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DESIGNING ERGONOMIC CONVEYANCE TOOLS FOR SULFUR MINERS IN THE IJEN CRATER

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ABSTRACT (80-100 words)

Sulfur mine is not an easy job and have a high risk. Lifting heavy equipment with a range of 80 kg-100 kg continuously at a less comfortable position and not ergonomic can cause injuries to the hands, legs, back, and neck. Working in environmental conditions with extreme temperatures can cause distress because of the heat or cold. This condition can cause dizziness, weakness/fatigue, heart rate is not constant, thirst, and fainting (loss of consciousness). Existing conveyance tool that is currently used to mine sulfur in Ijen crater is bamboo basket. The sulfur miner working conditions shows unsafe, unhealthy, ineffective, inefficient and uncomfortable environment. Therefore it is necessary to design conveyance tools that observing the behaviour of sulfur transportation and the needs of miners, material characteristics and the environment. Design conveyance sulfur performed by following the method of Ulrich product development consists of six phases. In addition, to get the design of products that comply with the wishes of consumers, then note also the value of the emphasis in the design of a product that is social, altruistic, functional and esthetif ('SAFE'). The final result is a product that is designed in the form of sulfur conveyance carts, which consists of a main frame, supporting frame, as well as the wheels and braking. Size products are designed with anthropometric miners at the Ijen crater.

Keywords: product development, value, ergonomic, surfur miner, conveyance tool

1. INTRODUCTION

Product design and its influence on buyer behavior have become a significant area of interest for both academics and practitioners in business (Bloch, 1995). In further, Kumar and Noble (2016) says that product design is often the first point of contact between the product and the buyer in retail aisles and search results on the internet. Researchers and managers should understand that product design is important in consumer and buyer behavior, yet they may not clearly and fully grasp the broad values that product design creates for consumers.

Sulfur mine is not an easy job and have a high risk. Lifting heavy equipment with a range of 80 kg-100 kg continuously at a less comfortable position and not ergonomic can cause injuries to the hands, legs, back, and neck. Related to Goetsch (2005), in order to develop and maintain an effective safety and health program, it is necessary to know not only the most common causes of death and injury but also the parts of the body most frequently injured. Typically, the most frequent injuries to specific parts of the body are as follows (from most frequent to least): (1) Back, (2) Legs and fingers, (3) Arms and multiple parts of the body, (4) Trunk, (5) Hands, (6) Eyes, head, and feet, and (7) Neck, toes, and body systems.

Working in environmental conditions with extreme temperatures can cause distress because of the heat or cold. This condition can cause dizziness, weakness/fatigue, heart rate is not constant, thirst, and fainting (loss of consciousness). The dangers of exposure to sulfur compounds to the body is determined by the number of compounds that influence, the length of direct contact, and how the compound entered to the body.

Miners was face a harsh environment, and no guarantee of safety. For the layman, is in the location of the sublimation of sulfur will feel dizzy and nauseous. Sulfur miners take sulfur from the crater floor to the rim of the crater is about 300 meters and along the path on the edge of the caldera down the Valley Paltuding towards the shelter of about 3 kilometers. The lives of the miners welfare sulfur relatively minimal. Raising the price of sulfur to 800 rupiah per kg in 2014 (tribunnews.com) is not much help miners to make ends meet, especially if it has a number of relatively large families. While it needs the higher-filled life. This is contrasts with the costs and health risks that must be borne by the sulfur miners. Extreme external environmental conditions affect the health problems caused by mining activities.

Goetsch (2005) says that the behavioral theory of accident causation and prevention is often referred to as behavior-based safety (BBS). Those who have studied psychology will recognize BBS as an innovative and practical application of standard behavioral theory to the field of occupational safety. These theories are relevant in any situation in which certain types of human behaviors are desired while others are to be avoided. One of seven basic principles off BBS that staes by Geller is identification of external factors that will help understand and improve worker behavior (from the perspective of safety in the workplace).

Figure 1 Sulfur basket as existing sulfur conveyance

Figure 1 shows existing conveyance tool that is currently used to mine sulfur and usage method. Based on the figures show a tough working conditions conducted by unsafe, unhealthy, ineffective, inefficient and uncomfortable. Therefore it is necessary to design tools that observing the behavior of sulfur transportation and the needs of miners, material characteristics and the environment.

2. THEORETICAL BACKGROUND

There are two basic elements in the research work (Wignjosoebroto, 2006) : (1) Thought to work towards achieving efficiency. Produce more systematic work steps circuitry logical sequences, and (2) Thought to consider human behavior as a central element suksesya work effort. Looking factors that influence human behavior in an effort to meet the workers in job satisfaction and needs.

By doing their research, Kumar and Noble (2016) conclude four core themes if design-based value emerged. They are Social, Altruistic, Functional dan Esthetif (hence-forth termed “SAFE”). Social value in a product design is defined as its ability to help consumers increase their perceived status in the community and/or improve their self-esteem. Altruistic value is ascribed to a design when consumers “reflect” on how the design can help others and how they can use it to showcase their self-identity. Functional value in a product's design is defined as the way it helps meet the practical or utilitarian needs of the consumer. This type of value reflects the cognitive assessment of the design elements that serve a purpose at what Norman (2004) describes as the behavioral

level. Esthetic value of the product design is defined as the consumer's perception of attractiveness and pleasure derived from its appearance.

In performing product design and development, Ulrich and Eppinger (2012) finalize the generic product development process as shows by Figure 2. Based on this figure, there are six phases that guidance the researcher to do product development. These six phases are: (1) phase 0: product planning, (2) phase 1: concept development, (3) phase 2: system level design, (4) phase 3: detail design, (5) phase 4: testing and refinement, and (6) phase 5: product launch.

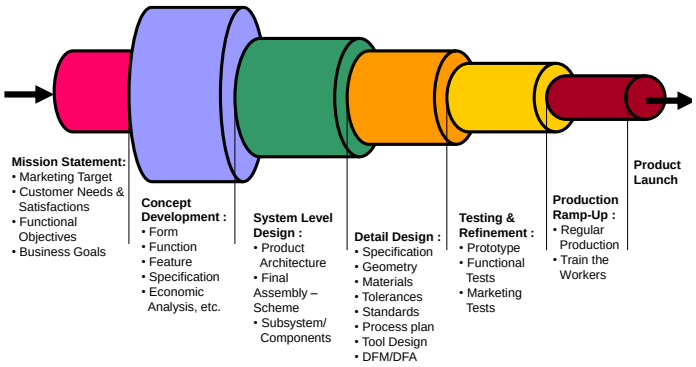


Figure 2 General product design and development (Ulrich, 2000)

Phase 0 – mission statement (planning) is a first stage that must be done. At this stage the mission prepared by considering the needs of consumers, the target market, and the objectives of product and business.

Phase 1 – concept development, the continuation of phase 0. At this stage shows the developing process of initial form, function of the product, specifications and economic analysis.

Phase 2 – system level design, containing activities that related with product architectural design, schematic assembly and identification subsystem/component. Winjoseobroto (2006) stated that anthropometric data will determine the shape, size and exact dimensions associated with products designed and humans that will operate/use the product. In this regard, the design of the product must be able to accommodate the dimensions of the body of the largest populations that will be using the product of the design.

Phase 3 – detailed design, contains more technical activities. Among these activities are the technical specifications, preparation of material, standard setting, determination of tools and machinery as well as DFA and DFM (Design for Assembly and Design for Manufacturing).

Phase 4 – testing and refinement. In this stage consists of various testing processes, such as testing the functionality and market testing which is preceded by the manufacture of prototype products. Function testing conducted to determine whether the function is designed on the product can be raised in accordance with the plan. While the market testing aims to determine the market response to new product launches.

Phase 5 – production ramp-up, the phase of regular production and training on labor which will make the product. After it entered the final stage, namely the launch of the product.

In the process of designing ergonomic product should consider work method and posture that related with energy cost of work (Sanders and McCormick, 1993). The energy cost for certain types of work, however, can vary with the manner in which the work is carried out. The differential costs of various methods of performing an activity are ilustrated by several method of carrying a load (double pack, head, rucksock, sherpa, rice bag, yoke, hands). The posture of workers while performing some tasks is another factor that can influence energy requirements. The energy cost of four work posture (bending : arm supported by thigh, bending : no arm support, kneeling : hand supported by floor, kneeling : no hand support, and squatting) shows different result in measurement.

Kroemer, et all (2001) stated that equipment at the workplace either may assist the material handler or may do the actual transportation. Equipment for assitance includes : (1) Lift tables, hoist, and cranes, (2) Ball transfer tables and turntables, and (3) Loading and

unloadig devices. Transportation equipment includes : (1) Nonpowered dollies, walkies, and trucks, (2) Powered dollies ('walkies') rider trucks, and tractors, (3) Conveyors and trolleys, and (4) Overhead and mobile cranes. Cart is one kind of nonpowered dollies that can take over the requirements of holding, carrying, pushing, pulling, lowering, and lifting of materials that would otherwise performed manually by a person.

3. RESEARCH METHOD

This research was following Ulrich and Epinger (2012) generic product development processes and also considering Kumar and Noble (2016) regarding value emerged in product design. Hence the detail research methodology that uses to designing sulfur conveyance tools.

Phase 0
In phase 0 conducted a field study to examine the current state of mining sulfur in the Ijen crater. Ethnographic studies conducted to understand the behavior and habits of miners at work. In this phase identified the desired value in the product are:

1. Social: conveyance easily during use
2. Altruistic: the design of conveyance tools that use less energy
3. Functional: the shape and size of the effective and efficient
4. Esthetif: Attractive design and durable material

Phase 1
In the phase 1 study design concept is based on an ethnographic study in Phase 0. Results from Phase 1 shows that the variables that must be considered in the conveyance tools to be designed is the shape, braking systems, capacity, price and size.

Phase 2
Phase 2 produces ergonomic design of conveyance tools and meet the important aspects of product value.

Phase 3
In the third phase is designing detail to produce design ergonomic conveyance tools. The measures used in the design of attention anthropometric sulfur miners working in the Ijen crater.

Phase 4
In phase 4 is producing conveyance tools that have been designed as a prototype. Further trials conducted directly on sulfur miners at the Ijen crater.

Phase 5
The product launch is done with the delivery of finished products to the sulfur miners at the Ijen crater.

4. RESULT AND DISCUSSION

Phase 0
Based on field studies that have been done, there are three main conditions that the spotlight for designing the conveyance of sulfur, namely:

1. Areas where the mine has a fairly steep road.
2. Conditions in the mines have erratic weather, sometimes dry, sometimes rainy.
3. The existence of a mountain of smoke that can harm the respiratory system sulfur miners at work.

Ethnographic studies conducted during one week of the mining of sulfur in the Ijen crater to get the voice of consumer. The activities are observation and interviews with miners. The results of an ethnographic study showed that the important thing of concern are:

1. Working method: conveying sulfur by using bamboo basket
2. The form of conveyance: in the form of a basket so it is entirely to be lifted
3. Volume of transport: not being able to carry a lot
4. Physical complaints: the shoulders, arms, and back

Phase 1
Concept development is done to obtain the conveyance tools to be made. Having regard to the results of the Phase 0 both field studies and ethnographic studies, the products produced in the form of carts which consists of main frame, supporting frame, as well as the wheels and braking.

Phase 2
The design of system-level bill of material producing structures of sulfur carts. Figure 3 shows the bill of material from level 0 to level 3. Level 0 main products, namely sulfur cart. Then level 1 is the main constituent of the product, namely 1 Main Frame, 2 Frame Support and 3 Wheels and Braking. While level 2 and level 3 is the components that make up the existing level on it. The main constituent material is stainless steel diameter of 1.5 "and 1.25", nuts and bolts, wheels, cables and brake. The advantages of a sulfur cart is appropriate braking system to track cheating with weights up to 120 kg.

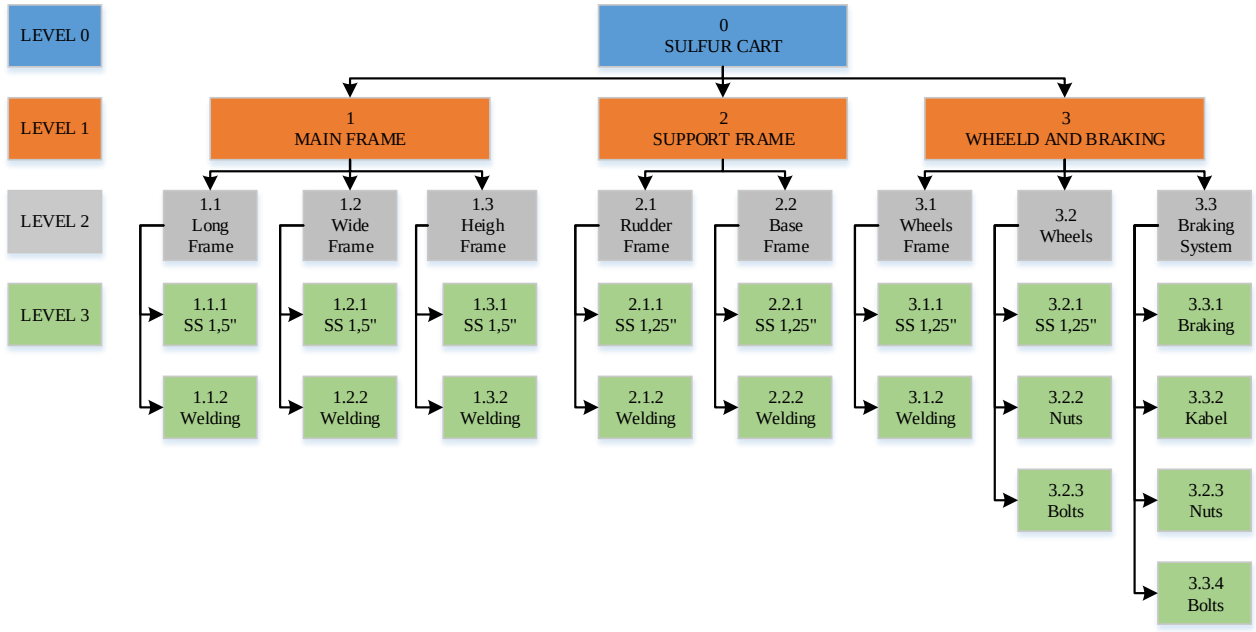
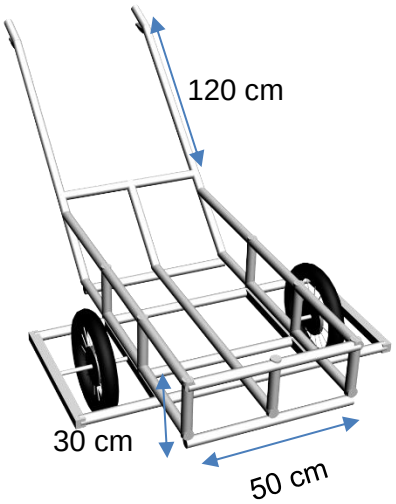


Figure 3 Bill of material sulfur chart

Phase 3
At this stage, has generated depiction of the final design of the carts used sulfur along with their sizes. Figure 4 shows several pictures of carts sulfur.



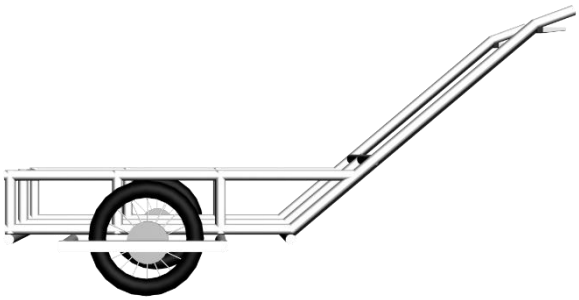


Figure 4 Sulfur cart design

Phase 4
Created two prototypes of products cart sulfur. Tests performed on the 30 miners. Figure 5 shows the process of use/testing by sulfur miners in various positions, carrying two baskets of sulfur and down the road in the Ijen crater.

Figure 5 Prototype testing process

Testimonials from users shows that the new product has the advantage of being able to answer the needs of sulfur miners. The advantages are:

1. Ergonomic design to customize the user anthropometry.
2. The size of the cart that can accommodate 120-150 kg of sulfur.
3. Matic braking system that provides convenience and safety during use.
4. Product weight less than 20 kg is lighter than the existing conveyances.

Phase 5
The final stage is the launch of the product. Before the launch, the product repaired in accordance with the results of prototype testing.

5. CONCLUSION

Design conveyance sulfur performed by following the method of Ulrich product development consists of six phases. In addition, to get the design of products that comply with the wishes of consumers, then note also the value of the emphasis in the design of a product that is social, altruistic, functional and esthetif ('SAFE').

Based on ethnographic study, which is made by the miners are working methods, forms of conveyance, transport volume, and physical complaints during use. Then the resulting product design in its design upon the form, braking systems, capacity, price and size.

The final result is a product that is designed in the form of sulfur conveyance carts, which consists of a main frame, supporting frame, as well as the wheels and braking. Size products are designed with anthropometric miners at the Ijen crater.

Based on prototype testing of sulfur cart, indicates that the resulting product design has been able to answer the needs of conveyance tools that effective, convenient, safe, healthy and efficient. The next improvement is to improve the draft order for the handle to make it more comfortable and safe when used.

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