PAPER • **OPEN ACCESS**

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

To cite this article: W R Pradani *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **528** 012011

IOP Conf. Series: Materials Science and Engineering **528** (2019) 012011 doi:10.1088/1757-899X/528/1/012011

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

W R Pradani[1], M Rahayu[2], S Martini[3] and M I Kurniawan[4]

Telkom University, Bandung, Indonesia
[1]windipradani@gmail.com, [2]mira.rahayu82@gmail.com, [3]srimartini59m@gmail.com, [1]Iccank.4596@gmail.com

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:

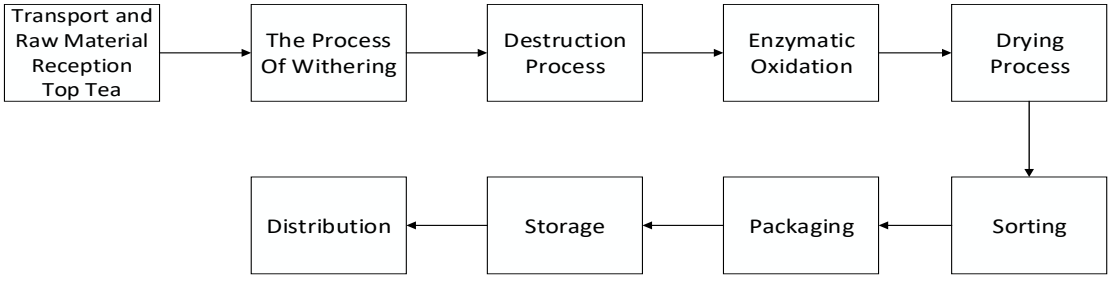

Figure 1. The Stages of Making Black Tea at PTPN VIII Ciater

In the drying process, a drying machine with a temperature of 100ºC - 120ºC 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).

Table 1. Recapitulation of PEI Score of Workers

LBA Safety Limit (N)	LBA Score (N)	OWAS Safety Limit	OWAS Score	RULA Safety Limit	RULA Score	PEI 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:

$$\text{Productivity} = \frac{\text{Effectiveness}}{\text{Efficiency}} \quad (1)$$

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].

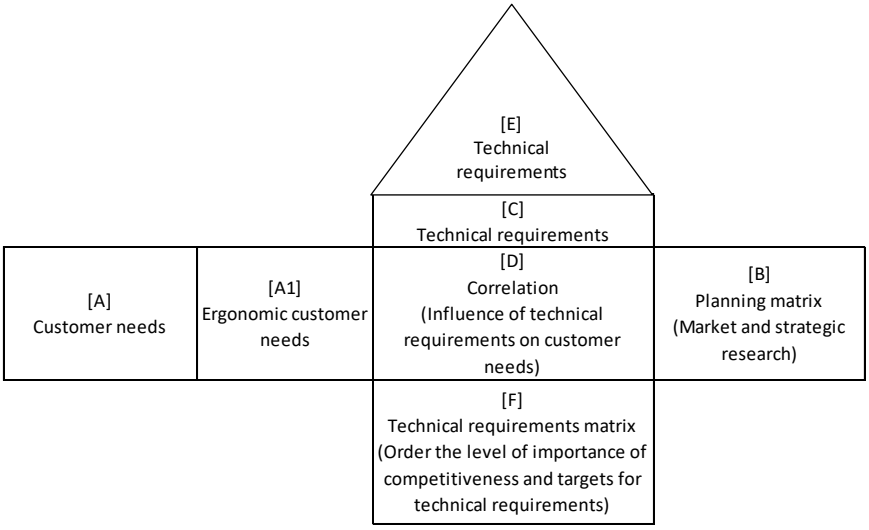

Figure 3. House of Ergonomic (HOE)

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.

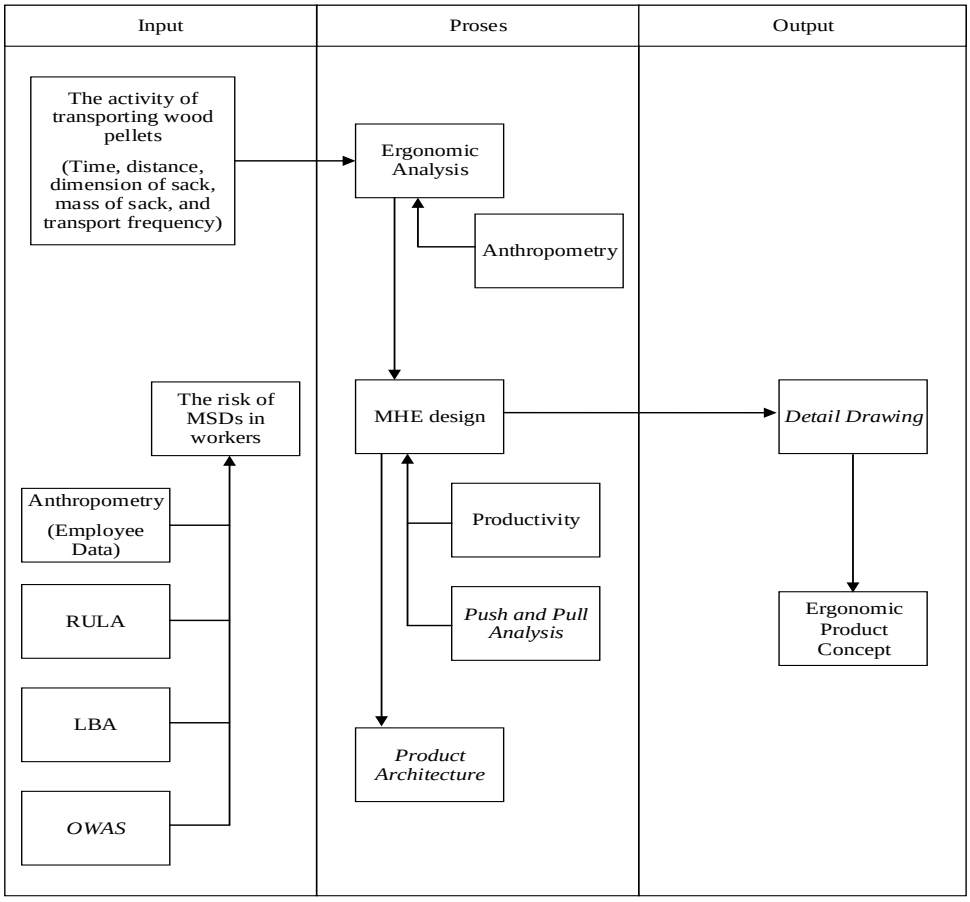

Figure 4. Conceptual Model of Research

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.

Table 2. Recapitulation Needs Statement

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.

Table 3. Final Specification of Trolley

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 desgin adjusts the dimensions of the worker	Product desgin adjusts the dimensions of the worker	-	List
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.

Figure 5. The Design of Wooden Pellet Transport Carrier

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.

Height	Percent	2.1 m push One push every 6 s	12 s	1 min	2 min	5 min	30 min	8 hr	7.6 m push One push every 15 s	22 s	1 min	2 min	5 min	30 min	8 hr	15.2 m push One push every 25 s	35 s	1 min	2 min	5 min	30 min	8 hr	30.5 m push One push every 1 min	2 min	5 min	30 min	8 hr	45.7 m push One push every 1 min	2 min	5 min	30 min	8 hr	61.0 m push One push every 2 min	5 min	30 min	8 hr
Initial forces																																			
	90	20	22	25	25	26	26	31	14	16	21	21	22	22	26	16	18	19	19	20	21	25	15	16	19	19	24	13	14	16	16	20	12	14	14	18
	75	26	29	32	32	34	34	41	18	20	27	27	28	28	34	21	23	25	25	26	27	32	19	21	25	25	31	16	18	21	21	26	16	18	18	23
144	50	32	36	40	40	42	42	51	23	25	33	33	35	35	42	26	29	31	31	33	33	40	24	27	31	31	38	20	23	26	26	33	20	22	22	28
	25	38	43	47	47	50	51	61	27	31	40	40	42	42	51	31	35	37	37	40	40	48	28	32	37	37	46	24	27	32	32	39	23	27	27	34
	10	44	49	55	55	58	58	70	31	35	46	46	48	49	58	36	40	43	43	45	46	55	32	37	42	42	53	28	31	36	36	48	27	31	31	39
	90	21	24	26	26	28	28	34	16	18	23	23	25	25	30	18	21	22	22	23	24	28	17	19	22	22	27	14	16	19	19	23	14	16	16	20
	75	28	31	34	34	36	36	44	21	23	30	30	32	32	39	24	27	28	28	30	30	36	21	24	28	28	35	18	21	24	24	30	18	21	20	26
96	50	34	38	43	43	45	45	54	26	29	38	38	40	40	48	29	33	35	35	37	38	45	27	30	35	35	44	23	26	30	30	37	22	26	26	32
	25	41	46	51	51	54	55	65	31	35	45	45	48	48	58	35	40	42	42	45	45	54	32	36	42	42	52	27	31	36	36	45	27	31	31	38
	10	47	53	59	59	62	63	75	35	40	52	52	55	56	66	40	46	49	49	52	52	62	37	41	48	48	60	32	36	41	41	52	31	35	35	44
	90	19	22	24	24	25	26	31	13	14	20	20	21	21	26	15	17	19	19	20	20	24	14	16	19	19	23	12	14	16	16	20	12	14	14	17
	75	25	28	31	31	33	33	40	16	19	26	26	27	28	33	19	21	24	24	26	26	31	18	21	24	24	30	16	18	21	21	26	15	18	18	22
64	50	31	35	39	39	41	41	50	20	23	32	32	34	35	41	23	27	30	30	32	33	39	23	26	30	30	37	20	22	26	26	32	19	22	22	28
	25	38	42	46	46	49	50	59	25	28	39	39	41	41	50	28	32	36	36	39	39	47	28	31	36	36	45	24	27	31	31	39	23	26	26	33
	10	43	48	53	53	57	57	68	28	32	45	45	47	48	57	32	37	42	42	44	45	54	32	36	41	41	52	27	31	36	36	44	26	30	30	38
Sustained forces																																			
	90	10	13	15	16	18	18	22	***8***	9	13	13	15	16	18	***8***	9	11	12	13	14	16	***8***	10	12	13	16	***7***	8	10	11	13	7	8	9	11
	75	***13***	17	21	22	24	25	30	***10***	***13***	17	18	20	21	25	***11***	***13***	15	16	18	18	22	***11***	13	16	18	21	***10***	***11***	13	15	18	***9***	11	13	15
144	50	***17***	22	27	28	31	32	38	***13***	***16***	22	23	26	27	32	***14***	***17***	***20***	20	23	24	28	***15***	***17***	20	23	28	***12***	***14***	17	19	23	***12***	14	16	19
	25	***21***	***27***	33	34	38	40	47	***16***	***20***	28	29	32	33	39	***17***	***20***	***24***	25	28	29	34	***18***	***21***	25	29	34	***15***	***18***	21	24	28	***15***	17	20	24
	10	***25***	***31***	38	40	45	46	54	***19***	***23***	***32***	33	36	39	46	***20***	***24***	***28***	29	33	34	40	***21***	***25***	29	33	39	***18***	***21***	24	28	33	***17***	***20***	23	28
	90	10	13	16	17	19	19	23	***8***	10	13	13	15	15	18	***8***	***10***	11	12	13	13	16	***8***	10	12	13	16	***7***	8	9	11	13	7	8	9	11
	75	***14***	18	22	22	25	26	31	***11***	***13***	17	18	20	21	25	***11***	***13***	15	16	18	18	21	***11***	13	16	18	21	***9***	***11***	13	15	18	***9***	11	12	15
96	50	***18***	***23***	28	29	33	34	40	***14***	***17***	22	23	26	27	32	***14***	***17***	***19***	20	23	23	28	***15***	***17***	20	23	27	***12***	***14***	17	19	23	***12***	14	16	19
	25	***22***	***28***	34	35	40	41	49	***17***	***21***	27	29	31	33	39	***18***	***21***	***24***	25	28	29	34	***18***	***21***	25	28	33	***15***	***18***	21	24	28	***15***	17	20	23
	10	***26***	***33***	40	41	46	48	57	***20***	***24***	***32***	33	37	38	45	***20***	***25***	***28***	29	32	33	40	***21***	***25***	29	33	39	***17***	***20***	24	27	32	***17***	***20***	23	27
	90	10	13	16	16	18	19	23	***8***	10	12	13	14	15	18	***8***	***10***	11	11	12	13	15	***8***	9	11	13	15	***7***	8	9	11	13	7	8	9	10
	75	***14***	18	21	22	25	26	31	***11***	***13***	17	17	19	20	24	***11***	***13***	14	15	17	17	21	***11***	13	15	17	20	***9***	***11***	12	14	17	***9***	10	12	14
64	50	***18***	***23***	28	29	32	33	39	***14***	***17***	21	22	25	26	31	***14***	***17***	***19***	19	22	22	27	***14***	***16***	19	22	26	***12***	***14***	16	18	22	***12***	14	15	18
	25	***22***	***28***	34	35	39	41	48	***17***	***21***	26	27	31	32	37	***18***	***21***	***23***	24	27	28	33	***17***	***20***	24	27	32	***14***	***17***	20	23	27	***14***	17	19	22
	10	***26***	***32***	39	41	46	48	56	***20***	***25***	***30***	32	36	37	44	***21***	***25***	***27***	28	31	32	38	***20***	***24***	28	32	37	***17***	***20***	23	26	31	***16***	19	22	26

Figure 6. The Result of Push Analysis [1]

Height	Percent	2.1 m pull							7.6 m pull							15.2 m pull							30.5 m pull					45.7 m pull					61.0 m pull			
		One pull every							One pull every							One pull every							One pull every					One pull every					One pull every			
		6	12	1	2	5	30	8	15	22	1	2	5	30	8	25	35	1	2	5	30	8	1	2	5	30	8	1	2	5	30	8	2	5	30	8
		s		min				hr	s		min				hr	s		min				hr	min				hr	min				hr	min			hr
Initial forces																																				
	90	14	16	18	18	19	19	23	11	13	16	16	17	18	21	13	15	15	15	16	17	20	12	13	15	15	19	10	11	13	13	16	10	11	11	14
	75	17	19	22	22	23	24	28	14	15	20	20	21	21	26	16	18	19	19	20	20	24	14	16	19	19	23	12	14	16	16	20	12	14	14	17
144	50	20	23	26	26	28	28	33	16	18	24	24	25	26	31	19	21	22	22	24	24	29	17	19	22	22	27	15	16	19	19	24	14	16	16	20
	25	24	27	31	31	32	33	39	19	21	28	28	29	30	36	22	25	26	26	28	28	33	20	22	26	26	32	17	19	22	22	28	16	19	19	24
	10	26	30	34	34	36	37	44	21	24	31	31	33	33	40	24	28	29	29	31	31	38	22	25	29	29	37	20	22	25	25	31	18	21	21	27
	90	19	22	25	25	27	27	32	15	18	23	23	24	24	29	18	20	21	21	23	23	28	16	18	21	21	26	14	16	18	18	23	13	16	16	19
	75	23	27	31	31	32	33	39	19	21	28	28	29	30	36	22	25	26	26	28	28	33	20	22	26	26	32	17	19	22	22	28	16	19	19	24
95	50	28	32	36	36	39	39	47	23	26	33	33	35	35	42	26	29	31	31	33	33	40	24	27	31	31	38	20	23	27	27	33	20	23	23	28
	25	33	37	42	42	45	45	54	26	3	39	39	41	41	49	30	34	36	36	38	39	46	27	31	36	36	45	24	27	31	31	38	23	26	26	33
	10	37	42	48	48	51	51	61	30	33	43	43	46	47	56	33	38	41	41	43	44	52	31	35	40	40	50	27	30	35	35	43	26	30	30	37
	90	22	25	28	28	30	30	36	18	20	26	26	27	28	33	20	23	24	24	26	26	31	18	21	24	24	30	16	18	21	21	26	15	18	18	22
	75	27	30	34	34	37	37	44	21	24	31	31	33	34	40	24	28	29	29	31	32	38	22	25	29	29	36	19	22	25	25	31	19	21	21	27
64	50	32	36	41	41	44	44	53	25	29	37	37	40	40	48	29	33	35	35	37	38	45	27	20	35	35	43	23	26	30	30	37	22	26	26	32
	25	37	42	48	48	51	51	61	30	34	44	44	46	47	56	34	39	41	41	43	44	52	31	35	41	41	50	27	30	35	35	43	26	30	30	37
	10	42	48	54	54	57	58	69	33	38	49	49	52	53	63	38	43	46	46	49	49	59	35	39	46	46	57	30	34	39	39	49	29	34	34	42
Sustained forces																																				
	90	8	10	12	13	15	15	18	6	8	10	11	12	12	15	**7**	8	9	9	10	11	13	7	8	9	11	13	**6**	7	8	9	10	6	7	7	9
	75	10	13	16	17	19	20	23	**8**	10	13	14	16	16	19	**9**	**10**	12	12	14	14	17	**9**	10	12	14	16	**7**	9	10	11	14	7	8	10	11
144	50	**13**	16	20	21	23	24	28	**10**	**13**	16	17	19	20	23	**11**	**13**	14	15	17	17	20	**11**	13	15	17	20	**9**	**11**	12	14	17	**9**	10	12	14
	25	**15**	20	24	25	28	29	34	**12**	**15**	20	20	23	24	28	**13**	**15**	**17**	18	20	21	24	**13**	15	18	20	24	**11**	**13**	15	17	20	**11**	12	14	17
	10	**17**	22	27	28	32	33	39	**14**	**17**	22	23	26	27	32	**14**	**17**	**19**	20	23	24	28	**15**	**17**	20	23	27	**12**	**14**	17	19	23	**12**	14	16	19
	90	10	13	16	17	19	20	24	**8**	10	13	14	16	16	19	**9**	**10**	12	12	14	14	17	**9**	10	12	14	17	**7**	9	10	12	14	7	9	10	12
	75	**13**	17	21	22	25	26	30	**11**	**13**	17	18	20	21	25	**11**	**14**	15	15	18	18	22	**12**	13	16	18	21	**10**	**11**	13	15	18	**9**	11	13	15
95	50	**16**	21	26	27	31	21	37	**13**	**17**	21	22	25	26	31	**14**	**17**	**19**	19	22	23	27	**14**	**17**	19	22	26	**12**	**14**	16	19	22	**12**	14	16	18
	25	**19**	**26**	31	33	37	38	45	**16**	**20**	26	27	30	31	37	**17**	**20**	**22**	23	26	27	32	**17**	**20**	23	27	32	**14**	**17**	19	22	26	**14**	16	19	22
	10	**22**	**29**	36	37	42	43	51	**18**	**23**	29	31	34	36	42	**19**	**23**	**26**	27	30	31	37	**19**	**23**	27	31	36	**16**	**19**	22	25	30	**16**	19	21	25
	90	11	14	17	18	20	21	25	**9**	11	14	15	17	17	20	**9**	**11**	12	13	15	15	18	**9**	11	13	15	18	**8**	9	11	12	15	8	9	10	12
	75	**14**	19	23	23	26	27	32	**11**	**14**	19	19	22	22	26	**12**	**14**	**16**	17	19	19	23	**12**	14	17	19	23	**10**	**12**	14	16	19	**10**	12	13	16
64	50	**17**	**23**	28	29	32	34	40	**14**	**18**	23	24	27	28	33	**15**	**18**	**20**	21	23	24	28	**15**	**18**	21	24	27	**13**	**15**	17	20	23	**12**	14	16	20
	25	**20**	**27**	33	35	39	40	48	**17**	**21**	27	28	32	33	39	**18**	**21**	**24**	25	28	29	34	**18**	**21**	25	28	33	**15**	**18**	21	24	28	**15**	17	20	25
	10	**23**	**31**	38	40	45	46	54	**19**	**24**	**31**	32	37	38	45	**20**	**24**	**27**	28	32	33	39	**21**	**24**	28	32	38	**17**	**20**	24	27	32	**17**	**20**	23	27

Figure 7. The Result of Pull Analysis [4]

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/rtp.v8i1.2687.

[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/JTIUMM.Vol18.No1.43-54