Vol. 06, No. 02, July 2022, pp. 178-192

INTERNATIONAL JOURNAL OF INNOVATION IN ENTERPRISE SYSTEM

Journal homepage: https://ijies.sie.telkomuniversity.ac.id
e-ISSN: 2580-3050, DOI: https://doi.org/10.25124/ijies.v6i01.165

Design Of Safety Signs Using Ergonomic Function Deployment Method At PT.XYZ

Dita Kusuma Ningsih[1*], Heriyono Lalu[2], Sheila Amalia Salma[3]

[1] Department of Industrial Engineering, School of Industrial and System Engineering, Telkom University
Jl. Telekomunikasi No.1, Bandung, 40258, Indonesia
ditakusumaningsih@student.telkomuniversity.ac.id

[2] Department of Industrial Engineering, School of Industrial and System Engineering, Telkom University
Jl. Telekomunikasi No.1, Bandung, 40258, Indonesia
heriyonolalu@telkomuniversity.ac.id

[3] Department of Industrial Engineering, School of Industrial and System Engineering, Telkom University
Jl. Telekomunikasi No.1, Bandung, 40258, Indonesia
sheilaamalias@telkomuniversity.ac.id

[*]ditakusumaningsih@student.telkomuniversity.ac.id

ARTICLE INFO

Article history:
Received 13 July 2022
Accepted 26 July 2022
Published 31 July 2022

ABSTRACT

PT. XYZ is a company engaged in manufacturing by processing raw materials into semi-finished goods or finished goods. Because the company routinely produces these products and involves machinery, it will allow small to serious work accidents to occur. Based on the hazard event data owned by the company, there are 5 very diverse events that will be analyzed in the risk control hierarchy to minimize hazard events. The results of the risk control hierarchy analysis have two hazard events that have safety sign design criteria. Therefore, research was conducted to design safety signs in the area of explosive materials and loading progress in minimizing hazard events using safety signs assessment and Ergonomic Function Deployment approaches. The data needed in the design are anthropometric data, layout data, customer statements and level questionnaires interest and satisfaction. From the results of the safe sign assessment, the signal word is obtained, determining the location, height, model, and material of the safety signs. The results of the safety signs assessment will be used for the Ergonomic Function Deployment approach. From the results of the Ergonomic Function Deployment, the results obtained are the size of safety signs, safe reading distance, type of layout, use of language and font size on safety signs. There are two types of designs, namely explosive material and loading progress safety signs. The design of safety signs refers to the ANSI Z535 standard so that the design of safety signs has detailed signal words, symbols, signs, and word messages.

Keywords:
Slag Processing; Risk Control Hierarchy; Safety Signs; Safety Signs Assessment; Ergonomic Function Deployment; ANSI Z535 Standard

1. INTRODUCTION

The work environment in Indonesia is inseparable from the potential risk of work accidents that result in accidents and health problems due to work. According to the International Labor Organization (2018), the rate of work accidents and various occupational safety and health threats in Indonesia is still quite high. Various work accidents still often occur in the production process, every day there are 6000 cases of work accidents that result in fatal victims, in Indonesia every 100,000 workers there are 20 fatal victims due to work accidents. According to calculations by the International Labor Organization (2018), the losses that must be borne due to work accidents in developing countries, Indonesia is also among the highest, reaching 4% of gross national product (GNP). The ILO revealed that more than 250 million accidents in the workplace and more than 160 million workers became ill due to hazards that occur in the workplace and 1.2 million workers died due to accidents and illness at work [1]. Industrial developments in the world are increasingly advanced so that occupational health and safety is the focus of attention [2]. One of them at the company PT. XYZ. PT. XYZ is a company engaged in steel mill services such as operating special equipment for transporting liquid slag in pots, providing cleaning equipment for pot furnaces, and providing hot metal transport services using equipment such as multi movers. Apart from operating in the service sector, PT. XYZ is engaged in manufacturing which processes raw materials into semi-finished goods or finished goods. The company produces two kinds of slag products, namely precious slag ball and Precious slag grid. In carrying out its work PT. XYZ has firm values which are shown in Figure 1.

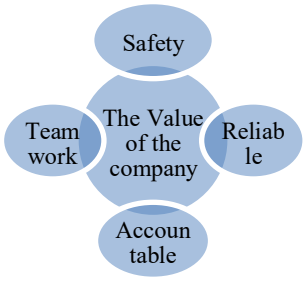


Figure 1 – Firm Value PT. XYZ

Based on the value of the company, PT. XYZ puts forward the value of safety within the company by making various efforts to ensure the availability of resources to support the company's goals in creating safe and healthy working conditions and environments. Occupational safety and health are thoughts and efforts to ensure the integrity and perfection of both physical and spiritual [3]. Occupational Health and Safety is a condition in the workplace that is healthy and safe both in terms of work, the company as well as for the community and the environment around the factory or workplace [4]. Because the company prioritizes the value of safety, this research will focus on handling accidents at PT. XYZ. In Figure 2 is an accident graph of PT. XYZ from 2007 to 2020.

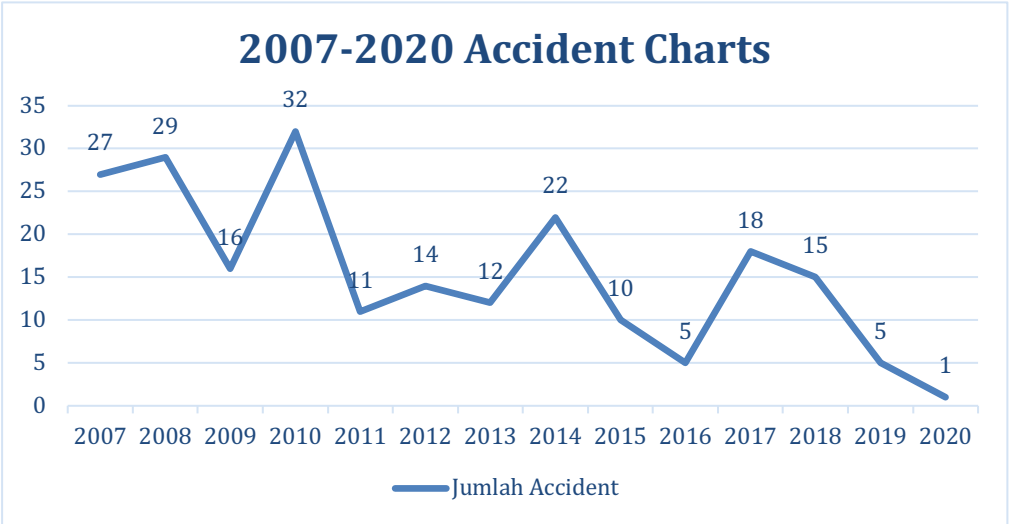


Figure 2 – Accident Charts

In the Figure 2 above, it can be seen that there are data on the number of accidents from 2007 to 2020 at PT. XYZ. In the graph there is an increase and decrease in accidents every year. The highest number of accidents occurred in 2010

*ditakusumaningsih@student.telkomuniversity.ac.id

with 32 accident cases, while the lowest number of accidents occurred in 2020 with 1 case. The development of industry in the world is increasingly advanced so that occupational health and safety is the focus of attention [2], so that on the accident graph, PT. The XYZ risk control hierarchy will be analyzed from 2019 to 2020. Factors causing the incident are unsafe conditions and unsafe actions. Unsafe acts and unsafe conditions are direct causes of accidents, a deeper analysis comes to indirect (common) causes, which include three elements: inadequate safety knowledge, inadequate safety awareness, and inadequate safety habits [5]. In this study will focus on the series of accidents in the last two years at PT. XYZ. The following is a breakdown of accident data on precious slag production in the last two years, which can be seen in Table 1.

Table 1 – Event Description

No	Location of the incident	Event Description
1	Workshop	At the time of welding, sparks occurred due to the unstable welding machine, so that it hit the rear glass of the unit and the rear glass cracked.
2	Front of Workshop	The operator slipped and fell down the stairs.
3	MRP	The front tire stepped on the skull, so the skull grazed the diesel tank causing the diesel tank to leak.
4	Area Slag	There was an explosion of liquid slag, when the loader dredged the slag material in the pit, causing the loader's cabin glass to crack.
5	Seiving PS Ball	When the flexsus wants to pass from PM, there is a truck on the left loading and the loader unit 1469 on the right, the right rear flexsus body bumps the Ha-beam of the PS Ball sieving pole.

In Table 1 there are several very diverse events. So that risk control is needed to minimize the potential for work accidents or hazards to workers. Therefore, the important role of the precious slag production department for the company should be immediate efforts to prevent such incidents from happening again. Before doing a hierarchical analysis related to hazard events, an analysis related to existing controls is needed by the company. In the Table 2 is the existing control for each event.

Table 2 – Existing Control

No	Event Description	Existing Control
1	At the time of welding, sparks occurred due to the unstable welding machine, so that it hit the rear glass of the unit and the rear glass cracked.	Check the condition of the welding machine before use.
2	The operator slipped and fell down the stairs.	There is no clear action to avoid this yet
3	The front tire stepped on the skull, so the skull grazed the diesel tank causing the diesel tank to leak.	There is no clear action to avoid this yet
4	There was an explosion of liquid slag, when the loader dredged the slag material in the pit, causing the loader's cabin glass to crack.	To avoid unwanted things that are directly related to the source of the hazard, workers always work according to the Work Instructions and job safety analysis.
5	When the flexsus wants to pass from PM, there is a truck on the left loading and the loader unit 1469 on the right, the right rear flexsus body bumps the Ha-beam of the PS Ball sieving pole.	Notification of safe distance to transportation.

After knowing the existing controls that have been carried out by the company, then control or control of hazards in the work environment is carried out which are actions to minimize or eliminate the risk of work accidents through elimination, substitution, engineering control and warning system, administrative control and personal protective equipment [6]. Table 3 is the conclusion from the results of the Risk Control Hierarchy Analysis [7].

Table 3 - Risk Control Hierarchy Analysis

No	Incident Description	Reason	Risk Control Suggestion	Risk Control Criteria
1	During welding, sparks occurred due to the unstable welding machine, so that it hit the rear glass of the unit and the rear glass cracked.	The operator did not apply the work instructions, causing errors in the welding machine.	Giving rewards and punishments for discipline in implementing company regulations.	administration
2	Operator slipped and fell down the stairs	Incorrect layout of the factory which causes rainwater to pool in the staircase area, causing the operator to slip.	Factory layout redesign.	Substitution
3	The front tire stepped on the skull, so the skull grazed the diesel tank causing the diesel tank to leak.	There is friction of the skull against the diesel tank.	The transfer of the diesel tank or hazardous materials to a better place and avoid the danger.	Elimination
4	There was an explosion of liquid slag, when the loader dredged the slag material in the pit, causing the loader's cabin glass to crack.	Because there is slag material that is still liquid	Provision of safety signs for explosive materials.	Design
5	When the flexsus wants to pass from PM, there is a truck on the left loading and the loader unit 1469 on the right, the right rear flexsus body bumps the Ha-beam of the PS Ball sieving pole.	There is no sign of the transportation area that is operating or loading progress.	Providing safety sign for loader operation.	Design

Based on the results of the hierarchical analysis of risk control, there were two incident description which are explosive material and loading progress that could be handled with the same risk control criteria. With the design of a safety sign, it can overcome two hazard events so that a safety sign design will be carried out in the hazard event. Safety signs are one way to provide information to workers about occupational safety and health hazards from a particular activity, area or work equipment. So, with the safety signs, everyone, both workers, guests, and contractors can anticipate as early as possible about the dangers in the area, this is also to minimize the risks that can occur [7]. Safety signs are not the main control and cannot eliminate or reduce hazards and cannot prevent accidents. However, a safety sign can provide interesting attention, provide an alert attitude to dangers that are not visible to the eye or a warning alert to actions that are not visible to the eye or a warning alert to actions that are not allowed, provide general information and provide direction to company guests will the existence of dangers that can be expressed in various forms and images that can be seen from a distance or close, as well as reminding employees where to use personal protective equipment, indicating where safety emergency equipment is located and so on [8]. For this reason, this study will focus on designing safety signs that refer to the ANSI Z535 standard for the dump truck loading area and explosive material area at PT.XYZ.

2. METHOD

2.1 Method Conceptual

Systematics design displays the design flow in a structured, systematic, and detailed manner. Systematics design describes the planned and systematic steps in the design to get the design results, a description of the data collection mechanism. It aims to clarify the reader about the stages in designing a safety sign. These stages become a reference for researchers to conduct their research and produce results in accordance with the research objectives. Conceptual Method Development is a framework that describe the model and stages in conducting research, starting from the object to be studied as well as the related variables in the problem under study. The following is a Figure 3 of conceptual methods in control design work accidents on the object of research PT. XYZ.

*ditakusumaningsih@student.telkomuniversity.ac.id

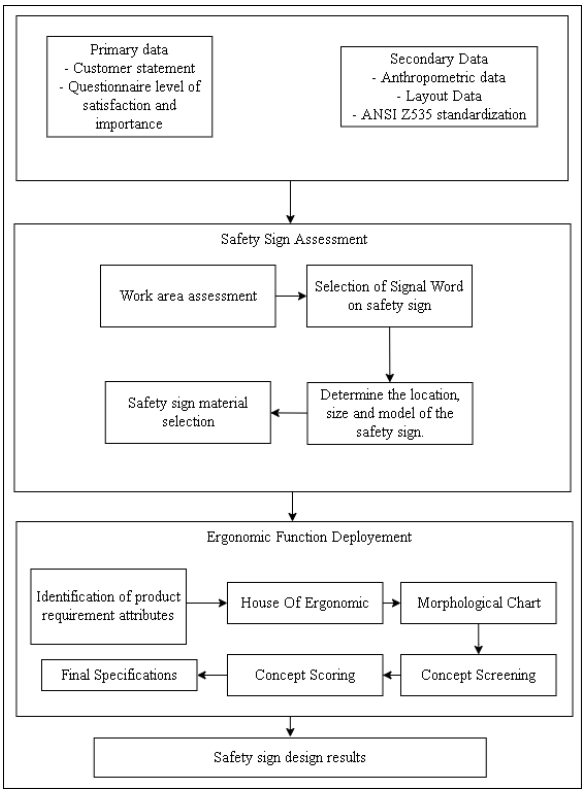


Figure 3 – Method Conceptual

2.2 Data Collection

The data collection carried out in this study was divided into two groups of categorized data. An explanation of the collection of the two categories of data can be seen below.

a. Data Collection Primary Data
   Primary data obtained from interviews. The target respondents who will be interviewed are production operators. Interviews were conducted to determine the customer statement and the results of the questionnaire on the level of satisfaction and interest in the product to be designed.
b. Data Collection Primary Secondary
   Secondary data is obtained from data from the study of literature and owned data or company historical data. The company's historical data is obtained in the form of the layout of the company. And for data sourced from literature studies, namely anthropometric data and data regarding the provisions of the application of the ANSI Z535 standard.

2.3 Data Processing

At the data processing stage, it is carried out with the stages of safety sign assessment which is an assessment of the work area which aims to determine the specifications and criteria of safety signs that will be implemented in the field. This research was conducted to design safety signs in the area of explosive materials and loading progress in minimizing hazard events. Safety signs assessment is used to assist in determining the number, design, material, and size of safety signs or safety visual media. The following are the stages of the safety sign assessment. For assessing safety sign, this research is based on ANSI Z535 standard. In line with [9], ANSI Z535 standard has information to define colors, symbols, lines, which are used in designing safety signs.

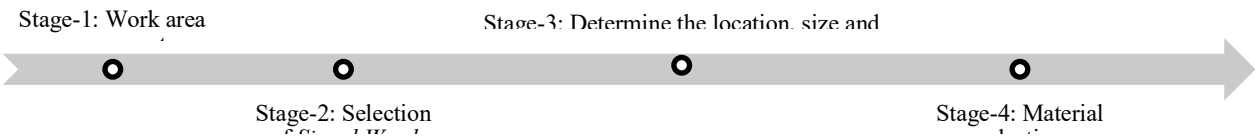


Figure 4 – Safety Signs Assessment

2.4 Design Stage

At the design stage is the stage in designing the safety sign. The design stage uses the Ergonomic Function Deployment approach. Ergonomics is a discipline concerning the study of human capabilities, limitations, and functions as it applies to information in designing consumer products, equipment, and tools [10]. The ergonomics is an independent subject developed from the beginning of the 20th century, and it is the frontier applied science which studies the comprehensive performances such as comfort ability, production efficiency and safety under various conditions [11]. Ergonomic Function Deployment is an extension of Quality Function Deployment (QFD) with the distinction of adding new relationships between consumer desires and the ergonomic aspects of the product. This relationship will complete the form of the house of quality matrix which also translates into the desired ergonomic aspects. In the EFD method, the design is based on the ergonomic aspect of the user in order that the product is designed in accordance with the principles of ENASE (Effective, Convenient, Safe, Healthy and Efficient) [12]. In Figure 5 Following what is the structure of the House of Ergonomics [13].

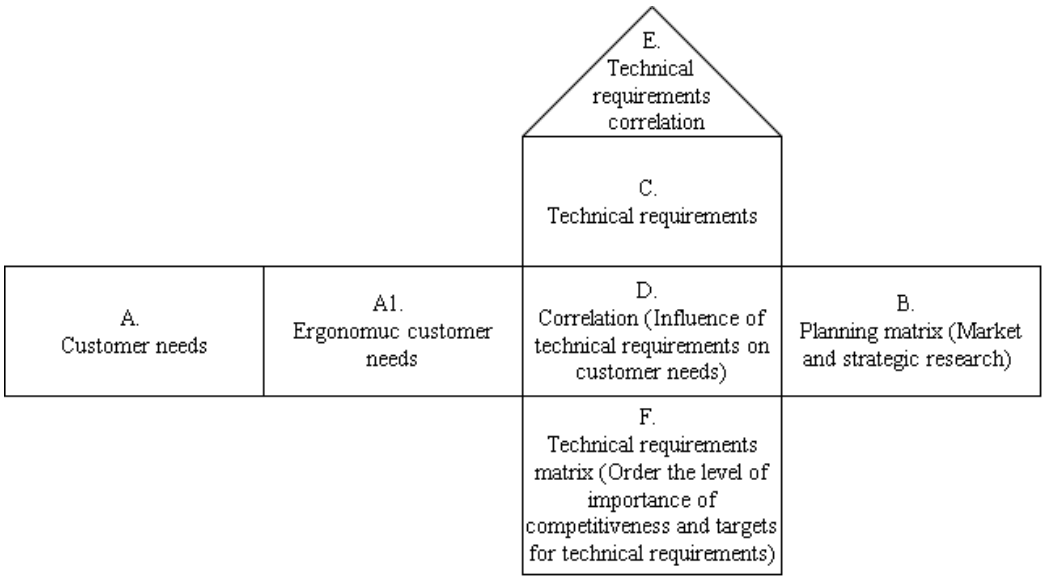


Figure 5 – House Of Ergonomic

Based on figure 4 can is known that HOE has stages [14], namely:

1) Part A
   Containing amount of needs as well as desire from customer, consumer desire determined based on qualitative market research. Most quality experts now agree that good product quality is that can meet the needs and desires of consumers.
2) Part A1
   is a translation of consumer needs which are included in the ergonomic aspect. This translation must be done correctly in order to make it easier for the design team to determine the characteristics of the technical aspects.
3) Part B
   This matrix contains market planning and strategic research containing several assessments, namely:
   - Importance to Customer (ITC)
     In the ITC column, it contains about how important an attribute needs to the customer. To get the ITC value, the following formula is used:
     Performance Weighted = Total Respondent x Weighted Score
     Where total respondent multiplied by weighted score equals to performance weighted.
     $$ITC = \frac{Total\ Performance\ Weighted\ Importance\ Level}{Number\ of\ Respondents}$$
     Where total performance weighted importance level devided by number of respondents is equal to importance to customer (ITC).
   - Customer Satisfaction Performance (CSP)
     In the CSP column, it contains the level of customer satisfaction with the attributes of a product's needs. To get the CSP value, the following formula is used:
     $$CSP = \frac{Total\ Performance\ Weighted\ Satisfaction\ Level}{number\ of\ Respondents}$$
     Where total performance weighted satisfaction level devided by number of respondents is equal to customer satisfaction performance (CSP).
   - Goal
     Goal is the target value by considering the value of ITC with CSP.

- Improvement Ratio (IR)
  Improvement Ratio is the multiplication of the Goal factor with the level of customer satisfaction. Here is the IR formula:
  $IR = \frac{Goal}{Customer\ Satisfaction\ Performance}$
  Where goal devided by customer satisfaction level is equal to improvement ratio (IR).
- Sales Point (SP)
  Sales Point is the selling power of a product based on how well customer needs are met. SP has three values, namely:

Table 4 – Sales Point

Score	Information
1	Attribute no have power sell (power sell low)
1.2	Attribute have power sell currently
1.5	Attribute have power sell high

- Raw Weight (RW)
  Raw weight value is obtained from the multiplication of ITC, IR and SP. The following is the formula used to calculate the RW value:
  RW = ITC x IR x SP
- Normalized Raw Weight (NRW)
  Normalized Raw Weight is the percentage value of each attribute requirement. The NRW value can be calculated using the following formula:
  $NRW = \frac{RW}{Total\ RW}$
  Where raw weight (RW) devided by total raw weight is equal to normalized raw weight (NRW).

4) Part C
   There is a direction of goodness which is divided into three:

Table 5 – Direction of Goodness

Direction of Goodness	
abbreviation	**Value**
MTB	More The Better
LTB	Less The Better
TB	Target Best

5) Part D
   The strength of the relationship is indicated by using certain symbols.

Table 6 – Symbol Connection Need Statement with Product Tenchnical Requirements

Symbol Connection Need Statement with Product Technical Requirements			
Score	**Strength Connection**	**Symbol**	**Information**
0	Not there is	blank	Not there is Connection
1	Weak	△	Weak relationship _ between matrix
3	Currently	○	Medium relationship _ between matrix
9	Strong	◎	Strong relationship _ between matrix

6) Part E
   The fifth part of the HOE is Technical Correlation, a matrix that looks like a roof. Where this matrix is used to identify appropriate exchanges that occur, this matrix shows the relationship between one attribute and another. The strength of this relationship is indicated by the following symbols:

Table 7 – Symbol Technical Correlation

Symbol of Relationship Between Technical Requirements		
Symbol	**Relationship Strength**	**description**
⊕	Strong Positive	Strong relationship and value is directly proportional
+	Medium Positive	Medium relationship and value is directly proportional
blank	No effect	Have no relationship
·	Medium Negative	Medium relationship and inversely value
⊖	Strong Negative	Strong relationship and inverse value

7) Part F
is the last stage in making the House of Ergonomics which contains the final calculation to get a conclusion or rating. Part F contains the following:
1. Target: contains data on the minimum or maximum nominal goals to be achieved and derived from technical requirements.
2. Units: contains units of each previously defined technical requirement.
3. Weight: the weighting is based on the results of the calculations in section D.
4. Priority: obtained after ranking from the weights that have been obtained

3. RESULT AND DISCUSSION

3.1 Data Processing

In data processing, specifications of the product to be designed will be produced, namely the safety sign. The design specifications will use the stages of the safety signs assessment, where this stage is the result of an assessment based on field conditions. The following are the stages in obtaining safety sign design specifications:

3.1.1 Work Area Assessment

In conducting observations, consideration is needed to determine the type and number of safety signs that will be designed according to field conditions and references. The following are things that must be considered in designing safety signs (Table 8).

Table 8 – Work Area Assessment

Name Safety Signs	Category Selected	Work Area Overview
Explosive Material and Loading Progress	This type of safety sign is a warning sign because a warning is needed to keep workers away from danger.	

3.1.2 Choose Signal Word

In choosing signal words, consideration is needed to determine signal words on safety signs that will be designed according to field conditions and references. The following are things that must be considered in the selection of signal words in the design of safety signs (Table 9).

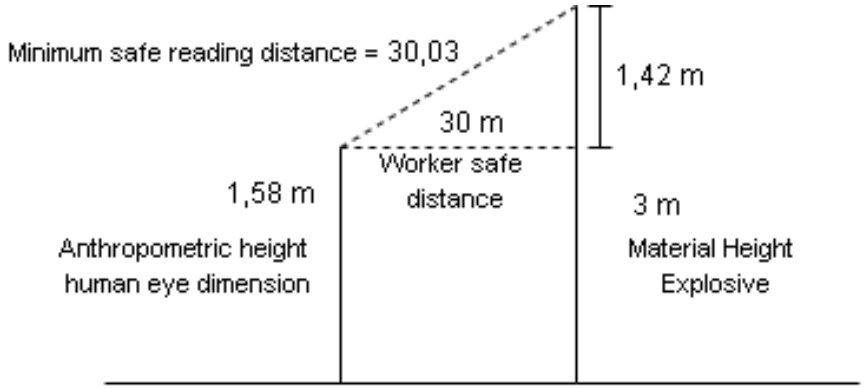
Table 9 - Signal Word

Signal Words		
Name Safety Signs	**Category Signal Words**	**Reason**
Explosive Material	Danger	Sources of danger to explosive materials can cause lifelong disability to death, so signal words are needed in the form of danger in red.
Loading Progress	Caution	The source of danger to the loading area can cause mild to moderate injury, so a signal word in the form of a caution is required with a yellow color.

3.1.3 Determining the Location, Size and Model of Safety Signs

In designing safety signs, consideration is needed to determine the location, size and model according to field conditions and references. The following are considerations in determining the location, size and model according to field conditions or field survey results (Table 10).

Table 10 - Location, Size, Model

Name of safety sign	Items	Information
Explosive Material and Loading Progress	Location	Safety signs will be installed at the end of the MRP and sieving area roads so that the safety signs can be read by loader operators who will go to the area.
	Tall	The height of the safety signs applies the eye height of the workers so that the height of the safety signs will apply the 50th percentile with a value of 1.58 meters [15]. By making measurements according to the anthropometry of the sign user, the factors that cause fatigue and for the operator can be reduced so that the operator does not feel too tired when looking up for a long time [16].
	Model	Installation of safety signs will be assisted by iron poles with a flat model because they are clearly visible.
	Minimum reading distance	The minimum reading distance used is 30.05 meters, which is a round down from the results of the Pythagorean multiplication of the height distance of the safety signs and the worker's safe distance. $\sqrt{30^2 + 1{,}42^2} = 30{,}03\ m$ Where square root of working safe distance squared plus height squared is equal to minimum reading distance.  **Figure 6 - Minimum reading distance**

3.1.4 Choosing Material

In designing safety signs, consideration is needed to determine the material according to field conditions and references. The following are considerations in determining materials according to field conditions or field survey results (Table 11).

Table 11 - Material

Name of safety sign	Items	Information
Explosive material and Loading Progress	Material Base	The use of the base material for safety signs uses aluminum, because aluminum can be resistant to corrosion, chemicals, abrasion and has strong durability for both indoor and outdoor installation.
	Sticker Material	The use of sticker material on safety signs uses kiwalite material, because this material has various advantages that can support the placement of safety signs in outdoor areas such as being durable outdoors for more than 5 years, having the property of reflecting light when exposed to sunlight or lights so it will look very clear, scratch resistant, weather resistant, adhesive (feel strong), easy to maintain and clean.
	Pole Material	The use of pole material on safety signs uses galvanized pipe material, namely steel pipes that are coated with melted zinc. This makes Galvanized pipes stronger and more durable and has a high resistance to rust. In addition, galvanized pipe has advantages such as being outdoor for more than 15 years, resistant to scratches, not absorbing water, having strong adhesion, and easy to maintain and clean.

3.2 Design Stage

At the design stage, an ergonomic function deployment approach will be used. At the ergonomic function deployment stage, the results of the safety signs assessment will be used in the form of design specifications that will become the target specifications for each need statement. From the results of the ergonomic function deployment, the final specifications and design concepts will be selected based on the results of the customer statement. The following are the stages of the ergonomic function deployment:

3.2.1 Identification of product requirement attributes

In the early stages of Ergonomic Function Deployment, namely by searching for product needs. The product requirement attribute is obtained from the results of observations and interviews with company workers regarding the problems felt by workers related to the product to be designed. After collecting data using the customer statement collection method which can be seen in the table and customer statement data which has been interpreted into a statement of needs which are grouped based on ergonomic aspects, namely ESHCE (effective, safe, healthy, comfortable and efficient) [17] which can be seen in Table 12.

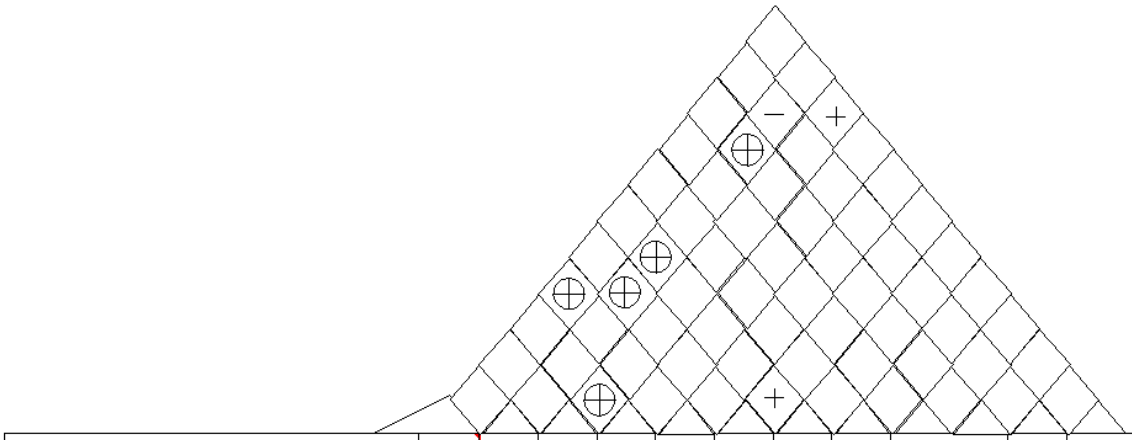
Table 12 – Identification Of Needs

No	Aspect Ergonomics	Need Statement	Code
1	Effective (Achieving company targets)	Sign with easy understand	V1
		Sign could read with clear	V2
2	Safe (Operator spared from distraction)	Signs have the right material	V3
		Sign has a durable material	V4
3	Healthy (No there is risk health)	Sign could give information existence risk danger	V5
4	Comfortable (Operator condition without anxiety)	Dimension appropriate sign _ with anthropometric data	V6
		Sign with the right model	V7
		Sign with distance read minimum safe	V8
5	Efficient (Achieving targets with minimum effort)	Sign with standard layout	V9
		Sign with location in accordance	V10

In the Table 10 is a need statement based on the ergonomics of the product. Based on the effective dimension, there is a need statement, namely signs that are easy to understand and signs that can be read clearly. From the Safe dimension, there is a need statement, namely Signs have appropriate materials and Signs have durable materials. As well as in the Healthy Signs dimension, it can provide information about the risk of danger. In the Comfort dimension, the dimensions of signs are in accordance with anthropometric data, Signs with the appropriate model, and Signs with a minimum safe reading distance. And on the Efficient dimension, Signs with standard layouts and Signs with appropriate locations.

3.2.2 House Of Ergonomic

Then the making of House Of Ergonomics (HOE). The product requirement attributes that have been obtained will be translated into the House of Ergonomics to see how the various aspects of the product requirements attribute are related. HOE is an exploration of needs, product technical requirements, the relationship between consumer needs and technical requirements, and the relationship between technical requirements. In HOE there is a ranking for each technical requirement, this ranking is obtained from the results of the contribution to each technical requirement that has been normalized by the contribution. Normalization of the contribution to the HOE is carried out in order to get the same contribution scale, namely 0-1 units. Figure 7 is the result of the House of Ergonomics in the design of safety signs.



	Direction of Goodness	TB	MTB	MTB	MTB	MTB	TB	TB	TB	TB	TB	TB	TB	Normalized raw weight
		Language use	Height font	Material Type	Material Life	Contains Word Messages	Sign Length	Sign Height	Pole Height	Model Type	Safe Distance	Standard Layout Type	Type of hazard location	
		1	2	3	4	5	6	7	8	9	10	11	12	
1	Sign with easy understand	9	1	0	0	9	0	0	0	0	0	0	0	0,10
		0,878579	0,09762	0	0	0,878579	0	0	0	0	0	0	0	
2	Sign could read with clear	1	9	0	0	9	0	0	0	0	9	0	0	0,11
		0,105912	0,953209	0	0	0,953209	0	0	0	0	0,953209	0	0	
3	Sign have the right material	0	0	9	9	0	0	0	0	0	0	0	9	0,06
		0	0	0,524978	0,524978	0	0	0	0	0	0	0	0,524978	
4	Sign has a durable material	0	0	9	9	0	0	0	0	0	0	0	9	0,10
		0	0	0,878477	0,878477	0	0	0	0	0	0	0	0,878477	
5	Sign could give information existence risk danger	1	1	0	0	9	0	0	0	0	0	3	3	0,11
		0,112396	0,112396	0	0	1,011568	0	0	0	0	0	0,337189	0,337189	
6	Dimension appropriate sign _ with anthropometric data	0	0	0	0	0	9	9	9	0	0	0	0	0,10
		0	0	0	0	0	0,878579	0,878579	0,878579	0	0	0	0	
7	Sign with the right model	0	0	0	0	0	0	0	0	9	0	0	3	0,11
		0	0	0	0	0	0	0	0	1,034438	0	0	0,344813	
8	Sign with distance read minimum safe	0	9	0	0	0	0	0	0	0	9	0	9	0,10
		0	0,933755	0	0	0	0	0	0	0	0,933755	0	0,933755	
9	Sign with standard layout	0	0	0	0	0	0	0	0	0	0	9	0	0,11
		0	0	0	0	0	0	0	0	0	0	0,953209	0	
10	Sign with location in accordance	0	1	3	0	0	1	1	1	0	3	0	9	0,11
		0	0,105912	0,317736	0	0	0,105912	0,105912	0,105912	0	0,317736	0	0,953209	
	Unit	Binary	cm	Binary	Tahun	Binary	cm	cm	m	Binary	m	Binary	Binary	
	Target/Value	Ya/Tidak	0,4 - 20,3	Ya/Tidak	> 5	Ya	100 - 200	100 - 300	1,58	Ya/Tidak	30,5	Ya/Tidak	Ya/Tidak	
	Contribution	1,096887	2,202892	1,721191	1,403455	2,843356	0,984491	0,984491	0,984491	1,034438	2,2047	1,290398	3,972421	
	Contribution Normalization	0,05293	0,106301	0,083056	0,067724	0,137206	0,047507	0,047507	0,047507	0,049917	0,106388	0,062268	0,191689	
	Ranking	8	4	5	6	2	10	10	10	9	3	7	1	

Figure 7 – House of Ergonomic

Each relationship between matrices has how much the relationship and there is also an interaction relationship between the technical characteristics that affect each other. The formation of HoE can be considered for product development. Technical characteristics have a priority indicating a higher priority, so if there is a trade-off in the product development, the highest priority is not recommended to be modified first because it will affect product attributes and other technical characteristics. The product requirement attributes that have been obtained will be translated into the House of Ergonomics to see how the various aspects of the product requirements attribute are related. HOE is an exploration of needs, product technical requirements, the relationship between consumer needs and technical requirements, and the relationship between technical requirements. In HOE there is a ranking for each technical requirement, this ranking is obtained from the results of the contribution to each technical requirement that has been normalized by the contribution. Normalization of the contribution to the HOE is carried out in order to get the same contribution scale, namely 0-1 units. Figure 7 is the result of the House of Ergonomics in the design of safety signs.

3.2.3 Morphological Chart

The morphology graph shows the number of concepts that are alternative options in this study in accordance with the statement of needs or attributes of product requirements that have been obtained. Based on the functions that have been selected in the decomposition, then the options are described using a morphology chart to make it easier to combine several to create a proposed concept that is in accordance with the wishes of the user. statement and further consideration will be given to the selection of the concept. Figure 8 shows the resulting design concept.

Function / Option	Sign material that is suitable for the location	Durable sign material	The dimensions of the sign are comfortable when used	Type of model on sign	Minimum safe reading distance from signs	Type of layout on signs	Location according to the installation of signs	The use of language is easy to understand	Font size on signs	Can provide information on hazard events
Concept A	Reflektif	15 Year	Sign length = 120 cm Sign height = 100 cm Pole height = 1.58 m	Flat	30,5 Meter	Three panel sign	Outdoor	Bahasa Indonesia	10,2 Cm	Contains Signal word, message word and symbol panel
Concept B	Reflektif	15 Year	Sign length = 120 cm Sign height = 100 cm Pole height = 1.58 m	Flat	30,5 Meter	Two pael sign	Outdoor	Bahasa Inggris	12,7 Cm	Contains Signal word, message word and symbol panel
Concept C	Reflektif	15 Year	Sign length = 80 cm Sign height = 60 cm Pole height = 1.58 m	Flat	30,5 Meter	One panel sign	Outdoor	Bahasa Inggris	8,1 Cm	Contains Signal word, message word and symbol panel

Figure 8 - Design Concept

3.2.4 Concept Screening Matrix

Concept screening matrix is a translation need statement into product criteria. This stage begins with the selection criteria. Selection criteria can contain more than one need statement as long as the need statement is still in one criteria the same one. criteria based on the need statement owned Selection criteria obtained from customer needs and stakeholder needs that can be seen in the Table 13.

Table 13 – Selection Criteria

Selection Criteria	Needs Statement
Convenience Use	Sign with easy understand
	Sign could read with clear
	Sign with location in accordance
	Sign with standard layout
Ergonomics	Dimension appropriate sign _ with anthropometric data
	Sign with distance read minimum safe
Suitability standard product	Sign have the right material
	Sign has a durable material
	Sign could give information existence risk danger
	Sign with the right model

Table 14 – Concept Screening Matrix

	Concepts			
Selection Criteria	**A**	**B**	**C**	**Reference**
Convenience Use	+	0	-	0
Ergonomics	+	+	0	0
Suitability standard product	+	0	-	0
Cost Production	+	0	-	0
Safety Manufacturing	+	+	+	0
Sum +'s	5	2	1	
Sum 0's	0	3	1	
Sum -'s	0	0	3	
Net Score	5	2	-2	
Rank	**1**	2	3	
Continue?	YES	YES	NO	

In this concept screening seen that who gets Rank 1 and Rank 2 are concept A and concept B will be next step by step concept scoring matrix (Table 14).

3.2.5 Concept Scoring Matrix

Concept assessment is an analysis of existing concepts to select one of the concepts that can be developed and become a finished product. At this stage will choose concept scoring to re-select the results of the concept that has been created with concept filtering. In Table 15 are percentage to each need statement for weighting selection criteria in the scoring matrix. Concept scoring is done to determine which concept is the best out of a number of combination of alternative options on morphological chart by level of importance consumers [18].

Table 15 – Weight Criteria

Selection Criteria	Weight
Convenience Use	32.13%
Ergonomics	15.74%
Suitability standard product	38.33%
Production Cost	15,00%
Safety Manufacturing	5.00%

The selection criteria weights are obtained by means of add up the percentage for each need statement under the same criteria. Then the weight of each selection criteria is multiplied with ratings. Ratings are earned with compare the proposed concept with the product existing. Ratings are used in calculations concept scoring matrix. Rating is required for compare each product criteria proposal with existing product criteria. Evaluation draft conducted to increase amount alternative solution to differentiate which one is better between competing concepts. Because it needs the real difference in each draft selected, so that needed more scale specific. Table 16 is 1 to 5 scale of evaluation the concept of concept scoring in Table 17.

Table 16 – Scale Evaluation

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Table 17 – Concept Scoring

		Concepts			
		A		B	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score
Convenience Use	32.13%	4	1.29	3	0.96
Ergonomics	15.74%	4	0.63	3	0.47
Standard Product Suitability	38.33%	5	1.92	3	1.15
Production Cost	15,00%	4	0.60	3	0.45
Safety Manufacturing	5.00%	4	0.20	4	0.20
Total Score		4.63		3.24	
Rank		1		2	
Continue?		**DEVELOP**		**NO**	

Based on the concept assessment matrix, the chosen concept that will be used in product design is concept A with a total score of 4.63. Concept A has the advantage that by using Indonesian on the safety sign, it can make it easier for users or users to read information related to hazard events.

*ditakusumaningsih@student.telkomuniversity.ac.id

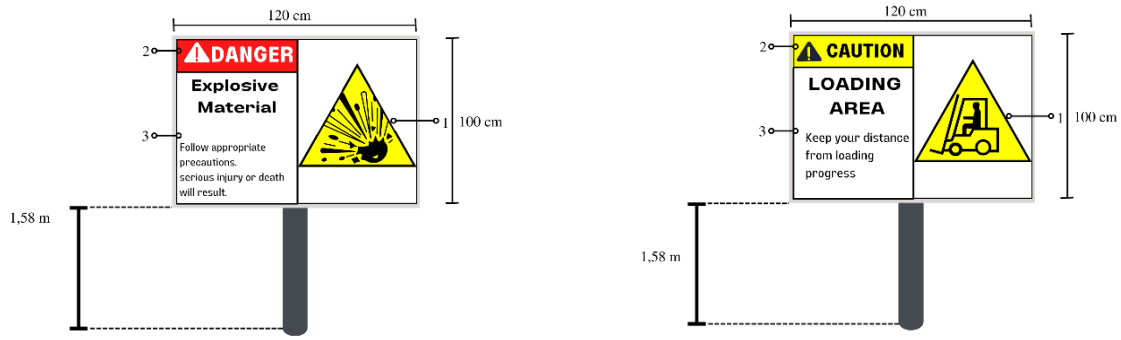
3.2.6 Final Specification

Based on the results of concept scoring before, then we get a concept a design that fits the attributes of the need along with the final specifications of the design of safety signs. The following is the final specification of the selected ergonomic safety signs (Table 18).

Table 18 – Final Specification

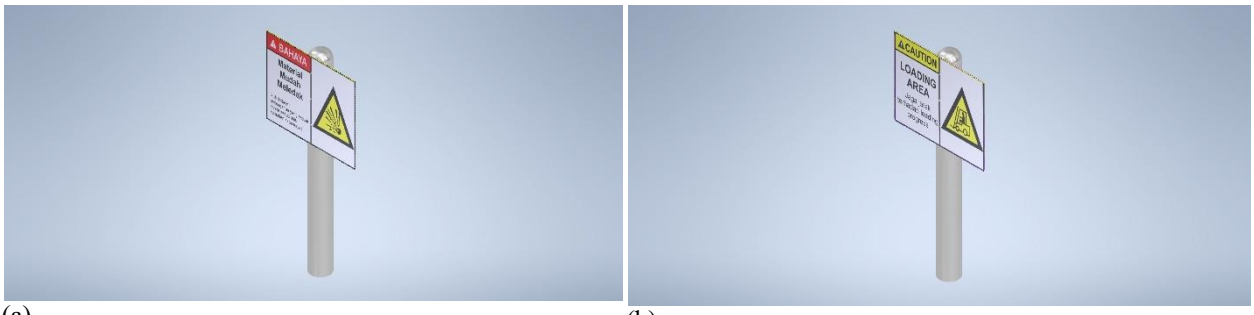
Specification			
Explosive Material		**Loading Progress**	
Location	Outdooor	Location	Outdooor
Number of installs	2	Number of installs	2
Signal Word	Danger	Signal Word	Caution
Background Color	Red	Background Color	Red
Geometric Shape	Hazard Alerting	Geometric Shape	Hazard Alerting
Layout Panel	Three panel signs	Layout Panel	Three panel signs
Height from the ground	158 cm	Height from the ground	158 cm
Letter Height	10,2 cm	Letter Height	10,2 cm
Point Size	400	Point Size	400
Font Style	font sans serif	Font Style	font sans serif
Model	Flat	Model	Flat
Minimum reading distance	30,5 meters	Minimum reading distance	30,5 meters
Language Usage	Indonesian	Language Usage	Indonesian
Sign Length	120 cm	Sign Length	120 cm
Sign Height	100 cm	Sign Height	100 cm
Material	1. Kiwalite 2. Galvanized 3. Aluminum	Material	1. Kiwalite 2. Galvanized 3. Aluminum

The results of the implementation of ergonomic safety signs design specifications are: improvement of the design of the proposed design concept. As for the physical form of enhancement The ergonomic design of safety signs can be seen in Figure 9 and 10.



(a) (b)

Figure 9 – (a) Dimensions of explosive material signs (b) Dimensions of loading progress signs



(a) (b)

Figure 10 – (a) 3D of explosive material signs (b) 3D of loading progress signs

Safety signs are designed with consideration of the minimum safe reading distance of 30.5 m, with that distance the point size and height of the letters have been determined according to the standard, namely 10.2 cm and point size 400 so that it can be ascertained that the safety signs can be read clearly. Safety signs are designed using reflective material, the material is reflecting light very brightly when a light or light shines on it. Reflective materials are also highly recommended for outdoor use, so it can be concluded that safety signs will get good lighting with the aim of being clearly legible and easily recognizing the safety colors. Safety signs are designed with location in mind so that the placement of safety signs is installed facing the entrance to the explosive material area and loading progress so that workers heading to the explosive material area and loading progress will see the K3 signs before doing their respective jobs and have enough time to complete the work. read the word message of the safety signs that have been designed. Placement of safety signs will be installed at 2 different points but in the same area, which has the danger of explosive material and loading progress. The two points are installed at both ends of the road in the area of explosive material and loading progress.

4. CONCLUSION

Requirements in the design of safety signs are that safety signs must be clearly visible, safety signs are well lit, workers in the work area must have sufficient time to read the message conveyed, safety signs are not placed in the same area, safety signs must be visible in all directions, and separate unrelated safety signs. The design of safety signs in determining the design specifications is carried out using a safety sign assessment by considering good criteria data, anthropometric data, layout data and field survey results. From the results of the safe sign assessment, the signal word is obtained, determining the location, height, model and material of the safety signs. The results of the safety signs assessment will be used through the Ergonomic Function Deployment approach. From the results of the Ergonomic Function Deployment, the results obtained are the size of safety signs, safe reading distance, type of layout, use of language and font size on safety signs. There are two types of designs, namely explosive material and loading progress safety signs. The design of safety signs refers to the ANSI Z535 standard so that the design of safety signs has detailed signal words, symbols, signs and word messages.

Disclaimer

The authors whose names are written certify that they have no conflict of interest.

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