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Tool Design for Reducing Excessive Transportation in a Textile Industry: Case Study in a Textile Company in Indonesia

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ABSTRACT

This research aimed to design a tool that can reduce one type of waste on the production floor, namely excessive transportation in the form of a waste of transportation time. The design of the tool was carried out by inspecting to the details of the failures that occurred in the previous means of transportation. This development research implemented stopwatch time study method and failure mode and effect analysis to find out the value of the loss of transportation time and the types of failures that cause it. The sample of the transportation process time was taken by simple random sampling method from the intensity of the transportation process per month, based on the type of transportation process on the production floor of a textile company. Then the design of the tool was carried out using the morphological matrix method and weighted objectives table to create the design that fits the needs. The results show that the prediction of the amount of excessive transportation in the form of a waste of time can be minimized by 8,11 hours. Moreover, the new design tool also has a safe structure due to its attained maximum equivalent stress was 17.4 MPa which was smaller than the maximum yield stress of the ST37 material.

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1. Introduction

Based on data released by the Ministry of Trade of the Republic of Indonesia that textiles and textile products are the second leading commodity after palm oil in non-oil and gas export activities in 2020 [1]. This explains the role of the textile industry in Indonesia in absorbing labor, absorbing foreign exchange, and encouraging economic growth.

The word textile can convey technological information because in its manufacture it applies several technologies such as weaving techniques [2]. Weaving is an activity of making cloth which is carried out by crossing (weaving) two types of yarn (weft yarn and warp yarn) vertically and horizontally with a certain pattern to form a woven cloth. According to the Big Indonesian Dictionary, the word "industry" is contextually an organizational activity that processes products with the help of machines. The textile industry is an organizational activity that processes yarn into fabric by crossing (weaving) warp and weft yarns using the help of machines and supporting equipment.

Since the implementation of the ASEAN Economic Community (AEC) program in 2016, Indonesia has faced various challenges to dynamics in the ASEAN free market. This has an impact on the trade of textile products in the international market as well as the national market, so that the performance of business actors in this case the textile producer or industry needs to be optimized to create and improve products with the best quality standards to meet consumer desires.

The performance of business actors, in this case producers or industries, can be assessed from the production process that occurs. Where an effective and efficient production process can be a benchmark of company performance [3]. However, business actors are less aware of waste of time that arises in production activities. So that it has an impact on the lack of detection and measurable analysis to take an attitude towards that waste in the production process. In fact, the waste that occurs can reduce the company's efficiency in absolute terms.

There are seven wastes commonly known as the seven wastes. The seven wastes consist of: waiting time, excessive transportation, unnecessary movement, storage, defects, excessive production, and excessive process [4] and [5]. There are many alternative attitudes that can be taken to minimize waste in the production process in the company. One of them is by designing an effective tool to minimize waste. Based on the theory of seven wastes, tool design solutions can be one of the appropriate approaches to overcome waste [6], [7], [8].

Seeing the many failures in the material transportation process, it was necessary to make improvements by designing tools to reduce one type of waste on the textile production floor, namely excessive transportation. By considering aspects of wasted transportation time and the possibility of failure of the transportation process that causes waste of transportation time, it was expected that the design of this new tool can reduce excessive transportation in the form of a waste of time.

2. Method

This study uses a development research design. According to [9] design development research is research that seeks to develop certain tools or products based on needs. The object that will be developed is a means of material transportation in a textile company in Central Java, Indonesia with an excessive transportation approach.

The method used to identify excessive transportation is a stopwatch time study which is used to map the time wasted per month. The sample of the transportation process time is taken from the population in the form of the intensity of the transportation process per month, based on the type of transportation process on the production floor. The sampling technique was done by simple random sampling method. Failure mode effects analysis (FMEA) is used to identify the types of failures in transportation equipment that cause excessive transportation.

The method used to design transportation equipment with an excessive transportation approach is morphological analysis which is used to find several types of concepts that are suitable for alternative solutions. And the weighted objectives table is used to select one concept that best fits the expectations of several types of concepts.

The stopwatch time study method is a method that measures work in a short and repeated time using a time measuring device, namely a stopwatch. There are steps that must be done in this method. Among them are determining the types of work, where there are 38 types of transportation processes in one textile company being studied which will then be measured in time for each type of transportation process.

Testing the adequacy and uniformity of the data was conducted after time measurement. The transportation time data in this study was assumed to be uniform because the transportation conditions on the production floor cause the transportation time data to have a large deviation. According to [10] the sample size is said to be feasible in research if it consists of between 30-500 samples. In this study, 30 data of transportation time were taken for each type of transportation, and it was assumed to be sufficient.

After the data was uniform and sufficient, determining the performance rating using the Westinghouse System and allowance was important. Performance rating and allowance are useful for finding normal time and standard time.

FMEA is a powerful method for comparing a machine or system from the point of view of failure risk. The FMEA method can also serve to consider technological design improvements [11]. According to [12] FMEA is an engineering technique used to identify errors or potential failures that exist in signs, processes, or service structures that occur. There are three main components in FMEA, including severity, occurrence, and detection, see Tabel 1, 2, and 3.

Table 1. Severity component that measures the impact of the seriousness of the failure effect [adopted from [12]]

Severity	Rank	Description
No effect	1	No noticeable effect.
Very minor	2	Low impact on process, operation, or operator.
Minor	3	Some of the product is repaired during operation.
Very low	4	Repair 100% on the product during operation.
Low	5	Part of the repair and approval of the product after the operation is over.
Moderate	6	Repairing and approval of 100% of the product after the end of the operation.
High	7	Part of your product is scrap. Slowing down the process speed or additional workload.
Very high	8	The product is 100% scrap. Operation is stopped, shipping can not be performed.
Hazardous with warning	9	The operator influences the safety of the maintenance personnel by determining the potential fault condition or not meeting the regulatory requirements,
Hazardous without warning	10	A possible fault condition has no effect on the safety of the operator, the maintenance personnel or legal requirements, without any indication being given.

Table 2. Occurrence component that measures the frequency of failures [adopted from [12]]

Occurrence	Rank	Frequency/1000	Probability
Very Rare	1	<0.001	$<1*10^{-6}$
Very Rare	2	0.001	$1*10^{-6}$
Low	3	0.01	$1*10^{-5}$
Low	4	0.1	$1*10^{-4}$
Intermediate	5	0.5	$5*10^{-4}$
Intermediate	6	2	$2*10^{-3}$
Too High	7	10	$1*10^{-2}$
Too High	8	20	$2*10^{-2}$
Too High	9	50	$5*10^{-2}$
Too High	10	>100	$>10^{-1}$

Table 3. Detection component that measures the cause of the failure that will occur based on its control [adopted from [12]]

Detection	Rank	Description
Almost Certain	1	Failure prevention system recognized by the vehicle
Very High	2	Detection by automatic control in the process before production
High	3	Automatic control in process, stopping faulty production
Moderate High	4	Automatic warning on next operation, stopping faulty production
Moderate	5	Automatic control in production station, operator warning
Low	6	Various device controls or qualitative controls in the process
Very low	7	Audio/visual controls or qualitative controls
Remote	8	Audio/visual controls
Very remote	9	Indirect and random controls
Absolutely uncertain	10	It cannot be detection and controls

Morphological analysis is a method of finding alternative product concepts with a systematic approach. This method displays alternative solutions with component specifications that will be used in a product. Morphological analysis can be explained by the form of a morphological matrix [13]. Morphological matrix is a solution to determine alternative product concepts. The morphological matrix can use the structure of functions that have been obtained using previous methods [14].

The weighted objectives table is a consideration table that is used as a comparison tool from several different alternative concepts. This comparison is obtained by ranking the level of importance based on a list of considerations. The first rank with the highest score is the concept that meets the most consideration and is the best concept [15]. According to [16] there are 26 considerations in the design of a product, see Table 4.

Table 4. Design considerations

Design Considerations			
No	Considerations	No	Considerations
1	Functionality	14	Noise
2	Strength/stress	15	Styling
3	Distortion/deflection/stiffness	16	Shape
4	Wear	17	Size
5	Corrosion	18	Control
6	Safety	19	Thermal properties
7	Reliability	20	Surface
8	Manufacturability	21	Lubrication
9	Utility	22	Marketability
10	Cost	23	Maintenance
11	Friction	24	Volume
12	Weight	25	Liability
13	Life	26	Remanufacturing/resource recovery

In this study, only 6 considerations were taken to choose the best design concept, including strength, safety, weight, cost, manufacturability, and shape.

The flow of this research consists of several stages based on the design process, and each process has steps that are in accordance with the context of the stages of the design process, see Fig. 1.

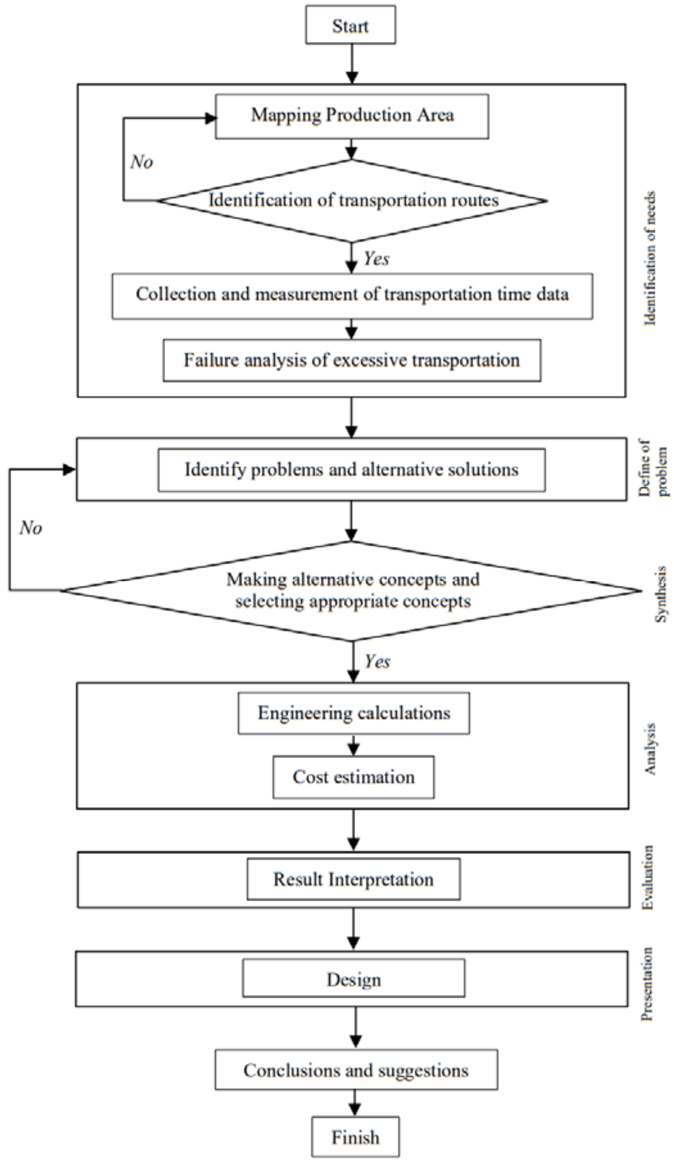

Fig. 1. Research flow

Accuracy in the selection of data collection techniques is very dependent on the objectives to be achieved [17]. The method used in data collection is non-systematic observation to find out about the textile production process, the transportation process in textile production, the tools used in the transportation process, and the types of failures that occur. Unstructured interview method was used to obtain information about the textile transportation process, design expectations, and the degree of importance of design considerations. Documentation method is also used to retrieve information and data from the company. The information that will be taken in this research is various data on excessive transportation and production record data that can define the intensity of transportation per month.

3. Results and Discussion

The production process in the textile company studied is divided into 2 types of processes. That are the weaving process of weaving 1 which uses a shuttle machine and weaving 2 which uses a rapier machine. From the types of processes that occur on the production floor, the material transportation process flow is obtained.

From the types of processes that occur on the production floor, the material transportation process flow is obtained. There are 38 types of material transportation processes that occur on the production floor. The types of materials carried include yarn, DTY/Leno yarn, pallets, filled beams, empty beams, filled rollers, empty rollers, fabrics, starch, and accessories. The materials are transported using several types of tools such as rapier beam truck, beam shuttle carriers, hand lift, forklift, weft yarn carriers, shuttle roller carriers, rapier roller carriers, empty beam carriers, rapier weft yarn carriers.

From 38 types of transportation processes, time measurements were made using a stopwatch and 30 times data were taken for each type of transportation. This time data is then searched for the normal time by considering the adjustment value of the performance rating using the Westinghouse System.

Table 5. Transport adjustment value

No	Factor	Adjustment	Value
1	Skill	Good (C2)	+0,03
2	Condition	Fair(C2)	+0,02
3	Efforts	Good	-0,03
4	Consistency	Average	0,00

To see the loss of time from the transportation process per month, it is necessary to carry out transportation intensity data per month on the production floor. This transportation intensity data is obtained from existing PPIC data.

From the data of standard time and transportation intensity per month, the value of transportation time per month will be obtained. Where the value of transportation time per month is the product of the standard time and the intensity of transportation per month.

The monthly transportation time data is the same as the waste of time data per month. Last, month's waste of time data was grouped based on the type of tool used. It aimed to see which tools contribute the most time wastage.

$TF = F_{skill} + F_{condition} + F_{efforts} + F_{consistency}$
$TF = 0,03 + 0,02 – 0,03 + 0,00$
$TF = 0,02$
Adjustment value

$P = 1 + TF$
$P = 1 + 0,02$
$P = 1,02$
Normal Time (WN)

WN = time average x adjustment value

Normal time is used to determine the standard time required for the material transportation process. Standard time is the operator time in carrying out work activities. Standard time really considers the allowance value.

In the transportation time in this study, the allowance value is assumed to be 0. This is because the transportation process is carried out in one process without any allowance for personal needs and the work attitude is always the same, so the standard time is the same as normal time.

Table 6. Wastage of transportation time in one month

No	Tool type	Transportation (T). type; material	Standard time (seconds)	Intensity	Waste/ month (seconds)
1	Manual	T. warping to beam sizing stock; material = filled beam	27.54	659	18148.86
		T. sizing machine to empty beam stock; material = empty beam	42.84	97	4155.48
		T. empty beam to warping machine; material = empty beam	56.10	659	36969.9
		T. beam stock to sizing machine; material = filled beam	99.96	97	9696.12
		T. filled sizing beam to shuttle beam stock; material = filled beam	47.94	829	39742.26
		T. filled roll to shuttle roll stock; material = filled roll	28.56	7689	219597.84
		T. empty roll stock to shuttle machine; material = empty roll	26.52	7689	203912.28
		T. leno machine to rapier; material = leno yarn	67.32	297	19994.04
2	Hand lift	T. warehouse to warping stock; material = original yarn	90.78	533	48385.74
		T. warehouse to pallet stock; material = yarn	90.78	170	15432.6
		T. warping stock to warping machine; material = original yarn	45.90	194	8904.6
		T. warping stock to warehouse; material = yarn (swp)	90.78	53	4811.34
		T. warping machine to rewind machine; material = yarn (swp)	19.38	30	581.4
		T. rewind to warping stock; material = yarn (rwd)	57.12	30	1713.6
		T. starch warehouse to starch stock; material = starch	132.60	59	7823.4
		T. inspecting to warehouse; material = fabrics	105.06	730	76693.8
3	Rapier roll carriers	T. inspecting to rapier; material = empty roll	34.68	1969	68284.92
		T. rapier to inspecting; material = filled roll	42.84	1969	84351.96
4	Rapier weft yarn carriers	T. warehouse to rapier stock; material = yarn (weft)	62.22	498	30985.56

Table 7. Wastage of transportation time in one month continued

No	Tool type	Transportation (T). type; material	Standard time (seconds)	Intensity	Waste/ month (seconds)
5	Beam shuttle carriers	T. shuttle beam stock to draw in = material = filled beam	72.42	438	31719.96
		T. draw in to after drawn in stock in shuttle machine; material = filled beam	67.32	438	29486.16
		T. after draw in stock to shuttle machine; material = filled beam	94.86	399	37849.14
		T. filled beam stock (tying) to shuttle machine; material = filled beam	84.66	490	41483.4
		T. shuttle machine to empty beam stock; material = empty beam	65.28	490	31987.2
		T. shuttle machine to accessories; material = accessories	58.14	399	23197.86

		T. accessories to shuttle machine; material = accessories	46.92	399	18721.08
6	Rapier beam truck	T. rapier beam stock to sizing; material = beam empty beam	104.04	149	15501.96
		T. sizing filled beam to rapier beam stock; material = filled beam	144.84	149	21581.16
		T. rapier beam stock to draw in; material = filled beam	79.56	58	4614.48
		T. rapier to empty beam stock; material = empty beam	70.38	297	20902.86
		T. draw in beam stock to rapier beam stock; material = filled beam	75.48	145	10944.6
		T. tying beam stock to rapier stock; material = filled beam	159.12	152	24186.24
		T. rapier stock to rapier machine; material = filled beam	57.12	297	16964.64
7	Weft yarn carriers	T. weft stock to weft; material = yarn	78.54	261	20498.94
		T. weft to shuttle machine; material = yarn (weft)	159.12	2909	462880.08
8	Empty beam carriers	T. empty beam stock to sizing machine; material = empty beam	61.20	415	25398
9	Shuttle roll carriers	T. inspecting to shuttle roll stock; material = empty roll	73.44	770	56548.8
		T. filled shuttle roll stock to inspecting; material = filled roll	91.80	770	70686
Total waste of time/month					1838321

From the grouping of transportation time per month based on the type or means of transportation, we get the type of transportation that has the largest transportation processing time per month. These results are obtained from the accumulation of each transportation process based on the transportation equipment used.

The time accumulation based on the tool was then mapped using a Pareto diagram. It aimed to see which tools account for the highest time wastage per month.

Table 8. Waste of time accumulation based on the tool

Wastage of transportation time in one month				
No	Tool type	Seconds	Hours	Percentage
1	Manual	552217	153,40	29.60%
2	Weft yarn carriers	483379	134,30	25.91%
3	Beam shuttle carriers	214445	59,57	11.50%
4	Handlift	164346	46,05	8.81%
5	Rapier roll carriers	152637	42,40	8.18%
6	Shuttle roll carriers	127235	35,34	6.82%
7	Rapier beam truck	114696	32,26	6.15%
8	Rapier weft yarn carriers	30986	8,01	1.66%
9	Empty beam shuttle carriers	25398	7,05	1.36%

Total waste of time/month	1865338	518,78	100.00%

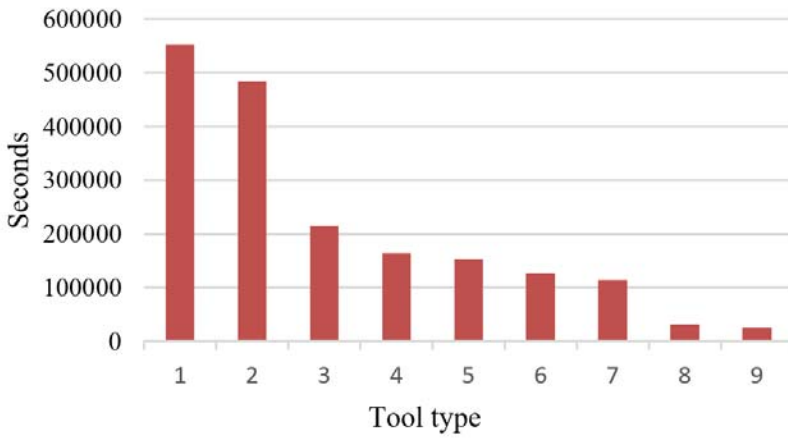

Fig. 2. Waste of time accumulation based on the tool diagram

From the Table 7, it is found that the highest waste of transportation time is in the manual transportation process. However, this can be influenced by the high intensity or the number of manual transportation processes on the production floor, so that the design of tools in the manual process may not necessarily answer the company's needs.

The analysis needs to be continued on the failure model that occurs in the means of transportation. Due to the failure factor in a transportation process is the reason why excessive transportation can occur. In the next stage, the tools analyzed were narrowed down, with only the largest 3 taken. These are manual processing, pallet carts, and beam shuttle carriers.

Table 9. FMEA transportation tools

Tools type	Potential Failure Mode	Potential Failure Effects	Sev	Potential Causes	Occ	Detective Control	Det	RPN
Manual	Material fall	Generates a waste of time, and some of the material is damaged but can be repaired quickly.	3	Operator fatigue from carrying heavy loads	4	Operator visual observation	8	96
	Operators experiencing fatigue	Generates a waste of time	2	Too long holding heavy loads with frequent often intensity	10	Operator visual observation	8	160
Weft yarn carriers	The means of transportation are not running smoothly	Generates a waste of time	2	Small Cart Tires	10	Operator visual observation	8	160
				There are many potholes in the transportation route	10	Operator visual observation	8	160

Beam shuttle carriers	The means of transportation are not running smoothly.	Generates a waste of time	2	Tires of small transportation equipment with nylon material	10	Operator visual observation	8	160
	Operators experiencing fatigue	Generates a waste of time	2	Too long holding heavy loads with frequent often intensity	10	Operator visual observation	8	160
	Load beam dropped during shuttle machine line setting	Generates time waste, and there are some damaged and wasted yarn materials due to collapsing	7	There is no locking place for material with a suitable beam position on the shuttle machine path in the transportation equipment	10	Operator visual observation	8	560

From the analysis using the FMEA method, it is known that the highest failure rate occurs in the beam shutle carrier. Judging from the many types of failures that occur and the high RPN value is 560 on the potential for material to fall, so that the design of the tool would continue to focus on the transport of the beam shuttle carrier. Where the transportation process using a beam shuttle carrier produced the third largest transportation time and the beam shuttle carrier also has a high failure rate.

From the various potential causes of the beam shuttle carrier and the design expectations of the new device, various alternative solutions were obtained through interviews and long discussions with the company. These various alternative solutions are used to select the concepts as desired.

Table 10. Alternative solution from FMEA table

Tools	Potential Failure Mode	Potential Failure Effects	Sev	Potential Causes	Occ	Detective Control	Det	RPN	Alternative Solusi
Beam shuttle carriers	The means of transportation are not running smoothly.	Generates a waste of time	2	Tires of small transportation equipment with nylon material	10	Operator visual observation	8	**160**	Tires Expanded to 5” with rubber material
									Tires Expanded to 6” with rubber material
	Operators experiencing fatigue	Generates a waste of time	2	Too long holding heavy loads with frequent often intensity	10	Operator visual observation	8	**160**	Using screw jack
									Using hydraulic jack.
	Load beam dropped during shuttle machine line setting	Generates time waste, and there are some damaged and wasted yarn materials due to collapsing	7	There is no locking place for material with a suitable beam position on the shuttle machine path in the transportation equipment	10	Operator visual observation	8	**560**	Use thread lock
									Using lock with a hole on the beam shaft.
									Using a simple hinge lock

Table 11. Design Expectations from company

Expectations	Alternative solution
Lifting pedestal replaced is not done on yarn anymore	Material is stacked on the beam shaft
	Material is stacked on a flange beam
Easy material transportation	Motor propulsion
	Manual propulsion
Tools do not take up space	Small and slim tool shape
The material must be light but strong	Using ST37 material
	Using aluminum material

	Using Douglas fir material
The frame must be light but strong	Using Rectangular Hollow Section (RHS)
	Using SHS Square Hollow Section (SHS)
	Using angle section

The selection of concepts from the next tool is mapped using a machine morphology matrix. From this machine morphology matrix 3 possible concepts were taken.

The next step was determining the design considerations that would be compared with each concept that had been made from the morphological matrix. This consideration was used to assess the design concept and take a design concept from several design concepts that had been made using the weighted objectives table method.

Table 12. Tool design morphological matrix

No	Solution / Sub expectations	a	b	c
1	Easy material lifting	Using screw jack	Using hydraulic jack	-
2	Lifting pedestal replaced is not done on yarn anymore	Shaft support	Flange support	-
3	Easy material transportation	Motor drive	Manual drive	-
4	Tools do not take up space	Small tool	-	-
5	Materials can be locked on tool	Thread lock	Simple hinge lock	Lock using beam shaft hole

Table 13. Tool design morphological matrix continued

No	Solution / Sub expectations	a	b	c
6	Tires enlarged and tire material changed	Using 5" rubber castor tires	Using 6" rubber castor tires	
7	Tool material must be light and strong	ST37	Alumunium	Douglas fir wood
8	Frame must be light and strong	Rectangular Hollow Section	Square Hollow Section	Angel Section

From the morphological matrix above, 3 alternative concepts were taken. This alternative concept was a proposal from the designer which would then be re-analyzed. The proposed alternative concepts are:

Concept 1 = 1a-2b-3a-4a-5b-6a-7c-8c

Concept 2 = 1b-2a-3b-4a-5c-6b-7b-8b

Concept 3 = 1a-2a-3b-4a-5b-6a-7a-8a

Determination of the level of importance using the weighted objectives table method was carried out after conducting interviews. The results of the value of each level of importance from the selected design considerations as seen in Table 14.

Tabel 14. Level of importance

Consideration		1	2	3	4	5	6	7	Votes	Level of importance
Strength	A	A	A	B	C	A	A	B	4	0.19
Safety	B	B	D	E	D	C	C	C	3	0.143
Weight	C	D	F	D	F	F	E	E	4	0.19
Cost	D								4	0.19
Manufacturability	E								3	0.143

Shape	F	3	0.143
Total votes		21	1.00

An assessment was carried out in accordance with design considerations. Assessment was carried out to get the concept that fitted the needs. The rating scale was notated from 1 to 5, with provisions from least appropriate to most appropriate to needs.

Table 15. Design concept assessment results

Consideration		Level of importance (L)	Concept 1		Concept 2		Concept 3	
			Score (S)	S x L	Score (S)	S x L	Score (S)	S x L
Strength	A	0.19	1	0.19	4	0.76	3	0.57
Safety	B	0.143	2	0.286	3	0.429	3	0.429
Weight	C	0.19	4	0.76	3	0.57	3	0.57
Cost	D	0.19	4	0.76	3	0.57	3	0.57
Manufacturability	E	0.143	3	0.429	2	0.286	4	0.572
Shape	F	0.143	5	0.715	5	0.715	5	0.715
Total Score		1.00		3.14		3.33		3.43

It was found that the design of the beam shuttle transportation tool in concept number 3 has the highest value from several considerations that have been made. The research continued with the design of the tool according to concept number 3.

After designing the tool based on the selected concept. Then the modeling was done using a 3-dimensional design.

Length	: 1.97 meter
Width	: 0.44 meter
Maximum height	: 0.870 meter
Maximum lifting height	: 14 cm
Weight	: 28.6 Kg
Mover	: Manual
Maximum weight of beam	: 250 Kg
Weight with beam	: Max 278.6 Kg
Lift mechanism	: Screw jack
Lift support	: beam shaft

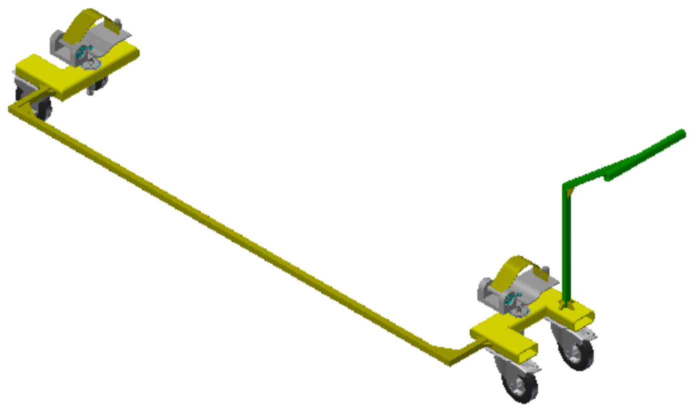

Fig. 3. Beam shuttle carriers' concept 3

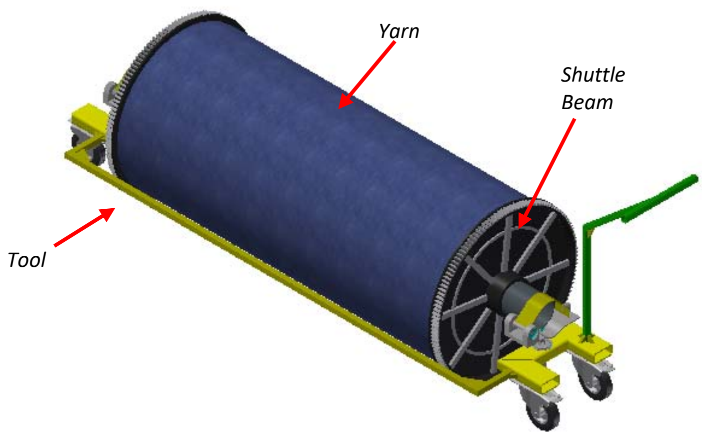

Fig. 4. Beam shuttle carriers' concept 3 with filled beam

It is known that the bar chart image of the tool loading is as follows with a length of 1675 mm and maximal weight of material is 250 kg with guided roll support. From the Fig. 5, Ay and By is 125 kg.

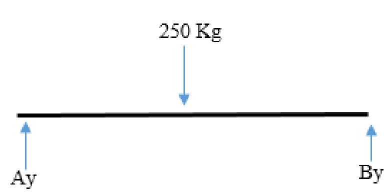

Fig. 5. Loading diagram on the device

Because the condition is symmetrical then Ay is equal to by 125 kg. It is known from the above calculation that the load acting on each base of the legs is 125 kg. After being analyzed using Ansys software, it was found that the equivalent stress (von-Mises) of the frame was at least 0.00075 MPa and a maximum value of 17.4 MPa, where the maximum yield stress of ST37 was 220 MPa.

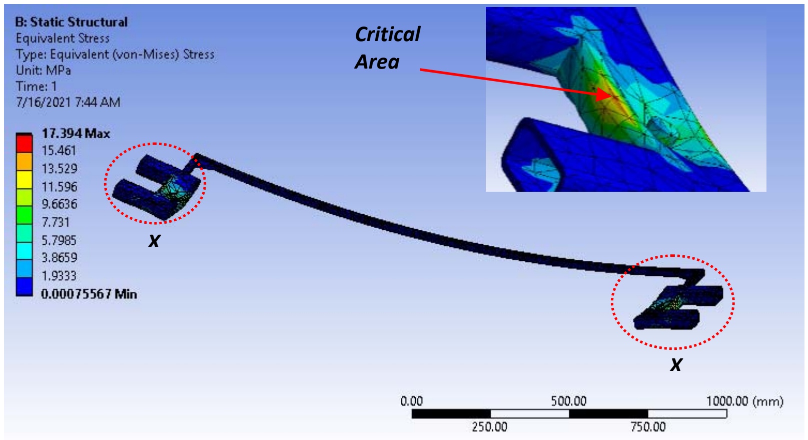

Fig. 6. Von-mises analysis

The maximum equivalent stress value (von-Mises) is smaller than the maximum yield stress of the material, so that the frame or structure of the designed fill beam lifting device is safe.

The following is a bar diagram of the loading of the foot base with a length of 300 mm and weight is 250 kg with guided roll support.

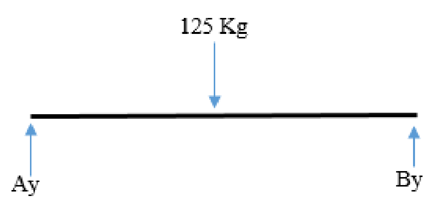

Fig. 7. Loading diagram on base frame

Because the condition is symmetrical then Ay is equal to By is 62,5 kg. The maximum load that works on each wheel of the beam shuttle carrier is 62.5 kg, so that the transportation equipment requires rubber castor wheels with specifications that can withstand a minimum load of 62.5 kg.

The frame uses a rectangular hollow section material with ST-37 material with a thickness of 4 mm and an outer size of L x P = 80 mm x 40 mm so that the size of the inner hole is L x P = 72 mm x 32 mm.

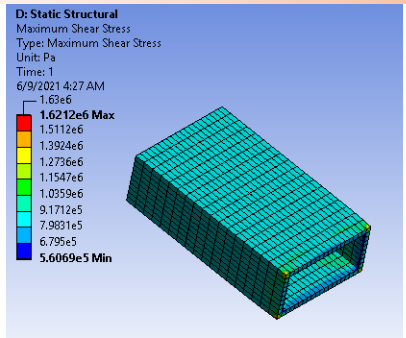

Fig. 8. Rectangular Hollow Section Analysis

$\varsigma_{allowable}$ = 0,85 x Tuts ST-37/SF
$\varsigma_{allowable}$ = 0,85 x 37/3
$\varsigma_{allowable}$ = 0,85 x 37/3
$\varsigma_{allowable}$ = 10,5 kg/mm^2

The compressive stress acting on the frame is 1.63 kg/mm^2 and the allowable stress with a safety number of 3 is 10.5 kg/mm^2. The value of the allowable stress is greater than the compressive stress acting on the frame, so that the frame is safe with maximum loading from the existing beam.

Screw Jack Calculation

W = (3,14/4 x dc^2) x Fec/SF
W = (3,14/4 x dc^2) x 37/7
125 = 0,785 dc^2 x 5,287
dc^2 = 5,5 mm

It was known that the core diameter of the screw jack is 5.5 mm. So based on the table, the lowest core diameter was taken, which was 17 mm. Then the specifications of the screw jack were as follows:

Nominal D = 22 mm
Major diameter = 22 mm (bolt), 22,5 mm (nut)
Depth of thread = 2,5 mm (bolt), 2,75 mm (nut)
Area of Core = 227 mm^2
Pitch = 5 mm
Maximum Loading of Welded Joints

It is known that the electrode used in the utility workshop is type E6013 with a diameter of 3.2 mm (1/8”) for a 4 mm thick plate. so that according to the table the AUC value is 28.4 kg/mm. The maximum loading is:

F_{frame} = AUC x L
F_{frame} = 28,4 kg/mm x 306,28 mm
F_{frame} = 8698 kg

$F_{frame\text{-}jack\ housing}$ = AUC x L
$F_{frame\text{-}jack\ housing}$ = 28,4 x 65
$F_{frame\text{-}jack\ housing}$ =1846 kg

It is known that the welding connection on the base frame can withstand a maximum load of 8698 Kg and on the base frame connection with the jack housing of 1846 kg. Meanwhile, at the base frame connection point the working load was 62.5 kg and the base frame connection with the jack housing the working load is 125 kg. So that the welding joint designed is safe against the lifting load of the filled beam material.

Shear stress at the base frame connection:

T_{frame} = F/h x l
T_{frame} = 62,5/4 x 306,28
T_{frame} = 62,5/1225,12
T_{frame} = 0,052 kg/mm^2

Shear stress at the base frame connection and jack housing:

$T_{frame\text{-}jack\ house}$ = F/h x l
$T_{frame\text{-}jack\ house}$ = 125/4 x 65
$T_{frame\text{-}jack\ house}$ = 125/260
$T_{frame\text{-}jack\ house}$ = 0,5 kg/mm^2

The allowable shear stress in the welded joint is 0.40Sy. Sy value in ST-37 material is 22.5 kg/mm^2. Then the allowable shear stress is:

0,40Sy

0,40 (22,5 kg/mm^2) = 9 kg/mm^2

The value of the allowable shear stress is greater than the calculated shear stress for both the base frame welding and the base frame welding with the jack housing. Then welding can be declared safe.

The estimated cost of making the beam shuttle carrier consists of the cost of raw materials, manufacturing costs, and the cost of the patent rights for the beam shuttle carrier. The amount of the cost of the idea of a design was determined by the designer himself, which was taken as a percentage of 20% of the material cost plus the cost of workmanship. The total cost required is seen in Table 16, 17, and 18.

Table 16. cost of raw materials

No	Components	Quantity	Price	Total
1	Plat 2 mm 250 x 300	4 pcs	Rp21.000,00	Rp84.000,00
2	Plat 10 mm 100 x 125	2 pcs	Rp20.000,00	Rp40.000,00
3	Rectangular Hollow 80 x 40-4	2 meters	Rp42.000,00	Rp84.000,00
4	Square hollow 20 x 20-2	3 meters	Rp17.000,00	Rp51.000,00
5	Round hollow 27 mm-3 mm	1 meter	Rp30.000,00	Rp30.000,00
6	Rubber castor tire 5” max load 125 kg	4 pcs	Rp50.000,00	Rp200.000,00

7	Round bar ST37 diameter 70 mm	4 Kg	Rp50.000,00	Rp200.000,00
8	Round bar ST37 diameter 25 mm	12 Kg	Rp30.000,00	Rp360.000,00

Table 17. Materials cost

No	Components	Quantity	Price	Total
1	Square bar 60 ST37	2 Kg	Rp 30.000,00	Rp60.000,00
2	Nut M8	2 pcs	Rp3.000,00	Rp6.000,00
3	Bearing in Diameter 15 out diameter 40	2 Pcs	Rp 20.000,00	Rp40.000,00
4	Bearing in Diameter 47 out diameter 55	2 Pcs	Rp 40.000,00	Rp80.000,00
Total				Rp1,235,000.00

Table 18. Manufacturing cost

Minimum Cost Standard in Purworejo	Working time/month	Income/hour	Build time	Power	Manufacturing cost
Rp1,900,000.00	182 hours	Rp10,439.56	28 hours	2 men	Rp584,615.38

Idea fee: 20% x (materials cost + manufacturing cost): 20% x (Rp 1,235,000.00 + Rp 584,615.38)

Idea fee = Rp 363,923.00

Total cost: Materials cost + manufacturing cost + idea fee: 1,235,000+584.615+ 363,923

Total cost = Rp 2,183,538.00

After the design of the beam shuttle carrier transportation tool was provided with a locking place with a hinge system, then the type of failure of the fill beam was dropped when setting the shuttle machine path no longer occurs. This was because the tool has not shifted and was not tilted, so the tool can enter the lines of the shuttle machine without having to reset it. But only one type of failure can be calculated how much time wasted was reduced after optimization. On other failures, the reduced time wastage is immeasurable. Because this research only reached the design phase. Time wasted in other failures in the transportation process using a beam shuttle carrier could only be calculated or measured if the tool had been built and tested in the field. The following is a prediction of time wastage that can be reduced in the transportation process using a new tool design as shown in Table 19.

Tabel 19. Prediction of Waste Excessive Transportation Value that can be minimized

Tool	The type of transportation of the beam shuttle carrier	Waste of time/month old tools	Minimized time wastage based on failure type			Waste of time/month new tools
			Beam dropped	Tool not running smoothly	Operator fatigue	
Beam shuttle carriers	T. shuttle beam stock to draw in	31719.96	N	C	C	31719.96
	T. draw in to after draw in stock in shuttle	29486.16	N	C	C	29486.16
	T. after draw in stock to shuttle machine	37849.14	12453.588	C	C	25395.552
	T. filled beam stock (tying) to shuttle machine	41483.4	15293.88	C	C	26189.52

T. shuttle machine to empty beam stock	31987.2	N	C	C	31987.2
T. shuttle machine to accessories	23197.86	N	C	C	23197.86
T. accessories to shuttle machine	18721.08	N	C	C	18721.08
Total in seconds	214445	27747.468	-	-	186697.332
Total in hours	59,57	8,11	-	-	51,46

Description: N = Not applicable
C = Can't be measured

Based on the Table 19 the waste of time/month new tools is 51.46 hours. It is less 6.11 hours than waste of time/month old tools.

4. Conclusion

The material transportation equipment that has the largest excessive transportation impact was the beam shuttle carriers which has the highest failure value and many types of failures that cause a waste of time. By using a new tool, predictably the waste of transportation time can be reduced to 8.11 hours. so that the waste of time per month is reduced from 59.57 hours to 51.46 hours.

The new beam shuttle carriers have a safe structure. Judging from the maximum equivalent stress value of the tool, which was 17.4 MPa, which is smaller than the yield stress value of the ST37 material, which is 220 MPa.

Judging from the welding aspect of the structure, where the maximum shear stress at the frame connection is 0.052 kg/mm^2 and the maximum shear stress at the jack housing weld connection which is 0.5 Kg/mm^2 is smaller than the allowable shear stress which is 9 kg/mm^2. Thus, the new beam shuttle lifting transport equipment has a safe welding structure.

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