Design for Human Safety and Health in Manufacturing System

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Abstract. The purpose of this research is to make a tool designed to assist workers in carrying out production activities and prevent work accidents caused by machinery. The method used in this study is the Ulrich method. Ulrich method that used in this research is to explain the steps in designing a product. The results obtained in this study are 12 concepts available. These concepts must be evaluated and filtered very carefully to get maximum results. The Pugh method is used to assist in the process of evaluation and screening of concepts so that the 3 selected concepts will be developed. Concept evaluation for the three selected concepts must be done by comparing the rank and weight value of each concept to make it easier to use formulas so that it can help in the assessment process. One concept chosen will be used to design the product. The conclusion is in designing a product, several phases must be passed so that the results obtained will be satisfying and in accordance with the references used. The benefit that will be felt with this tool is that workers can avoid work accidents and work becomes easier to improve the production process.

1. Introduction
Design for human safety and health in manufacturing systems is a design tool that will be used by workers in assisting activities on the production floor. This tool is made by following the steps found in a reference book, Ulrich Eppinger and several national and international journals that explain product design and explain health and safety. In addition, there is a quote from PERMENAKER No. 5 of 1996, which explains the function of occupational health and safety (K3) [1].

Design is a process of interrelated decisions whose aim is to define a proper configuration and efficient management strategies for a production system which assembles components into a final product. Several are the dimensions to consider in design [2]. Choosing the right design concept at the conceptual design stage in the product development process is an important decision [3]. This technology has met the needs of the industry today because of its shorter design and improved design quality [4]. Manufacturers are encouraged to produce products quickly with high quality and low cost so they can compete in the global market [5]. One area of business that often uses social media as a promotional site and offers its products is the fashion business. [6] To achieve sustainable product design, it is very important to use sustainability assessments during the product design process [7]. In the study of Rafiq M. Choudhry et al, it said in his journal reviewing the relevant literature on 'design for safety' in general, with particular emphasis on construction. It is ensured that the designer must have the responsibility to handle occupational health and safety for construction workers and building users and there is significant value for the improvement of studies and design practices for safety in the construction industry [8]. The research of Mandal A and Ganguly S said the results of their research using Flexicurve Ruler in Agricultural and Corporate Professional workers showed complaints of shoulder and waist pain that showed a risk of dysfunction in the shoulder, pelvic girdle and spine. By utilizing this information, therapeutic and ergonomic interventions can be applied and the application of
modern sophisticated machines to improve postural conditions can reduce their stress and work disability [9].

Previous research that has advantages and disadvantages makes this research more focused on designing a product, with the aim of creating a tool designed with the Ulrich method that illustrates the steps of product design making this research successful in creating a product that can be used by workers to improve work safety and the production process. The tool helps workers push the cassava into the iris machine only by pushing the lever and it will avoid the work habits that are bent.

2. Method
Research activities are carried out in the cassava chip manufacturing industry that produces cassava chips and banana chips located in the village of Cicadas, Subang Regency, which counts for about 2 months from May to June. The data obtained is the data from the open questionnaire and customer statement that distributed to all employees who work there. The data is processed and then the results are obtained to design a product that is a work tool on the production floor. Designing a tool requires a method so that the desired product becomes appropriate, and the method used is the product design and development book written by Karl T. Ulrich and Steven D. Eppinger.

Designing a product there are several stages that must be passed from starting with the mission statement, there are steps to identify customer needs, set target specifications, design product concepts, choose product concepts, test product concepts, set final specifications, plan development paths to the development plan. All of that can be called a concept development process [10]. The following is an illustration of the product design flowchart in figure 1.

![Figure 1. Concept development process](image)

3. Results and Discussion
Begin with processing occupational health and safety questionnaire data relating to product design results from respondent workers who have been classified and according to the level of need. Then proceed to the concept development phase which is mandatory for designing a product, then obtained a mission statement that is to make cassava-booster products that have been obtained from the identification of customer needs and the degree of importance of customer needs. The next step is to determine the target specification list, which is a technical description of the needs to be realized, a comprehensive list of target specifications is made and a set of metrics for the criteria and target specifications are determined [10].

The next step enters conceptualization, which consists of the process of clarifying the problem described in a black box, determining the solution classification tree and the solution combination table. In the combination table, there are 3 subproblems, namely design framework with iron, wood and plastic plate solutions. Energy thrust with iron and hydraulic solutions, and energy transformation with iron solutions hollow and bearing [10,11]. The combination table can be seen in table 1.

| Table 1. Combined table concept |
|----------------------------------|
| **Design Framework Design** | **Push Energy** | **Energy Transformation** |
| Iron plate | Per iron | Iron Hollow |
| Wood | | |

![Table 1](image)
At the drafting stage, the concept has 12 available concepts, then evaluating and filtering out concepts from 12 concepts using the method of Pugh to assess the best concepts. Concept screening is done with several selection criteria prepared and compared with 12 concepts to be developed, after which the values are added +, -, 0, final grade, ranking and proceed. [10] can be seen in Table 2.

**Table 2. Screening of Concepts**

| Selection Criteria       | Concept 1 (Reference) | Concept 2 | Concept 3 | Concept 4 | Concept 5 | Concept 6 | Concept 7 | Concept 8 | Concept 9 | Concept 10 | Concept 11 | Concept 12 |
|--------------------------|-----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Safe when operated       | 0                     | 0         | 0         | 0         | 0         | 0         | 0         | 0         | -         | -         | -         | -         |
| Easy to operate          | 0                     | +         | +         | +         | 0         | 0         | +         | +         | -         | 0         | +         | +         |
| Easy to repair           | 0                     | 0         | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
| Strong tools             | 0                     | 0         | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
| Attractive tools         | 0                     | 0         | +         | +         | +         | 0         | 0         | 0         | 0         | 0         | 0         | 0         |
| Ergonomic tools          | 0                     | +         | +         | +         | 0         | 0         | 0         | 0         | 0         | 0         | 0         | 0         |
| Convenience when made    | 0                     | 0         | +         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
| Ease of assembling       | 0                     | -         | +         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
| Ease of care             | 0                     | +         | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
| Amount (+)               | 0                     | 3         | 5         | 3         | 0         | 0         | 2         | 2         | 0         | 0         | 0         | 1         | 1         |
| Amount 0                 | 9                     | 5         | 0         | 1         | 3         | 3         | 2         | 4         | 1         | 2         | 1         | 1         |
| Amount (-)               | 0                     | 1         | 4         | 6         | 6         | 6         | 5         | 3         | 8         | 7         | 7         | 7         |
| Final Value              | 0                     | 2         | 1         | -3        | -6        | -6        | -3        | -1        | -8        | 7         | -6        | -6        |
| Ranking                  | 2                     | 1         | 2         | 4         | 6         | 7         | 5         | 3         | 11        | 10        | 8         | 9         |
| Continue?                | Yes                   | Yes       | Yes       | No        | No        | No        | No        | No        | No        | No        | No        | No        |

The results of the concept evaluation and concept screening produced 3 concepts which will be continued to the last step, namely the concept evaluation. The chosen concept is concept 1, which used as a reference or comparison, concept 2 and concept 3. In the assessment of the concept, there is several selection criteria, the value weights will be used for the 3 concepts multiplied by the rating value so that there is a weight value. Then there are the total values, rank and proceed? [10], can be seen in Table 3

**Table 3. Concept Evaluation**

| Criteria Selection       | Weight | Concept 1 (Reference) | Concept 2 | Concept 3 |
|--------------------------|--------|-----------------------|-----------|-----------|
|                          |        | Rating | Value Weight | Rating | Value Weight | Rating | Value Weight |
| Safe when operated       | 20%    | 3      | 0.6         | 3      | 0.6         | 3      | 0.6         |
| Easy to operate          | 5%     | 3      | 0.15        | 4      | 0.2         | 3      | 0.15        |
| Easy to repair           | 10%    | 3      | 0.3         | 3      | 0.3         | 2      | 0.2         |
| Strong tools             | 10%    | 3      | 0.3         | 3      | 0.3         | 2      | 0.2         |
| Interesting tools        | 15%    | 3      | 0.45        | 3      | 0.45        | 4      | 0.6         |
| Ergonomic aids           | 10%    | 3      | 0.3         | 3      | 0.3         | 3      | 0.3         |
| Ease when made           | 10%    | 3      | 0.3         | 3      | 0.3         | 3      | 0.3         |
Criteria Selection

| Criteria Selection     | Weight | Concept 1 (Reference) | Concept 2 | Concept 3 |
|------------------------|--------|------------------------|-----------|-----------|
|                        |        | Rating Value Weight    | Rating Value Weight | Rating Value Weight |
| Ease of assembling     | 10%    | 3 0.3                  | 3 0.3     | 3 0.3     |
| Ease of maintenance    | 10%    | 3 0.3                  | 3 0.3     | 2 0.2     |
| Total value            |        | 3                      | 3.05      | 2.85      |
| Ranking                |        | 2                      | 1         | 3         |

Continue? No Yes No

Concept evaluation results in one concept selected from 3 concepts that have been selected, and the concept is concept 2 with a total value of 3.05. The figure below is a selected figure from concept 2. The concept 2 combination table combines the design framework with the iron plate solution, combined with the thrust energy with per iron solution and the energy transformation with the solution bearing [10], can be seen in table 4.

| Design Framework Design | Push Energy | Energi Transformation |
|-------------------------|-------------|-----------------------|
| Iron plate              | Per iron    | Iron Hollow           |
| Wood                    |             |                       |
| Plastic                 | Hydraulic   | Bearing               |

Concept 2 has a solution in frame design using an iron plate with a length of 90 cm. The energy thrust solution used is per iron with a length of 10 cm, and for energy transformation. The solution used is a bearing with a diameter of 1.2 cm. Product design can be seen in Figure 2. This product also has a quality value that is a consideration for the manufacture of products using lean six sigma [12].

Figure 2. Selected Concept Design

4. Conclusion
The conclusion of this research is the achievement of the initial objective of this study is to propose an increase in occupational health and safety. One of the supporting factors of occupational health and safety is security in design material handling systems, machinery and equipment movement. This is achieved with the proposed cassava booster product, which can be used by workers. The process begins with the selection of 12 concepts given. After it is filtered up to 3 best concepts selected, concept 1 is used as a reference, concept 2, and concept 3 then the narrowing concept is assessed to determine the
best concept to be made and the second concept is selected consisting of an iron frame plus iron per thrust and combined with bearings as impulse transportation.

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