Design of Wood Pellets Carrier using Ergonomic Function Deployment (EFD) Approach to Increase Productivity of Work: A Research at PTPN VIII Ciater

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Abstract. This study aims to design a wood pellets carrier using Ergonomic Function Deployment (EFD) approach to improve productivity of work. This research was conducted at PT. Perkebunan Nusantara VIII, Ciater. There is a manual transport activity of wood pellets where to carry 30 tons of wood pellets is done by 5 workers each of which must carry a maximum of 60 kg of wood pellets. In the process of designing the trolley, knowing the worker complaints using NORDIC Body Map questionnaire and then analysed the value of the existing work posture. In addition, the making of needs statement for the EFD approach is based on the ergonomics concept is ESHCE (Effective, Safe, Healthy, Comfortable and Efficient) and another product design stage to generate an ergonomic trolley design. After generated the ergonomic trolley design then carried out analysis of push pull and productivity. By comparing the existing productivity and proposal productivity, it can be said that this wooden pellet transport trolley can increase work productivity in the drying work station.

Keywords: wood pellets carrier, Ergonomic Function Deployment, Ergonomic trolley design

1. Introduction

Indonesia is a tropical country and also an agrarian country that has a fertile soil structure that makes it possible to be utilized as agricultural land or plantation. One of the important plantation commodities for Indonesia today is the tea commodity. Tea plantations become a leading business sector that can absorb a lot of workforce. PT. Perkebunan Nusantara VIII which is one of the State-Owned Enterprises in the agricultural sector where the company produces various types of plantation products in Indonesia and among them are plantation and tea leaf production. Tea produced one of them is Orthodox tea. The stages of making black tea are as follows:
**Figure 1.** The Stages of Making Black Tea at PTPN VII Ciater

In the drying process, a drying machine with a temperature of 100°C - 120°C which is fueled by wood pellets is required. The wood pellets are imported from the supplier and then brought into the room where the drying process takes place. In the existing process, the wood pellets are removed by manual transport by the five workers. In the process of transportation, workers must carry two bags of wood pellets weighing 30 kg / sack with a distance of five meters. Frequency of transport into the drying work station is approximately 100 times back and forth within a maximum of three hours.

**Figure 2.** Documentation of workers during the wood pellets transporting activities

To find out the complaints of the workers while transporting is to make observations, interview directly with workers and by distributing questionnaires NORDIC Body Map to the workers concerned. After knowing the complaints from workers, then the next step is to assess the work attitude. Appropriate approaches to performing a work attitude assessment are the Posture Evaluation Index (PEI) derived from integration of Lower Back Analysis (LBA), Ovako Working Posture Analysis System (OWAS) and Rapid Upper Limb Assessment (RULA).

![Image](image1.png)

**Table 1. Recapitulation of PEI Score of Workers**

| LBA Score Safety Limit (N) | LBA Score (N) | OWAS Score Safety Limit | OWAS Score | RULA Score Safety Limit | RULA Score | PEI Score Safety Limit | PEI Score |
|----------------------------|---------------|-------------------------|------------|-------------------------|-----------|-------------------------|-----------|
| ≤ 3.400                    | 5971          | ≤ 2                     | 2          | ≤ 4                     | 7         | ≤ 2                     | 3.68      |

According to the above exposure, the problem is not very supportive to the aspect of ergonomics. It strongly opposes the concept of ergonomics that has the concept to create an EASNE work system (effective, safe, convenient, healthy and efficient). Therefore, it is necessary to design the Material Handling Equipment (MHE) which resembles the trolley so that later can be used to reduce the workload of the operator and also can increase work productivity by using Ergonomic Function Deployment (EFD) approach. So that the needs of operators can be met and can increase work productivity in drying stations especially for the process of transporting wood pellets.
2. Methods

2.1. Productivity
Productivity in general is the ratio between the inputs used with the output produced. One of the steps taken by a company in order to improve its productivity is by making improvements of tools (technology) or by increasing human resources. The formula of productivity is as follows:

\[
\text{Productivity} = \frac{\text{Effectiveness}}{\text{Efficiency}}
\]  

(1)

2.2. Ergonomic
Ergonomics is a science that studies and examines the limitations and advantages of humans, then the information obtained will be used to design products, machinery, facilities, environment and work system. The main objective of an ergonomic application is the application of good aspects of health, safety, and working comfort to achieve good quality of work. At a higher level of ergonomics aims to create optimal working conditions. Ergonomics and K3 (Occupational Safety and Health) are two things that can not be separated because they have the same goal that is in improving the quality of work [1].

2.3. Ergonomic Function Deployment (EFD)
Ergonomic Function Deployment (EFD) is a development of Quality Function Deployment (QFD) by adding new aspect that is by adding new relationship between consumer desire and ergonomic aspect of product [2][3]. The relationship is made with the House of Quality (HOQ) format but since this method is in the ergonomic domain, it is called House of Ergonomic (HoE). The description of the HoE is as follows [4].

![Figure 3. House of Ergonomic (HOE)](image)

2.4. Conceptual Model
This research designs a trolley that will be used to transport wood pellets using EFD approach. To design the trolley, the first thing to do is to identify the activity of transporting the existing wood pellets and to identify what the complaints are often experienced by the workers by looking at scores produced by LBA, OWAS and RULA [6]. In this EFD approach, the formation of needs statement is based on the concept of ergonomics is ESHCE (Effective, Safe, Healthy, Comfortable and Efficient). After that will be analyzed in terms of ergonomic and after emerging an MHE design or trolley design, will be analyzed whether the trolley can increase productivity and how many forces are required to
push the trolley by using push pull analysis. The results of the trolley design will then be made technical drawings to know the dimensions in each part.

| Input | Process | Output |
|-------|---------|--------|
| The activity of transporting wood pellets (Time, distance, dimension of sack, mass of sack, and transport frequency) | Ergonomic Analysis | Detail Drawing |
| The risk of MSDs in workers | Anthropometry | |
| Anthropometry (Employee Data) | Ergonomic Analysis | |
| RULA | MHE design | |
| LBA | Productivity | |
| OWAS | Push and Pull Analysis | |
| | Product Architecture | |

**Figure 4.** Conceptual Model of Research

3. Result and Discussion

3.1 Identifying Needs Statement

In the stage of identifying needs statement will be done by using statement needs statement which is determined from EFD variable that is EASNE. So get the results recapitulation needs statement as follows.

| No. | Needs Statement |
|-----|-----------------|
| 1   | The product has a maximum carrying capacity. |
| 2   | The product is safe when in use. |
| 3   | Products can reduce the workload of workers and reduce the risk of work accident. |
| 4   | The product has a comfortable size when in use. |
| 5   | The product has an ergonomic design. |
| 6   | Products can be raise and lower. |
| 7   | Products can minimize the power released by the user. |
| 8   | The product can minimize the number of required operators. |
| 9   | The product has tools. |
3.2 Create the HoE

HoE is a method used to find information that contains product identification as a consideration in developing a product. HoE consists of the relationship between the needs statement and the needs matrix and the relationship between the needs matrix. After establishing the HoE and determining other aspects required in the EFD is determining the final specification that will be used to make the wooden pellet transport trolleys design. The final specification in this study is as follows.

| No. | Needs Matrix                | Part Specification | Target Value | Unit |
|-----|-----------------------------|--------------------|--------------|------|
| 1   | Maximum weight of trolley   | Maximum weight of trolley | 360          | kg   |
| 2   | Product material standard   | Product material standard | -            | List |
| 3   | Trolley locking system      | Wheels locking system | Yes          | Binary |
|     | Trolley frame locking system |                    | Yes          | Binary |
| 4   | Transport time              | Transport time     | 180          | Sec  |
| 5   | High of trolley             | High of paltform   | 15           | cm   |
|     |                             | High of frame      | 93           | cm   |
|     |                             | High of handle     | 5            | cm   |
|     |                             | Diameter of wheels | 15           | cm   |
| 6   | Width of trolley            | Width of platform  | 110          | cm   |
|     |                             | Width of frame     | 110          | cm   |
|     |                             | Length of handle   | 80           | cm   |
| 7   | Length of trolley           | Length of platform | 138          | cm   |
|     |                             | Length of frame    | 138          | cm   |
|     |                             | Width of handle    | 15           | cm   |
| 8   | Diameter of handle          | Diameter of handle | 5            | cm   |
| 9   | Product design adjusts the  | Product design adjusts the | -            | List |
|     | dimensions of the worker    | dimensions of the worker |
| 10  | Hydraulic system            | Hydraulic system   | Yes          | Binary |
| 11  | Number of operators         | Number of operators | 1            | Person |
| 12  | High of tool                | High of aids       | 220          | cm   |
| 13  | Width of tool               | Width of tool      | 11.5         | cm   |
| 14  | Length of tool              | Length of tool     | 84           | cm   |

After obtaining the desired final specification, then made a wooden pellet transport trolleys design. The following is the result of the wooden pellet transport cart design.
As mentioned earlier that the wooden pellet sacks coming from the supplier in once arrived at PT. Perkebunan Nusantara VIII, Ciater brings 20 - 30 tons or a maximum of 1000 bags of wood pellets. The transportation activity of this sack of wood pellets is carried out by 5 (five) operators with the load to carry each operator is a maximum of 6000 kg with the frequency of transporting as much as 100 times back and forth. The total time required for manual handling activities from truck to sack in a drying work station is 3 hours. With the design of this wooden pellet transport trolley is expected to increase productivity at the drying station. This trolley can accommodate a maximum of 360 kg or 12 bags of wood pellets so that the frequency of transport approximately 83 times back and forth. So the total time it takes the workers to transport the wooden pellet sacks is 2 hours 49 minutes.

To find out how many forces are required by the worker to push the carrier's carrier cart. In doing the calculation of push pull analysis can be done by using 2 (two) ways that is with Table Snook and Ciriello and also with analysis of MHL in software Jack 8.2. Below is the result of push pull analysis using Snook and Ciriello Table.

![Figure 6. The Result of Push Analysis [1]](image-url)
So, obtained the value of initial push force limit of 40 kg and sustained push force limit of 26 kg. Then for the initial pull force limit of 35 kg and sustained pull force limit of 25 kg.

4. Conclusion

Based on the results of data processing and analysis, then obtained some conclusions that can solve the problems in this study. Here is the conclusion that has been obtained.

1. The product of wooden pellet carrier trolleys is able to meet the objectives of the research that can design a product that can improve work productivity by applying the concept of ergonomics (ESHCE) in the process of designing.

2. In designing the wooden pellet transport trolley, the material which will be applied to the product is Alluminium Alloy for platform, frame, wheel and hydraulic while Stainless Steels for handle and ladder.

3. Based on the calculation of push pull analysis found that to operate the trolley requires power to push for 40 N and power to attract 35 N.

5. References

[1] Yassierli et al. 2007 The influence of age on isometric endurance and fatigue is muscle dependent: A study of shoulder abduction and torso extension. Ergonomics. 50(1) pp 26–45 doi: 10.1080/00140130600967323.

[2] Ulrich K T and Eppinger S D 2012 Product Design and Development. 5th Ed. (New York: McGraw-Hill)

[3] Surya R Z and Badruddin R 2015 Aplikasi Ergonomic Function Deployment (Efd) Pada Redesign Alat Parut Kelapa Untuk Ibu Rumah Tangga. Jurnal Ilmiah dan Penerapan Keteknikan Pertanian 8(1) https://doi.org/10.17969/rtv8i1.2687.

[4] Adrianto R, Desrianty A and M F H 2014 Usulan Rancangan Tas Sepeda Trial Menggunakan Metode Ergonomic Function Deployment (EFD). 02(02) pp 353–63

[5] Snook S and Ciriello V M 2002 Liberty Mutual Tables for Lifting, Carrying, Pushing and Pulling
also known as the Snook Tables. *Ergonomics* 34 pp 1197–213

[6] Bintang A N and Dewi S K 2017 Analisa Postur Kerja Menggunakan Metode OWAS dan RULA. *Jurnal Teknik Industri* 18(01) pp 43-54. https://doi.org/10.22219/TTU.M.Vol18.No1.43-54