Redesign the layout of agro-industry by using occupational safety and health analysis at tempe chips SME

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Abstract. Layout is an important factor of agro-industry to improve productivity and reduce potential risk of work accident. The objective of this research was to redesign the layout of Tempe Chips Small and Medium Enterprise (SME). Bu Nurjanah Tempe Chips SME Malang, East Java was selected as research location because of poor lay out system and it has same character with Tempe Chips SME that had fire accident. This research used Occupational Health and Safety Analysis and Systematic Layout Planning (SLP) approach in designing agro-industry layout that consist of activity relationship chart, activity relationship diagram, and area needs. The results of the research showed that Tempe Chips SME has potential fire hazards and food contamination. Regarding the Occupational Safety and Health standard, this research advice re-layout for several production facilities such as access to drinking water, toilets and washing facilities, and clean cafeteria to improve effectiveness of production.

1. Introduction

In agroindustry sector, it is very important that companies produce good quality products and meet consumer demand. Plant layout improvement can be a tool for response to increasing industrial productivities, where layout design has a significant impact on manufacturing systems [1, 2]. The effective layout is an important factor of agro-industry which can improve productivity and meet the change of technology and customer demand. Therefore, the effective layout is success factor of manufacture companies [3]. Layout design is a major base of industry [4]. Layout planning aims to develop efficient production [5]. A good layout must have a straight flow, a planned transfer method, and a minimum displacement distance [6]. The designing layout process consists of analysis, planning, and arrangement of facilities, physical equipment and human. There are several ways that can be used to design a facility layout, one of which is Systematic Layout Planning (SLP) [7].

Occupational Safety and Health is procedures to ensure the protection of workers and others in the workplace. The Decree of the Minister of Manpower R.I. No. Kep. 463 / MEN / 1993 regulates the production resources to be safely and efficiently used. The protection of life and health at work is a fundamental workers’ right [8]. However, the lack of knowledge from the workforce on aspects of Occupational Safety and Health will lead to potential workplace accidents. There is still poor working condition especially in developing countries [9].

East Java is one of the provinces in Indonesia that has many Small and Medium Enterprises (SME)-based processed food products. SMEs are part of the industrial, trade, hotel and restaurant sectors which are one of the main contributors to the East Java economy. Malang City is one of the
locally based processed food production areas, especially tempe chips in East Java. Tempe chips business is a part of SMEs that have an important role in Malang City, East Java.

Recently there was an accident at the tempe factory in Malang City, which took place October 4th, 2017 on Jalan Raya Candi V RT / RW 5/5, Karangbesuki Village, Breadfruit District, Malang City [10]. The alleged cause of the incident was due to workplace accidents caused by poor exit arrangements and lack of work safety equipment provided by business owners.

The fire at plant in Jalan Raya Candi V is still in the process of being investigated, thus limiting people to enter the location. Therefore, this study took a similar place to analyse, namely Bu Nurjanah's chips which make tempe chips with the concept of home industry. The objective of this research was to redesign the layout of Tempe Chips SME.

2. Methods

2.1. Occupational safety and health analysis

2.1.1. Risk of accident

The risk of accidents is composed of employees fell, hit by falling objects, knock or hit by objects, the effect of high temperatures, exposure to electrical, contact with hazardous materials or radiation, factory fires, and omissions of employees. Measurement of the risk of accidents is the calculation of the frequency of occurrence in one week. The timeframe of this measurement is sufficient as the periodic checks can be done daily or weekly [11].

2.1.2. Hazard of the manufacturing process

This measurement to identify hazards in the manufacturing process was through observation. The observed hazard composed of physical, chemical, and biological. Physical hazards consist of noise, extreme temperatures, lack of lighting intensity, vibration, and radiation. Chemical hazards consist of fluid contamination acids, solvents, vapours and smoke, and flammable materials. Biological hazards consist of acute and chronic infections, parasites, fungi, and bacteria [12].

2.1.3. Employee knowledge about personal protective equipment (PPE)

This measurement is conducted by interviews to employees about the importance of PPE such as masks, boots, headgear and protective gloves. In addition, the measurement through the observation of the use of PPE by employees in the workplace [13].

2.1.4. Employee health

Measurement of employee health is to observe the availability of clean water, first aid box, rest areas, and health insurance. Variable availability of water is measured by observing the access and ease of employees to obtain clean water. Variable availability of first aid box is measured by observing emergency rescue facilities by the company. Variable availability of a rest area is measured by observing the availability of cafeteria, a place of worship and a place to relax. Health insurance variables is measured by observing their health insurance enrolled in health agency [12].

2.2. Designing proposed layouts with systematic layout planning (SLP)

Several stages in designing layout using SLP, which include:

a. Material flow analysis

The first step in planning this layout is analysing the flow of material. This map of the operating process will describe the work order for each work station and the time needed in one production process. The map of the operation process consists of a sequence of activities, distance, and time.

b. Activity Relationship Chart (ARC)

The second step was to analyse the relationship between activities between work stations with Activity Relationship Chart (ARC). Several reasons for the association are symbolized by letters A, I, E O, U and X. These letters show how the activities of each work station will have a direct or close relationship with each other.
c. Requirements for available area
The formula used in searching for area needs is [6]:

\[
\text{Area} = \text{Length} \times \text{Width} \times \text{Number of stations available}
\]  

(1)

d. Layout design
Consideration of previous variables. Completing the design results with the aesthetic aspects needed [6].

3. Results and Discussion
Tempe chips SME was located in Sanan, Malang, East Java. Size of store is 8 x 1.5 m, while the production house area is 11.8 x 5.2 m. Store and production house are located in a different location. Store is located in front of the Sanan Gate and production house is located behind store. Tempe chips processing consist of tempe slicing, frying and packaging, mostly used traditional technology. For example, in tempe slicing process manual knife was used, resulting differences in the thickness of the tempe chips. In the frying process, tempe chips SME used frying technique by dipping the entire material in hot oil in a big pan. In the draining oil, tempe chips SME used newspapers, while in the packaging process, the candle flames were used. Tempe chips SME did not have Occupational Safety and Health standard and the current layout was designed based on the function of the work station.

3.1. Occupational safety and health analysis
a. Risk of work accidents
Work accident risk analysis was conducted to identify how often accidents occur in the production process in Tempe chips SME. Based on the analysis for one week [11], only 3 to 4 times the effects of high temperatures have occurred due to high temperatures in frying. The potential accident is fire because the packaging process was manually done using candle flame. Storage of tempe chips only used plastic bags with no special arrangement, may also causes the fire to quickly and easily spread in the production room.

b. Hazard of the making process
The stages of the process of making tempe chips affected the quality of the tempe chips. Potential hazards found include:

1) Food Contamination
   Contamination caused by employees can take place during working hours. Employees who did not wearing PPE during the production process led to the spread of *Staphylococcus aureus* bacteria in the finished products. Oil draining process was using newsprint which may also cause to lead contamination in the finished product.

2) Fire at the factory
   Packaging tempe chips used a candle which placed on the table without any protective tools. Also, the packaging station was near flammable materials such as plastic, so that it can make the fire spread easily when there is a fire. Moreover, there is no fire extinguishers in the production area, which make a greater risk of fire.

3) Poor layout
   Tempe chips SME splits layout based on the function of the work station. The dough is placed arbitrarily in traffic area, packing stations and storage of finished products are in the same room and there was only one exit. Emergency doors must be at least one, the key of emergency exit must be placed in a position that is easily accessible. Also, there should not be anything that blocks access to the emergency exit.
c. Employee knowledge about PPE
Based on the interview of 7 employees, only two employees who know the importance of PPE. During the work, the employees did not use PPE at all of the production process. The absence of the use of PPE was caused by ignorance of the importance of PPE by employees and owners.

d. Employee health
Based on observations, the tempe chips SME did not have first-aid box facility, rest areas, places of worship and employee health insurance in collaboration with health agency. But Tempe Chips SME has met the availability of clean water, hand washing facilities, bathrooms, washing equipment, and pantry.

3.2. Designing proposed layouts with systematic layout planning (SLP)
The first step of SLP is identification of the initial layout and activities of tempe chips SME. Figure 1 illustrates the initial layout of Tempe Chips SME. The activities mapping, length, and time in production of tempe chips are explained by Table 1.

![Figure 1. The initial layout of tempe chips SME](image)

Table 1. The activities mapping, length, and time in production of tempe chips

| Activities               | Code | Length (m) | Time (minute) |
|--------------------------|------|------------|---------------|
| Tempe slicing            |      | 0          | 20            |
| Tempe shorting           |      | 0          | 8             |
| Moving to kitchen        |      | 5.2        | 4             |
| Coating                  |      | 1          | 15            |
| Frying                   |      | 1.5        | 17            |
| Oil draining             |      | 0          | 5             |
| Moving to packaging      |      | 3          | 2             |
| Packaging                |      | 0          | 25            |
| Storage                  |      | 2.4        | 3             |
| **Total**                |      | 13.1       | 109           |

The initial layout of the Tempe Chips SME has an area of 47.32 m². The layout is divided into 6 work stations, there are area of slicing, coating, frying, oil draining, packaging, and storage. In the slicing area, there is no hand washing facility. In the entrance area there is a room that was not
optimally used. Area of product packaging and storage are in the same room without any partition. The dough is placed on the floor (traffic area).

This initial layout design was not optimal in terms of handling the material and Occupational Safety and Health standard, as follows:

a. Material flow analysis

The observations on the production process are described by the operation map process [6]. Map of the Tempe Chips SME operation process as shown above. From the results of Table 1, it is known that in the process it usually takes ~109 minutes while the length of the material flow path handling from the entrance to the packaging process is a total length of 13.1 m.

b. Activity Relationship Chart (ARC)

The relationship value A indicates that between departments must be close together. The relationship value X indicates that inter departments are not expected to be close [6]. The Activity Relationship Chart of the Tempe Chips SME is showed in Figure 2.

c. Area needs

The final step was to calculate the area needs in the Tempe Chips SME [6]. The area obtained for room needs was equal to 53.61 m². Recapitulation of overall area needs is showed in Table 2.

![Activity Relationship Chart](image)

**Figure 2.** The activity relationship chart of the tempe chips SME

**Table 2.** Recapitulation of overall area needs

| Work station                | Length (m) | Width (m) | Total (m²) | Unit | Total Area Needs (m²) |
|-----------------------------|------------|-----------|------------|------|-----------------------|
| Slicing                     | 2.8        | 3.2       | 8.96       | 1    | 8.96                  |
| Coating, frying and oil draining | 7.2    | 2.7       | 19.44      | 1    | 19.44                 |
| Packaging and storage       | 2.2        | 1.3       | 2.86       | 1    | 2.86                  |
| Stock room                  | 1.9        | 2.5       | 4.75       | 1    | 4.75                  |
| Pantry                      | 2.1        | 1.3       | 2.73       | 1    | 2.73                  |
| Water faucet                | 1.1        | 0.9       | 0.99       | 1    | 0.99                  |
| Toilet                      | 1.8        | 1.1       | 1.98       | 1    | 1.98                  |
| Store                       | 8          | 1.5       | 12         | 1    | 12                    |
| **Total**                   | **53.61**  | **53.61** |            |      |                       |
d. Proposed layout

Regarding the Occupational Safety and Health standard, this research advice re-layout for several production facilities. Re-layout advice consists of two design proposal that consider the relationship level, the flow of material handling and focused on reducing the risk of accident and hazards of manufacturing process. Two proposals layout design shown in Figure 3 and Figure 4.

Figure 3. First proposed layout for tempe chips SME

Figure 4. Second proposed layout for tempe chips SME

Differences between the proposed layouts are the first proposal layout uses the empty room as a storage area. Meanwhile, on the second proposal layout, there is emergency exit and the empty room used as a shelf space to put personal belongings of employees. Table 3 shows the path length for each proposed layout. Comparison of the difference between the initial layout and proposed layout is explained in Table 4.
Table 3. Track length comparison of the initial and proposed layout

| Activity            | Initial Layout | First Proposed Layout | Second Proposed Layout |
|---------------------|----------------|-----------------------|------------------------|
| Tempe slicing       | 0              | 0                     | 0                      |
| Tempe shorting      | 0              | 0                     | 0                      |
| Moving to kitchen   | 5.2            | 5.2                   | 5.2                    |
| Coating             | 1              | 2                     | 0.6                    |
| Frying              | 1.5            | 0.1                   | 1.7                    |
| Oil draining        | 0              | 0                     | 0                      |
| Moving to packaging | 3              | 3                     | 3                      |
| Packaging           | 0              | 0                     | 0                      |
| Storage             | 2.4            | 3                     | 2                      |
| Total               | 13.1           | 13.3                  | 12.5                   |

Table 4. Comparison of the difference between the initial layout and proposed layout

| Initial Layout | Proposed Layout |
|----------------|-----------------|
| The possibility of contamination of the product is very big in the flour for coating which placed on the traffic area | The dough is placed at the end of area and it is not disturbing the employee's back and forth path [6] |
| In the entrance area there is a room that is not used optimally | Space near the entrance is used as a storage area for the product so this will facilitate the production process because there are no items piled up near the door [11] |
| There is no fire extinguisher and first aid box | Tempe Chips SME should add a fire extinguisher to reduce the total damage produced by both fire and the fire-fighting process [15] and a first aid box is added in the production area to handle minor injuries of employees. |
| There is no emergency exit | Add an emergency exit to the production area because it has important role in the fire safety of buildings [14]. This emergency exit must be placed in the frying area, because the level of hazard in the area is higher than the others. The recommended exit is rolling door |
| There is no space to put personal belongings of employees and PPE | In the layout of the proposal, there are shelf space to put personal belongings of employees and increase awareness of the importance of PPE using in production process [11] |

4. Conclusions
The production of tempe chips has a number of work processes that can cause risks of processing. Regarding the Occupational Safety and Health standard, this research advice re-layout for several production facilities such as access to drinking water, toilets and washing facilities, and clean cafeteria to improve effectiveness of production. First layout design had 13.3 meters track length, while the second layout design had 12.5 meters track length. Such measurement was found to have positive impact on reducing the material handling.
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