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Emergency Exit Facilities Analysis in Fire Emergency Conditions for Footwear Manufacturing: An Indonesian Case Study

Sakti Aji Lesmana

Industrial Engineering Department, Faculty of Engineering, Universitas Mercu Buana

Jl. Raya Meruya Selatan, Kembangan, Jakarta 11650

Indonesia

ABSTRACT

As we might know that work and safety has become one of lean foundation that mentioned in lean house along with heijunka, KANBAN, SEIRYUNKA, STABILIZATION, JIT, KAIZEN and JIDOKA. *Safety is number one or as priority is reflected in Anzen Daiichi which includes the establishment of a Health and Safety Committee. One of the fields of study studied in occupational safety is how to make anticipation when a fire emergency occurs. In addition to fire suppression so that it does not spread, the most important thing is to save the workforce in the building or around the fire. It is also mentioned in the Indonesian Minister of Public Works Decree "KEPMEN No.10 / KPTS / 2000"," PERMEN No.26 / PRT / M / 2008", concerning about Technical Requirements of Fire Protection Systems in Buildings and the Environment. This study will focus on the feasibility of emergency exit facilities at labour-intensive companies with a workforce of more than 15,000 employees. An evaluation of the adequacy of the facility will also provide an overview of how well the layout design is done in anticipation of an emergency. Comparison of theoretical emergency exit needed with actual exist in factory would be used as reference to improve leadership knowledge and could be used to strengthen analysis of emergency plan at the audit tools from customer. Theoretical calculation result of Emergency Exit required in PT. PIN is very sufficient when compared to the existing rules.*

Key Words: *Emergency Exit, Layout Design, Lean Manufacturing, Work Safety*.

1. INTRODUCTION

The footwear industry is one of the labor-intensive industries utilize more than 15,000 workers to be able to produce 1.5 million pairs of footwear every month provided that all the needs for materials and work processes are within the company itself. To regulate such a large workforce, this industry really needs the right method that does not only focus on achieving its production results. In lean manufacturing, it is known that we will focus on 3 main things in the industry, namely leadership, people and processes. The safety factor must be in all three because to make work safety a culture, a safe combination of leadership, workers and processes is needed. A combination of leadership, workers and safe processes is necessary to create safe working conditions and create a safe work culture [1]. Organizational culture and leadership are known to be the most important aspects in implementing Lean and other quality systems [1].

The most important factors associated with concern for a low level of work security are a lack of concentration in the workplace, disregard for safety regulations, different worker backgrounds and handling of tools, bad quality of machines and materials [2]. There is a significant effect of the level of security and comfort at work on increasing worker productivity on the influence of the OHS program on the level of worker productivity directly or indirectly [3-4]. One of the subjects in OHS is the level of safety of buildings and facilities against extraordinary events, namely fire.

One of the requirements that a building that has a high occupancy rate is considered safe is the existence of an "emergency exit" facility that can guarantee easy evacuation of its occupants in the event of an emergency. The definition of ease of evacuation here means: evacuation speed and evacuation safety.

Emergency exit facilities that can guarantee easy evacuation will at least significantly reduce the possibility of the number of fatalities in the workforce in the event of an emergency, whether caused by natural events or by human actions. Qiquan, W and The exit route must be free from obstructions and should not be covered by any objects [5]. Facilities for "emergency exit" that are not well organized and planned, or are even used for other things besides the evacuation function of residents, can actually become a means of trapping death for the occupants.

2. LITERATURE SURVEY

The benefit obtained in eliminating waste is the ease of adjusting to fluctuating market demands so that the company ableto survive in competition [6]. An emergency that befell a building is an unusual condition, which tends to harm its occupants [7-8].

This situation can be caused by nature (e.g. earthquakes, landslides, volcanic eruptions, flash floods), or by technical and man-made problems (fire, building collapse due to construction failure/error). Of the several emergency conditions mentioned above, the one that gets the most attention because it often occurs is an emergency due to fire, so that the government and experts issue many requirements related to building safety against these fire hazards.

Fire is a fire that is uncontrollable beyond human ability and desire [9]. The danger of fire must be anticipated by means of fire protection, which means that every effort is made to prevent uncontrolled ignition of fires, which can threaten the safety of human life and property. Fires in buildings can cause losses in the form of human victims, property, disruption of the production process of goods and services, environmental damage and disturbance of community peace [7]. Fire disasters are disasters caused by unwanted fire which can cause losses in the form of property and casualties [8].

According to SNI 03-1746-2000 [10], it is said that the "means of escape and rescue" is a continuous and unobstructed passage from any point in the building to the public road, consisting of three clear and separate parts; exit access, exit and discharge exit. The rescue escape components include:

1. Exits, corridors and horizontal exits
2. Class A ramps and class B ramps (to get off)
3. Class B ramps (to climb)
4. Emergency stairs

3. OBJECTIVE OF THE STUDY

The main objective of this research is to calculate the number of emergency exits required based on theory and comparing with existing condition in the company. Researchers will identify all buildings in the company and calculate the ratio of their needs. This is needed due to risk level for labor-intensive companies in dealing with emergency conditions such as fire or others.

4 .RESEARCH METHODOLOGY

The method used in this research is to calculate and analyze the need for Emergency Exit facilities in fire emergencies based on ISO standards and applicable government regulations, and ends with analysis and conclusions also suggestions as can be seen in Figure 1. The data taken are primary data and secondary data. Primary data is data obtained by direct observation within the company, especially interviews with the HSE (Health, Safety, and Environment) department. Secondary data is data obtained from company records and reports, such as the layout and number of workers in each building in the company.

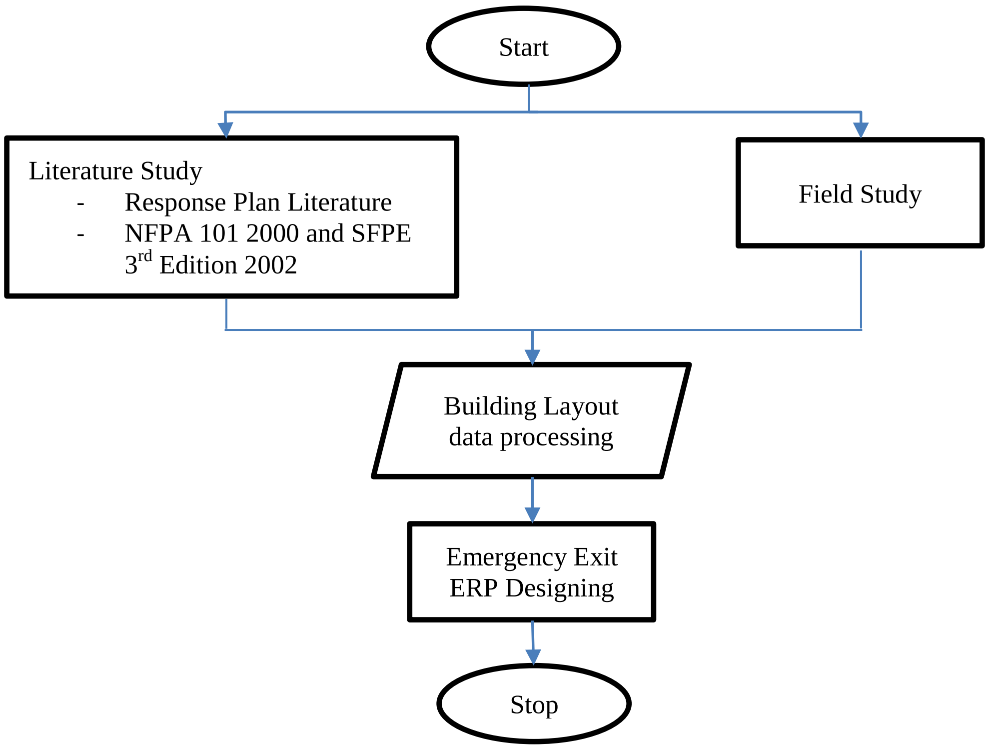

Figure 1 Research Flow Diagram

Self-rescue facilities, namely building facilities, which during a fire emergency can be used by occupants to save themselves by leaving the building. This self-rescue facility is divided into three parts, namely the evacuation route (emergency doors, corridors and emergency stairs), exit signs and muster points. Emergency door is a door that can be used in case of emergency. According to Ramli (2010), emergency exit criteria can be calculated based on the following formula: exit criteria according to Ramli (2010):

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Door Width

$$U = \frac{N}{40 \; x \; T} \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Where

N : Number of people

T : Limit/time in minutes (3 ', 2.5', 2 ')

U : Number of Exit Rate Width required

Number of Doors

$$E = \frac{U}{4} + 1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

Where

E : The number of exits

Corridor/escape routes are safe routes assigned to reach the meeting point in the event of an emergency. Corridor criteria according to Ramli (2010): non-slippery, free of obstacles, length of time out (low risk = 3 minutes, moderate risk = 2.5 minutes and high risk = 2 minutes) and long distance traveled (low risk = 30 meters, moderate risk = 20 meters and high risk = 15 meters).

5. RESULT AND DISCUSSION

There are 6 buildings in the PT. PIN factory with identical dimensions and layouts that have been standardized for company productivity purposes. The shape and layout of the building as in Figure 2.

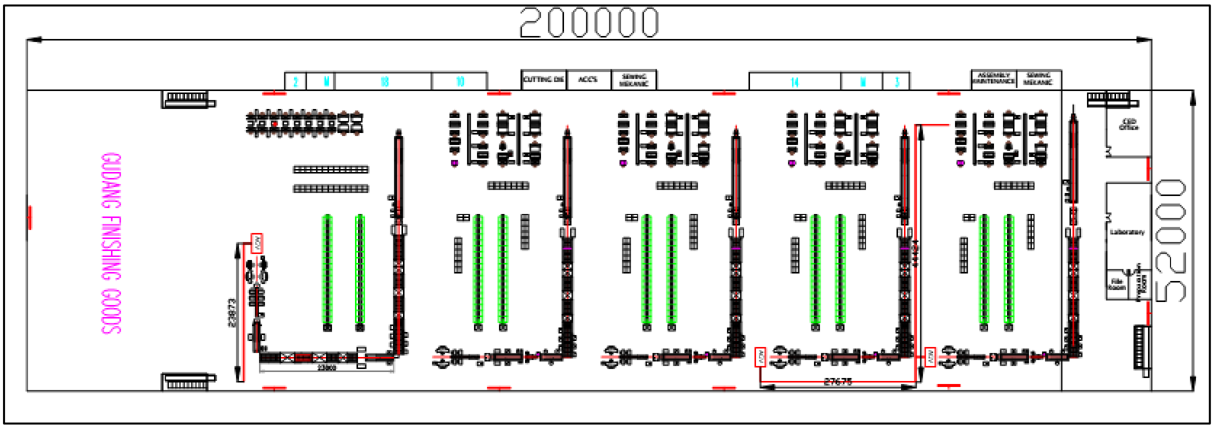

Figure 2. The layout of the PT. PIN

1. Data on building area and number of workers

In table 1, data will be provided for further calculation purposes, namely data on building area, temporary area, permanent area, as well as the number of workers in each building.

Table 1. Building and labor data

Name of Building	Temporary Area (m^2)	Permanent Area (m^2)	Building Area (m^2)	Number of Workers (person)
Factory 1	10,400	520	9,880	2,574
Factory 2	10,400	520	9,880	2,485
Factory 3	10,400	520	9,880	2,844
Factory 4	10,400	520	9,880	2,653
Factory 5	10,400	520	9,880	2,517
Factory 6	10,400	520	9,880	2,455

The temporary area is the total area of the factory building, while the permanent area is obtained from the area of permanent buildings in the factory such as administrative offices and others that become permanent. Thus, the area that can be used for production activities is represented by the building area.

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2. Calculation of the standard number of workers per building

By using the 2012 NFPA 101 standard (the density factor of the factory building is 9.3 m^2/person, then in Table 2. it can be seen that the maximum number of people who can work in each building is based on the usable building area.

Table 2. People standards according to NFPA 101 of 2012

Building Name	Building Size (m^2)	Density Factor Provisions; NFPA 101, 2000 (m^2/person)	Maximum number of workers (person)
Factory 1	9,880	9.3	1,062
Factory 2	9,880	9.3	1,062
Factory 3	9,880	9.3	1,062
Factory 4	9,880	9.3	1,062
Factory 5	9,880	9.3	1,062
Factory 6	9,880	9.3	1,062

3. Emergency exit

An emergency exit requirement can be calculated with equations (1) and (2) which have been previously described in the sub-section of the method. Table 3 describes the number of emergency exits currently in each building and the specifications for each of these doors.

Table 3. Number of emergency exits and their size

Building Name	Number of Emergency Exits (unit)	Emergency Exits Width (m)	Height of Emergency Exits (m)	Type of Emergency Exits	Building Type
Factory 1	7	1.8	4	Iron, slide	Factory
Factory 2	7	1.8	4	Iron, slide	Factory
Factory 3	7	1.8	4	Iron, slide	Factory
Factory 4	7	1.8	4	Iron, slide	Factory
Factory 5	7	1.8	4	Iron, slide	Factory
Factory 6	7	1.8	4	Iron, slide	Factory

In equation (1) mentioned earlier, there are several things that need to be considered carefully, especially regarding the constant 40 which shows the exit rate of people in units of one minute with a door width of 28 inches or the equivalent of 0.71 meters (OHSA 1910.36). According to OHSA 1910.36, there are several requirements for the minimum criteria for emergency exits, including;

1. Permanent
2. Must go directly to an open area
3. Must be easy to open, and allow opening from the inside
4. The minimum width is 28 inches (0.71 m)
5. Minimum height is 7.5 feet (2.28 m)
6. Made of fireproof material or coated with a fireproof coating with a minimum resistance of 1 hour.

The constant exit rate of 40 persons per minute for a door width of 0.71 m will be converted to a linear equation if the current available door is 1.8 m. So, for a door width of 1.8 meters, the exit rate of people will be 100 people per minute. Equation (1) also states the constant "T" which represents the standard time for evacuating people in a building. According to Kep.Men.Naker No.186 of 1999, this factory building is classified as a building that has a serious fire hazard risk and the specified evacuation duration is 3 minutes. Therefore, the T that will be used is 3 minutes. Table 4 provides an overview of the results of calculating the need for emergency exits in each of the existing buildings in the company.

Table 4 Calculation of Needs for Emergency Exits

Building Name	Number of workers (N_{act})	Evacuation Time (T)	U_{act}	E_{act}
Factory 1	2,574	3	9	4
Factory 2	2,485	3	9	4
Factory 3	2,844	3	10	4
Factory 4	2,653	3	9	4
Factory 5	2,517	3	9	4
Factory 6	2,455	3	9	4

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In table 4 also could be seen that the number of workers or N used is the actual workforce in each building in the company. This is done because the actual Density Factor level of the building can be determined by the number of workers working in the building.

6. CONCLUSION

Emergency exits requirement at PT. The PIN is very adequate because several standards given in OHSA 1910.36, all have been fulfilled; also the calculation results of the need for emergency exits are less than the existing emergency exits. Table 5 shows the comparison between the standard calculation of emergency doors and the actual existing emergency exits. This of course also needs to be seen by the distance between the door and the farthest point from the location of the worker in each area.

Table 5. Comparison of Standards with Actual Emergency Exits

Building Name	Number of Emergency Exits Actual (Unit)	Number of Standard Emergency Exits (Unit)	GAP (Unit)
Factory 1	7	4	3
Factory 2	7	4	3
Factory 3	7	4	3
Factory 4	7	4	3
Factory 5	7	4	3
Factory 6	7	4	3

The distance between the worker at the farthest point from the emergency exit can be divided into several areas so that all workers in the building can feel comfortable and safe at work, and there is no need to panic when there is a fire because the evacuation routes and emergency evacuation doors are sufficient. Further research needs to be done to calculate the farthest distance from the worker's place to the emergency exit which is determined based on the area.

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