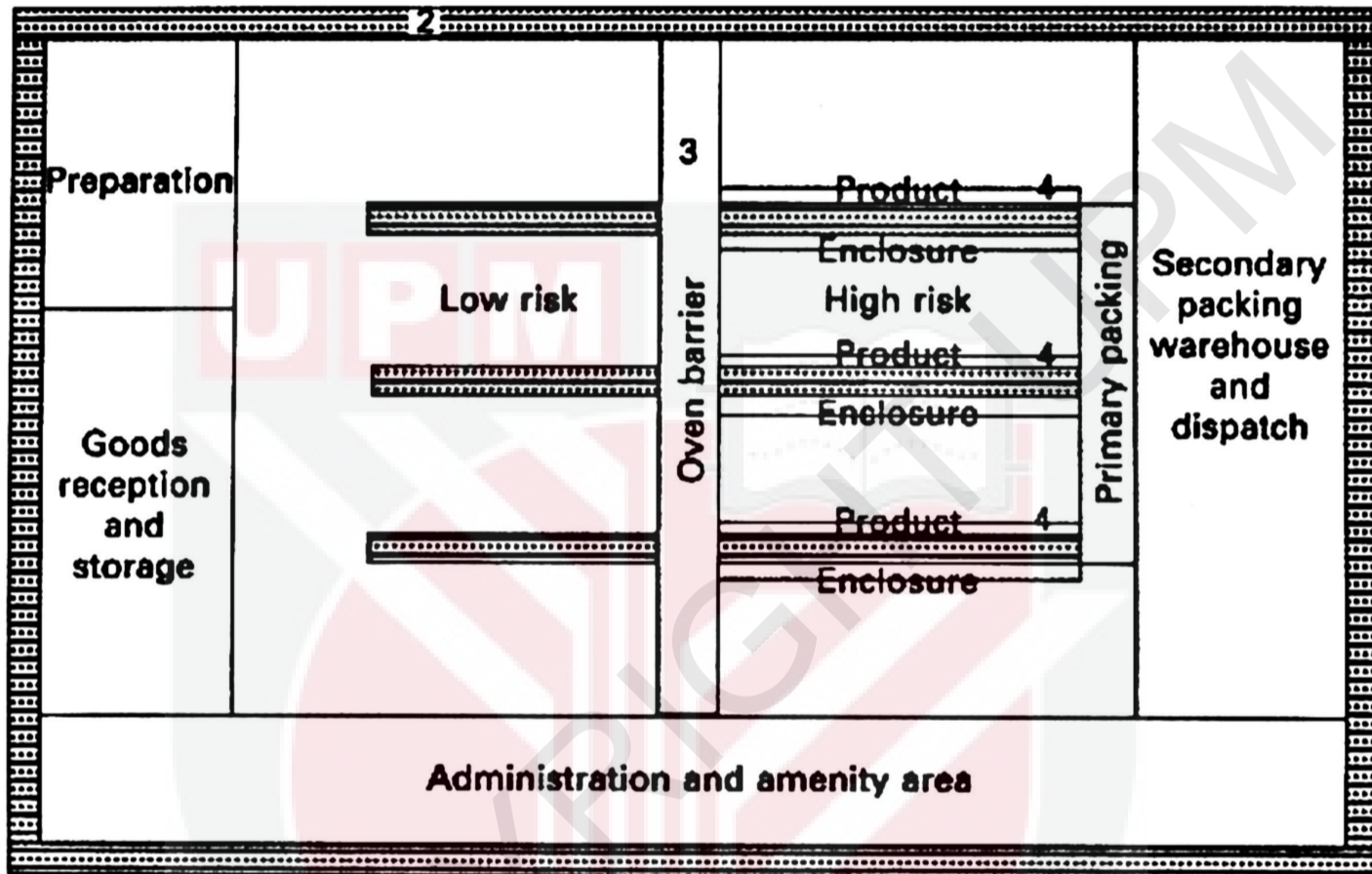


Figure 2.6.1: Schematic Layout of a Factory Site Showing 'barriers' Against Contamination. (1) site, (2) main factory buildings, (3) walls of high risk area, (4) product enclosure within high risk (Holah, 2014)

Other hygienic design aspects that have been explained by Moerman (2010) in Table 2.6.2

below:

Table 2.6.2: Hygienic Design Aspects

Design	Technical implementation
Zoning	Zoning and the establishment of barriers
Layout	Appropriate layout and design of the food factory according to hygienic requirements
Integration of Piping	Hygienic, chemical-resistant, durable and easy to maintain piping system
Penetration of Piping through Walls, Ceilings and Floors	Not run in the vicinity of or cross utilities that transport process aid
Chemical and Wear-resistant Floors	Sloped toward drains and provided with curbed wall floor junctions
Lighting	Illuminate horizontal and vertical working surfaces evenly
Piping	Sanitary Insulation of Piping
Control panel	Hygienically control panel design with high ingress protection rating

2.7 Integrated Design Method for Food Factory

There are many general design method that can be used to design food factory. The literatures are mostly aimed to provide comprehensive understanding on individual design of factory components and describe the variety design of factory approach. Holah (2011) has stated in his design regarding the solution on hygienic design for different parts of the factory. Meanwhile, the principles of food process with explanation on processing line, operating parameters, mass and energy balance, fluid properties and thermodynamic has been described by Saravacos and Kostaropoulos (2002) in their literature. Yet, a step-by-

step procedure to design an entire specific factory from beginning is hardly found in the literatures. Thus, it is not well understood how every individual design fit in the overall design process and often, overlook the unique considerations for food processing SMEs.

Hasnan et al. (2018) has specifically covered the procedural form (stage by stage) to design the entire burger patties factory with explicit requirement on production efficiency and hygiene. The procedures also oriented the design according to the manufacturing system elements such as material, process, machine, facilities, logistic and operators. The design starts with the production output and capacity planning in accordance to demand, process planning, machine capacity and selection, layout design, space and workforce allocation and building design. The advantages of the procedures is the simultaneous incorporation of hygienic and efficiency techniques in the design of food factory system. At the end of the design, a new food factory specification can be obtained with a defined Production Program, Process Specification and Flow Sheet, Machine List, Room Design Data Sheet, Space and Workforce Program, Layout and Building Specification. The procedure flow is given in Figure 2.7.1 and Figure 2.7.2 (Hasnan et al., 2018) which will be used in this final year project. The details of the design procedure is given in Chapter 3 Methodology.

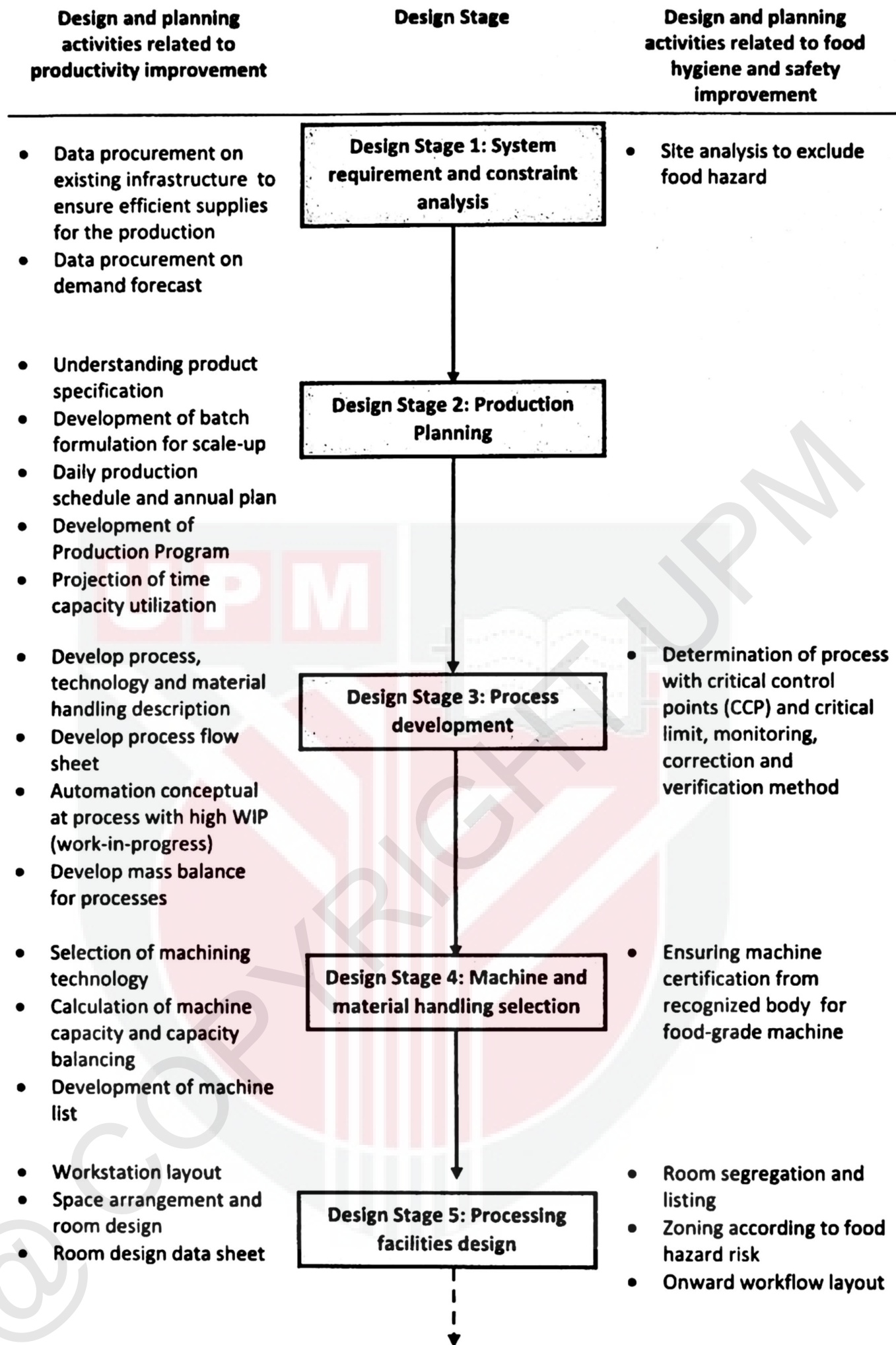


Figure 2.7.1: Design Procedures for Food Factory System (Hasnan et al., 2018)

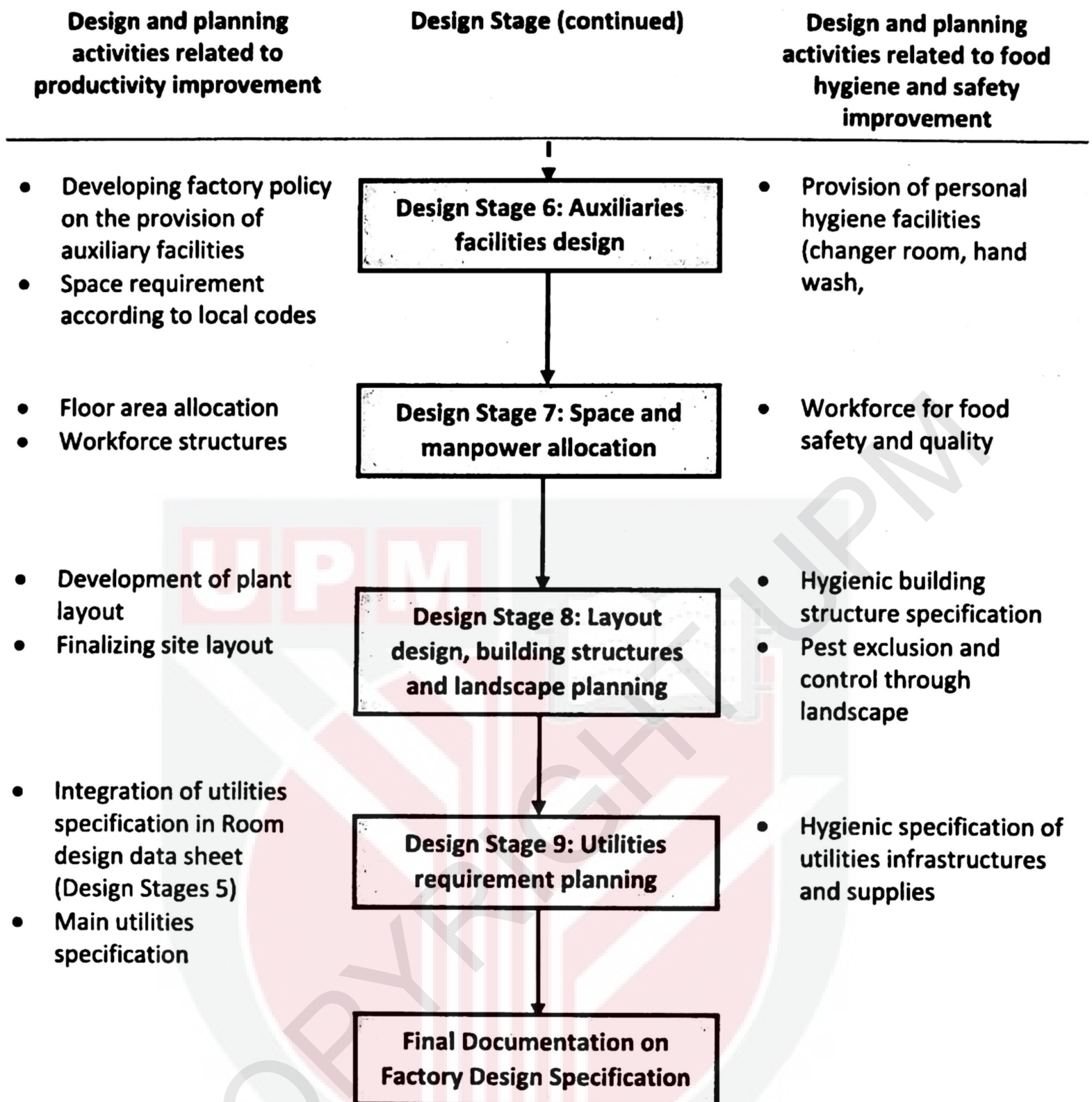


Figure 2.7.2: continued: Design Procedures for Food Factory System (Hasnan et al., 2018)

2.8 Design Analysis Method

This section provides the design analysis method that were found to be useful for this study. It is important to carry out design analysis to evaluate whether the factory system design developed in this study is able to achieve the required productivity and hygienic design.

2.8.1 Productivity Analysis using Simulation and Modelling Analysis

Simulation software is an analysis tools that widely used in manufacturing system design areas which helps to imitate the characteristics of the systems by using a several method and applications (Dwijayanti et al., 2010; Amit et al., 2012; Negahban and Smith; 2014; Rani et al., 2014a). Arena, QUEST, IGRIP, ProModel and Witness are the simulations software tools that commonly used for design analysis (Dwijayanti et al., 2010; Rani et al., 2014a). There is a study such as Discrete event simulation modelling of patient service management with Arena by Guseva et al., (2018) were using Arena software to evaluate the workload staff in the clinics and also to determine the number of doctors required for the patient in order to improve the efficiency of clinic operations in terms of service and time consumptions. For the factory design, simulation software helps the designer or engineer to design the factory system based on the output requirement output needed by the manufacturer as the software can run the system and show its behaviour when the system is operating (Dwijayanti et al., 2010; Amit et al., 2012; Negahban and Smith, 2014). By using the simulation software, the user can observe the effect systems with a different variables such as time and decide to use a suitable characteristics through the simulation process. With the simulation software, the system environment can be controlled and determined based on the user requirement while the experiments need to be repeated several times in order to get an accurate results (Altiok and Melamed, 2007). Basically, simulation are preferable to be used as it can verify the design functions and characteristics as the cost of plant development and testing are expensive and involved another parties. Because of that, simulation are recommended to be used to improve the existing system since it did not disturb and effected the actual system when the evaluation is performed (Amit et al., 2012; Rani et al., 2014a).

In food processing industry, simulation software are widely used to calculate the productivity lead time in order to have an efficient productions (Rani et al., 2014a). It can be showed by Hecker et al. (2010) that used a simulation models to study the effect of changes on the operators working time in a bakery factory. The study managed to resolve the problems such as the bottlenecks, the waiting time between the station and the utilization of the machines occurs in the factory. Amit et al. (2012) had redesigned the layout of snack processing plant using systematic layout planning (SLP) approach. The proposed layout was evaluated using ARENA Simulation Software and showed improvement in total travel distance, total travel time, total travel cost and output. Abed (2008) reported that the productivity of the food processing which is rusk production were increased by using the simulation software as it can improved production outputs and solved the bottlenecks problem in the factory. In the service sector, Flexsim Modeling and Simulation are used to analyse the fast food service capability by using a fast food restaurant in Malaysia as an example to improve their operational performance in order to overcome poor service operations (Heng and Zhongmin, 2016). The above studies have shown that simulation is a suitable method to analyse problems faced by food manufacturers and improve the performance of the factory systems. Nevertheless, simulation can only provide reliable evaluation, when the model is validated and verified (Rani et al., 2014).

For this project, FlexSim software are used for investigating the effectiveness of the developed juice factory design in increasing productivity. FlexSim is a powerful yet easy-to-use software for simulation. A comprehensive and innovative simulation engine is hidden behind drag and drop controls, drop-down lists and many other intuitive features

that make it accessible for anyone to model the manufacturing system and analyse the change in model setting. All simulation model are created to a defined scale and are presented using 3D visuals, so it becomes easy to view and recognize bottlenecks in the production line or other deficiencies within the system. FlexSim also gives decision makers the tools to confirm their observations, with impressive statistical reporting and analysis built right into the software.

2.9 Hygienic Design Analysis

The hygienic design evaluation is carried out based on a review of technical drawings and design specifications before the actual building is constructed. In addition, the European Hygienic Engineering and Design Group (EHEDG) database has recommended the use Hygienic Design Checklist Tool, developed by the American Grocery Manufacturers Association (GMA), to quantitatively evaluate whether the designs complied with the hygienic design principles. Another useful hygienic design checklist has also been developed by EHEDG which is named as Hygienic Building Design Checklist and is contained in DOC 44 Hygienic Design Principles for Food Factories. However the checklist only provide qualitative results compared to Hygienic Design Checklist Tool by GMA showed in Figure 2.8.1.



11 Hygienic Building Design Checklist

Site

- Have appropriate surveys been undertaken to ensure that the site (soil, water, subsurface structures etc.) is free of hazardous chemicals and/or pollution?
- Has a survey been undertaken to list the potential hazards to the food product from the surrounding site environment (Industrial activities, farm activities, water sources, waste areas, pests etc.) with particular reference to prevailing wind conditions?
- Is the site subject to flooding and is there adequate freeboard over water levels?
- Is the site free of structures and vegetation that could encourage or harbour pests?
- Are raw materials, finished product or packaging stored on the site which could be subject to deliberate or accidental contamination?
- Are entrances to the production facilities and walkways appropriately lit at night?

Boundary fences and walls

- Is the site secure from unwanted pest and human activities?

Buildings

- Are buildings appropriate to the food processing operations that they contain?
- Are buildings sited with respect to prevailing winds and ground levels?
- Is the level of the factory floor higher than the surrounding ground levels?
- Is adequate space available to allow hygienic operations, maintenance, cleaning and pest control activities?
- Is sufficient space available above, below and around equipment and service structures to ensure that they are effectively cleaned, maintained and free of pests?
- Is personnel access to food production areas adequately controlled with a minimum of entrances?
- Does the structure adequately prevent the ingress of external hazards, particularly with respect to doors, windows, service entries, exhausts and drainage?
- Are the flows of product, packaging, personnel, services and wastes designed to minimise cross-contamination?

**Figure 2.8.1: A partial view on Hygienic Building Design Checklist by EHEDG
(2014)**

In this study, the GMA Hygienic Design Checklist Tool is used to evaluate the drawing and designs specification of the juice factory. The complete GMA checklist tool is provided in the *Appendix C*. The use of GMA checklist provides an insight on GMP design achievability, since the GMA council consisted of a Standards Committee that examines the standard-setting bodies including Codex and ISO (GMA, 2016).

The checklist is divided into ten sections as shown in Table 2.8.1. Every section has several criteria to be evaluated and scored. The questions are answered by either “S” for satisfactory, “M” for design is marginally acceptable, “U” for unsatisfactory or “NA” for

requirements is not applicable in that design case. Points are automatically given by the tool based on the answers. A full score shows the hygienic design is satisfactory, while a score of less than 100% requires the design to be improved (Nikoleiski, 2012).

Table 2.8.1: Ten sections in GMA Facility Design Checklist

Section	Principles
1	Distinct Hygienic Zones Established In The Facility
2	Personnel and Material Flows are Controlled to Reduce Hazards
3	Water Accumulation Controlled Inside Facility
4	Room Air Flow and Room Air Quality Controls
5	Site Elements Facilitate Sanitary Conditions
6	Building Envelope Facilitates Sanitary Conditions
7	Interior Spatial Design Promotes Sanitation
8	Building Components and Construction Facilitate Sanitary Conditions
9	Utility Systems Designed To Prevent Contamination
10	Sanitation Integrated Into Facility Design

The total points for the checklist is 1000 corresponding to 106 criteria. If the evaluation scores is between 50 to 100%, a continuous improvement is required. The score below 50% shows the hygienic design is unsatisfactory and a redesign is required (Nikoleiski, 2012).

CHAPTER 3

METHODOLOGY

This chapter presents the method used to achieve the objectives of this research project. Firstly, there will be an overview about the case study company. Next, the work flow of the project is presented. Every stage of the project will be explained on how it was performed.

3.1. Case Study Object

Prior the design stages, it was important to understand the company's profile and its current production. Therefore the information was procured by periodically discussion with the companies, site observation and document's revision. The following sections described the information on the company and its production.

3.1.1. Company's Profile and Product

Company X is a local company producing pomegranate juice since 2012. It also is one of the small and medium enterprise (SME) company. Based on SME Corp, a small and medium enterprise is a defined as a company with a small number of full time employees which not exceeded 200 employers and having an income or sales not more than 50 million per year. The main product produced by Company X is pomegranate juice named

Jus Minda and the production of the juice is located at a small premise in Jalan Gerimis, Kuala Lumpur. The floor size of the premise are not stated in the information of the project since it has some confidential issues. In this company, the total numbers of workers including the operator in administration and production department is 6 workers. Every month, the productivity of the company is about 720 litre and produced 2400 bottles of pomegranate juice bottled in 0.33 litre PET bottles and also bottled in 0.5 litre bottle according to customer's demand per month. The cost of the juice per bottle is RM 1.50 and it is sold for RM 3.00 per bottle. The current process flow for the production of the pomegranate juice is shown in 3.1.1 below:

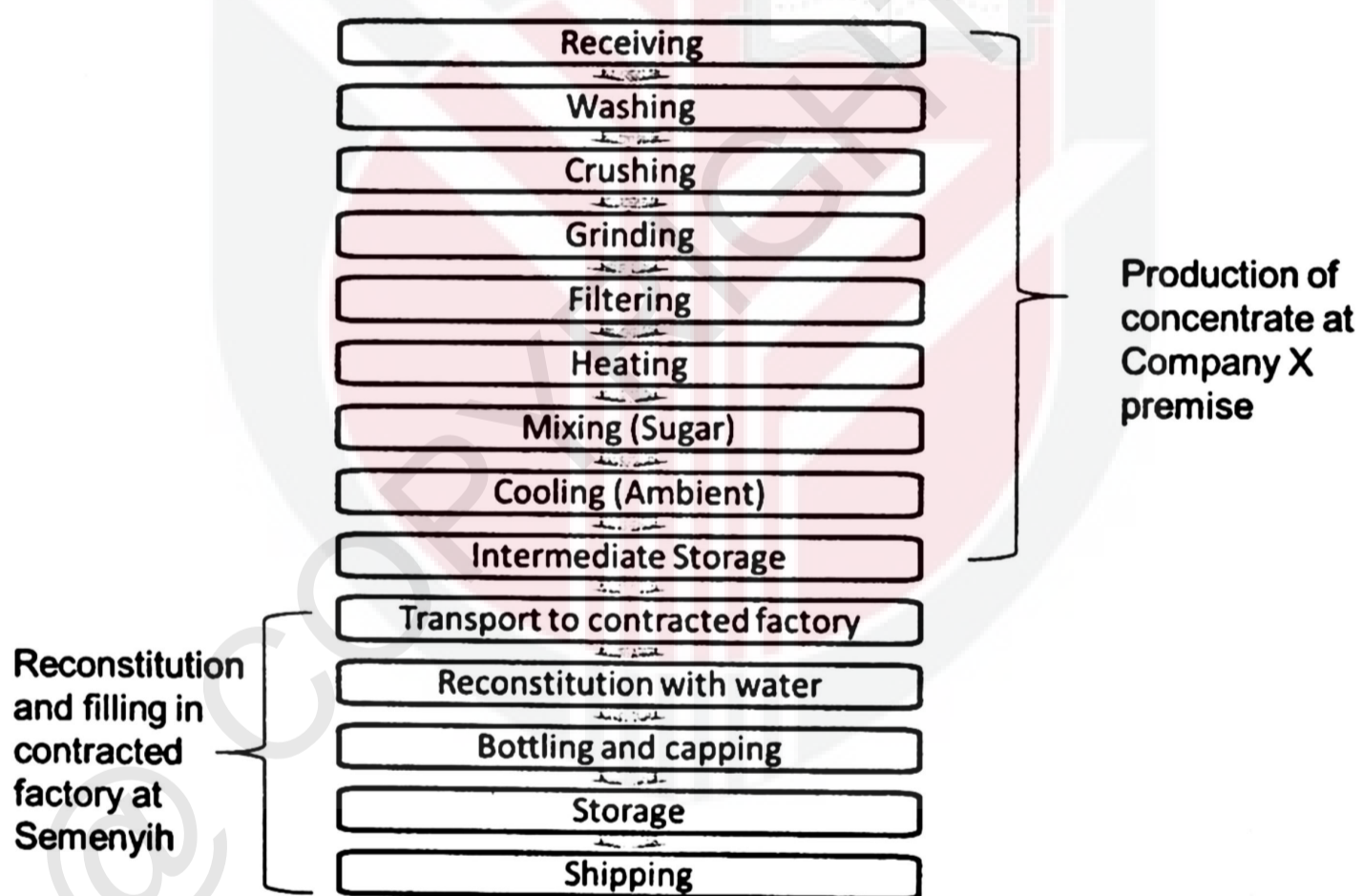


Figure 3.1.1: Current Processes of Pomegranate Juice

3.2. The Overall Methodology

For the overall methodology of the projects are consists of a few phases namely project initiation, design and engineering, project monitoring and closing of the project. The chart in Figure 3.2.1 showed the 4 phases of the project.

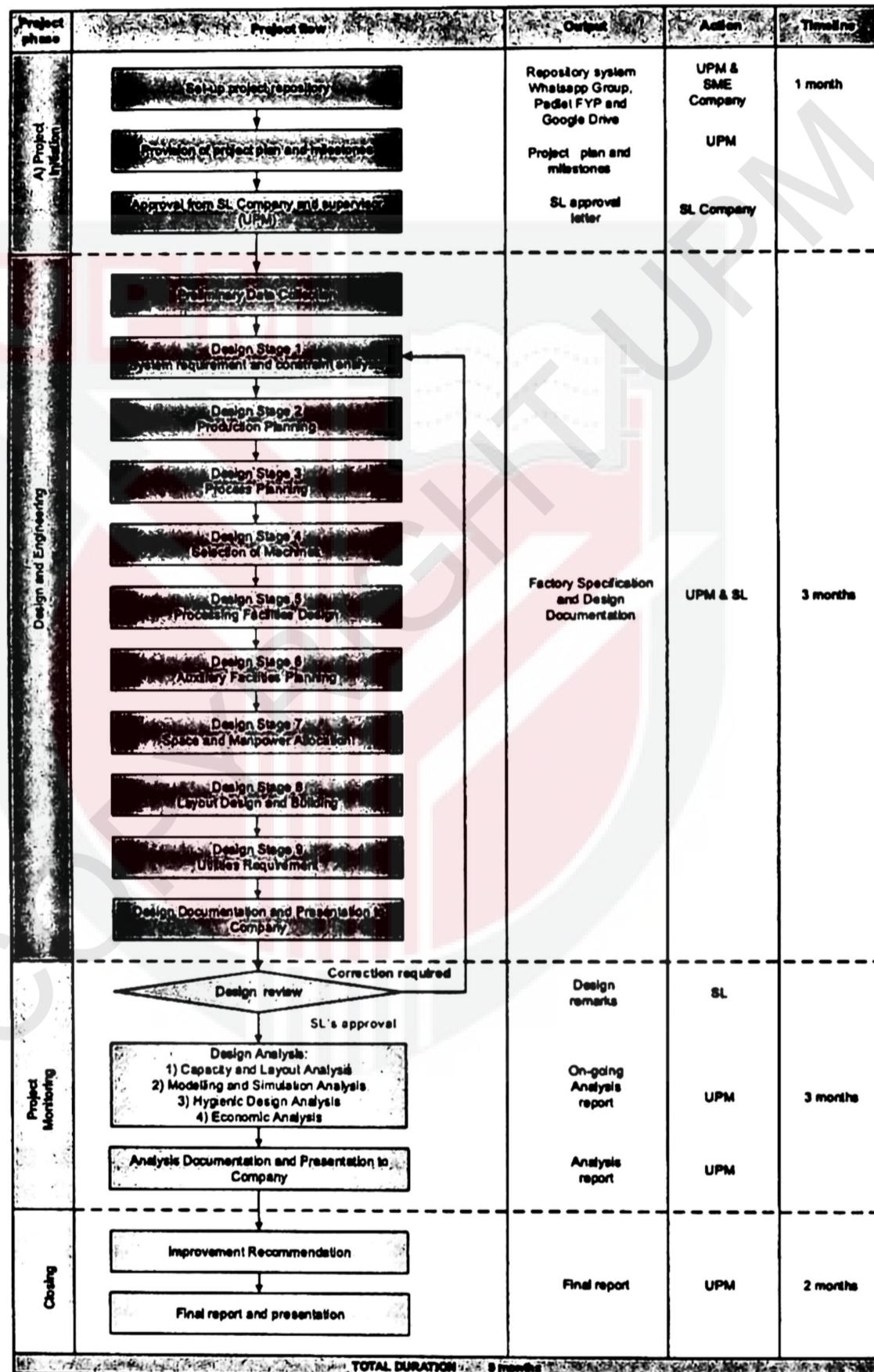


Figure 3.2.1: Overall Methodology

3.2.1. Phase 1: Project Initiation

The project begins with setting up the project repository to allow communication between parties involved in the project. This include WhatsApp group, Google Drive and Padlet software that helps to store the journals and references. The project plan, proposal and schedule was developed and submitted to the department as well as the Company F. Upon approval by the department and the industry, the project proceeded to Phase 2: Design and Engineering that is detailed out in Section 3.2.

3.2.2. Phase 2: Engineering and Design

Before proceeding with the design activities, the potential location of the New Factory X in Pusat Perindustrian Sungai Chua, Kajang was visited on 15 February 2019 located in Figure 3.2.2. The New Factory is to be accommodated in a terrace factory which have a 9 m x 30 m x 3 m measurement on the ground floor.

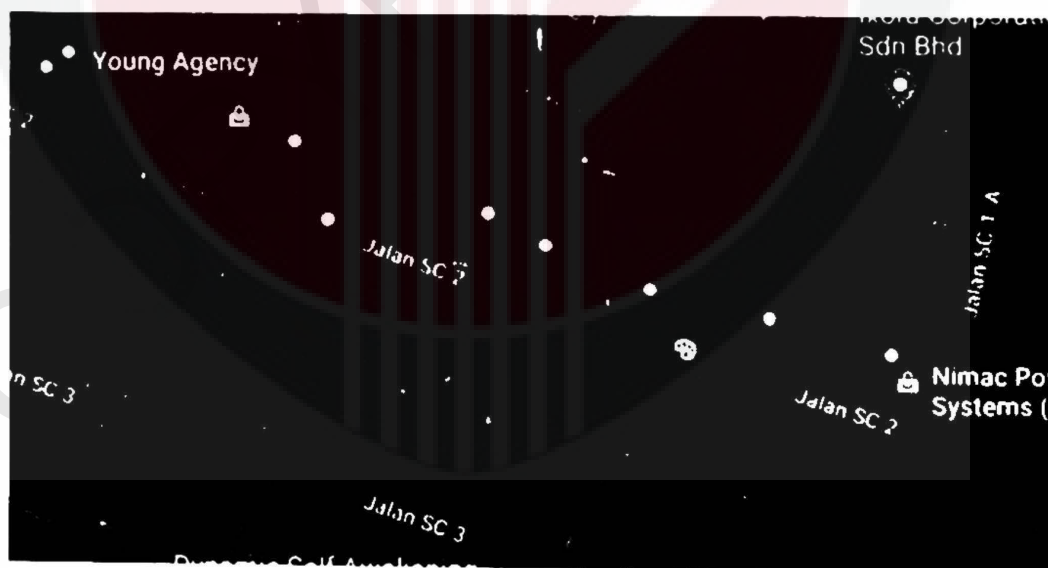


Figure 3.2.2: Location of Factory X

This project applies nine design stages as shown in Figure 3.2.3 for the factory system of pomegranate juice (Hasnan et al., 2017). The execution of the design stages are described in Section 3.2.2.1 to 3.2.2.9.

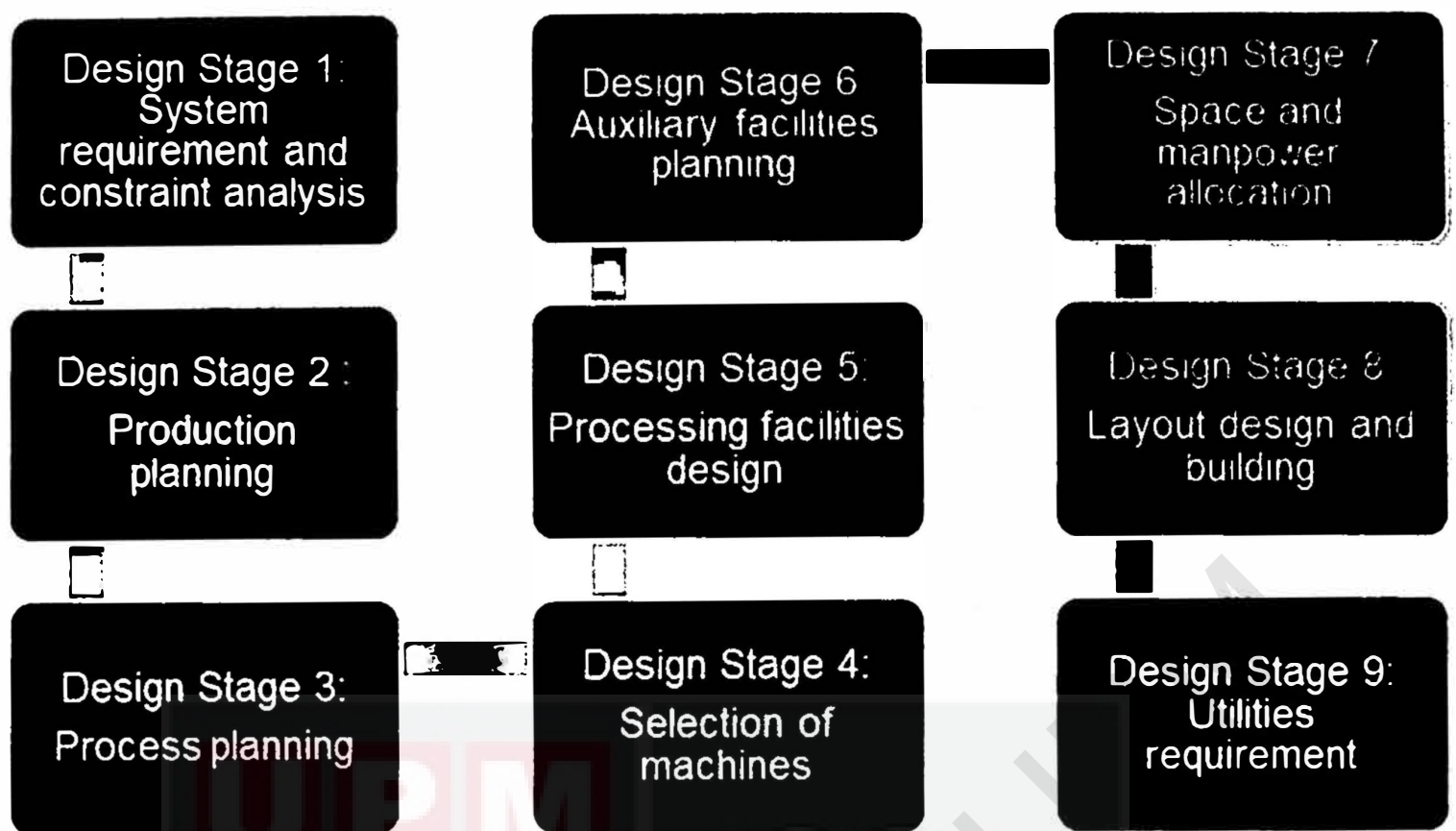


Figure 3.2.3: Nine Design Stage

3.2.2.1 Design Stage 1: System Requirement and Constraint Analysis

Design Stage 1 was required to address the production size, and the external conditions that the designated pomegranate juice factory must satisfy. This was performed as follows:

3.2.2.1.1. Production Requirement of the Pomegranate Juice

The production requirement was defined by the specifying total expected yearly production volume (PV) for the pomegranate juice based on the demand forecast.

3.2.2.1.2. Compliance to Statutory Requirement

The local code of practice that related to the food factory designs, premise and the production of drinks were reviewed in order to ensure the design of the factory system will comply with the statutory requirement. The codes and related legislation were requested from the local authority (LA) which is Majlis Perbandaran Kajang and also

searched from the Food Safety and Quality Department (FSQD) website in Ministry of Health.

3.2.2.1.3. Site Analysis

The analysis was done based on the basic data of the property e.g. exact location, property size, shape, contour, building height, floor loading, traffic access, available utilities and market proximity. The purpose of this analysis was to determine the constraints and advantages that would affect the factory design.

3.2.2.1.4. Plot Plan

Upon completing the site analysis, the plot plan was sketched as to provide the first overview on the arrangement of the factory. The food processing activities was decided to be accommodated in a single-storey floor. The property was oriented to have access to the existing road (where available) and the building façade would face the main road for show-purpose of company's signage. The data on the existing utility supply (voltage supply, water pressure, communication line) was checked and detailed out with the services provider. The services were checked whether they conformed to the local authority requirement on food processing.

3.2.2.2. Design Stage 2: Production Planning

Design Stage 2 was required to plan the production as to meet the system requirement.

The following planning activities were performed.

1) Understanding of Products

The juice products was defined in term of the composition of juice, bottle type and size as well as the secondary packaging. This was aided by the product specification and a model

shop sample that was obtained from Company X. Taking into account the unique characteristics of food materials, other attributes such as shelf-life, perishability, and nutrients compositions were also defined (Manzini and Accorsi, 2013).

2) Development of Production Program

Production Program was developed by tabulating an annual production output for the juice product. The content of Production Program includes the types of juice, unit sale size, primary and secondary packaging, forecasted production volume for one year period in the first phase.

3) Development of Batch Formulation

The product formulation or the recipe was obtained from Company X and was then reformulated as the batch formulation with one batch size (B) was decided to be 300 litre. This batch size was decided by considering the commonly available small-scale mixer loading size that can be found in the juice industry. This also ensures the availability of the mixer to be purchase from the market. Other information that was needed was the listing of the materials sources, material specifications, the volume of the juice produced every day, the packaging and identification number of the product produced and the preparation of the inspection of incoming and the shipping process of the product. The quantity of material required per batch must consider the estimated yield and losses after the processing complete. This is done by or using industrial estimation for yield and losses based on historical production data.

4) Calculation of Production Days Capacity Per Year (DP)

D_P determines the number of available days for production activities and was calculated using Equation 1.

$$D_P = D_W - (D_{M/R} + D_{Clean}) \quad \text{Equation 1}$$

Whereby,

$$D_W = 300 \text{ days (average working days/year)}$$

$$D_{M/R} = \text{number of days for scheduled maintenance (5 days)}$$

$$D_{Clean} = \text{number of scheduled cleaning days (5 days)}$$

a) Daily production time, T_{DP} using Equation 2.

$$T_{DP} = (S_D \times T_{Shift}) - T_{Idle} \quad \text{Equation 2}$$

b) Calculation of production hour capacity per year (T_P)

T_P is the yearly production hours capacity and can be calculated using Equation 3.

$$T_P = D_P \times T_{DP} \quad \text{Equation 3}$$

c) Calculation of number of batches per year (n_B/a) using Equation 4.

$$\sum n(B)/a = \left(\frac{PV}{B}\right) \text{ in batches/year} \quad \text{Equation 4}$$

With,

$$PV = \text{Production volume/year (L/year)}$$

$$B = \text{Batch size} = 300 \text{ L}$$

d) Batch Cycle Time (t_{BC})

The batch cycle time, t_{BC} is the time taken to complete one cycle (batch) of production and was calculated based on method suggested by Jung (2010) using Equation 5.

$$t_{BC} = \frac{T_p}{\sum n(B)/a} \text{ in hr/batch} \quad \text{Equation 5}$$

e) Number batch per day, B_D using Equation 6

$$B_D = \frac{T_{DP}}{t_{BC}} \quad \text{Equation 6}$$

f) The actual number of production days, D_x

D_x is different from D_P as D_x determine the actual number of days taken to complete the total number of batches per year (nB/a) while D_P tells us the number of available days throughout the year for working on the production (time capacity). D_x was calculated using Equation 7.

$$D_x = \left(\frac{n(B)/a}{\text{Number of batch per day}} \right) \quad \text{Equation 7}$$

g) The utilization of production time capacity, (U_D)

(U_D) is determined as the ratio of the actual number of production days (D_x in days/y) relative to the production day capacity (D_P in days/y). This is given in the Equation 8 as adapted from Groover (2007).

$$U_D = \frac{D_x}{D_P} \quad \text{Equation 8}$$

When $U_D \geq 1$, this implies the $\sum D_x$ has exceeded D_P . Thus, the production activities are not able to meet the demand in a timely manner. This requires the company to consider decreasing the batch cycle time or increasing the batch size, number of shift, operator, machines and duplicating the production line. The ratio value of 0.6 to 0.8 is recommended since this means the production capacity is not too “tight” and able to meet

the customer deadlines as well as cater the surge demand (Saravacos and Kostaropoulos, 2005).

3.2.2.3. Design Stage 3: Process Planning

Design Stage 3 is required to develop the processing steps for the production of yam bean snack. The planning steps were executed as below:

1) Process Flow Development

This was done by firstly discussed with the company on their existing process. Based on their requirement for the process function, operation, technological requirement and products improvement suggestion, a new process flow was developed based on the review on the existing processes for the juice reconstitution in the literatures. The testing of the process flow was carried out by the company themselves and was not included in this scope of the project.

2) Process Technology

The common technology for each individual process step in the process flow was researched. The parameter and operation were selected based on process purpose. Illustrations on the common processing technology are included during the process planning. Full automation was proposed for the process with the high number of Work-In-Progress (WIP) to reduce throughput time such as packing or filling.

3) Process Flow Sheet

Process flow sheet was developed by using the ASME flow diagram concept since the ASME symbol allows the designer to visualize the state of operation, whether “storage”, “process”, “movement” or “quality control” (Jung, 2010). This enables the designer to

detect whether the designated process flow has too many movements, recurrent storage or over-processing that can prolong the throughput time and consequently improve the process flow.

The sheet was separated into 5 divisions: receiving, raw material storage, processing and packaging, finished product storage and shipping. The arrangement of the process steps based on these divisions enables the designer to detect any material flowing in crisscross or backward manner, which could imply lagging in throughput time and hygiene issue (Hasnan et al., 2019).

3.2.2.4. Design Stage 4: Selection of Machines

At this design stage phase, the selection of the machines with suitable specifications that fulfil the functions, capacity and also safe to operate with the certificate from Standard and Industrial Research Institute of Malaysia (SIRIM) were chosen. Hygienic design of machines and machine's feature were also the aspects need to be considered in the selection process as it can promotes sanitation practice and maintenance cost of the production. The selection of machines were performed based on the following procedures:

1) Machine Type, Function and Operational Feature

Machines with correct function and operation were selected as to meet the process specifications obtained from Design Stage 3.

2) Machine Capacity and Quantity

The capacity and number of machine as to meet the Production Program were calculated and had a reserve capacity with the range of 20 to 40% (Baker, 2013; Jung, 2015; Saravacos and Kostaropoulos, 2015). The calculation method was as below:

Calculation procedure for machine capacity

Two types of machines are considered for capacity planning namely, 1) machine that runs continuously such as a filling machine and 2) machine that has to be loaded batch wise to run such as a mixer. The calculation of the capacity planning has to take account on the following SME product characteristic:

- SME usually use standard universal machines that are available in the market (Baker, 2013)
- SME must be able to cater sudden increase in demand since their customer usually vary from time to time and thus their demand also varied. Based on Saravacos and Kostaropoulos (2002), Baker (2013) and Jung (2015), it is useful to provide 20% to 30% reserve capacity for machines.
- It is common for the food factory to conduct overlapping operations, with no duplicate equipment for SME (Baker, 2013). Hence, the batch cycle time (t_{BC}) is the time needed to complete the slowest individual process (Fuente, 2011).

With the above assumptions, the capacity of continuous machines (MC_{CM}) is calculated using Equation 9, whereby k represents the reserve capacity percentage e.g. 30%. $\sum Q_i$ is the total annual throughput that go through the machine, while $T_{M,E}$ is the annual

estimated machining time as allocated based on time study techniques (time measurement at the existing production, historical data or using standard time based on expert opinions.

$$MC_{CM} = \frac{\sum \varrho + k \left(\sum \varrho \right)}{\sum T_{ME}} \quad \text{Equation 9}$$

Equation 10 provides Q when the annual numbers of batch ($n(B)/a$) for that product assortment and its throughput quantities (q) that go through the machine are known.

$$Q = q \times n(B) / a \quad \text{Equation 10}$$

$T_{M,E}$ is the sum of machining time ($t_{m,E}$) taken to process the throughput for all product assortments. Since the machines are not yet available during the design, the time study technique is again proposed to estimate $t_{m,E}$ based on Van der Vorst (2001). Van der Vorst (2001) proposed that every process should time window in order to ensure the required customer lead time can be met. The estimation of $t_{m,E}$ must ensure that $t_{m,E} \leq t_{BC}$, (since t_{BC} is the time to complete the entire batch). Usually $t_{m,E} \approx t_{BC}$, when the machine is loaded with the highest WIP (Prajapati and Deshpande, 2015). Equation 11 provide the calculation of $T_{M,E}$, when the annual numbers of batch ($n(B)/a$) for the product assortment are known.

$$T_{M,E} = t_{m,E} \times n(B) / a \quad \text{Equation 11}$$

The capacity of batch wise machines is referred to the filling level or the maximum load capacity. The selection of load capacity should considers the material's density and must be enquired to the machine supplier. The calculation of batch wise capacity requires the designer to determine the highest throughput quantity (q_{max}) that should be loaded into the machine at one time. The q_{max} should represent 80% of the actual machine loading

capacity (MC_{BM}), giving the reserve capacity of 20% (Hasnan et al., 2016). Hence, Equation 12 is used to calculate MC_{BM} .

$$MC_{BM} = q_{\max} / 0.8 \quad \text{Equation 12}$$

1) Machine Configuration

This was addressed by specifying the preferred system interface, control logic, control panel layout and machines accessories (Browser, 2013). Since SME usually experience space constraints, the following machine length can be a guide: ≤ 2.4 m requires small footprint, up to 3.6 m for medium and 4.8 m requires large spaces (adapted from AVI, 2010).

2) Material Handling Specification

The required material handling equipment was analysed based on checklist provided by Stephens and Meyers (2013). The analysis considered the method to move materials between machines, workstation and storages. Standardized material handling equipment are desired to minimize the number of trips between two stations with the same amount or size of materials.

3) Standard Compliances

In Malaysia, the design and fabrication of any machine need to comply the product certification scheme by Standards and Industrial Research Institute of Malaysia (SIRIM). Less breakdowns can be expected from the certified machines. For imported machine, the SMEs need to verify SIRIM's acceptance of the standards and codes carried by that machines.

3.2.2.5. Design Stage 5: Processing Facilities Design

3.2.2.5.1. Zoning and Segregation

In this stage, the zoning and room planning has been designed in this stage to have an efficient production area. The location of the every machine is planned according to the suitability of processes involved in the wet and dry zone that been separated in the production area. The zones are segregated according to their major functions which are receiving area, shipping area, storage, and productions area. The functions of zones separation is to differentiate which zones are in the low risk and high risk area of the factory in order to be a hygienic factory. Usually, low risk area are the area where the processing activities take place before the process of decontamination happened while high risk area are the area where the processing activities are take place after decontamination process (Holah and Lelieved et al., 2011). In the high risk area, the recontamination are must be prevented to ensure the product are safe from the pathogens (Lelieved et al., 2011, 2014). After the room and zones segregations of the factory X are determined, the room list are produced based on the functions of the rooms. The room list helps the planning of the design process to be more efficient according to the segregations of rooms.

3.2.2.5.2. Room Design Procedures

Schematic room layout is developed and the layout planning are proposed according to storages, production and transition (receiving/shipping).

Storage Room: Storage room is to be planned based on unit load system and consideration on clearance requirement for hygiene (GMP). The unit load can be packaging itself or any equipment that hold the goods together such as trays, pallets or bags. The procedures are

only proposed for shelving and floor-standing storage as these are reported to be the widely applied storage system in the processing of convenience food and small scale processing (Schwarz et al.,2011; Hui, 2014).

Production Room: Production room is to be planned based on consideration space for individual workstation and then all the workstation will be combined to form a single production room.

Method to design storage room

1. Determine the storage capacity
2. Select the storage method either shelving method or floor-standing method.
3. Determine other storage equipment such as trolley.
4. Determine the number of operators and doors that can access into the room.
5. Determine the room dimension.
6. Determine the temperature and the humidity of the room

Method to design production room:

1. Determine the process of the productions involved.
2. Identify the number of machine used and machine size based on the process.
3. Design the layout of the productions room with onwards flow of productions and determine the number of operators needed for the process. The layout must be followed the requirement of GMP. The requirements of the hygienic design of the factory are listed below:
 - The distance of the machine and other adjacent items is minimally 1 metre.

- The distance of the machine and another machine must be at least 0.45 metre.
 - The width of working space is at minimum 1 m (Jung, 2010).
 - The working space of the operator must at least has the width between 0.875 to 1 metre.
4. Determine the number of operators used and doors that can access into the room.
 5. Determine the room dimension.
 6. Determine the temperature and the humidity of the room.

3.2.2.6. Design Stage 6: Auxiliaries Facilities Design

There are four types of auxiliaries facilities required to be design in Design Stage Six. The auxiliary's facilities are personal hygiene facilities, production office, laboratory and service room. In this study, the following auxiliary facilities are chosen to be made available in the factory:

- 1) Personal hygiene facilities: toilets, change room, hand-wash station. Break room is not provided and operators are not allowed to eat within manufacturing premise.
- 2) Service: workshop, cleaning room for utensils, chemical storage, switch room, waste water treatment and tool storage
- 3) Administration: Only production supervisor office is designed to accommodate administration task and document related to operation. Other offices are located at first floor and will not be designed in this study.
- 4) Laboratory for Quality Control.

3.2.2.7. Design Stage 7: Space and Manpower Allocation

All rooms from Design Stage 5 and 6 are compiled together to ensure that the production area is sufficient to be operate. After that, the manpower such as number of staff required at each workstation is allocated based on the task required at unit operations.

3.2.2.8. Design Stage 8: Layout Design and Building

For design stage 8, the production flow for the factory X system are developed. A layout of a factory for juice processing are designed based on the hygienic design requirements and to minimize the consumptions of energy and time. Then, the building structure and landscape of the factory also must be developed according to the hygienic design requirement. There are a few requirement needed to be taken before designing the food factory.

3.2.2.8.1. Layout Design of Food Factory

A good layout of a factory is the important criteria or requirement for the food factory to have a Good Manufacturing Practice (GMP) certificate. By having a GMP certificate, a smooth flow of productions of the factory can be ensured and efficiency of the productions can be obtained. To have a good factory layout, auxiliary's facilities, production zone and the process flow of pomegranate juice from receiving of raw materials until the shipping of the product must be designed according to GMP requirement.

Steps to design the factory layout

1. Determine the number of rooms and the facilities needed in the factory.
2. Segregate the rooms and determine the zones from each room.
3. Identify the room locations in the factory layout based on their priority to the productions.
4. Use onwards flow and spine plant layout to design the rooms and the facilities inside the factory.

The onwards flow is a flow where requires the materials and operators to move onwards starting from the receiving area to the shipping area. This flow can prevents the cross contamination to occur on the food processing productions since the flow are onwards (Baker., 2003; Bonne., 2005; Clarke., 2009). Moreover, the adjacency of the rooms can be determined based on the functions of the rooms and the auxiliaries facilities can be designed based on the movement and requirement of the workers inside the factory.

Spine plant layout is a type of layout that have a main aisle called “central spine” with the workstations whether it located on either side of the factory (Langevin et al., 1997). The central spine is a space or area used for the operators or materials to move between rooms or a temporary space for WIP (Langevin et al., 1997; Tompkins et al., 2010). Spine plant layout used onwards flow inside the factory and the room segregation based on their functions to the productions of the factory. Besides that, the individual rooms and the layout of the factory did not have a fixed size as long as it fit into the spine aisle and cross contamination did not occur. For the limitations, the receiving area was used as the starting point of this layout and the rooms are place according to the closeness relationship. The rooms also can be located at the opposite of central spine if there any size constraints as

long as the process of designing layout did not causing the cross contamination to occur (Hasnan et al., 2019).

3.2.2.8.2. Landscape Design Specification

For the landscape design, the fence must be equipped along the factory and the guarding are necessary to ensure the safety of the factory. The outer lamp and enclosed external drainage are provided to avoid the attraction of the pest. Lastly, the small plants or bushes are prohibited inside or outside the factory.

3.2.2.9. Design Stage 9: Utilities Requirements

For the last design stage, the utilities requirements of the factory such as ventilation system, lighting health and safety, piping, compressed air, electrical appliance, water supply waste water treatment are determined based on the capacity and the requirements needed in the factory and it is not included in this scope of project as it will be suggested for future work based on the current developed design.

3.2.3. Phase 3: Project Monitoring

After the design stages was completed, the next steps were the design review by the company and the design analysis to test the productivity improvement and the compliance to hygienic design.

3.2.3.1. Design Review and Analysis

The resulted design specifications of the new factory was presented to the Company X comprising of design and planning outcomes from Design Stage 1 to Design Stage 9 namely 1) System Requirement, 2) Production Plan, 3) Process and Technology, 4) Machine Capacity and Selection 5) Processing Facilities Design, 6) Auxiliary Facilities Design, 7) Space and Workforce, 8) Layout and Site Plan and lastly 9) Utilities Plan. Improvement were made based on the Company's input and were finalized in Chapter 4. The design specification were analysed using simulation analysis and hygienic design analysis.

3.2.3.2. Simulation Analysis using FlexSim Express Software

FlexSim express software is a simulation modelling software developed by FlexSim Software Product Inc that used to simulate the overall process based on the calculated capacity. The software used is in the latest version which is FlexSim 18.12. Through this simulation process, it can run the process and show whether the process and the capacity of the designated factory are suitable within the output needed from the factory. In this project, the model of the existing and new Factory X were developed using FlexSim 3D model interface. The operation of both models were simulated and analyzed to evaluate the productivity improvement and reduction of production lead time in the new factory

compared to the existing factory. The new factory model was build based on the resulted design details in Section 4.2.1 to Section 4.2.9.

3.2.3.2.1. Development of the Current Model and Simulation Run

The model interface of FlexSim showed in Figure 3.2.4 are consists of main menu, toolbar, simulation control bar, quick properties, library and toolbox.

Table 3.2.1

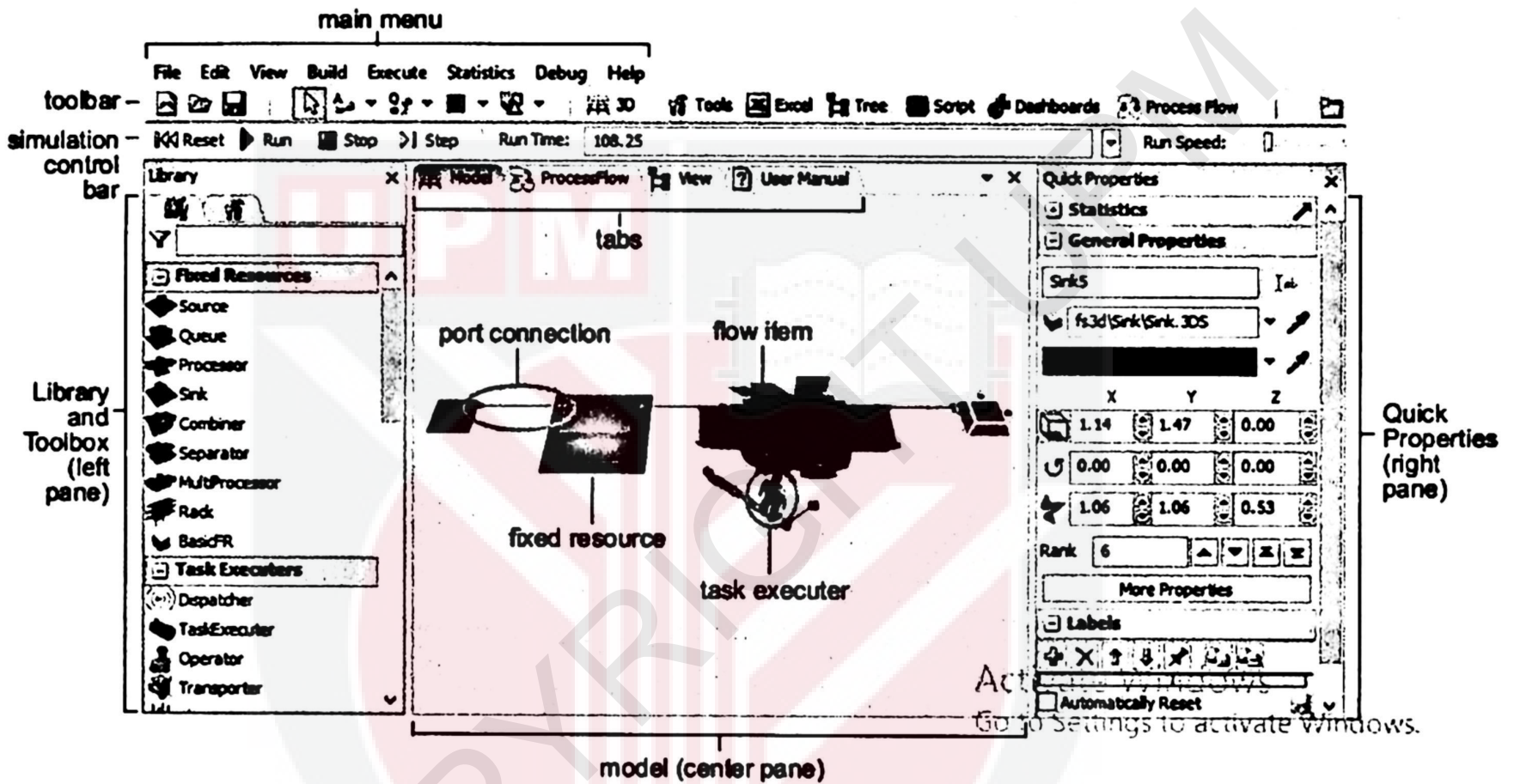


Figure 3.2.4: 3D Model Interface

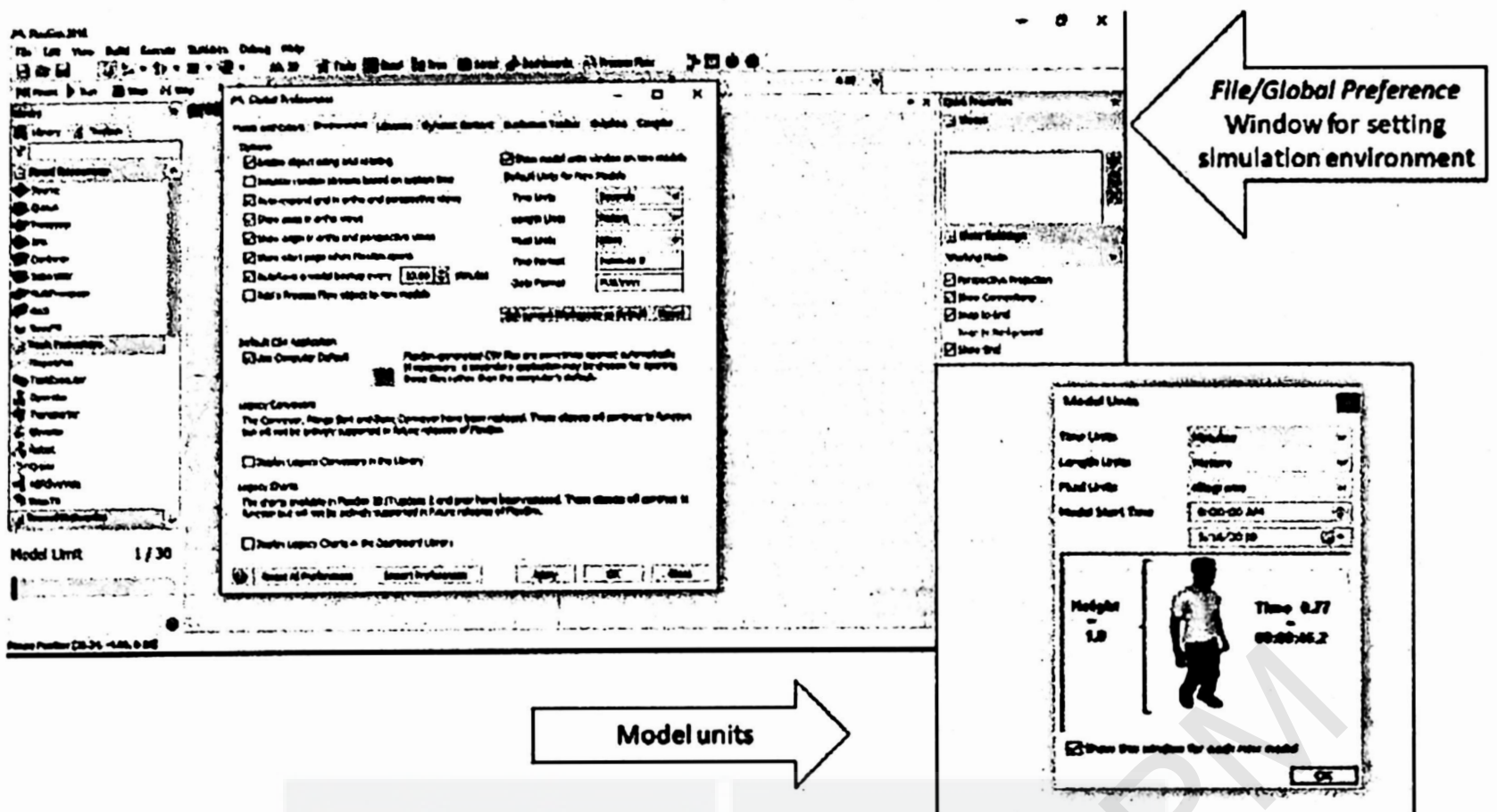


Figure 3.2.5: Model Unit Interface

Time and space in the simulation environment are dimensionless until the user decides what the dimensions should be. To change the defaults go to the File / Global Preferences / Environment and select the desired units. FlexSim then has to be closed and reopened for the change to take effect; however, it is best to decide on the units prior to building a model and set them based on the following means. When starting a new model, a screen appears, as shown in Figure 3.2.5, showing the definition of units. The values are used during some reporting and internal calculations. All data input for the model should be consistent with these units. For example, if the time unit is seconds, the time between arrivals and cycle time for a processor would both have to be expressed in hours. As a result, statistics that are generated the simulation, such as the amount of time a processor is operating, will be interpreted in seconds. Once selected, the units may not be changed until a new model is opened. The units for a model are saved with the model file.

Space is also dimensionless. The default unit of space on the simulation layout screen is one grid unit of size 1 m x 1 m x 1 m. The user has to decide the actual units that the default grid space represents. Equipment can be scaled appropriately. Movable equipment, such as fork, trucks, have speed values assigned to them as the number of grid units traveled per clock unit. Consistent data values are critical to the success of a simulation.

Flow items interact with objects in a simulation. Objects might perform an operation, create a delay, or move the items. Thus, a simulation model is simply a collection of these objects and flow items put together in such a manner as to simulate the behavior of a system. In order to develop the 3D model of the factory, it was important to understand the *objects* in the 3D Simulation Model, whereby they are the basic building block in the developed model. The basic object used in developing factory models are flow items, source, sink, queue, processor, conveyor, combiner and separator.

All the objects can be resized and rotated using Resize and Rotate Object function. The properties of the object can be defined using Quick Properties (single click) or Properties Window (double click).

3.2.3.2.2. Data Collection and Data Entry

Below are the data required to build the system model and are entered into the Properties Window in Figure 3.2.6 of the modelled objects:

- Time for material to enter the production room
- Number and type of equipment at every workstation
- Number of operator at every workstation
- Type of throughput material at machine and its quantity or size

- The sequence in which every type of ingredient enter the machine
- Distance between workstation (in meter) or layout
- Interstation movement of material handling equipment (type, quantity, time)
- Processing time
- Set-up time
- Operator's speed of working

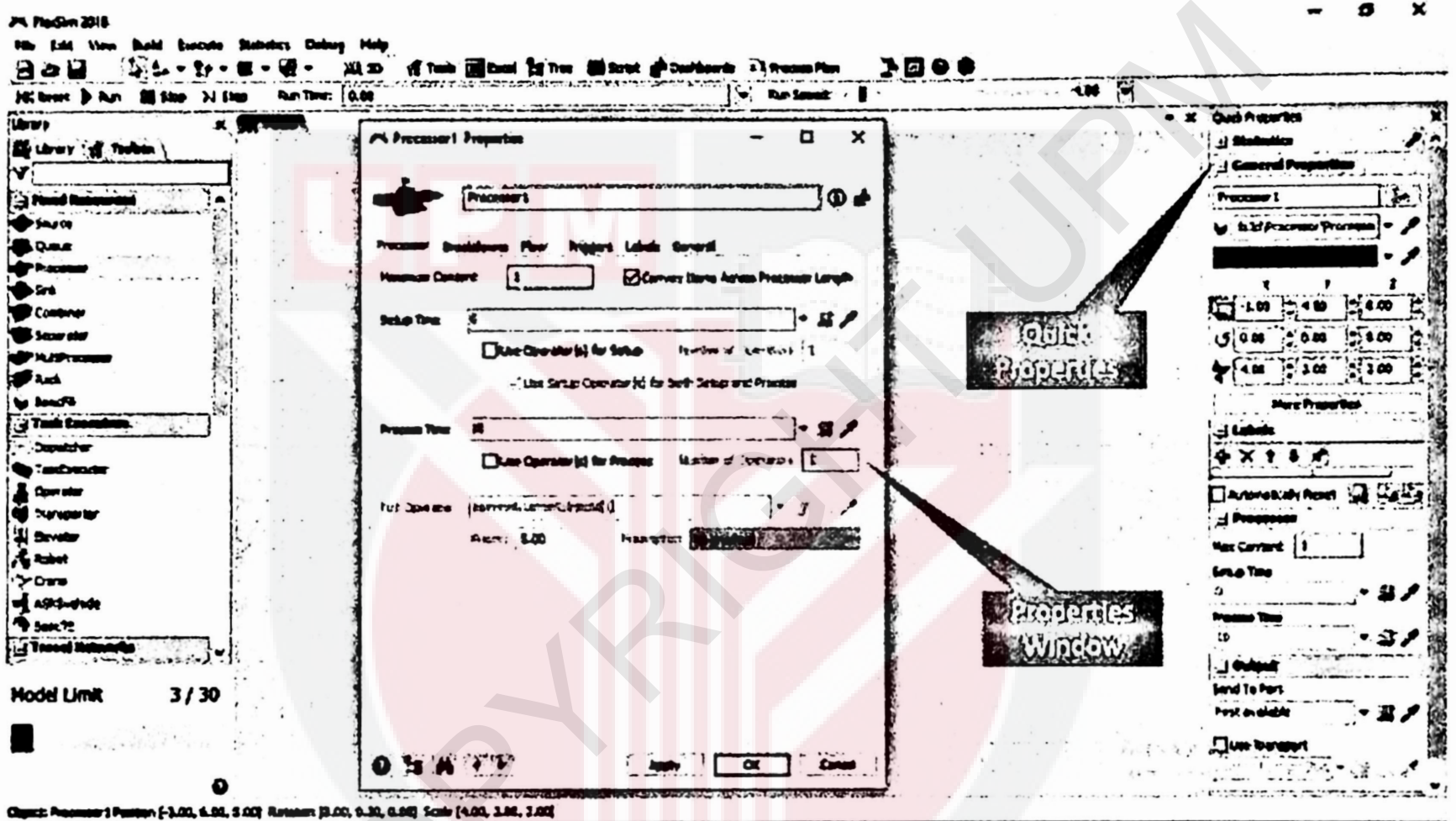


Figure 3.2.6: Properties Window

Particular attention was given for the processing time, where by this refer to the time taken for one unit of throughput raw material to be processed by the machine or operator (Equation 13). Exemplarily at washing sink station, the $t_{process}$ is equal to the time taken to wash one batch of pomegranate fruits (15 kg) at wash station. At peeling station, $t_{process}$ is referred to finish peeling a batch of pomegranate fruits.

In order to obtain $t_{process}$, the data are enquired to the Company X and some are observed during the production. In order to simulate such activity as close as possible to the real situation, a probability distribution model is required to represent the random pattern of $t_{process}$ for every process step. This distribution model is needed by FlexSim to generate the random $t_{process}$ in the simulation run. Based on the literature recommendations, it is found that the triangular distribution is best applied to represent the random pattern of $t_{process}$, when limited access/control is available to the studied system (Altiok and Melamed, 2007). The triangular distribution requires three parameters for the $t_{process}$: the minimum possible value (a), the most common value or mode (c) and the maximum possible value (b). The triangular distribution assumes that $t_{process}$ values to be in an interval, $S = [a, b]$, with the mode, c , being some point between a and b ($c \in [a, b]$). The likelihood, $f(t_{process})$, increases linearly in the subinterval $[a, c]$ and decreases linearly in the subinterval $[c, b]$, so that the density has a triangular shape as in Figure 3.2.7.

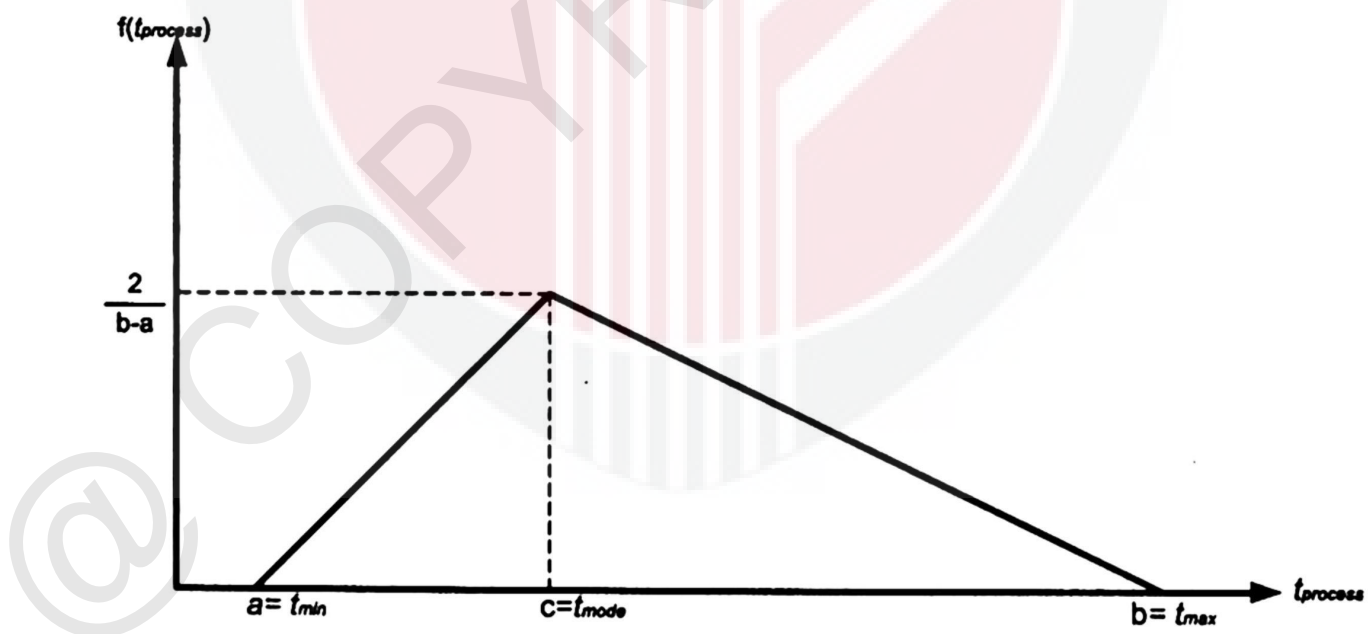


Figure 3.2.7: Triangular Distribution of $t_{process}$

The Flexsim simulation generates $t_{process}$ values based on $f(t_{process})$.

$$f(t_{process}) = \begin{cases} \frac{2(x-a)}{(b-a)(c-a)}, & \text{if } a \leq t_{process} \leq c \\ \frac{2(b-x)}{(b-a)(b-c)}, & \text{if } c \leq t_{process} \leq b \\ 0, & \text{otherwise.} \end{cases} \quad \text{Equation 13}$$

Since the mode does not have to be equally between the minimum and the maximum value, the triangular distribution does not have to be symmetric. In this study, the values of a , c and b are enquired or measure at the existing Company X.

3.2.3.2.3. Simulation Run

The current Factory X model was built based on the data did not include the receiving, shipping and storage activities. This was because the study was aimed to evaluate the production efficiency in relation to the throughput time performance. The definition of throughput time is limited to the amount of time required to turn raw materials into finished goods on the manufacturing floor (Bragg, 2011). The development of model applied the “objects” provided by Flexsim. The objects were able to model the manufacturing elements such as food material, machines, operators, processes and workstations and also the occurring event in the production such as the food material entering the production room or workstation, movement of material, batching and finished products in cartons leaving the production room.

Due to the limitation of the trial software, the simulation cannot be run with multiple replication and only run as a single statistic mode. The trial software trial and does not

have license of additional features called Experimenter to run the simulation many time.

Therefore, need to verify and validate the model with the company.

When the simulation runs, the dashboard as in Figure 3.2.8 was developed to analyse the manufacturing lead time, operator's utilization, waiting time and processing time, which are useful to deduce the productivity of the New Factory X.

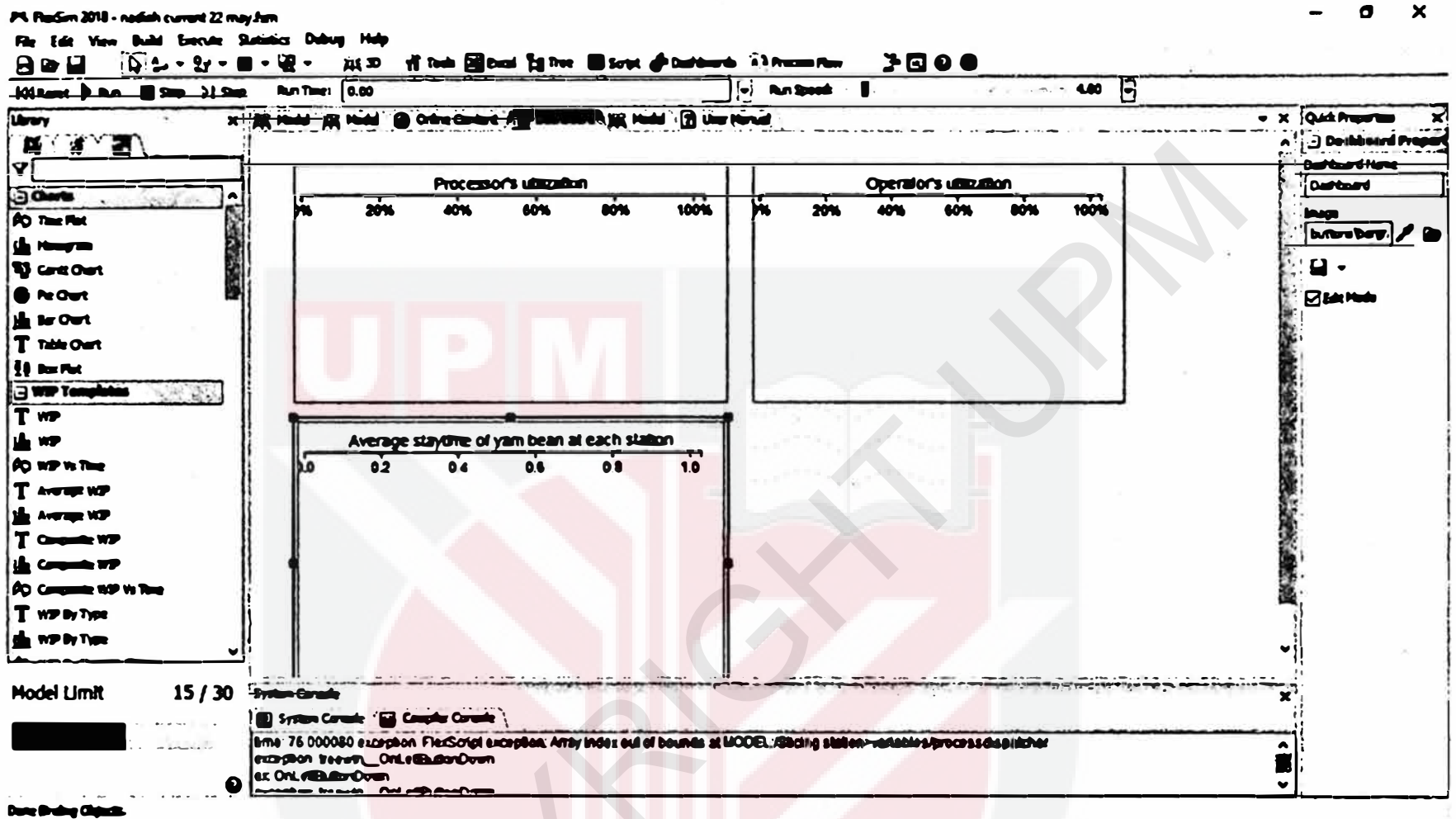


Figure 3.2.8: Developed Dashboard for Simulation Analysis

3.2.3.2.4. Verification and Validation of Factory X Model

The verification was performed to ensure that the model was correctly constructed while the validation was to show that the simulated model could accurately represent the real system. The verification was done based on Little's formula, as in Equation 14, where must be satisfied by λ using the simulation values (Alwadood et al., 2010; Rani et al., 2014). \bar{N} is the average amount of raw material in the system, \bar{W} is the average time spent by raw material in the system and λ is the average rate of raw material entering the

system. Rani et al. (2014a and b) as well as Altiok and Melamed (2007) have shown that if the difference between \bar{N} and λ do not exceed 10%, then the system models are considered verified.

$$\bar{N} = \lambda \bar{W} \quad \text{Equation 14}$$

The validation was done by comparing the simulated processing times at workstations and the batch cycle time with the actual data obtained at the existing Factory F (Equation 15). The widely applied validity tolerance is 10% namely the simulation output should not deviate by more than 10% of the real system output (Altiok and Melamed, 2007; Rani et al., 2014a).

$$\text{Difference} = \frac{|\text{Simulation Output} - \text{Actual Output Data}|}{\text{Actual Output Data}} \times 100\% \quad \text{Equation 15}$$

3.2.3.2.5. Development of New Model and Simulation Analysis

Once the model for the current Factory X was verified and validated, the New Factory X model was constructed with the similar modelling approach, but included several modifications due to the developed new design specifications. The modifications were aimed to reduce the production time and achieved the required productivity (processing time, wait time and move time).

3.2.3.2.6. Data Analysis and Design Review

The analyses below were carried out to measure and compared the production efficiency between the current Factory X and the new proposed model:

- 1) **Production lead time:** the total lead time required to finish one batch of production (adapted from Rani et al., 2014a). This also represented the throughput time required for one batch of raw material to be transformed into finished products.
- 2) **Productivity:** This is determined based on the ratio of the produced number of finished cartons to the time (adapted from Rani et al., 2014a)

The discussion was conducted in relationship to operator's utilization, processing time at each works station and handling time (setup, queue). After the design stages was completed, the next steps were the design review by the company and the design analysis to test the productivity improvement and the compliance to hygienic design.

3.3.3 Hygienic Design Checklist Tool Software

The hygienic design evaluation was carried out based on a review of technical drawings and design specifications before the actual building is constructed. The evaluation was performed using Hygienic Design Checklist Tool, developed by the American Grocery Manufacturers Association (GMA), to evaluate whether the designs complied with the GMP hygienic design principles. The hygienic design checklist tool software showed in Figure 3.2.9 below is the checklist used to ensure all the aspect in design of the factory is following the hygienic design requirements. By using the checklist, it can reduce and prevent the potential of the contamination of the product during the production and storage process. The existing factory was not evaluated due to confidential issues. The checklist is divided into ten sections:

1. **Distinct Hygienic Zones Established In The Facility**
2. **Personnel and Material Flows are Controlled to Reduce Hazards**
3. **Water Accumulation Controlled Inside Facility**

4. Room Air Flow and Room Air Quality Controls
5. Site Elements Facilitate Sanitary Conditions
6. Building Envelope Facilitates Sanitary Conditions
7. Interior Spatial Design Promotes Sanitation
8. Building Components and Construction Facilitate Sanitary Conditions
9. Utility Systems Designed To Prevent Contamination
10. Sanitation Integrated Into Facility Design

Every section has several criteria to be evaluated and scored. The questions are answered by either “S” for satisfactory, “M” for design is marginally acceptable, “U” for unsatisfactory or “NA” for requirements is not applicable in that design case. Points are automatically given by the tool based on the answers. A full score shows the hygienic design is satisfactory, while a score of less than 100% requires the design to be improved (Nikoleiski, 2012). The total points for the checklist is 1000 corresponding to 106 criteria. If the evaluation scores is between 50 to 100%, a continuous improvement is required. The score below 50% shows the hygienic design is unsatisfactory and a redesign is required (Nikoleiski, 2012).

CATEGORIES						Points Earned	Possible Points	Percent Earned
PRINCIPLE #1 - Distinct Hygienic Zones Established In The Facility						0	150	0%
PRINCIPLE #2 - Personnel and Material Flows are Controlled to Reduce Contamination						22.5	100	23%
PRINCIPLE #3 - Water Accumulation Controlled Inside Facility						70	400	17.5%
#	Description	S	M	U	NA	Comments	Points Awarded	Points Available
PRINCIPLE #1 - Distinct Hygienic Zones Established In The Facility								
1.01	Facility drawings show hygienic zones. (Ready-to-eat vs. raw, high care vs. low care, etc.) where applicable. Hygienic zones should be clearly demarcated on the plant schematics with colors or other markings to facilitate easy identification					The high risk area is the pecking area, however it is not clearly segregated from the low-risk area does not clearly demarcated on the plant schematic given by the company.	0.0	25.0
1.02	Separate locker rooms and lunch rooms should exist for RTE/high risk and non-RTE/lower risk personnel, or provisions to separate high risk and low risk employees exist					Locker room is not even available. Operators store their belongings at receiving area and cabinets at the front of dry storage. No provisions for high risk and low risk separation	0.0	25.0
1.03	Restroom facilities are not located in RTE/high risk zones (see point 10.08)					Rest room is located outside manufacturing area	25.0	25.0
1.04	Separate storage areas for tools and spare parts exist to minimize contamination from non-RTE/lower risk zones to RTE/high risk zones					Tools for high risk is stored in dedicated cabinets while other parts stored in miscellaneous storage	12.5	25.0
TOTAL								

Figure 3.2.9: Interfaces of the Hygienic Design Checklist Tool

3.2.4. Phase 4: Project Closing

The design specifications and resulted design analysis were presented to the Company X. Upon approval by the company, the economic analysis based on Return of Investment (ROI) and payback period were estimated. The final report was documented in form of project thesis and supplementary documents such as machines catalogues. Further improvement when required are documented in the report for future works.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the outcomes of project which is the analysis of the production problems at the current premise. The design outputs for the new factory with solution to increase the productivity and integration of hygienic design for food safety implementation also been discussed in this chapter. Then, simulation analysis is used to verify the productivity improvement in the new factory system and hygienic design analysis is used to verify the readiness of the new factory system for the food safety practice. Lastly, total estimated cost, ROI and payback period required were calculated in order to establish the new factory system.

4.1. Existing Processes of Company X and Problems Related to Productivity and Food Safety

The current production begins with receiving of whole fruit pomegranates, washing with water, peeling off the skin to get the arils, grinding the arils, filtering to remove particulates and obtain the juice, slow heating (evaporation) to obtain pomegranate concentrate, mixing of concentrate with sugar for sweetening and preservation purpose, cooling at ambient and then intermediate storage. The concentrate is then brought to the contracted factory in Semenyih, Selangor for reconstitution with potable water according

to the specified ratio and proceed to bottling, capping, warehouse and shipping to customers. The overall process is summarized in Figure 4.1.1.

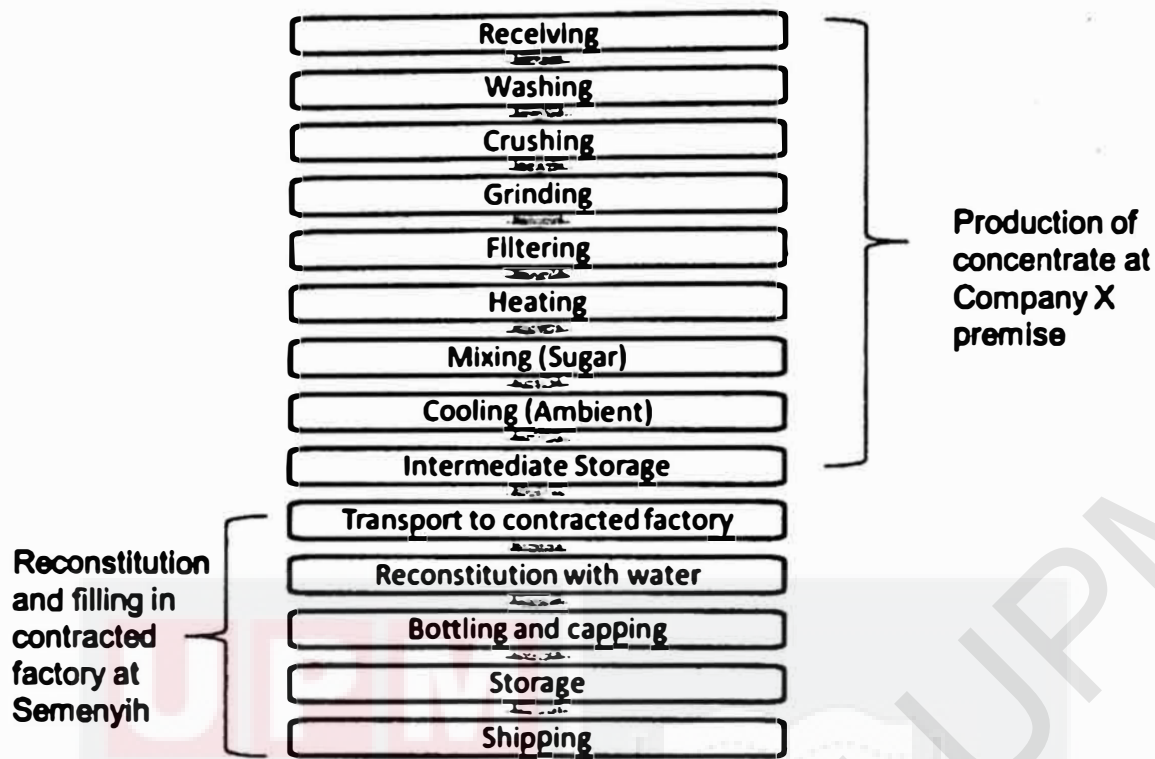


Figure 4.1.1: Current Processes at Company X

The preparation of current juice is accommodated in the layout as shown in Figure 4.1.2. Due to the inconsistent quality of pomegranate fruits that require the concentrate to be added with high sugar amount as well as uncertain fruit supplies and prices in the local market, the company has changed their business model to the production of reconstituted juice. The supply of concentrate is secured from Genç Yemişçiler Dış Limited in Turkey that will import the concentrate maintained at 4°C using reefer containers to Company X. Company X only has to reconstitute the concentrate according to the recipe and thus, plan to pursue a proper factory for the complete production.

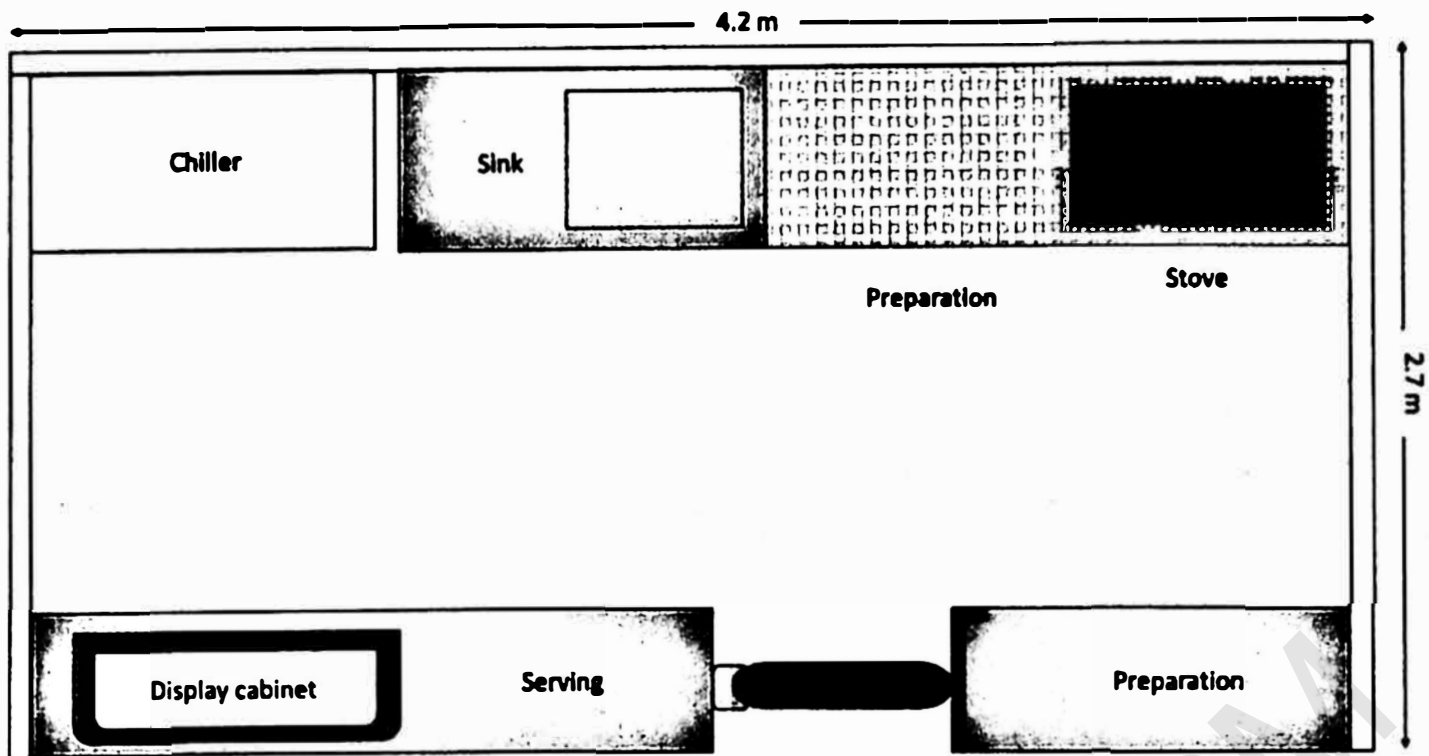


Figure 4.1.2: Current Layout for Juice Production

Nevertheless, the new factory system should be able to solve the low productivity and difficulties to implement food safety in the current processes. Table 4.1.1 below summarizes the issues related to the current processes.

Table 4.1.1: Problems Related to Productivity and Food Safety at the Current Production

Process Step	Productivity issue	Food safety issue	Improvement suggestion
Receiving of raw materials and packaging	None	Despite the thorough quality check during receiving, a systematic documentation of the quality control is missing, which may affect the traceability of the product.	A proper documentation of raw material specification and quality check is required for traceability. However, the development of documentation is not within the scope for the project.

Table 4.1.1 Continued

<p>Storage of raw materials and packaging</p>	<p>The storage was not sized according to production demand and can be congested.</p>	<p>No separation between raw materials and packaging.</p>	<p>All storages are sized based on the required storage capacity. (Design stage 5)</p> <p>The storage of food and non-food must be physically separated. (Design Stage 5 and 8)</p>
<p>Washing</p>	<p>The process takes normally 0.4 to 0.5 hour to complete for one batch production (30 kg of fruits) and can be extended up to 0.8 hour.</p>	<p>The process uses running tap water or sometimes immersion and only successfully remove dirt. Yet, the wash might not be adequate for removing microbial contamination or may cause cross-contamination for the next wash in the same sink (Banach, 2015).</p>	<p>Since the company is changing the business model to the reconstituted juice, the process steps washing to the transportation for the contracting filling would be omitted and not performed anymore. A new process specification must be developed (Design Stage 3)</p>
<p>Crushing</p>	<p>Pressure is applied manually on the fruits so that they are crushed and the pericarp is broken. The aril (flesh) will be exposed and separated from the pericarp after few times of crushing.</p> <p>The manual process takes normally 3 hour to complete for one batch production and can be extended up to 4 hour.</p>	<p>The manual process are concerned with neglect of worker hygiene practice.</p>	<p>(Design Stage 3)</p>

Table 4.1.1 Continued

<p>Grinding</p>	<p>Only the aril is channelled to the grinding machine because the pericarp will give an astringent taste to the juice.</p> <p>The aril (80% from 30 kg) is being grinded for normally 1 hour to extract the maximum amount of juice.</p>	<p>The manual process are concerned with neglect of worker hygiene practice.</p>	<p>Since the company is changing the business model to the reconstituted juice, the process steps washing to the transportation for the contracting filling would be omitted and not performed anymore.</p>
<p>Filtering</p>	<p>The juice is filtered using strainer to remove seed and solid particles and obtain the clear juice. The whole process takes normally about 0.5 hour.</p>	<p>The manual process are concerned with neglect of worker hygiene practice.</p>	<p>A new process specification must be developed (Design Stage 3)</p>
<p>Evaporation</p>	<p>Each batch containing 12 L of pomegranate juice is heated slowly in a stainless steel pot for 2 hours to obtain the concentrate. The temperature must be controlled manually to avoid overheating.</p>	<p>None</p>	

Table 4.1.1 Continued

<p>Mixing with sugar (During the 2-hour- evaporation, the sugar is added as preservatives)</p>	<p>None</p>	<p>Granulated sugar is added into each batch of pomegranate juice to compose 25% of the total content which is considered high according to MOH (2012). The high added-sugar can negatively interact with the available polyphenols and hence lowered the antioxidant capacity in the juice (Lončarić, 2018). Nevertheless, the high sugar content able to preserve the juice up to 1 year.</p>	
<p>Natural cooling</p>	<p>The juice is cooled to ambient temperature (~4 hour)</p>	<p>Cooling time is not controlled and the surrounding environment is concerned with neglect of sanitation practice and improper segregation.</p>	
<p>Intermediate storage</p>	<p>The juice is stored temporarily before being transported to the bottling factory (overnight ~12 hour)</p>	<p>Possible contamination during transport</p>	
<p>Shipping to contracted factory</p>	<p>None</p>	<p>Possible contamination during transport that takes about 1.2 hour</p>	

Table 4.1.1 Continued

<p>Reconstitution with potable water and mixing</p>	<p>The process takes about 0.5 hour with reconstitution ratio 1:2 and automated (no issues).</p>	<p>None</p>	<p>The required batch size for the reconstitution process must be determined to meet the production demand (Design Stage 1 and 2)</p>
<p>Bottling and capping (filling)</p>	<p>The juices are bottled in PET bottle of size 0.35 L, 1 L and 1.5 L manually and takes time almost 25 minutes to 30 minutes per batch.</p>	<p>Possible pathogenic growth due to manual filling and absence of pasteurisation process.</p>	<p>The juice must be pasteurised before the filling process. The new production will use standardized PET bottle of 0.3 L. The process bottling, capping and labelling is integrated in one station and automated due to high WIP. The station is accommodated in clean area. (Design Stage 5 and 8)</p>
<p>Chill storage maintained at 4°C</p>	<p>Storage capacity must be addressed to ensure adequate space and volume.</p>	<p>Exceeding storage capacity may lead to insufficient refrigeration, while too low storage may lead to temperature fluctuation.</p>	<p>All storages are sized based on the required storage capacity (Design Stage 5) The required cooling load by the refrigeration equipment is determined (Design Stage 9)</p>

Table 4.1.1 Continued

Distribution in refrigerated condition	None	Temperature is maintained at 4°C yet a proper record is missing.	A proper record is needed for monitoring, verification and correction action is required for traceability and HACCP implementation. However, the development of documentation is not within the scope for the project.
----------------------------------------	------	------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

As the company has decided to change their business model for the reconstitution production, the following nine design stages describe the new factory system that address the required productivity and hygienic design to facilitate the implementation of food safety once the operation runs.

4.2 Design Specification and Production Plan of Factory X

This section presents the resulted design outcome and production plan for the new Factory X.

4.2.1 Design Stage 1: System Requirement and Constraint Analysis

4.2.1.1 Production Requirement of the Pomegranate Juice

The designated Factory X would produce a total of 450,000 bottles of pomegranate juice in 300-ml PET bottles per year based on the current consumer demand.

4.2.1.2 Compliance to Statutory Requirement

The compliance to the statutory requirement is the important aspect need to be concern for the Company X to design and built the factory. There are the requirements such as

codes and legislation by the Food Safety and Quality Department (FSQD) in Ministry of Health and local authority in charge and at the factory area needed to be followed by the company. Company X proposed the factory to be built in unit of terrace lot at an industrial area and the design of the building was fit for the food processing factory in Figure 4.2.1 such as exposed drainage, large openings to the outside environment and factory finishes that is not food grade.



Figure 4.2.1: Factory Condition

So there will be a few changes especially for the structure, layouts and electrical source for the factory. In order to have a proper design for food processing factory, the changes of the structure for the building must be submitted to the local authority in charge and approved.

The local authority charged in the proposed Factory X was Kajang Municipal Council. There are codes and legislation to be followed by the Company X to design and built the food processing factory in this area. The legislations for the every company to start up the business under Kajang Municipal Council are listed below:

- Local Government Act 1976

- Road, Drainage & Building Act 1974
- Licensing, Business Trade and Industrial By-Law (MPKJ) 2007

Meanwhile, in term of food processing, below are the required law and standards to be complied:

- Food Act 1983
- Food Regulations 1985
- Food Hygiene Regulation 2009
- Codex Stan 247-2005, Codex General Standards for Fruit Juice and Nectars
- MS 1514 Good Manufacturing Practice
- MS 1400 Hazard Analysis and Critical Control Points

4.2.1.2.1 Site Analysis

The prospect location for the factory is known as Pusat Perindustrian Sungai Chua, Kajang showed in Figure 4.2.2. The building is in the terrace lot unit which have a size about $9 \times 30 \times 3$ m with respective to length, width and height. There were sufficient infrastructures such as electricity, water, road, highways and also drainage system in this area. It will be easier for the company to deliver their product as there were traffic accesses nearby such as SILK Highway that connect the town and PLUS highway.

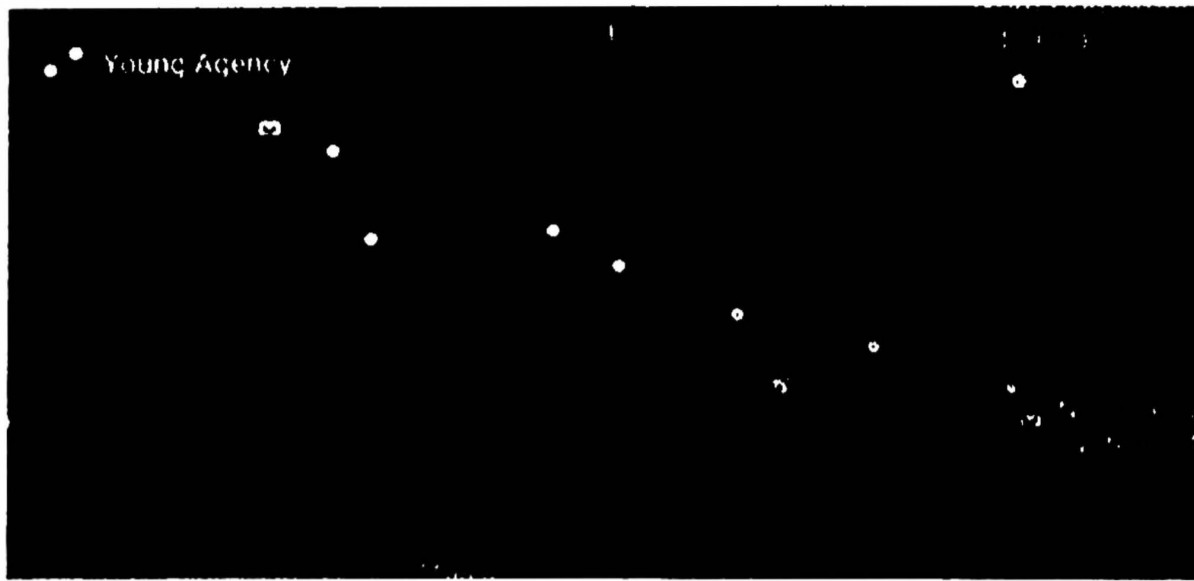


Figure 4.2.2: Prospect location of New Factory X

For the utilities for the factory, Tenaga Nasional Berhad (TNB) allocate about 415 V for the small scale industry to be used using Tariff -D. Next, the communication network at the site was provided by a telecommunication company named Telekom Malaysia Berhad (TM). As for the portable water line, Syarikat Bekalan Air Selangor (SYABAS) will supply the water source and Indah Water Consortium Company (IWK) responsible to manage the effluent drainage in order to avoid the pollution to the environment. Moreover, IWK also had given the requirement for effluent or waste characteristics to be determined before the disposal happened.

4.2.1.2.2 Plot Plan

The plot plan of the new Factory X are sketched in Figure 4.2.3 below based on the size of the factory for the design purpose.

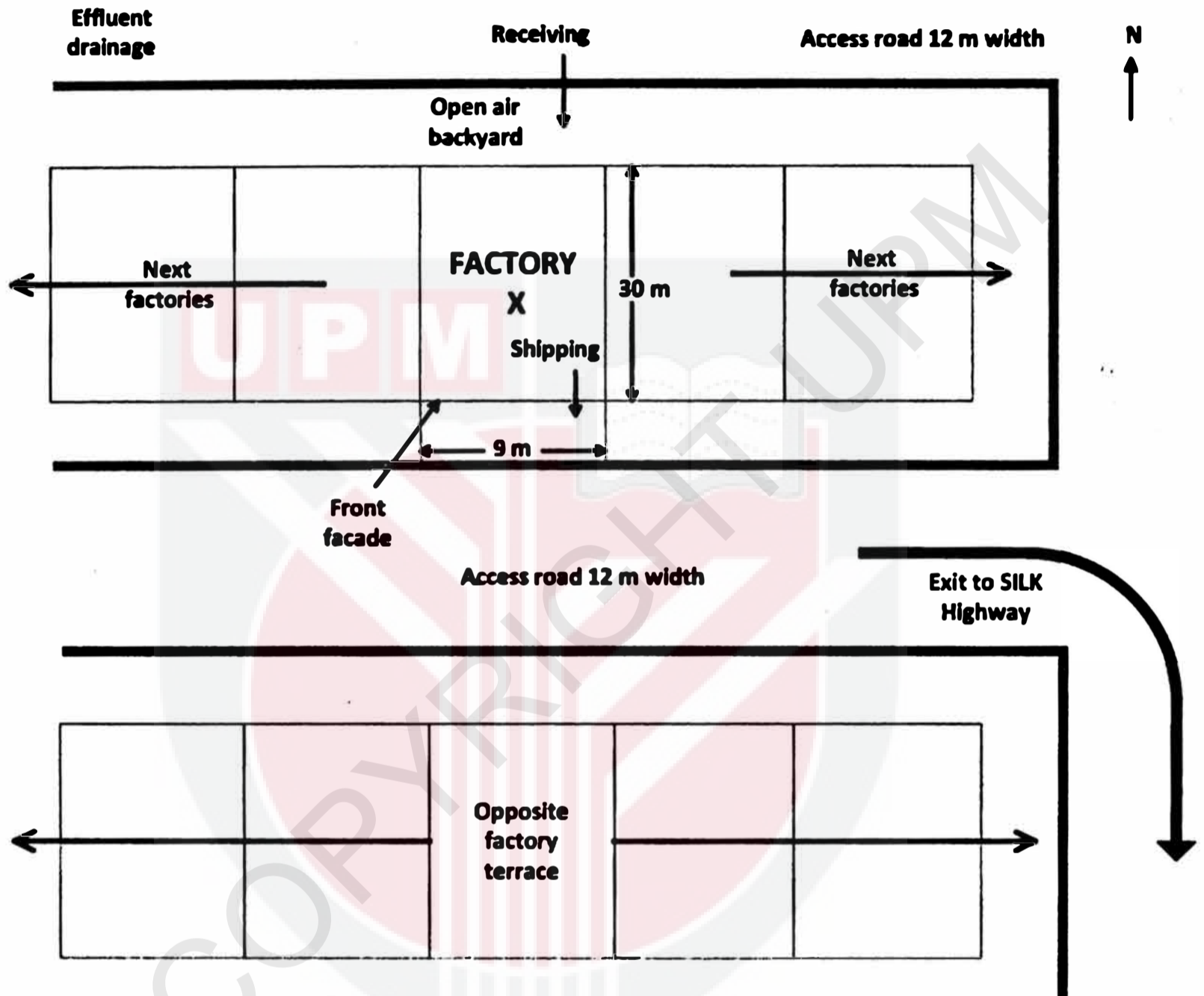


Figure 4.2.3: Plot Plan of New Factory X

4.2.2 Design Stage 2: Production Planning

The product is named as Jus Delima Minda as in Figure 4.2.4. The type of bottle used is polyethylene terephthalate (PET) and been packed into 300 ml PET bottle. As for the current production of the pomegranate juice, Company X produced 7500 litre per month but the demands of the customer are increasing to 11,250 bottles per year which require the Company X to produce about 375,000 bottles per month. For the current productions, the pomegranate juice is bottled in a several of packaging such as 1 L, 500 ml, and also 330 ml. As for the new designed production, the juice are bottled into 300 ml of bottle in order to have a constant an efficient productions. For the secondary packaging after the PET bottle is the corrugated box which is illustrated in Figure 4.2.5. There are 10 bottles of juice inside the box with the size of 10 × 265 × 155 mm.



Figure 4.2.2: Jus Delima Minda

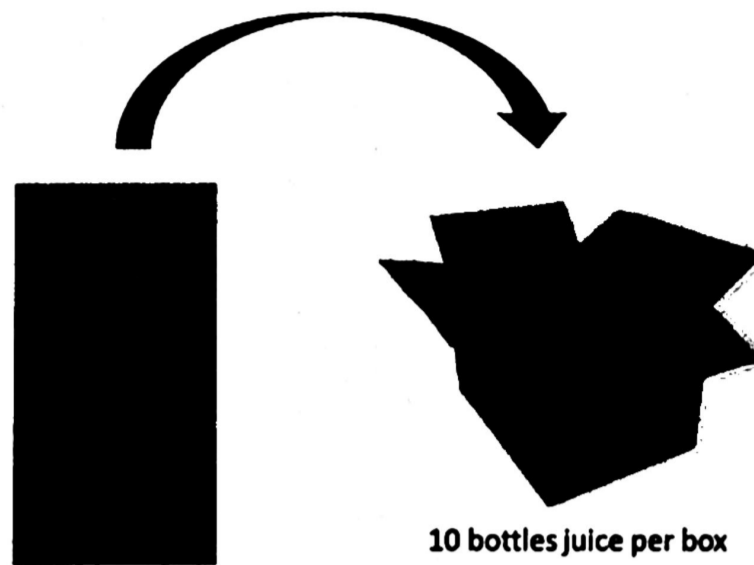


Figure 4.2.3: Product Packaging

The batch formulation is given as in Table 4.2.1.

Table 4.2.1: Batch Formulation for Pomegranate Juice

Product name	Pomegranate Juice	
Batch cycle time (h/batch)	4.51	
Batch Size (Liter/batch)	300 L	
Estimated loss	0.27 % (Hasnan et al., 2014)	
Output		
Product	Number of bottle per batch	Number of bottle per carton
Pomegranate Juice	1000	10
Ingredients		
Ingredients	Qty/batch (L/batch)	
Filtered Water	75	
Pomegranate Concentrate	125	

The Production Program is given in Table 4.2.2 and plans the factory system to produce annually 450,000 bottles per year or production volume of 135,000 L/y.

Table 4.2.2: Production Program of Pomegranate Juice

Product	Product Name	Volume Per Year (L/y)	Unit Sales Packaging		Unit Sales/Year (unit sales/y)
			Type	Volume in L/unit sale	
Pomegranate Juice	Jus Delima Minda	135,000	Carton Box	0.3	450,000

The production plan is given in Table 4.2.3.

Table 4.2.3: Production Plan of Pomegranate Juice

Planning Details	Value	Equation for calculation	Measurement/ Specification values
Number of production days/year, D_p	290 days/y	1	D_w = the number of working days after excluding holidays (300 days) $\frac{D_m}{r}$ = the number of days for scheduled maintenance (5 days) D_{clean} = the number of scheduled cleaning days (5 days)
Daily production time, T_{DP}	7 h/ day	2	$S_D = 1$ shift/day $T_{Shift} = 9$ h/day $T_{Idle} = 2$ h/day
Production hour capacity per year, T_P	2030 h/y	3	$T_P = D_p \times T_{DP}$
Number of batches per year, $n_{B/a}$	450 batches/y	4	$PV = 135000$ L/y $B = 300$ L/batch

Table 4.4 Continued

Batch cycle time, t_{BC}	4.51 h/ batch	5	$t_{BC} = T_P/(n_B/a)$
Number batch per day, B_D	1.5 ~ 2 batch/day	6	$B_D = T_{DP}/t_{BC}$
Actual number of production days, D_x	225 days	7	$D_x = (n_B/a)/ B_D$
Utilization of time capacity, U_D	77.6 %	8	$U_D = \frac{D_x}{D_P} \times 100\%$

From the production plan details above, the utilization of time capacity, U_D is 77.6 % and thus, 22.4 % of production time capacity is reserved for capacity buffer purpose such as sudden machine break down and shortage of operators.

4.2.3 Design Stage 3: Process Specification

There are several process needed to be taken to produce pomegranate juice. The processes consists of receiving of raw materials, storage of raw materials, weighing, mixing, pasteurization, bottling and capping, labelling, boxing and palletizing, finished product storage and shipping.

4.2.3.1 Process Description for the Production of Pomegranate Juice

The process steps is summarized in Figure 4.2.6 with receiving, storages, main production line and shipping.

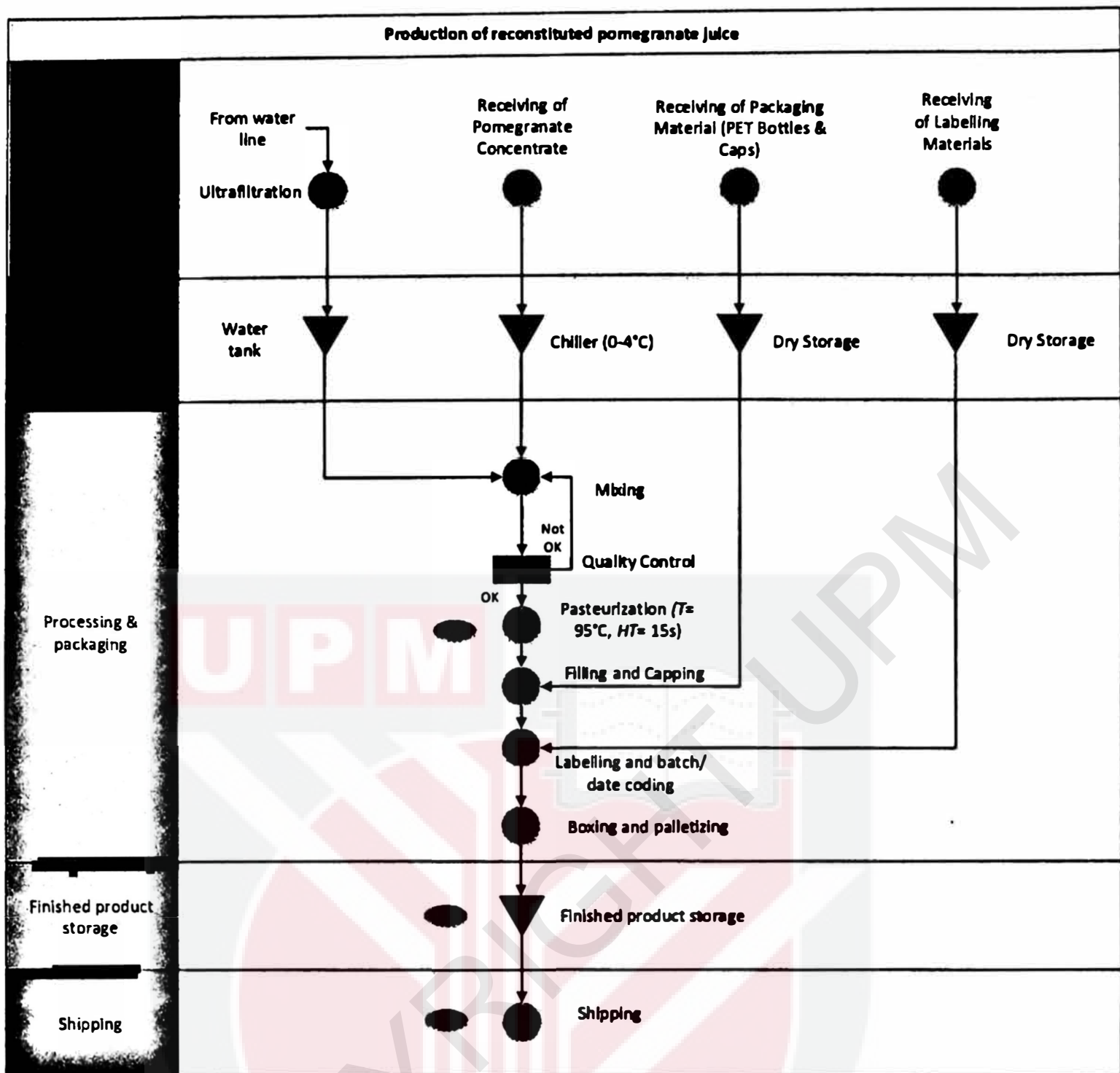


Figure 4.2.4: Process Steps of Pomegranate Juice Production

1) Raw Material Receiving

During the receiving process, the concentrates are received in aseptic bag of size 15 L /bag. The production expects to receive 12, 000 L in every 3 months. The concentrates undergo the incoming inspection process to check the import certification and temperature which should be maintained at 4°C. Meanwhile the packaging materials such as bottle, labels and caps must be received in well-condition. All the defected materials will be returned to suppliers. The receiving area will be equipped with two- wheel hand truck,

four-wheel dolly and hand operated low-lift pallet truck to assist the handling of incoming raw materials as in Figure 4.2.7.

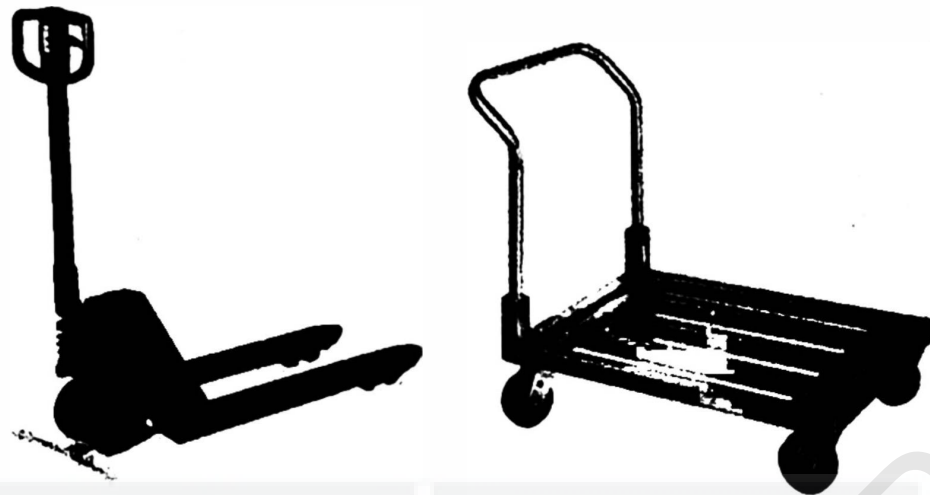


Figure 4.2.5: Four-Wheel Dolly and Hand Operated Low-Lift Pallet Truck

2) Raw Material Storage

The pomegranate concentrate will be stored inside the cold room with temperature about 4 °C to avoid the quality changes while the packaging materials are placed in the dry storage room. All the concentrates are stored on pallets while the packaging material are stored on shelved without opening their outer packing to maintain its hygiene.

3) Batch Mixing

The concentrates are emptied from the aseptic bag into mixer and water is added to reach the right dilution degree, according to owner's recipe and complying to Codex Stan 247-2005, Codex General Standards for Fruit Juice and Nectars. The Codex required the reconstituted pomegranate juice to attain the minimum Brix level of 12° (FAO, 2005). In this mixing process, the pomegranate concentrate are mixed with treated water in the mixing tank in Figure 4.2.8 according to the ratio 1:2. The function of this process is to mix the concentrate and water in order to have the consistent taste. Based on the

experience, the minimum time for mixing is 30 minutes since the both of liquids did not contain solid particle.

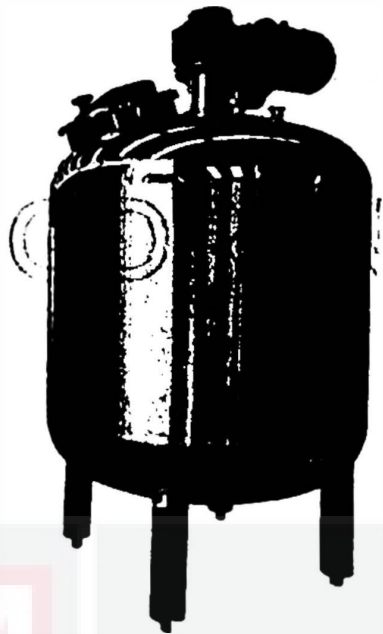
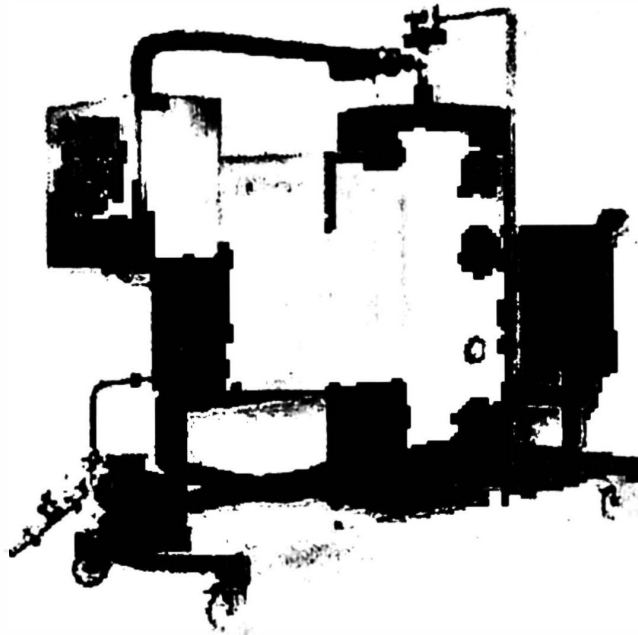


Figure 4.2.6: Mixing Tank (Solution Pack Machinery, 2019)

4) Pasteurization

Pasteurization is the process to kill the pathogens inside the food and beverages by using heat. The temperature used for pasteurization is 80°C in a 5 minutes (Petruzzi et al., 2017). For the juice productions, the tubular heat exchanger in Figure 4.2.9 is commonly used to pasteurize the juices to kill the pathogens and bacteria accumulated during the mixing and weighing process. The pasteurization process is chosen instead of the sterilisation because the long exposure of heat to the food may affect the taste, nutritional values such as antioxidants and appearance of the juice. The number of microorganisms in the juice can be reduced to the safe level namely 4.39 log reduction of aerobic plate count (Maturin & Peeler, 2001). Hence, the shelf life can be prolonged as the number of microorganisms in the juice is reduced. In addition, the juice is acidic with pH below 4.3 and thus the pasteurisation process is adequate.



ELECTRICAL OR STEAM HEATED

Figure 4.2.7: Tubular Heat Exchanger

5) Aseptic Filling and Capping

The process after the pasteurization is aseptic filling and capping process. The machine for this process is illustrated in Figure 4.2.10 below. The pasteurized pomegranate juice will flow in the piping to the bottling section that must be accommodated in aseptic chamber. The chamber is enclosed in a microbiological isolator in which the environment is sterilized before starting production. The sterility is maintained during production with an overpressure of sterile air. The pomegranate juices are bottled into pre-sterilized (by supplier) 300 ml bottle and hermetically sealed with sterilized cap. The checker at that section will check the cap integrity and the volume of the juice to ensure the volume of the juice entering the bottle is consistent. It is important to prevent the re-introduction of micro-organisms, including mould spores, during filling. These procedures are covered by GMP.



Figure 4.2.8: Aseptic Filling and Capper (Solution Pack Machinery, 2019)

6) Labelling

The labels of the bottles are manually placed into the bottle before entering the shrink labelling machine in Figure 4.2.11. The label must have a consistency in terms of colours, size and thickness before it being used. The operator must check the bottles during the process to avoid the inconsistency of the product produced.

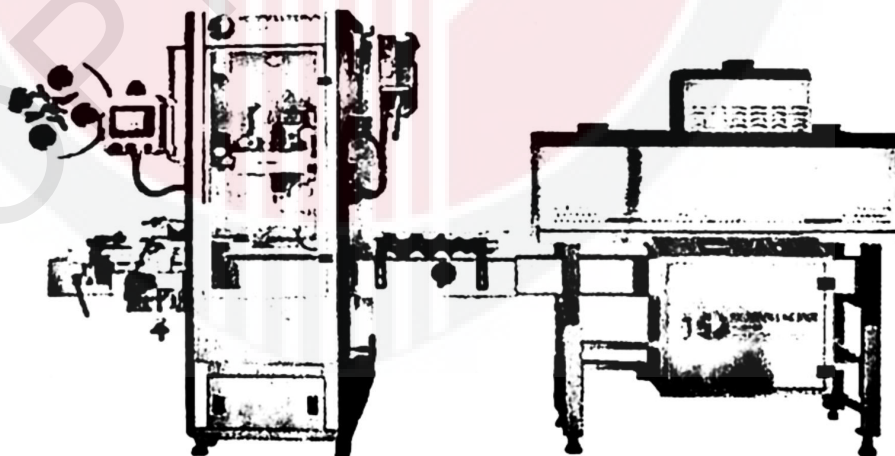


Figure 4.2.9: Labelling Machine

7) Boxing and Palletizing

The finished products are manually packed by operators in to the box contain 10 bottles of pomegranate juices. The box must be seal properly to protect the product. The box will be sent to the finished product storage and stored on pallet with each pallet can bear 200 number of boxes and can be maximally stacked in two stacks showed in Figure 4.2.12. The finished goods storage is well ventilated and maintained at ambient temperature. Since the primary packing has been done aseptically, the pasteurised juice can be stored under ambient conditions.

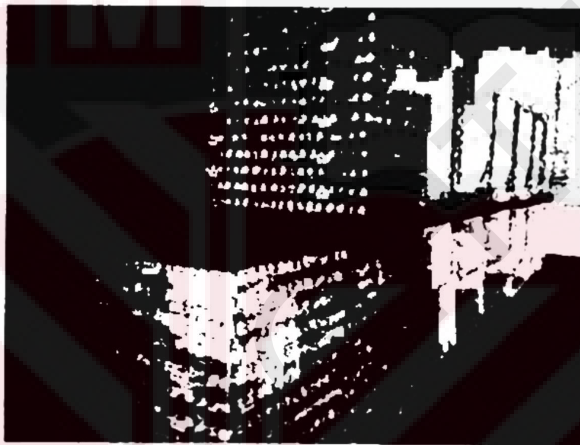


Figure 4.2.10: Free-standing Pallet Storage (LeGroup Industries, 2013)

8) Shipping

Lastly, the finished good are transported into the customers. The finished product must be transported in a well maintained vehicle. The vehicle also must be clean and sanitized before taking the product from the factory to avoid the cross contamination from happened.

4.2.4. Design Stage 4: Machine Selection

In the table 4.2.4, the list major machine used in the production of pomegranate juice is chosen. All of the machines is chosen based on the capacity needed for each process and utilize only 80% of the capacity. This is because the remaining 20% are used as a reserve capacity for the future increasing production ((Hasnan et al., 2014).

Table 4.2.4: List of Major Machine Used

Machine code	Machine description	Model	Size (L x W x H) and Space Req.	Number of Units	Capacity Performance	Utility Requirement
M1	Mixer	M 500	700 x 800 x 1250 mm	1	370 Litre	P = 1.5 kW
M2	Pasteurizer	EPAS 420	1100 x 800 x 1650 mm	1	500 Litre	P = 3.6 kW
M3	Bottling Machine	SFF- LPF 12	1707 x 1306 x 2421 mm	1	48 bottles per minute	P = 24 kW
M4	Capper Machine	SPF CM - 1	1025 x 952 x 1950 mm	1	48 bottles per minute	P = 24 kW
M5	Labeller Machine Solution Pack Machinery	SPL- SLM- 150		1	150 bottles per minute	P = 24 kW

4.2.5 Design Stage 5: Processing Facilities Design

For this stage, the facilities inside the factory are designed based on the requirement of GMP in order to have an efficient and hygienic production process. There are several steps needed to be taken before designing a facilities inside the factory. Since the factory is located in a terrace lot buildings, the space needed are limited due to the design of the buildings.

There are several facilities such as production room, storage room for raw materials and finished products, laboratory, office and receiving and shipping area are designed in this project. The main outputs of this stage are the Room List and Room Design Data Sheet. The Room List provides all the processing room that should be made available in this factory and is given in Table 4.2.5. Every room must be provided with Room Design Data Sheet in which this section demonstrates the Room Design Data Sheet for Production Room and for the concentrate storage.

Table 4.2.5: Room List for Pomegranate Juice Factory X

Storage	Production	Transition
Concentrate cold room	Production hall (low-risk)	Receiving facility
Packing material store (bottles, caps and labels)	Filling room Boxing room	Shipping facility
Finished product storage		

4.2.5.1 Design of Raw Material Cold Room (Storage)

The data sheet as shown in Table 4.2.6 contains the data used to design the finished product storage and Table 4.2.7 design details for the concentrate cold room. Section A

lists down the equipment in the room that has been determined at Process Specification (at Design Stage 3). Section B set the condition such as low-risk zone, room temperature of 4°C and so on. Section C list down the utility that need to be provided. Section D records the structure of the room, while Section E presents the schematic layout of the room.

Table 4.2.6: Data Sheet Design of Finished Product Storage Planning

Finished Product Storage Planning	
Shipping (Litre/Year)	
n(b)/y	450
Litre/batch	300
Qship	135000
Number of Box per Year (nbox)	
Qship	135000
Qlitre/box	12
nbox	11250
Stock Lead Time, Tstock	
min lead time (days)	2
max lead time (days)	3
Tstock	2.5
Shipping Frequency (fship)	
Dp	300
Tstock	2.5
fship	120
Number of Box per Shipping (nbox/ship)	
nbox	11250
fship	120
nbox/ship	93.75

Table 4.2.6 Continued

Minimum Stock Level (Msl)		
Restock Level		50
Average Consumption per day		37.5
Average Restock Period (day)		1
Minimum Stock Level, Msl		12.5
Storage Capacity, Cfp		
nbox/ship		93.75
Minimum Stock Level, Msl		12.5
Storage Capacity, Cfp		106.25
Number of Box in Storage		
Box per pallet		96
Box per day		200
Number of pallet		2.08
Average Restock Period (day)		1

Table 4.2.7: Example of Room Design Data Sheet for the Concentrate Cold Room

UPM		ROOM DATA SHEET			
Document Name :		Author:		Date:	Version:
Room Data Sheet for Production Room		Nur Syahida Laila binti Azmy		29/4/201 9	Draft
Building:	Factory X	Room Number:		CR 1	
Room:	Cool Room For Concentrate	Level:		Ground Floor	
Project Nr:	1				
Room Function:	To store the finished product before shipping process.				
Occupancy :		Person	Full Shift		Area: 27.9 m2
	2	Person	Minimum	1 h/d	Height: 3 metre
Working Hours:	9	hours			Width 6.2 metre

Table 4.2.7 Continued

A. Equipment		
1	Plastic Pallet (2 Units)	
2	Pallet Truck and Jack (1 Unit)	
3	Platform Trolley (1 Unit)	
B. Room Condition		
1	Zone:	Low Risk (GMP area)
2	Explosion Class:	Not specified
3	Room Temperature:	4 celcius
4	Humidity:	85 - 98%
5	Ventilation:	Ventilation Fans
6	Air Change:	7 Air Change/d
7	Air Over- /underpressure:	Normal Pressure
C. Room Utilities		
1	Water	Not Required
2	Wash Basin, rinse or sanitary equipment	Not Required
3	Floor Drainage	Not Required
4	Compressed Air	Not Required
5	Steam and Condensate	Not Required
6	Gas	Not Required
7	Liquid	Not Required
8	Vacuum	Not Required
9	Electical Power Supply	Required
10	Emergency Power Supply	Required
11	Lighting	110 Lux T8 Flouresecent Lamp, Protected in Sleeves Cover
12	Telephone	Not Required
13	Data Communication	Hand Record
14	Other Communication Equipment	Not Required
15	Smoke Detector	Not Required
16	Sprinkler	Not Required
17	Fire Extinguisher	Not Required

18	Operators Safety Equipment	Not Required
----	----------------------------	--------------

Table 4.2.7 Continued

D. Room Structure		
1	Flooring:	Resin Based Flooring Materials
2	Wall:	Polyurethane Wall
3	Ceiling:	Polyurethane Based Materials
4	Corner:	Coving at floor, wall and ceiling junction, 50 mm radius
5	Door:	Polyurethane insulation sliding door and double swing door with facing of polyester coated galvanized steel
6	External Window:	Not Permitted
7	Internal Window:	Not Permitted
8	Others:	Not Required

E. Layout

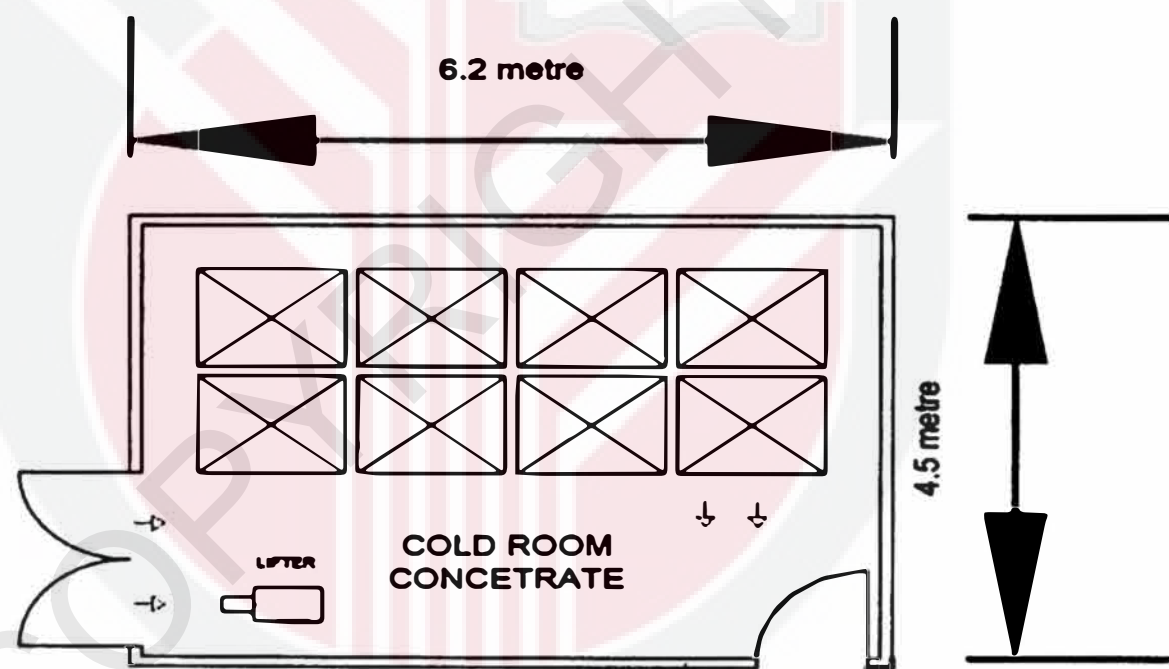


Figure 4.2.11: Layout of Cold Room for Pomegranate Concentrate

In Figure 4.2.13 above, it showed that the layout of the cold room for pomegranate concentrate. The layout is designed to store the concentrate before it is used in the juice production. Cold room of the concentrate are proposed to have 16 free standing pallet with

a standard size 1200 x 1000 mm x 860 mm. It also have a static load capacity of 1500 kg and can be loaded up to 700 mm height. The free standing pallet is used to hold the concentrate received from Turkey which in a bulk size with a 120, 000 Litre of volume that can be used for 3 months of productions. Besides that, the ventilation system are provided in the cold room to ensure the air flow to cold the room in order to preserve the quality of concentrate. Moreover, the lifter such as pallet truck and jack and platform trolley are provided inside the cold room for the load and unloading activities. The clearance between pallets to the wall is 0.5 m and between pallets is 0.1 m for safety and monitoring activity. The aisle is dimensioned as the width of lifter + 2 x 0.5 m for lifter movement while front zone had the width almost 6.2 m for manoeuvring the lifter (Jung, 2010). The dimension of the room is given as 6.2 m x 4.5 m x 3.0 m.

4.2.6 Design Stage 6: Auxiliary Facilities

The main design output is the auxiliary facilities design requirement. Particular consideration is given for personnel hygiene facilities. As recalled from the Room List in Table 10. There are low-risk production room and high-risk packing room. These called for the need of two change rooms and also hand wash station before accessing the production room and packing room-. The size of low-risk change room is planned to accommodate 3 operator/ change.

The high-risk change room and hand-wash station is positioned before accessing the packing room. They are provided in a single cabinet room and should be ventilated with over-pressure to prevent air contaminant from entering the room. A cross-over line is designed to separate the low risk side and high risk side of the change room. The size of high-risk change room is planned to accommodate 2 workers/change since only 2

operators are specified for packing task. It is expected for worker from low-risk area to change into high-risk clothing before entering packing room.

Since the company has specified ≥ 10 workers are to be employed in processing area, separate toilet is required for male and female operators. Each toilet is provided with one lavatory, urinal (for male) and hand-wash basin (UBBL, 1984). The location of toilets must be isolated from the processing area and be barriered by low-risk change room as in Figure 4.2.14.

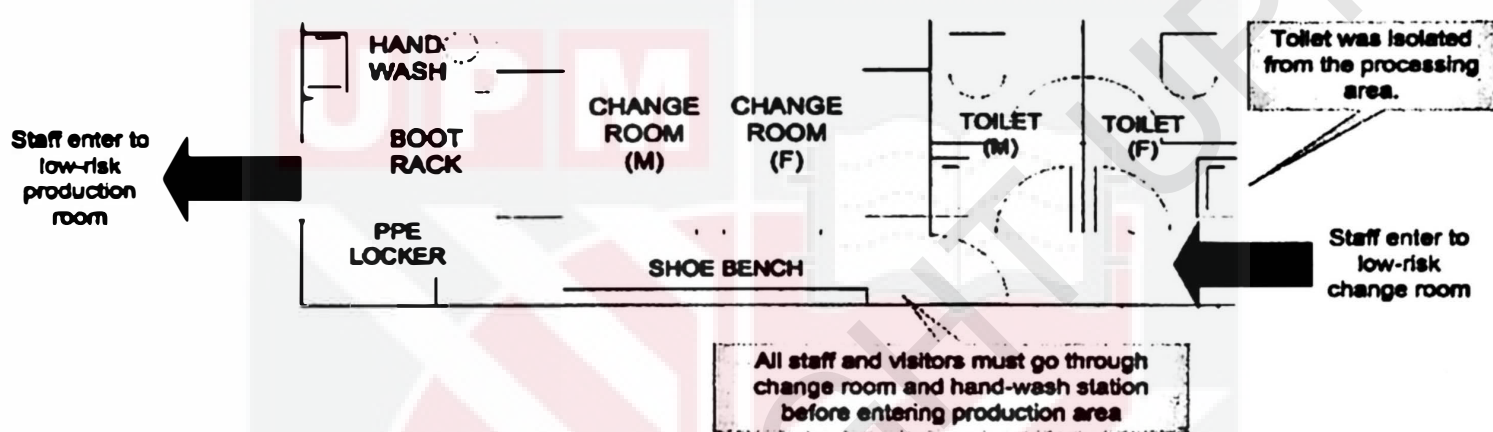


Figure 4.2.14: Layout of Low-Risk Change Room Hand Wash Station and Toilet

Other auxiliary facilities that are proposed to be on the same floor as the manufacturing floor are given in Table 4.2.9. These are office, laboratory, switch room, mechanical room, janitorial room, chemical store, CIP room, waste station and water filtration station.

Other common facilities such as break room, prayer room are not included as these could be located on the second floor of the building and out of this study scope. The laundry facility for boot and factory clothing is excluded and decided to be outsourced due to capital, staffing and space constraint.

Table 4.2.8: Proposed Auxiliary Facilities

Facilities	Important design details
Production and inventory office	Design according to a single office format with floor area 8 to 10 m ² . Ventilation rate according to the local guidelines while lighting uses LED or fluorescent T5 lamp.
Laboratory for QC/QA	The laboratory would have access to low-risk area and provided with hand wash/dry facility. Other compulsory equipment as in Meng et al. (2005) are to be provided. Fume extraction system is proposed to exhaust the heat and odour arisen due to cooking test activity. Provision of aisle width at minimum 1.2 m with staff working only on one side of bench (Meng et al., 2005)
Switch room	Switch board is to be wall-mounted with front access minimally 4.5 ft. (TNB, 2015). The room is designed to be lockable, has adequate ventilation, installed with anti-vermin netting at any opening. Emergency lighting is required. It is proposed to be located near the main power user in the factory to minimize power loss.
Workshop and tool storage	The room is required to house the quick repairing works, or overhaul small tools. Adequate light of 500-600 lx is proposed using T5 lamp or LED (Baker. 2013). Power supply is provided. The size planned is to accommodate maximum one technicians which is 1.5 m ² /technician with aisle width not less than 0.875 m (Jung, 2010)
Cleaning room	The room is required to clean utensils and pieces of equipment during production time. The size planned is to accommodate maximum two operators (1.5m ² /operator with aisle width not less than 0.875 m), wash-sink and space to place the utensils. An exhaust fan is specified to create negative pressure and to exhaust the aerosols. Floor sloping is required heading towards floor drainage

(equipped with fat trap) and then proceed to wastewater treatment facility.

Table 4.2.8 Continued

Storage for cleaning tool and chemical	The room is to store detergent, disinfectant and also tools for cleaning. No hazardous chemical is expected. The size planned for the room is to accommodate lockable storage shelves, storage box for cleaning tool and aisle width at least 0.875 m. The room itself must be lockable and secured.
Waste station (for solid and effluent)	The waste water treatment as well as dumpster are positioned outside the manufacturing premise in an open-air environment. The waste dumpster is provided lockable enclosure. Water source and drainage are required for cleaning. The total footprint for waste station is estimated as L 2.80 x W 1.96 = 5.49 m ² (Pakar Management, 2015).
Water treatment station	A station for small unit of water treatment process with estimated footprint of 1 m ² is required near the main water supply pipeline. The station must be secured from unauthorized access

The finishing structure of all facilities above do not need to be of food-grade materials except for cleaning room and laboratory, in which the structure such as flooring, wall and ceiling followed the GMP-area specification.

4.2.7 Design Stage 7: Space and Workforce Program

The main outputs at this stage are Workforce and Space Program. The Workforce Program is given in Table 4.2.9 with only one working shift/day is specified by the company.

Table 4.2.9: Workforce Program

Engineering and Maintenance	Machineries, building and infrastructure maintenance and checking, repair	1	8 h/d
Cleaning (non-production)	Cleaning	1	4 h/d
Logistic (Driver)	Shipping	1	8h/d

Table 4.2.9 Continued

Since Company X had capital constraints in hiring, the number of staff (N_{staff}) can be minimized by maximizing the utilization of working time. For example, the operators working in the raw material storage can also be working in the finished product storages as their time load is only about 1 to 2 h/d.

Department	Job scope/task	Manpower requirement	Time load/manpower
Management	Director	1	8 h/d
	Secretary	1	8 h/d
Administrative	General administration	1	8 h/d
	Sales and marketing	1	8 h/d
	Finance and accounting	1	8 h/d
	Purchasing	1	8 h/d
Production operation	Production management and planning	1	8 h/d
	Store control	2	1-2 h/d
	Receiving and shipping	2	1-2 h/d
	Juice production	3	7 h/d
	Aseptic filling and capping	2	4 h/d
	Boxing	2	4 h/d
Quality assurance and control	Raw material inspection, in-line processing, storage, quality control and analysis, HACCP and GMP	1	8 h/d

The Space Program is given in Table 4.2.10. The total floor area required to build the facilities are 238.12 m², which is about 84% of the available floor area in the building. The remaining 16% may be useful for other spaces such as aisles between or safety factor for the complete building layout.

Table 4.2.10: Space Program

Department	Room name	Room code	Length (m)	Width (m)	Area (m²)
Processing	Production room	PR01	11.50	4.90	56.35
	Primary packing room	PPR01	4.08	4.90	19.99
	Boxing room	BX01	4.95	4.10	20.30
	(Secondary packing(
	Dry storage	DS01	3.90	2.60	10.14
		SS01	3.50	2.60	9.10
	Packing material storage	PS01	3.58	2.60	9.31
	Cold room (raw material)	CRRM01	7.20	2.60	18.72
	Cold room (finished product)	CRFP	4.79	4.85	23.23
	Receiving area	RA01	2.00	4.10	8.20
Shipping area (outside aisle)	SHA01	1.50	4.85	7.28	
Auxiliary facilities	Office	OR01	2.62	2.75	7.21
	Laboratory	LAB01	2.08	2.80	5.82
	Workshop	WS01	3.07	1.41	4.33
	Switch room	SW01	1.75	1.41	2.47
	Cleaning room	CL01	1.80	1.96	3.53
	Store (cleaning)	CLS01	2.00	1.00	2.00
	Water filtration station	WFS	1.00	1.50	1.50
	Waste water treatment station	WWT	2.73	1.96	5.35
	Toilet (F)	TF01	1.38	2.19	3.02
	Toilet (M)	TM01	1.38	2.19	3.02
Change room(F)	CHRF01	1.95	2.19	4.27	

Department	Room name	Room code	Length (m)	Width (m)	Area (m ²)
	Change room (M)	CHRM01	1.95	2.19	4.27
	Hand wash station	HW01	1.75	2.90	5.08
Total floor area required (m ²)					238.12

4.2.8 Design Stage 8: Layout Design and Site Master Plan

The main design outputs at this stage are the plant layout, building structure specification and landscape.

4.2.8.1 Factory Layout

The newly redesigned Factory X is shown in Figure 4.2.14. The layout shows the spine aisle as the central core for the production traffic.

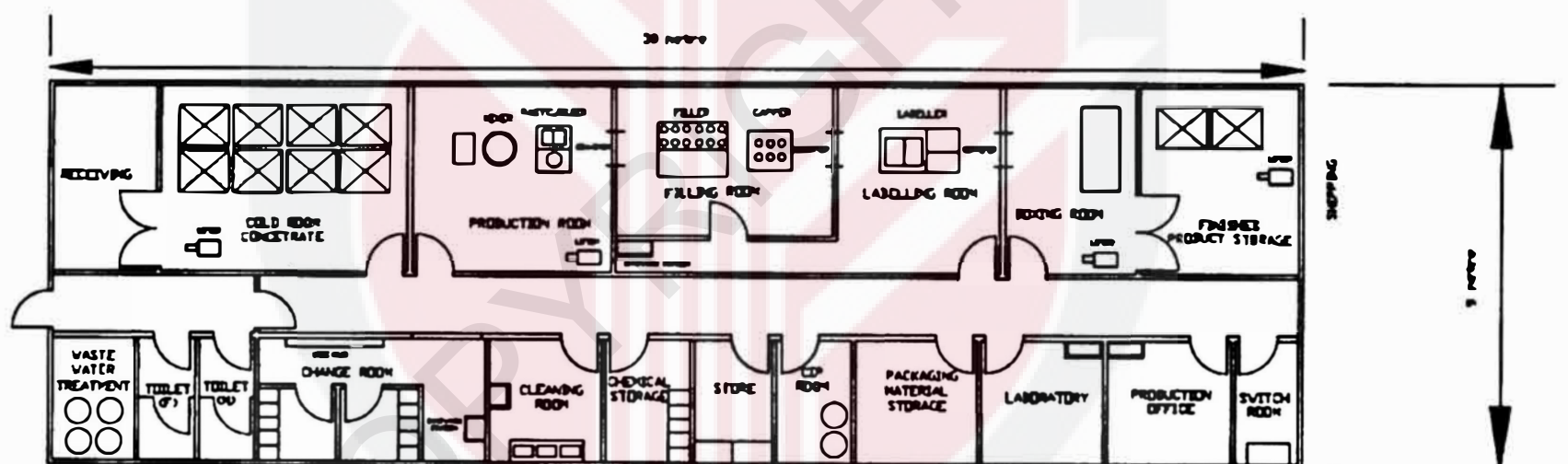


Figure 4.2.14: Layout Arrangement of Factory X

In Figure 4.2.14, the layout showed that the raw material such as concentrate, dry packaging materials are received from the Receiving Area at the eastern side of the premise. By using the spine aisle, the incoming materials managed to be stored directly to their specific storage room. During the productions, the raw materials which is pomegranate concentrate is brought to the production rooms or the area which the major machines are placed. The process of the mixing and pasteurization are take placed in the

primary processing area while the process such as filling and capping are in the separate room to maintain the hygienic of the product. After being bottled in the filling and capping room, the bottle are transferred into the labelling machine by using the conveyor. The labelled bottle are continuously moving to the boxing room for the packaging process. The process of boxing are in a manual process.

In the end of the production, the juices that being packed are placed in the pallet and transferred by using the hand and truck dolly and also trolley to transfer the finished product to the storage before shipping process. This new proposed layout showed that the flow of the production of juice are onwards and more efficient than the current production. There is no cross and backtracking in the material movement and it can reduce the cross contamination to the product. Moreover, transfer hatch located in high risk room such as in the boxing room is provided to allow the waste to be transfer to the outside room without exiting the room since it is to prevent the cross contamination.

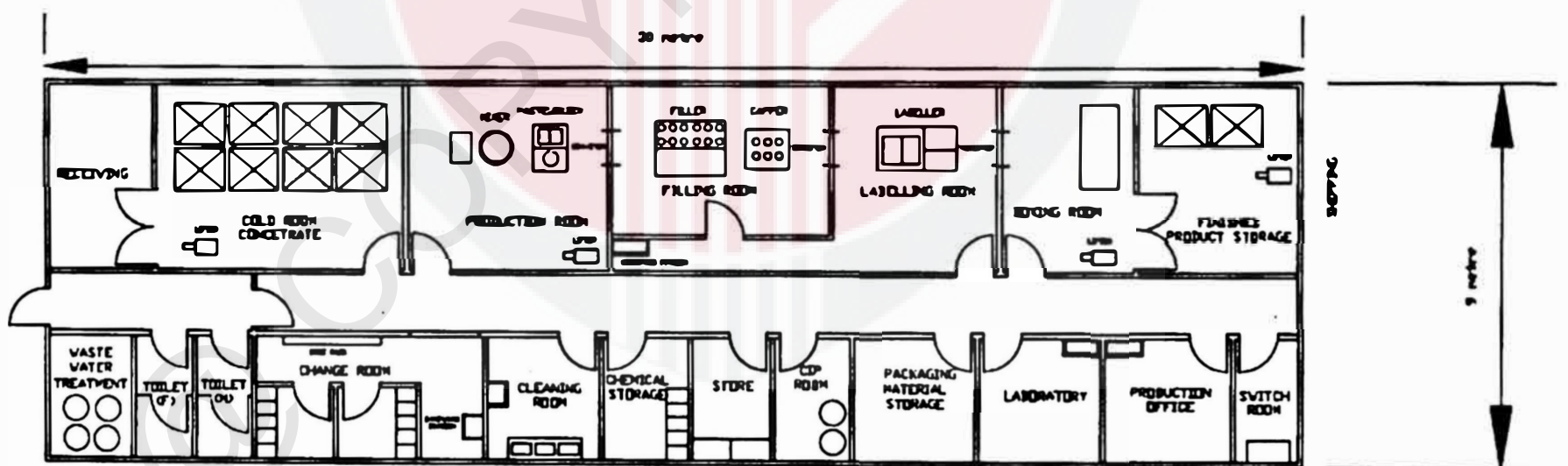


Figure 4.2.15: Material and Operator Movement in the Factory

Figure 4.2.15 shows the material and operator movement in the factory. The operators enter the building through staff entrance at the eastern side of the building, proceed to change room, hand-wash station and their respective workstations including laboratory. A change room is located before entering boxing room so the operator can change their

clothes before entering the boxing room. The operators are able to access the different rooms in the premise through direct access door or the spine aisle.

4.2.8.2 Site Master Plan

The proposed plot plan at Design Stage 1 was finalized with receiving area, shipping area and staff entrance being confirmed. The factory perimeter is specified to be fenced with grill to safeguard the factory from unauthorized access. The north side area is already covered with roadways up to 12 m while the southern side is covered with pavement and roadways up to 20 m, leaving no place for vegetation to grow.

The outer equipment placed in open air environment are the compressor, waste water treatment and water filtration station. The equipment are sited within the fencing area. The waste water treatment is located at the northern side of the building as such that the prevailing winds do not blow them into the building.

There is no security lighting designed outside the building. However, the shipping area, being located in an open air environment, is provided with fluorescent lamp that must be protected in a sleeve. Lamp roads provided by the local authority. The external drainage were readily built and run across the shipping as well as receiving area. The drainage is specified to be shielded with drain cover to disallow rodent from accessing the factory area.

4.2.9 Design Stage 9: Utilities Planning

The main design output are the utilities and building services plans as below and are elaborated in the following subsections:

1. Ventilation system specification
2. Lighting plan
3. Waste and effluent disposal layout plan
4. Electrical appliances and communication media configuration
5. Water production and distribution specification
6. Cleaning plan
7. Health, safety and security system

4.2.9.1 Ventilation System Specification

A mechanical ventilation with AHU system is required to regulate the temperature, humidity, particle removal in air, ventilation rate and to establish positive air pressure zones in the processing areas. Positive air pressure zones to ensure the air flows from Packing Room outward to the low-risk area and finally out of the building. Figure 4.2.16 shows the air flow design with Packing Room has the highest pressure, symbolized by “++” e.g. 30 Pa, “+” symbol shows the room are designed at lower pressure e.g. 15 Pa, while room with “0” signs for normal pressure. Cleaning Station and Toilets have negative pressure “-“, indicating that an exhaust system should be provided for removing odour, aerosols and condensates.

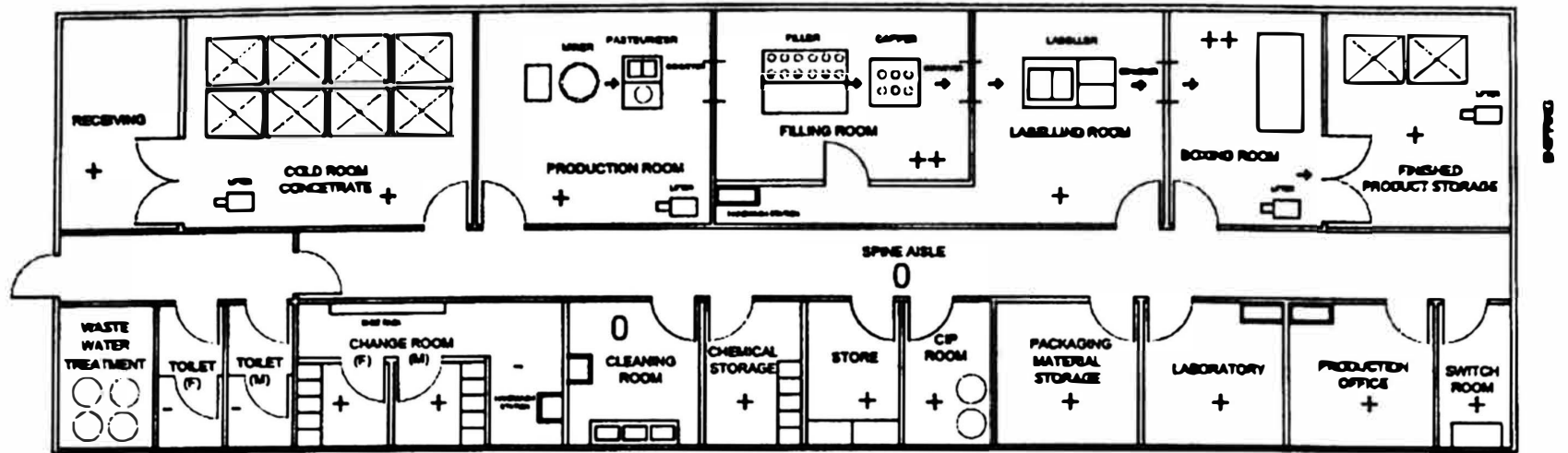


Figure 4.2.16: Ventilation System of Factory X

4.2.9.2 Lighting Plan

All lamps in the processing area and cleaning rooms are specified to be protected in plastic shields and sealed off to the ceiling. Special duty lighting is also given for emergency, exit lighting and insect traps. Table 4.2-11 summarizes the lighting plan for the Factory X. Daylights are facilities located in open-air environment. The illumination specification is specified to fit for food processing premise as adopted from Moerman (2011) and Baker (2013).

Table 4.2.11: Lighting Planning

General lighting			
Location	Fluorescent lamp type	Illuminance (lx)	
Primary processing (low risk)	T8	540	√
Weight station	T8	540	√
Spine aisle	T8	220	√
Primary packing	T8	540	√
Secondary packing	T8	500	√
Cold room (raw meat)	T8	220	√
Dry ingredients storage	T8	220	√
Pack material storage	T8	220	√
Cold room (finished products)	T8	220	√
Receiving dock	T8	110	√
Shipping dock	T5	110	√
Change room (M)	T5	100	X
Change room (F)	T5	100	X
Toilet (M)	T5	100	X
Toilet (F)	T5	100	X
Cleaning station	T5	100	√
Cleaning store	T5	100	X

Table 4.2.11 Continued

Hand wash and foot sanitizing station (low-risk)	T5	100	X
Hand wash and foot sanitizing station (high-risk)	T5	100	X
Switch room	T5	250	X
Single office with window	T5	300	X
Laboratory	T8	300	X
Workshop	T5	500	X
Location	T8	110	Fluorescent Lamp, Protected in Sleeves Cover
Spine aisle before entrance to Production Room	Insect light trap Receiving room	UV-Light for (Adhesive glue board traps), Black light (BL)	Made of stainless steel (AISI 304), wall mounted at least 2 m above ground, have a 30° sloped top surface, have a removable drawer to collect insect debris when electrocution occurs

4.2.9.3 Waste and Effluent Disposal Plan

For waste of the productions, the drainage of the factory are flowed into the waste water treatment column. The waste such as water produced from the toilets, sinks and another source of drainage are treated before it being discharge to the drain to avoid the contamination happened. Cleaning in Place (CIP) process is a method used to clean complete items of plant equipment or pipelines circuits without dismantling the equipment (Lenntech, 2019). In this juice production, CIP are important for the cleaning process since there are pipe circuits used to transfer the liquid to another machine. Moreover, the process is fast and efficient since the pipes are not being dismantled for the cleaning process. For this utilities, this is the recommendation for the waste and effluent disposal plan for future of Company X to be customized and developed.

4.2.9.4 Electrical Appliances and Communication Media Configuration

All electrical and electronic devices are to be enclosed in junction boxes, casings, closed cable housings and cabinets.

- Cables and conduits

Cables made of PVC, smooth type and rounded cross-section. Vertical installation of cables coming from ceiling will use electrical conduits in production room. In dry area wire trays and cable ladders are used. Cable trunking can be used for long distances cabling. Connections of cables and wires to housings must be sealed to avoid ingress of liquid. Conduit must be of non-spiral and non-corrugated type. Vertical installation within processing area is maximized, set off the wall or spaced away from adjacent surfaces to allow cleaning and never hang over open machines.

- Switch box and control system and electrical cabinet

The casing is made of stainless steel AISI 304, or plastic with smooth exterior finish. They must be dust- and water-tight for ingress protection particularly at the door of boxes. Connections of cables and wires to housings must be sealed, preferably from bottom of housing. The enclosures can be sealed to the wall with food standard silicon seal or spaced away from equipment or walls at least 30 mm and should be provided with an easily drainable 30° top roof. The distance between the cabinet base and the floor is at minimum 0.3 m.

- Telecommunication

Telephone for external communication and data processor are provided for manufacturing administration. During operation, real-data during processing activities such as inventory and quality control data are to be recorded per hand and not automated due to low skill of operators and the common changing of staff. These data and information are to be submitted to supervisor and administration staff for computational record.

4.2.9.5 Water Production and Distribution Specification

Water is used in the Factory X for processing, cleaning, sanitary and personnel hand wash. Potable water available from the local pipeline that complied with the National Drinking Water Quality Standards as supplied by the local water company (SYABAS, 2017). Yet, due to old or availability of sediment settling in the distribution pipe, it is possible to find contaminants in the water supplied. Therefore it is recommended that water supply is filtered with microfiltration technology where bacteria and fungi are effectively removed (Brillinger, 2011). Based on the water usage in the Factory X, Table 4.2.12 lists all points of water use for detailed water system design by structure engineer. The water used by

production and cleaning activities is estimated to be 5.56 m³/day (Pakar Management, 2015; Schwarz et al., 2011).

Table 4.2.12: Water Usage Requirement

Location	Tap	Hand-wash sink	Hot/cold water	Wash basin	Water closet
Receiving Facility	1				
Production Room	2				
Shipping Facility	1				
Hand Wash Station (low risk)		1			
Hand Wash Station (high risk)		1			
Cleaning Room				1	
Laboratory				1	
Production Office		1			
Toilet (F)		1			1
Toilet (M)		1			1
Total	4	5		2	2

4.2.9.6 Health, Safety and Security System

With regards to the most common accidental injuries and illness that take place in food industry, Table 4.2.13 proposed the design considerations according to their location in the factory. Some of these design aspects have been already specified in the previous Design Stages.

Table 4.2.13: Design Aspect Related to Occupational Health and Safety

Location	Event to lead to accidents and injuries	Accidental injuries/ occupational illness	Design aspects
Production Room Packing Room Boxing Room Steps	-Machines run unexpectedly during cleaning, maintenance or idle time -Hand and arm drawn into the running nip between the conveyor belt and the end roller.	Injuries due to machinery	Electricity isolation and safeguard designs
	Fall from steps or from roof void	Accidents due to work at height	Hands-rail at steps and roof void
Cold room flooring Production Room flooring Cleaning Room flooring	Slippery floor due to water spill or frost in cold room	Slip and trips	-Slip-resistance flooring due to water and frost. -Mark out change of floor level and the gradient should be gentle/ramped -Adequate lighting illumination

Table 4.2.13 Continued

All possible area with load-handling	Unstable load when moving or static	Struck by object and knives	-Provision of ramp at different floor level -Load securing accessories such as chain or gitter box
	-Lifting or lowering loads -Carrying and pushing / pulling load	Accidents due to manual handling and lifting Upper limb disorder	Provision of lifter for lifting load above worker height
Production Room	Filling and capper machine emit noise exceeding 85 dB (A)	Noise-induced hearing damage	-Provision of hearing protector -Fitting anti-vibration at machines foot

Fire safety and emergency system is incorporated in the detailed design by the structural engineer as to meet the requirement in UBBL Part VII and Part VIII (1984). Importantly, the following aspects are highlighted:

- 1) Automatic smoke or heat detection in dry storage room, and production room and alarm systems
- 2) Emergency power system and escape route
- 3) Portable extinguisher in hygienically designed box at Production Room, and storage rooms.

Security system based on camera and video surveillance is recommended to monitor unauthorized access to the factory area. An access control system as simple as manually lockable door is proposed at all main entrance and gates to outside equipment such as waste station.

4.3 Design Analysis

This section presents the design analysis to evaluate the effectiveness of the new factory design in improving the productivity and delivering the hygienic condition for the Factory X. A comparison analysis using actual buildings is desirable (Rani et al., 2014). However, such evaluation method would require the new building design to be constructed and compared to the current premise. This would involve administrative, authority approval, fund allocation, construction and commissioning which are not within the capability of this study (Darmawan, 2002).

Therefore, the analysis in this section were carried out using:

1. Simulation analysis for the productivity using FlexSim software.
2. Hygienic design scoring.

The analysis were done based on the design specifications such as drawings, figures, plans and design information. The design specifications of the existing production premise were obtained from the company's historical record, site observations and personnel information's. This included process flow, machine specification, building and facility specification, layout, and utility system. On the other hand, the design specification of the new factory design is obtained from the results in Section 4.2.

4.3.1 Factory Modelling and Simulation Analysis

4.3.1.1 Factory Modelling

In this study, the current and new factory modelling are developed by using the collected data and the new capacity of proposed factory. The factory modelling in Figure 4 (a) and 4 (b) in Table 4.3.1 shows the modelling for the processes of current premise and new factory X. This modelling helps to simulate the process of the pomegranate juice production by running the process using the data provided. Simulation analysis is used to analyse productivity and production lead time during the factory operates. The results are discussed in related to operator's utilization, processor's utilization and stay time of product at workstation. Simulation analysis shows that the productivity performance are obtained as Table 4.3.1 below.

Factory Modelling

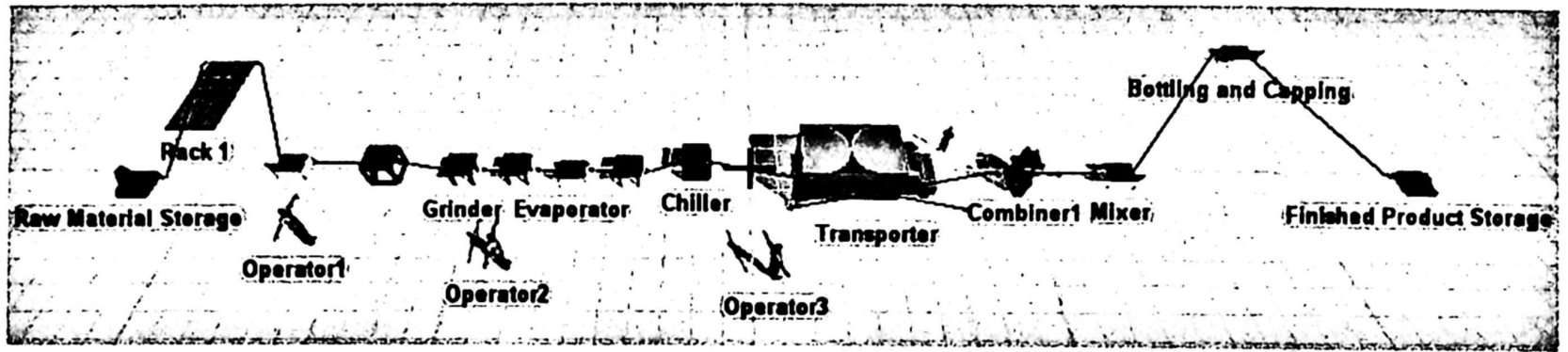


Figure 4 (a): Current Premise

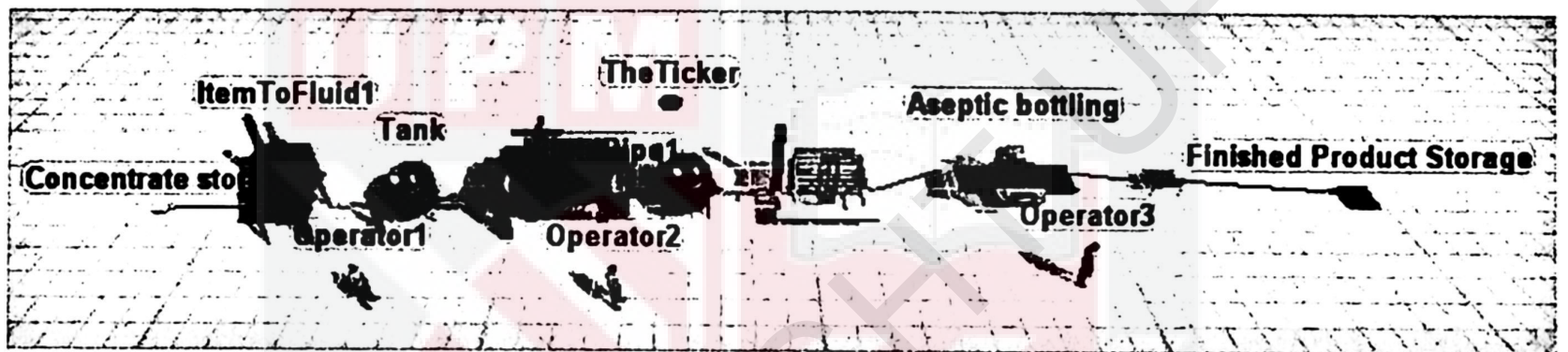


Figure 4 (b): New Factory X

Table 4.3.1: Factory Modelling of Current Premise and New Factory X

The factory modelling for the current premise in Figure 4(a) showed the process of pomegranate juice production. The receiving until the cooling process are in the manual process and the reconstitution of the juice are located at the contracted factory in Semenyih. The process of the pomegranate juice for current premise is using the fresh fruits and the manual works need to be done by the operators in order to extract the juice from the fruits. Because of that, the process of current premise are not efficient and have a longer production time compared to new factory X shown in Figure 4 (b). New factory X modelling showed that the process of the pomegranate juice is in automatic system and

the production of the juice is in one place only. Compared to the current premise, the workload of the operators also been reduced as most of the process in new factory are in automatic and the operator need to observe it from time to time.

Table 4.3.2: Productivity Performance of Current Premise and New Factory X

Analysis	Pomegranate Juice	
	Productivity (L/hr)	Production Lead Time (hr)
Current Premise	5	25
New Factory X	33 to 43	9

After the simulation process completed, the productivity performance of current premise and new factory X are determined. The simulation analysis in the Table 4.3.2 showed the productivity and the production lead time of the pomegranate juice production for one batch after completed the simulation process. Based on the table, the current premise has a low productivity of juice production which is 5 L/hour for one batch per day compared to new factory X which produced 33 to 43 L/hour per batch. The analysis shown that the manual process in the current premise had affected the productivity as the operators needs to spend more time on the crushing and grinding process. As for the new factory X, the productivity of the factory is higher than current premise which is 33 to 43 L/hour. This is because the production of the pomegranate juice has been improved where the pomegranate concentrated is used instead of the fruit juice. The process of extracting juice from the fruit are no longer used as the concentrate is imported from Turkey and the need to be reconstitute in the new factory. Next, the production lead time for current premise is 25.84 hour per batch and it is longer compared to the new factory X that need 9 hour to complete one batch of juice production. The production time lead of new factory X are

shorter than current premise because the production of the juice are in one place compared to the current premise which need to transport the juice for reconstitution process. Moreover, the time to store the juice before the transportation process to the contracted factory also lead to the longer time of the production. From this comparison, it show that the current premise have inefficient process that lead to the longer production lead time and low productivity and the new factory X had showed that the automatic system is more efficient for the company to increase their current production.

4.3.1.2 Graph of Simulation Analysis for Current Factory Modelling

For this section, the graph of the simulation analysis is discussed. The analysis showed the bar graph of the operator utilization, process utilization and average stay time of pomegranate in each station. The graph for the new Factory X are not discussed as there is a lack of data from the Company X. The graph of the simulation analysis are stated in Figure 7 .1 in Appendix A:

1) Operator Utilization

In the Figure 7 (a), the operators utilizations are illustrated by bar graph showing the idle and the utilize time by the operators. Operator1 showed the highest utilization rate which is 53 % during the productions while Operator 4 have a lowest utilization rate which is 86% from the total production time. From the simulation analysis in Figure 7 (a), operator 1 had a several task such as washing the pomegranate fruits and the evaporation process that require 4 hours and it has utilized the operator 1 energy compared to operator 2 which working in the process of filtering and cooling of the pomegranate juice. For operator 4, the utilization is about 86% and it is the lowest utilization of the working hours compared to operator 1 and 2. This is because, operator 4 is working on the automatic machine and

the process time are shorter than the manual process in the kitchen of Factory X. Idle time for operator 4 is higher which is 86% from the working time compared to operator 1 and 2 which having 53% and 71% of working time. This is because automatic system in the contracted factory are working in automatic system that require the observations during the production. The operator 4 did not have to do the process manually and just using the machine to run the process.

2) Average Stay Time of Pomegranate in Each Station

Stay time is the time where the product are being hold in each station during the working productions. In Figure 7 (b) above, the average stay time of pomegranate at each station is plotted. The average stay time of pomegranate in the chiller is higher compared to other process. This is because the time taken to store the evaporated pomegranate juice is about 8 hours before the shipping process. The pomegranate juice have to be store in the chiller to preserve the quality and avoid pathogens from grow. The lowest average stay time is mixer which required 30 minutes in the process. The mixing process are taken about 30 minutes for the concentrate to be mixed with filtered water. The second highest average stay time is evaporation and cooling process. In this process, the pomegranate juice need to be heat for 4 hours with the addition of sugar and cooled in ambient temperature for another 4 hours. It takes about 4 hours for the pomegranate juice in this process.

3) Process Utilization

The processes utilizations graph are plotted in Figure 7 (c). This graph showed the utilization percentage for all process in the production of pomegranate. Evaporation and cooling process has the highest processes utilization percentage which is 68% compared

to mixing, transportation, filtration and washing process which resulted about 95.5%, 96.9%, and 97.2%. This showed that evaporation and cooling process had utilized their maximum time for the production of pomegranate juice since the time taken for both process is in 8 hours compared to other process that required only 0.5 to 2 hours to be completed. The lowest processing time are in mixing process and transportation of the juice to contracted company which have 2.8 % from the production time. This is because the transportation of the juice are required about 1 hour and after the transportation completed, the operator just having the idle time instead of other operator. Automatic machine used in contracted factory also caused the processing time of mixing process are low since the operator just need to observe the texture of the juice without mixing it manually. From the graph in Figure 7.1, it can be concluded that the two separate productions place are the cause where the production output is lower since the time consumption for one batch are longer. This can cause the profit loss to the company and the demands of customers cannot be fulfilled since the productions output is low. The current productions proved that the new factory and processing system need to be developed in order to solve the problems.

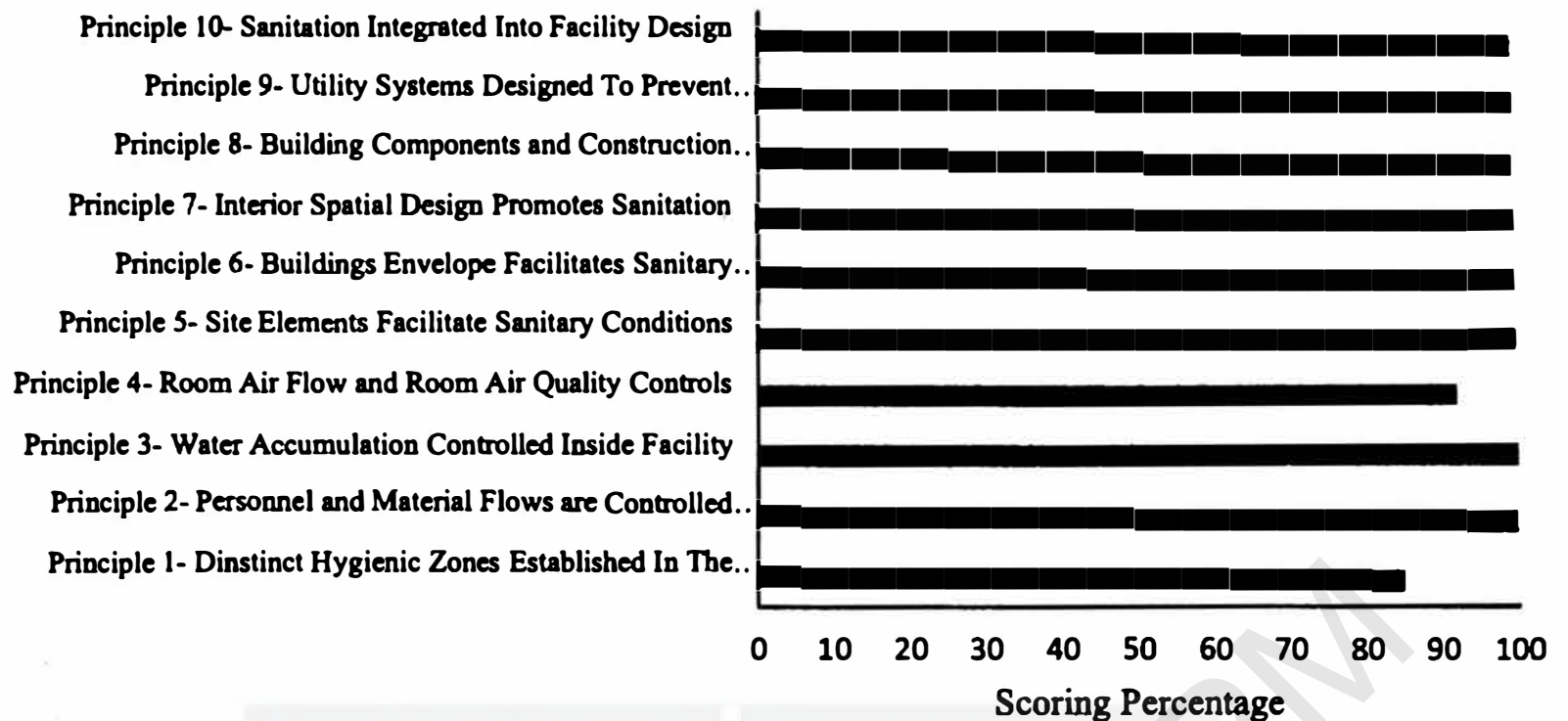


Figure 4.3.1: Score Percentage of Factory X and IFFS Design in the Ten Principles

The overall percentage score obtained for the ten principles are summarized in Figure 4.3.2. The total score is 990/1000 which is 97%.

The new design has scored full marks in most principles except for Principle 2- personnel and material flows are controlled to reduce hazards, Principle 3- water accumulation controlled inside facility, Principle 5- site elements facilitate sanitary conditions, Principle 6- buildings envelope facilitates sanitary conditions, Principle 7- interior spatial design promotes sanitation, Principle 8- building components and construction facilitate sanitary conditions, Principle 9- utility systems designed to prevent contamination and Principle 10- sanitation integrated into facility design. The hygienic design checklist showed that out of eight principle from ten principles are fulfilled in this new Factory X design to achieve a good hygienic environment and to comply GMP design. This full scores showed that the new Factory X are sustainable and more efficient than current factory.

Principle 1 and principle 4 did not managed to get full marks as there are some characteristics or aspects in the checklist are not able to be provided in this project. The separate storage area for tools and spare parts in this new Factory X are not separated as there are insufficient space inside the factory. Nevertheless, the tools and spare parts are being store in the workshops in the different separated box based on its origin risk area to avoid the contaminations. Next, only one unit quality lab in this factory is designed for both high and risk zones. Due to the insufficient space, the lab are used for both risk in the different time based on the usage consumptions. As for principle 4, there is no measure taken to prevent condensation through all seasons because of Malaysia weather is always being hot and humid throughout the year.

As a results, the hygienic design checklist showed that the new Factory X managed to have a proper hygienic factory which satisfy GMP standards requirements. The goals of the project have been achieved with this new Factory X design since it had increase the production output and also applied the hygienic aspect in the factory planning. With 97% score, the IFFS design is expected to be ready for GMP and HACCP system. Nonetheless, a continuous improvement at a very least expense is expected to be executed when required.

4.3.2 Project Closing

4.3.2.1 Economic Analysis of Company X for Pomegranate Juice Production

Economic analysis is the important part need to be calculate in order to know how much cost and time for the Company X to have the profit. In Table 4.3.2, the calculation of the cost for utilities and structures, production line of the juice, set-up cost, projected sales,

and operating cost. The net income for the first year of operating is about – RM 6000 and it shows that Company X will having the loss of profit since the ROI of the analysis is – 0.02. The ROI of Company X keep increasing for the second year and third year where the ROI are 0.33 and 0.72. The increasing ROI can be achieved if the company's is able to achieve the projected sales in the Production Program (Design Stage 1) from year to year. The factory is able to produce the Production Program, since the system has been designed to meet the Program. In the third year, Company X can manage to have payback period for their investment of is RM 365469.40. This investment cost however requires bank loan of minimally RM 350000. The premise is expected to be rented and thus, contribute to the lower investment cost.

Table 4.3.1: Economic Analysis of Company X

Details	Year		
	2020	2021	2022
Utilities and structures			
Structures renovation	100000.00		
Lighting	1000.00		
Ventilation	5000.00		
Commercial water treatment system	5826.00		
Piping, communication and electrical	20000.00		
Fire safety	2000.00		
Security	500.00		
Waste treatment	5243.40		
Cold room	39000.00		
CIP	27000.00		
Compressor	4000.00		
Production line (juice)			
Mixer	24000		
Tubular pasteuriser	29300		
Aseptic filler and cap (small)	65600		
Labelling	7000		
Other (printing, material handling)	10000		
Set-up cost (incl deposit)	20000		
Total start-up cost	365469.40		

Table 4.3-2 Continued

Projected sales	600000	1050000	1350000
Operating cost			
Raw material	300000	525000	675000
Paying rent	36000	36000	36000
Wages	168000	240000	240000
Overhead	26000	56000	64000
Maintenance	3000	3500	4000
Marketing	3000	1800	1800
Transport	9000	9000	9000
Administrative	7000	8000	9000
Bank	54000	54000	54000
	606000	933300	1092800
Net income	-6000	116700	257200
ROI	-0.02	0.32	0.70
Cumulative net income	-6000	110700	367900
Payback Period	Three years		

4.4 Discussion

A hygienic design of factory helps to productions to become more considerate about the hygienic issues occur in the factory that can effected the quality of the product. Moreover, the hygienic design aspect are one of requirement for GMP and HACCP certificate that helps the SME company to increase their productivity and chance to export their product to international level. Besides that, the machine used in the pomegranate juice is chosen based on the utilization value that required the machine to have about 20 -30% of space for the increasing upcoming productions. The process of the production of pomegranate also finalised based on the Company X current flow. The new process system are developed to reduce the time consumption of the productions. Next, the auxiliaries facilities such as laboratory, change rooms and toilet are designed in order for the workers to have sufficient facilities inside the factories.

The new factory X are located in terrace lot building and the space provided to design the factory are limited. The space and work program for each process and room are determined before the layout design because it is easier for the designer or engineer to estimate the sizing for each rooms and facilities inside the factory. After determine the space and work program for the production, the proper layout of the factory were developed based on the size of new factory X which is in terrace lot and the design process must be in detailed. The layout used is spine layout and the process of the pomegranate juice is in- line production. The spine layout can minimized the space used and also reduce the space for the operator to move from one room to the other room. From this project, the proper layout using onwads and spine aisle were designed to reduce the cross contamination inside the factory. Next, the simulation analysis had simulate the system

and showed the current process takes about 25.84 hour to produce one batch of juice and the new process are developed and take a shorter time of productions. The new factory X has the shorter production lead time which is 9 hour per batch. Lastly, the hygienic checklist tool of the new proposed factory are about 97% fulfil the hygienic aspect of the factory design and it showed that the proposed factory are more efficient and convenient to be used in the future.



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the project of food factory design of the pomegranate juice, it can be concluded that the hygienic design aspect was the important aspect needed to be considered during the design process. The low productivity and lack of hygiene problem for Factory X are solved with the new proposed factory design with the hygienic elements equipped. The new factory were designed with the GMP and hygienic aspect in order to be more efficient and increase the productivity. This project had help the Company X to produce the pomegranate juice based on the demands from the customers. The layout and processes were designed based on the output needed and the automatic machine is used to reduce the time consumption.

Simulation analysis also helps to simulate the system in order to see the behaviour of the factory system based on the design calculation and process of Pomegranate Juice. The analysis showed the current productions time and new plant productions time taken for one day of production. From the analysis, the difference between the two system are determined and the current production are improved to solve the problems occur. The

simulation analysis resulted from this project showed that the production has increased six times from the current juice produced. The lead time also has reduced to 65 % which required 9 hours to complete one batch per day compared to the current process which need 25.84 hours per batch. For the productivity of the production of pomegranate juice, it has increased to 33 to 43 litre per batch compared to current process that produced only 5 litre per one batch due to the manual process and transportation to the contracted factory.

Hygiene checklist tools principles are the checklist with ten principles of hygienic aspect needed to be measured and considered during the design process. Each of the principles are helping Company X to build the new factory with hygienic aspect. The comparison of the hygienic aspect of the current factory and proposed factory are made to ensure the new factory design comply with GMP aspects in order to apply the certificate. From the usage of hygienic checklist tool of the new proposed factory, about 97% of the aspect had been fulfil by the new factory X and it showed that the proposed factory are more efficient and convenient to be used in the future.

Lastly, this project had developed the hygienic new factory X by using 9 design stage, simulation analysis and hygienic checklist tool to design the facilities and utilities needed in order to have an efficiency production.

5.2 Recommendation

For future study, it was recommended that the design of factory would be extended to other planning aspects related to utilities supplies which includes ventilation system, lighting health and safety, piping, compressed air, electrical appliance, water supply waste water treatment. The planning can be conducted based on the determined plant capacity

in this study. The utilities planning is considered important as interruption of utilities supplies such as insufficient refrigeration, shortage of compressed air (for cutting processes) and inadequate lighting can slow the production operation and therefore affect the productivity as well as hygiene practice among the workers.

The recommendation for this project in the future are the process of food factory design must be followed the requirement of hygienic design. This is because food is the materials consumed by human every day and it need a good hygienic practice to produce the food. Besides that, the factory must be designed according to GMP requirement as it can ensure that the product produced are safe to consume. Next, the usage of simulation software before designing the real system are recommended to all the manufacturer before build in the factory. This is because simulation system showed the behaviour of our system and it helps to determine whether the system are good enough to fulfil our output of productions. Lastly, the hygienic design checklist must be used in the factory design as it helps to determine the hygienic aspect in our factory.

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APPENDICES

Appendices A: Simulation Analysis of Current Premise

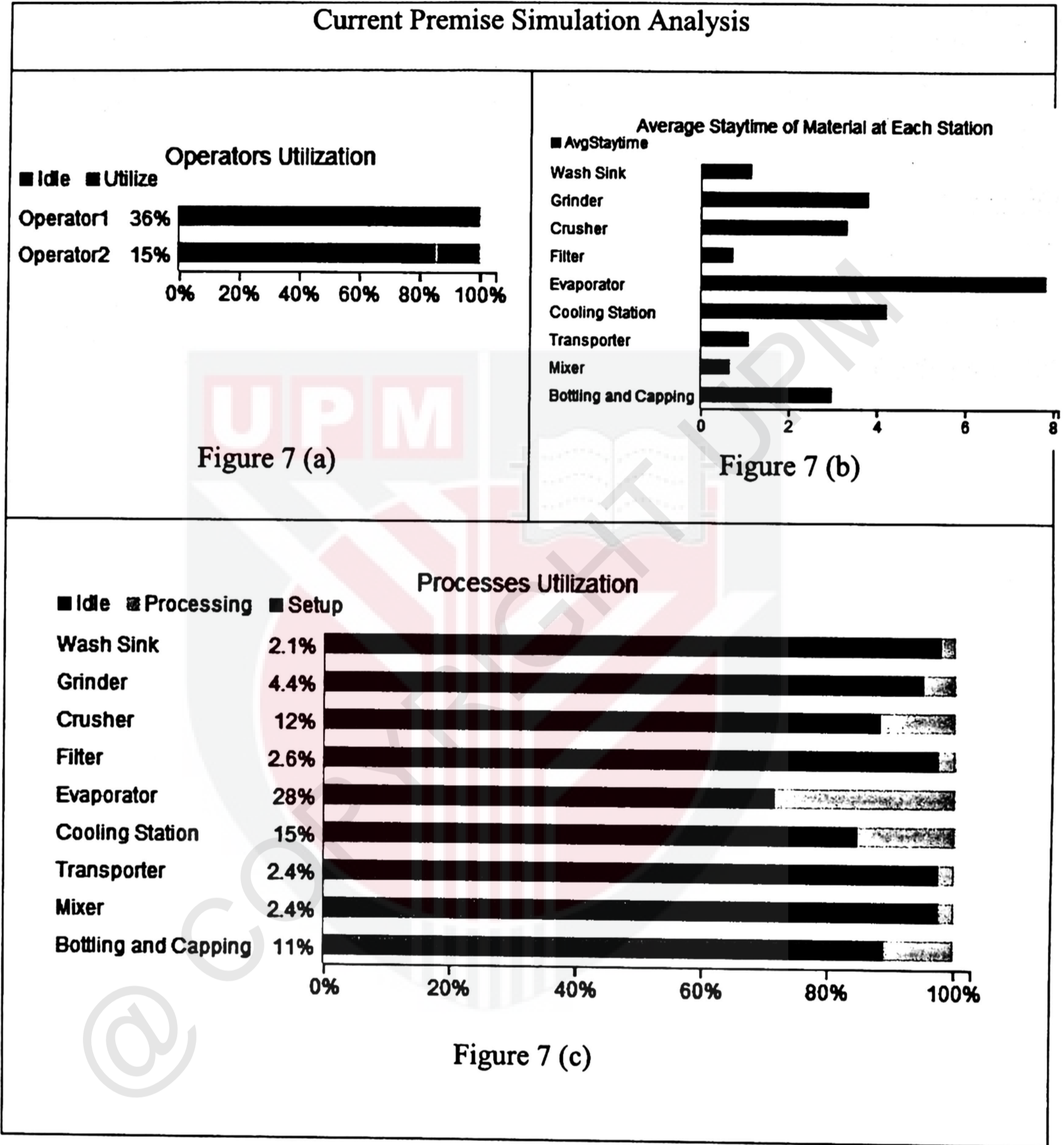


Figure 7.1: Simulation Analysis of Current Premise

Appendices B: Machine List Pomegranate Juice

a) Mixer

<https://jinzongmachinery.en.made-inchina.com/product/LXSxmRAYbFcd/China-Jinzong-Beverage-Liquid-Mixing-Tank-Vacuum-Mixing-Machine.html>

Jinzong beverage liquid mixing tank, vacuum mixing machine

Our company is an enterprise specialized in designing and manufacturing mixing tank, we can design and manufacture various types of mixing tank for users.

Main parameters and configuration

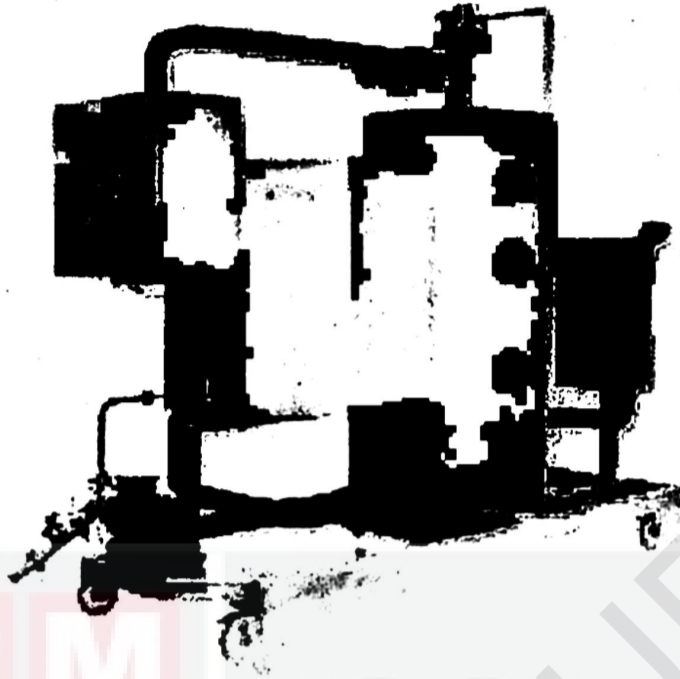
- 1) nominal volume: 50L-20000L and other general specifications and non-standard design and production.
- 2) the structure of the form: vertical, the use of conical, oval, dish shaped head, also apply to the need to close the heating, mixing, reaction, enzymatic hydrolysis and other process operation.
- 3) jacket forms: hollow heat conducting oil or water), semicircular coil pipe, honeycomb jacket (on demand system), heating or cooling efficiency is high.
- 4) insulation material: filling pearl cotton, rock wool, polyurethane foam, with good thermal insulation effect.
- 5) exterior surface of the cylinder body: use mirror polishing or 2B color matte or 2B matte surface polishing treatment, beautiful and clean appearance.
- 6) stirring device: at the top of the tank in the (partial) heart stirring, stirring side; agitator types: frame type, anchor type, push type, blade, scraping wall blade etc.
- 7) stirring speed: Low speed stirrer, high speed disperser or high speed homognizer.
- 8) level meter form: glass tube liquid level gauge, static pressure sensing type liquid level meter and so on (for selection).
- 9) feet form: adjustable three pyramid form or cylindrical tube.
- 10) equipment accessories configuration: quick open sanitary manhole, mirror, (liquid crystal digital display type or dial pointer type) thermometer, respirators, CIP cleaning machines, material liquid inlet and outlet, circular mouth, hot and cold media import and export interface, the nozzle can be according to the process of selection may increase or decrease).
- 11) tank equipment material: SUS304 or SUS316L SUS304 or Q235-B; jacket, cover cylinder for SUS304.



Working volume	Inner diameter	Outer diameter	Vessel height	Total volume
30L	400mm	500mm	400mm	44L
50L	400mm	500mm	600mm	69L
100L	500mm	600mm	650mm	130L
200L	600mm	700mm	1000mm	250L
300L	700mm	800mm	1250mm	370L
500L	900mm	1050mm	1150mm	650L

b) Pasteurizer

<https://www.juicing.systems/juice-pasteurizers/>



ELECTRICAL OR STEAM HEATED

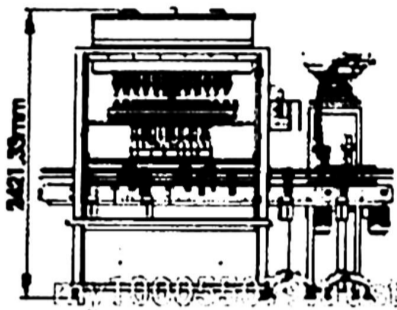
ELECTRICAL HEATED

Model	Dimensions (L x W x H)	Capacity	Boiler output	Performance	Frequency
EPAS 210	1100 x 800 x 1650 mm	210 Liter/h	18,0 kW	19,0 kW	400 V - 32 A
EPAS 300	1100 x 800 x 1650 mm	300 Liter/h	27,0 kW	28,0 kW	400 V - 63 A
EPAS 420	1100 x 800 x 1650 mm	420 Liter/h	36,0 kW	37,0 kW	400 V - 63 A

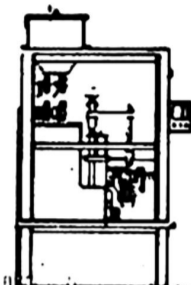
c) Piston Filler & Capper 6~12 Nozzles (Solution Pack Machinery)

https://my100055079.trustpass.alibaba.com/product/172647645231738223/Piston_Filler_Capper_6_12_Nozzles.html?spm=a2700.icbuShop.41413.15.6139124e3wxJSY

Front



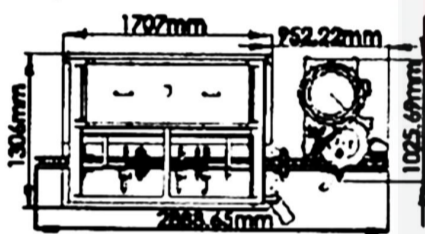
Side



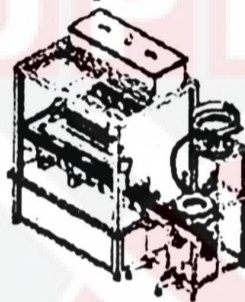
Rotary Capping Machine (SPF-CM-1)

Dimension	(L) 1025mm x (W) 952mm x (H) 1950mm
Cap Diameter	10-60mm (depends on cap design)
Cap Height	10-45mm (depends on cap design)
Bottle Diameter	15-100mm
Bottle Height	150-200mm
Cam Wheel Motor	3 phase, 0.37KW
Vibrator Bowl	1 phase, 220-240V AC, 3A
Working Voltage	1 phase, 220-240V AC
Power Requirement (230V)	2.4KW, 10.5A (±5%)
Country Origin	Malaysia
Material	Stainless Steel 304 or 316 (upon request)

Top



Perspective



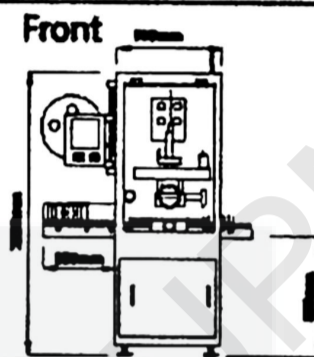
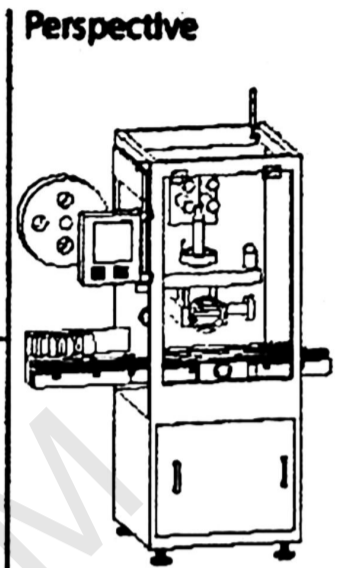
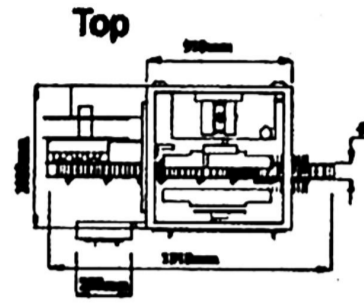
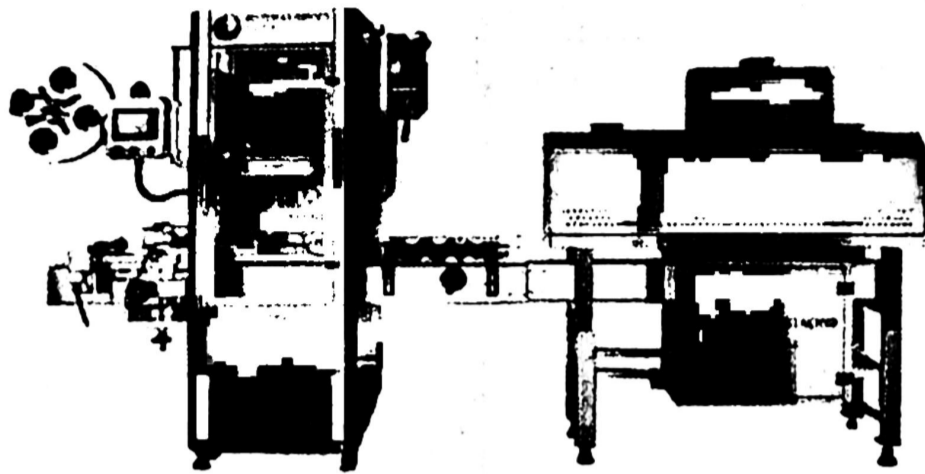
12 Head 1 Liter Linear Piston Filler & Capper (SPF-LPF-12)

Dimension	(L) 1707mm x (W) 1906mm x (H) 2421mm
Filling Range	100ml - 1000ml
Filling Accuracy	±0.5% - 2%
Filling Speed	24 - 48 bottles/min
Conveyor Motor	3 phase, 0.75KW
Main Motor	1 phase, 1.5 KW
Working Voltage	1 phase, 220-240V AC
Power Requirement (230V)	2.4KW, 10.5A (±5%)
Compressed Air Pressure	5-8 bar
Country Origin	Malaysia
Material	Stainless Steel 304 or 316 (upon request)

d) Labeller Machine (Solution Pack Machinery)



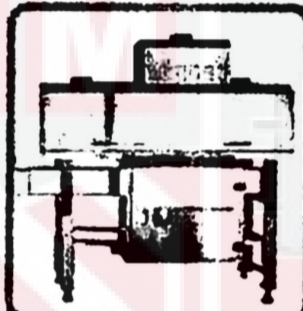
Auto-Sleeve Shrinking Label Machine



Precision & Simple Mechanical



Low Maintenance & Easy Changeable Parts



Shrink Tunnel Available in Electrical or Steam Heated

Auto-Sleeve Shrinking Label Machine

Model No.	SPL-SLAM-150	SPL-SLAM-300
Labeling Speed	150BPM	300BPM
Label Size	M50-M125mm	
Suitable Bottle Diameter	(D) 50-90mm	
Bottle Shape	Round Shape PET, PP, PE	
Applicable Scope	PVC material, Square Shaped bottle	
Electricity	13Amp / Single Phase	
Machine Dimension	(L) 1910mm x (W) 1020mm x (H) 2220mm	

Appendices C: Hygienic Checklist Design

#	Description	S	M	U	NA	Comments	Points Awarded	Points Available
PRINCIPLE #1 - Distinct Hygienic Zones Established In The Facility								
1.01	Facility drawings show hygienic zones, (Ready-to-eat vs. raw, high care vs low care, etc.) where applicable. Hygienic zones should be clearly demarcated on the plant schematics with colors or other markings to facilitate easy identification	X				The factory were designed with hygienic zones sections.	25.0	25.0
1.02	Separate locker rooms and lunch rooms should exist for RTE/high risk and non-RTE/lower risk personnel, or provisions to separate high risk and low risk employees exist	X				Separate locker rooms are provided	25.0	25.0
1.03	Restroom facilities are not located in RTE/high risk zones (see point 10.08)						25.0	25.0
1.04	Separate storage areas for tools and spare parts exist to minimize contamination from non-RTE/lower risk zones to RTE/high risk zones		X				12.5	25.0
1.05	Separate quality labs should exist for RTE/high risk and non-RTE/lower risk zones		X				10.0	20.0
1.06	Separate storage areas for sanitation crews exist for RTE/high risk and non-RTE/lower risk zones (e.g., vacuums, mops, brooms etc. are segregated)						30.0	30.0
TOTAL POINTS FOR THIS SECTION							127.5	150.0

PRINCIPLE #2 - Personnel and Material Flows are Controlled to Reduce Hazards								
2.01	Facility is designed such that movement of employees and visitors throughout the facility is controlled in a manner that does not contribute to potential cross contamination (e.g., employees working with raw product travel separate paths from those working with RTE product)						25.0	25.0
2.02	Facility is designed such that movement of contractors and maintenance personnel throughout the facility is controlled in a manner that does not contribute to potential cross contamination (such as separate areas)						20.0	20.0
2.03	Facility is designed to provide sanitary delivery of packaging materials, ingredients, and rework into RTE/high risk zones in a manner that does not contribute to potential cross contamination						25.0	25.0
2.04	Facility is designed for sanitary removal of trash from RTE/high risk zones (e.g., dedicated personnel/ travel paths/ dedicated and sanitized footwear for high to low hygiene areas)						30.0	30.0
TOTAL POINTS FOR THIS SECTION							100.0	100.0

PRINCIPLE #3 - Water Accumulation Controlled Inside Facility								
3.01	Floor design and drainage systems prevent standing water and avoid drain backups	X				galis	20.0	20.0
3.02	Wall and curb surfaces drain freely without pockets, ledges and nooks	X					15.0	15.0
3.03	Areas above ceilings do not accumulate water	X				roof dan drain	15.0	15.0
3.04	Equipment wastewater discharges are piped directly to drains	X					20.0	20.0
3.05	Drain pans are sloped to be free draining	X				free draining	15.0	15.0
3.06	All drip pans have continuous flow and are directed to a drain	X				wwt	15.0	15.0
TOTAL POINTS FOR THIS SECTION							100.0	100.0

PRINCIPLE #4 - Room Air Flow and Room Air Quality Controls								
4.01	Room temperature meets process requirements						15.0	15.0
4.02	Measures are taken to prevent condensation through all seasons		X				10.0	20.0
4.03	Facility airflow is from clean to less clean areas (high hygiene to low hygiene, high to low risk zones, RTE to non-RTE areas)	X					15.0	15.0
4.04	Critical process air is adequately filtered	X					10.0	10.0
4.05	Outdoor makeup air is properly filtered for the process requirements	X					15.0	15.0
4.06	Air handling system components meet the 10 Principles of Equipment Sanitary Design	X					15.0	15.0
4.07	Where appropriate, provisions are made to capture high concentrations of heat, moisture and particulates at the source	X					10.0	10.0
4.08	HVAC/refrigeration system components are located to avoid risks of product contamination	X					15.0	15.0
4.09	HVAC/refrigeration systems are dedicated to specific areas (RTE vs. non-RTE) and do not contribute to cross-contamination	X					10.0	10.0
TOTAL POINTS FOR THIS SECTION							115.0	125.0

PRINCIPLE #5 - Site Elements Facilitate Sanitary Conditions									
5.01	Driveways, parking lots and pedestrian walkways are paved and self							5.0	5.0
5.02	Landscaping and grounds are designed to minimize attraction and harborage of insects and rodents							5.0	5.0
5.03	Adequate trash receptacles in pedestrian traffic areas are provided. Receptacles shall be covered and/or managed to not be a source of contamination							5.0	5.0
5.04	Insect attractant lighting is positioned to draw insects away from the building. Lighting on the building limits the attraction of insects							10.0	10.0
5.05	Roof surfaces should be cleanable and self draining							5.0	5.0
5.06	Finished floor elevation is higher than adjacent grades to prevent storm water ingress into building							5.0	5.0
5.07	External operations (e.g., trailer cleaning, bulk storage, trash and waste management) are designed and positioned to prevent unsanitary impact (splashing, overflow, cross contamination, residues etc.) on the facility							5.0	5.0
5.08	External drainage is adequate to prevent standing water							5.0	5.0
5.09	Detention and retention basins are properly designed, maintained and operating to eliminate unnecessary standing water							5.0	5.0
5.10	A minimum 30" wide border of asphalt, gravel or concrete border or other acceptable material, is present on all exterior sides of the facility							5.0	5.0
5.11	Space is provided for storage of clean portable equipment							5.0	5.0
5.12	Soiled laundry collection locations are established, where applicable					x		0.0	0.0
5.13	Space is provided for boot storage and cleaning, where applicable							10.0	10.0
5.14	Trash collection is located in a manner that does not pose a risk to the product or the facility, and in locations that are cleanable and maintainable							10.0	10.0
TOTAL POINTS FOR THIS SECTION								80.0	80.0

PRINCIPLE #6 - Building Envelope Facilitates Sanitary Conditions									
6.01	Building envelope (e.g., shell, skin) is constructed of materials that are solid, impervious, and free of cracks and voids, and are compatible with cleaning methods	x						10.0	10.0
6.02	Roof flashing systems prevent harborage of insects, birds and rodents	x						5.0	5.0
6.03	Roof is sloped to provide positive drainage	x						5.0	5.0
6.04	Roof drainage is not a source of contamination	x						5.0	5.0
6.05	Canopies are totally closed	x						5.0	5.0
6.06	All louvers, fans, vents and openings have intact insect screens and are insect proof and/or self-closing	x						5.0	5.0
6.07	Doors are impervious, fully weather stripped, fit well and have solid cores	x						5.0	5.0
6.08	All door jams and window sills are firmly anchored to the slabs and fully	x						5.0	5.0
6.09	Window frames and door headers are fully filled and mounted flush with walls to eliminate edges	x						15.0	15.0
6.10	All voids associated with utility penetrations (e.g., electrical weather heads, gas mains, sprinkler risers) are fully filled with appropriate materials, then sealed	x						5.0	5.0
6.11	All concrete wall panels are caulked from roof to footing	x						10.0	10.0
6.12	Dock doors have a dock seal or shelter and are weather stripped	x						5.0	5.0
6.13	Dock pits, dock plates and levelers are designed to be cleaned and proper utilities are in place to facilitate proper cleaning							5.0	5.0
TOTAL POINTS FOR THIS SECTION								85.0	85.0

PRINCIPLE #7 - Interior Spatial Design Promotes Sanitation									
7.01	Aisles are wide enough for maintenance, sanitation and materials	x						10.0	10.0
7.02	There is sufficient access to building elements (e.g., columns, beams, bracing) for cleaning	x						10.0	10.0
7.03	There is sufficient access to the wall-floor interface for cleaning	x						10.0	10.0
7.04	Stationary equipment is sufficiently placed to allow cleaning and sanitation underneath and above the equipment (18 inches for non-contact equipment and 30 inches for food contact surfaces)	x						5.0	5.0
7.05	The layout is coordinated to allow access to clean and inspect overhead elements (e.g., ducts, piping, equipment, lights, diffusers)	x						5.0	5.0
7.06	There is a perimeter inspection zone of at least 18" between walls and any storage or placement of fixed equipment							20.0	20.0
TOTAL POINTS FOR THIS SECTION								60.0	60.0

PRINCIPLE 28 - Building Components and Construction Facilitate Sanitary Conditions						
8.01	Interstitial spaces separate process areas from utility services and overhead structural components, and are accessible for cleaning				5.0	5.0
8.02	Suspended ceilings should be avoided whenever possible. If absolutely necessary, a walk-on design should be used to allow personnel access for cleaning and they shall be smooth, cleanable and at a uniform height				5.0	5.0
8.03	Walls, and ceilings are smooth and cleanable with minimal joints and no cavities				5.0	5.0
8.04	All vertical and horizontal wall joints are sealed appropriately				5.0	5.0
8.05	All vertical surface to floor junctions have a cove and surfaces that are free of pits, erosion and voids				5.0	5.0
8.06	Concrete surfaces are solid, smooth, and free of pits, erosions and				5.0	5.0
8.07	Curbs (stainless steel, concrete and concrete with stainless steel inlay) go the full height to the curb-wall junction				5.0	5.0
8.08	Wall facings such as Fiberglass Reinforced Panels (FRPs) and Insulated Metal Panels (IMPs) are factory laminated or foamed-in-place for insulation (Check federal, state and local building code				5.0	5.0
8.09	Cavity and voids are absent in floor, wall and ceiling assemblies. All floor joints and cracks are sealed				10.0	10.0
8.10	Insulation that does not deteriorate, or retain or absorb moisture, such as closed cell or encapsulated insulation, is used in the facility				5.0	5.0
8.11	Horizontal structural members have no flat surfaces where dust or soil could accumulate				5.0	5.0
8.12	All-thread rods and "Unistruts" are not used and other threaded surfaces are minimized				5.0	5.0
8.13	Bases of drains are supported to prevent settling				5.0	5.0
8.14	All cracks, joints and voids are filled with appropriate materials				5.0	5.0
8.15	Caulking is minimized and done in a manner that is not a source for potential contamination (e.g., loose, flaking)				5.0	5.0
8.16	Items attached directly to a building surface have stand-offs				5.0	5.0
8.17	All mezzanine structures over a processing area are waterproof and drain properly				5.0	5.0
8.18	Doors and windows are constructed to prevent insect and rodent access, and harborage, are impervious, easily cleanable and resistant to wear and corrosion				5.0	5.0
8.19	Floors are constructed to prevent insect and rodent access and harborage, are impervious, easily cleanable and resistant to wear and				5.0	5.0
TOTAL POINTS FOR THIS SECTION					100.0	100.0

PRINCIPLE 9 - Utility Systems Designed To Prevent Contamination								
9.01	Horizontal piping, conduits, and light fixtures are not installed above exposed product or processing equipment							5.0 5.0
9.02	Piping and conduits are located and spaced to facilitate access, cleaning and sanitation, and are routed outside of process areas							5.0 5.0
9.03	Piping is adequately insulated to prevent condensation and the insulation is covered with material able to withstand the operating conditions and the cleaning methods used							5.0 5.0
9.04	Lockable fasteners are used on hangers and attachments to avoid risk of foreign material contamination							5.0 5.0
9.05	Glass components are used only where necessary, and are properly protected (e.g., shields or shatterproof coated) to avoid risk of foreign material contamination							5.0 5.0
9.06	Controls are in place to prevent moisture accumulation in air lines to minimize potential transfer of moisture through compressed air							5.0 5.0
9.07	Air gaps or mechanical backflow prevention devices, are used to prevent cross-contamination of the potable water supply							5.0 5.0
9.08	Where steam will contact product, or product contact surfaces, the steam supply system shall conform with requirements for the production of culinary steam					x		0.0 0.0
9.09	Bulk ingredient tanks are designed for proper cleaning and are accessible for regular inspection	x						5.0 5.0
9.10	Process and sanitary sewers are separated within the building	x						5.0 5.0
9.11	Waste and vent lines are not routed above product or process areas	x						5.0 5.0
9.12	Where possible, drain cleanouts are installed outside the processing area	x						5.0 5.0
9.13	Drains are accessible for cleaning and sanitation	x						5.0 5.0
9.14	Trench drains are avoided wherever an alternative is possible	x						15.0 15.0
9.15	Process sewers are made of materials compatible with the temperature and corrosiveness of the waste stream and cleaning compounds used	x						5.0 5.0
9.16	Air (gas) discharges from sewage lines, drain lines, and raw process areas are not vented in a manner that may contaminate air intakes	x						5.0 5.0
9.17	Sewage, drain lines, and air discharges from raw process areas are vented at least twelve inches below the level of fresh air intakes when located within 50 feet of each other (as these gases are typically heavier than air)	x						10.0 10.0
9.18	Drains are designed to avoid ingress of drain gasses into process areas (e.g., 'P' traps or other methods)	x						5.0 5.0
9.19	Interior drain lines do not run through high risk/high hygiene processing areas							5.0 5.0
TOTAL POINTS FOR THIS SECTION								105.0 105.0

PRINCIPLE 10 - Sanitation Integrated Into Facility Design								
10	Water temperature, flow and pressure meets specified requirements at point of use	x						10.0 10.0
10	Clean up stations are supplied with adequate hose hangers to keep hoses off the floor and where possible outside of process areas	x						10.0 10.0
10	Rinse systems must be designed to deliver the minimum pressures needed to complete the desired cleaning procedures	x						10.0 10.0
10	Adequate hand washing and sanitizing stations are provided at locations as required to maintain adequate hygiene requirements	x						10.0 10.0
10.1	Adequate interventions (e.g., hygiene junctures, foot baths, doorway foamers, boot washers) are provided at locations as required to maintain zones of control	x						10.0 10.0
10.1	Adequate systems (e.g., vacuum systems, dust collection systems, COP, CIP, equipment washers) are provided to facilitate proper cleaning, sanitizing and drying of equipment	x						10.0 10.0
10.1	Microbiology laboratories are located and constructed in a manner to prevent potential contamination to process areas (e.g., located in separate buildings, double door entries, negative air pressure)	x						10.0 10.0
10.1	Restrooms do not open directly from or into any processing area	x						10.0 10.0
10.1	Restrooms are designed to maintain negative air pressure versus their surrounding area						Exhaust Fan are equipped.	5.0 5.0
TOTAL POINTS FOR THIS SECTION								85.0 85.0