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Improvement of Transfer Trolley Driving System as Material Handling Based on Battery Using Quality Function Deployment (QFD) Method

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Abstrak.
Bagian terpenting dalam meningkatkan produktivitas di suatu perusahaan adalah keberhasilan material handling yang diterapkan. Di PT XYZ terdapat proses penting dalam pemindahan plat dari area warehouse ke area persiapan bahan, khususnya menggunakan transfer trolley sebagai material handling. Transfer trolley yang ada saat ini memiliki beberapa kendala saat beroperasi seperti kabel roll yang sering terlilit sehingga mengakibatkan sistem kelistrikan utama tidak stabil bahkan transfer trolley yang sering tiba-tiba berhenti karena kelebihan muatan. Tujuan dari penelitian ini adalah untuk memperoleh konsep rancangan transfer trolley yang sesuai dengan kebutuhan pengguna dengan menggunakan metode QFD sehingga meningkatkan utilitas transfer trolley. Metode yang digunakan dimulai dari penentuan kebutuhan pengguna dan diakhiri dengan perhitungan sistem penggerak motor, beserta gambar konsep transfer trolley. Hasil yang didapatkan pada konsep penggerak yang telah diputuskan dengan menggunakan metode QFD adalah transfer trolley menggunakan baterai sebagai sumber utama. Perhitungan motor yang dibutuhkan adalah 2 kW (2 Motor), serta kapasitas baterai yang dibutuhkan adalah 12 KWh dengan kemampuan operasional transfer trolley selama 5,28 jam per hari.

Kata Kunci: Material Handling, QFD, Transfer Trolley

Abstract.
The most important part of increasing productivity in a company is the ability to successfully material handling used. At PT XYZ there is an important process in moving plates from the warehouse area to the material preparation area, especially using a transfer trolley as material handling. The current transfer trolley has several obstacles when operating such as roll cables that are often tripped around resulting in unstable main electrical systems and even transfer trolleys that often suddenly stop due to overloading. The purpose of this study is to determine the concept of transfer trolley design in accordance with user needs using the QFD method thereby improving transfer trolley utilities. The method used starts from determining user needs and ends with the calculation of the motor drive system, along with the transfer trolley concept drawings. The results obtained on the concept of the drive that has been determined using the QFD method is the transfer trolley using the battery as the main source. Calculation of the motor used is 2 kW (2 Motors), as well as the required battery capacity of 12 KWh with operational capabilities of the transfer trolley for 5.28 hours per day.

Keywords: *Material Handling, QFD, Transfer Trolley.*

1. Introduction

The manufacturing industry in Indonesia, especially the heavy equipment mining sector, plays an important role in the country's economy. Over the past 5 years, Indonesia's mining sector has experienced a rapid increase in contribution to GDP, from only 7.18% in 2016 to over 12% by the end of 2022 [1]. The explosive growth of the mining industry has provided opportunities and challenges for businesses in this field to continuously improve their productivity and operational efficiency. Certainly to assist in increasing productivity, this is followed by the development of technology in the industries both inputs and outputs produced.

In terms of increasing the productivity of operational activities within the company, various innovation and technology development in tools and machinery is one of the keys to success in increasing productivity. One of those is material handling as a device used to reach the movements of moving, storing, and controlling certain loads in a production process [2]. The purpose of material handling is basically to reduce and eliminate inefficiency or waste, where activities such as transporting, moving and placing materials when needed take place as efficiently as possible.

PT XYZ is a manufacturing and engineering company for heavy equipment such as produce vessels, tower lamp, attachments, mixers, and others. In PT XYZ there is an important process that ensures the transfer of plates from the warehouse area to the material preparation area. This process is the initial stage before product fabrication is carried out in the fabrication area, such as the process of cutting plates and bending plates.

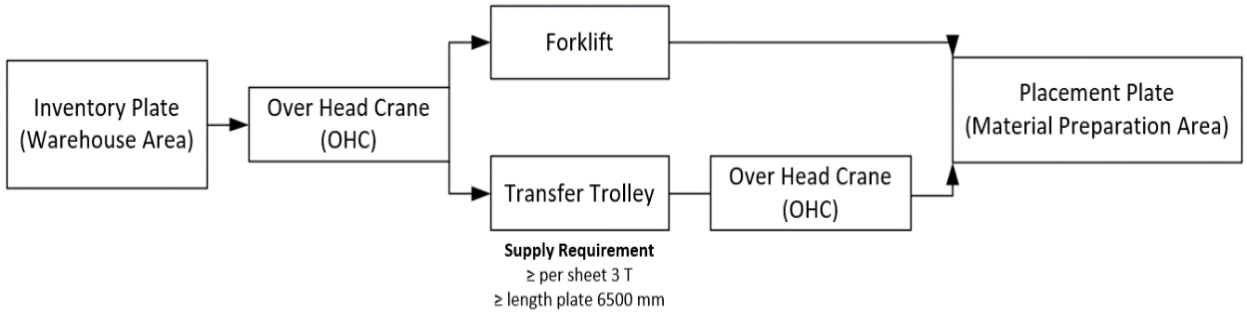


Figure 1. Supply Plate Process

The process of moving plates in this area involved a variety of material handling equipment, including an overhead crane, transfer trolley, and forklift. The overhead crane is used to pick up and receive the plate from its initial position. Meanwhile, the forklift and transfer trolley are used to supply the plate to the next area in order to continue the fabrication production process. The functions of the transfer trolley are used to supply plates that have a length dimension above 6500 mm or per sheet above 3 tons.

Considering the application of the material handling process in the warehouse and the material preparation area, there are various problems related to the material handling system, especially regarding the transfer trolley used. The system used on the transfer trolley is based on a wheel drive system and a rotary drive in the form of an electric motor, which in running it uses the main power source that comes from cable reels. In addition, the transfer trolley access path used using the Single Line Railway type. With the access path, during the process of moving the material handling transfer trolley, this equipment often malfunctions in the cable reels that are often tripped, resulting in unstable main electrical system. The other problem occurs during the delivery process, where during the ongoing process the transfer trolley is overloading which causes the device stopped instantly.

In the current practice, when the transfer trolley is having problems or is damaged, the plate supply process is temporarily replaced using material handling equipment, which is a forklift, by carrying the plate using two forklifts to the material preparation area. The possibility that occurs when continuing to use forklifts to deliver the plates is that the risk of work accidents can occur at any time.

On the other hand, the use of forklifts that are not in accordance with the company's standardization can also affect the safety aspects of work and other losses.

Several researches have proposed the solution to such material transfer problems. Aditya [3] has suggested the use of transfer trolley, in his study he made calculations on the appropriate main components, capable of accommodating a maximum load of 3000 kg. This study focuses on calculating the main components and assembly using Solidworks 2016, which is design base plate; rail wheels; shafts, bearings; driven wheel, then plate and shaft structure analysis using Ansys software.

Other research conducted by Al Sult, et al. [4] with the title "Electrically Operated Multipurpose Trolley" discusses the design and fabrication of industrial trolleys. Automatic trolleys are designed to solve problems when moving freight that measures the weight of freight directly from the trolley with easy movement and using electric power from batteries. The results of this study used Autocad and Creo V3 software for design and structural analysis, and this trolley is able to accommodate a load capacity of 9 kg by testing the time period.

In another research that discusses trolley products conducted by Nurjannah and Agung [5]. This research focuses on redesigning with the Quality Function Deployment (QFD) method to identify customer needs for trolley products. Among other customer needs, the most dominant customer need from the QFD results is to have strong material and thickness. By specifying the trolley which measures 70 x 50 x 67 cm, type of plate steel material, type of hollow steel frame material, type of steel pipe handle material, type of rubber wheel material, has a hand brake, and a rubber strap.

Another research using the same method was conducted by Aron, et al [6] regarding the design of the main steam jig at PT Tomoe Valve Batam. This jig is used to improve production quality and efficiency. This jig design has improved the company's production efficiency and quality. Researchers use Quality Function Deployment (QFD) to reduce production setup time because one jig has two main steam jigs 100A and 125A. So that the output can meet the needs of the company.

Another research conducted by Ahmad, et al. discussed Hammock product development using the QFD method in determining the characteristics of consumer desires and what companies can do to fulfill them with the title "Improvement of Hammock Sleeping Bag Products Using the QFD (Quality Function Deployment) Method". The result is that the development of hammock product designs requires changes in raw materials to give consumers a variety of choices [7].

Basuki, et al redesigned a corn kernel thresher using the QFD method. This research can be implemented into a real product that meets consumer needs, namely tools that are easy, comfortable, safe and easy to use. The HOQ results show the highest percentage, which the egonomic aspect with a value of 100%, dimensions of size with a value of 93%, shape design with a value of 87%. It was found that this design tool produced a product measuring 50x30x85 cm [8].

Ustman, et al. developed a design for a soy yeast mixing machine. The result of this research is to obtain machine design results that are in accordance with the wishes of consumers who are hygienic, ergonomic, efficient, and knock down systems, as well as the ease of mixing yeast using the QFD method. This research also hopes to be reviewed in terms of machine elements, mechatronics, and design techniques so that it is easy in the manufacturing process and the implementation of the required tools [9].

Based on the research that has been done, it is necessary to improve the material handling equipment at PT XYZ in the warehouse area. With the improvement of the design transfer trolley drive system based on battery, which expects to have a maximum safe load capacity of 20 tons, The method to be used in this research is the Quality Function Deployment (QFD) method. This method can help determine the expectations and requirements of the customer, thus the design needs of the machine specifications can be adjusted in the design of the transfer trolley drive system in the company's warehouse area effectively and precisely. It is expected that this research can increase the utility of using transfer trolleys.

2. Methods

This section will explain the theoretical or methodology steps of this research starting from determining the concept of transfer trolley, preparing of the design using QFD method, concept selection, and product design of transfer trolley.

2.1 Concept Determination

Before arranging the House of Quality, there is another part in the QFD method to compare the proposed product concept by considering aspects of each attribute of user needs. The determination of this initial concept is the first step before finalizing the design selection for the transfer trolley product. By determining three initial concepts that have different system characteristics. The goal is to determine, from three different concepts, the direction of improvement in accordance with the design criteria. The determination of the concept of transfer trolley design will be explained abstractly based on the concept to be determined.

2.2 Preparation of The Design Using QFD Method

In designing using the QFD method, there are several stages before finally reaching the final HoQ result. In the first stage, conducting an open survey by asking questions to users to get a list of desired user needs. By obtaining a list of user needs from the survey, the next step is the process of interpreting the list of users that were obtained. This user interpretation includes various lists of user requirements that have been grouped according to their level of importance and giving scores to each attribute according to their level of importance.
Furthermore, after obtaining user requirements from the company, the next step is to prepare HoQ (House of Quality) from the list of user requirements and technical requirements. As well as benchmark the concept of transfer trolley design in HoQ against the concept that has determined in the previous stage.

2.3 Concept Selection

This stage is a step to determine the assessment of the transfer trolley design concept as a reference for assessing the quality and performance of the design concept to be redeveloped. By considering the attributes of user needs in QFD.

2.4 Product Design

The next stage is to illustrate the final concept that has been selected by giving shape using software. By getting the results of two-dimensional, three-dimensional, and overall assembly drawings, as well as displaying the Bill Of Materials (BOM) to contain information about the types of materials used, the parts contained in the design, and the number of parts contained in the design.

3. Result and Discussion

3.1 Voice of Customer Identification

The list of user requirements (VOC) is obtained based on interviews conducted with users. The method used when conducting interviews with users is to attach questions that have been compiled previously, then continue by asking questions to users. Considering that the collection of the list of user requirements uses the one on interviews technique, it is necessary to interpret the voice of the customer both openly and implicitly.

The selection of users, which is on two warehouse operator staff (lead user) as the main user of the transfer trolley at PT XYZ who is responsible for delivering plates from the warehouse area to the material preparation area.

Table 1 Customer Interpretation

No	Voice of Customer	Customer Interpretation
1	Slow transfer trolley speed	Increased trolley transfer speed
2	Transfer trolley sometimes stops in the middle of the road with a certain load (overload)	Increased motor power
3	Sometimes the transfer trolley often breaks down usually because the cable is jammed	Drive system replacement or repair
4	The condition of the rail is not quite good, some parts are warped.	Rail repair
5	Production needs that require up to 4 sheets with 3 tons per sheet so that it is overloaded.	Increased loading capacity
6	Currently, the plate distribution is above 3 tons and the plate length is between 6 meters or above.	Extend the length dimension of the transfer trolley
7	Can use a long-distance remote	Using a wireless remote
8	Deteriorated structure	Structure update
9	When rainy conditions the transfer trolley is not used for fear of short circuiting	Using a water-resistant motor
10	The motor has experienced troubleshooting so the repair time is quite long	Ease of maintenance and quick upkeep
11	There is no safety sign in the area around the trolley when supplying	Improve OHS in the surrounding area by providing a buzzer

After the user interpretation is compiled, the next is to determine the attribute data for user modifications based on primary, secondary, and tertiary attributes. The attribute data for the transfer trolley modification can be seen in Table 2.

Table 2 Attribute Customer Importance Data

ATTRIBUTE			
No	**Primary**	**Secondary**	**Tertiary**
1	Performance & Speed	Increased transfer trolley speed	Expected rate of speed improvement
2		Extend the length dimension of the transfer trolley	Desired dimensions
3			Impact of expansion on overall
4		Increased motor power	Minimum motor HP
5	Complexity	Drive system replacement or repair	Type of drive system to be replaced
6			Convenient technical specifications of the drive system
7		Structure update	New materials or designs to be used
8			Structural parts that need to be updated

9	Reliability & Durability	Rail repair	Rail locations that need to be repaired
10		Using a water-resistant motor	Required water resistance motor specifications
11		Using a wireless remote	Type of wireless remote desired
12	Capacity	Increased loading capacity	Desired load capacity
13	Ease of Maintenance	Ease of maintenance and quick upkeep	Easy to find spareparts
14			Easy maintenance
15	Safety	Improve OHS in the surrounding area by providing a buzzer	Buzzer installation location

3.2 Determine Customer Importance

The next stage is to determine the level of importance of the results of the voice of customer or customer requirements that have previously been compiled based on primary, secondary, and tertiary attributes. Determination of customer importance is obtained directly, namely on the material preparation supervisor (end user) by providing an attachment in the form of a form to determine the priority scale 1-5 of user needs, the more priority scale then the level of importance given the higher the value of the attribute. The level of importance of the transfer trolley modification can be seen in Table 3.

Table 3 Customer Importance Data

No	Primary	Secondary	Tertiary	Customer Importance
1	Performance & Speed	Increased transfer trolley speed	Expected rate of speed improvement	5
2		Extend the length dimension of the transfer trolley	Desired dimensions	4
3			Impact of expansion on overall	3
4		Increased motor power	Minimum motor HP	3
5	Complexity	Drive system replacement or repair	Type of drive system to be replaced	5
6			Convenient technical specifications of the drive system	4
7		Structure update	New materials or designs to be used	4
8			Structural parts that need to be updated	5
9	Reliability & Durability	Rail repair	Rail locations that need to be repaired	2
10		Using a water-resistant motor	Required water resistance motor specifications	2
11		Using a wireless remote	Type of wireless remote desired	2

12	Capacity	Increased loading capacity	Desired load capacity	5
13	Ease of Maintenance	Ease of maintenance and quick upkeep	Easy to find spareparts	3
14			Easy maintenance	3
15	Safety	Improve OHS in the surrounding	Buzzer installation location	2

3.3 Determine Technical Requirements

In this phase is the answer to user needs in the form of technical specifications on the transfer trolley modification. The preparation of this technical requirement is also based on the results of discussions with engineering at PT XYZ, in order that the technical requirements are in accordance with company requirements. Technical requirement can be seen in Table 4.

Table 4 Technical Requirement Data

No	Technical Requirement
1	Specified use the currennt speed to increase performance
2	Transfer trolley dimensions 7000 x 1500 mm
3	Uses considerable motor power
4	Motors rated above or IP54
5	Handles a maximum load of 20 tons
6	Process cycle time capable of supplying 4 pieces of plate ≥ 15 tons without overloading
7	Selection of durable and non complex components
8	Using OHC wheels
9	Rail locations that need to be repaired in the supply area
10	All critical spare parts use the just in time system.
11	The system should have easy access for routine maintenance and repairs
12	Main frame design using H Beam and UNP types
13	The structural section that need to be updated are the main frames
14	Using the same type of remote on the hoist crane
15	Buzzer mounted on the back with loud noise level.

After the technical specifications are obtained, symbols are then given to determine the direction of improvement of these specifications. Among them consist of symbols (▲) maximized, (▼) minimized, and (○) already on target.

3.4 Determine Alternative Concept

a. Alternate Concept A (Fuel Consumtion)

Concept A adopted relies on the working principle of fuel utilization through the KUBOTA Z482 engine. Initially, the drive system is connected to the engine and the hydraulic pump. The hydraulic pump is activated by the engine, then this pump drives the hydraulic motor which is connected to the hydraulic system and control system. The hydraulic motor then directly drives the wheels on the transfer trolley. Some considerations on concept A include:

• This concept uses engines and hydraulic motors that have strong mechanism durability, however, the fast moving components used require maintenance that can be higher.
• By using engines and hydraulic motors, this transfer trolley is less environmentally friendly due to high carbon emissions.

b. Alternate Concept B (Battery)

Concept B is based on the principle of utilizing batteries as the main power source. As the main energy storage source that will provide full power to the transfer trolley drive system. The battery will provide electric current to the transfer trolley drive motor. The motor will directly respond to the movement of the wheel drive. This allows the transfer trolley can move efficiently without the need for additional transmission. Some considerations on alternative concept B include:

• Practicality of using batteries that are understood by engineers, but the cost required to buy batteries and chargers requires high costs.
• In addition to using batteries that are more environmentally friendly and have been studied by engineers, but the transfer trolley has challenges related to battery life.

c. Alternate Concept C (Grid Power)

This concept has a similar principle to the existing system, which uses cable reels. However, the system used is a cable reels system with single reels placed in the warehouse area. Generally this system involves winding the cable from the local main source connected to the reel, then this cable is coiled on the drum / reel and will provide power or control signals to the drive motor in the transfer trolley. The signal will be passed on according to the need to be driven by the motor to the drive wheels. Some considerations on concept C include:

• Using the reliability of cable roll technology, the transfer trolley is vulnerable to unexpected damage and the risk of cable entanglement can still occur.
• By choosing to use a long cable roll for space efficiency, this transfer trolley actually has difficulty in its operation due to the limited area available.

Figure 2. (A) Fuels Concept, (B) Battery Concept, (C) Grid Power Concept


A


B


C

3.5 House of Quality

Overall, to understand the process of working on QFD, the final stage is the House of Quality. At this stage, it can be seen in more detail the process of designing transfer trolley modifications in accordance with the requirements of user needs.

A. Relationship Matrix

Moreover, at the relationship matrix stage, symbols are given that indicate how strong the relationship is between customer requirements and technical requirements. The symbol used at this stage is using the H (High) symbol which indicates that it has a value of 9, the M (Medium) symbol shows that it has a value of 5, and for the L (Low) symbol shows that it has a value of 3. After giving the symbol, the next step is to determine the calculation of technical importance shown by the Equation 1.

$$\text{Technical Importance} = \frac{\text{sum of the relationship weights}}{\text{total sum of the relationship weights}} \text{ x } 100\% \quad (1)$$

B. Technical Relation

At this stage, we correlate the relationship of each technical requirement contained in the roof of the house of quality. The symbols used, which are "+ +" symbol has the definition of strong positive relation, "+" symbol has the definition of weak positive relation, "XX" symbol has the definition of strong negative relation, "X" symbol has the definition of weak negative relation. After determining the correlation between each technical requirement relationship, the next step is to determine the calculation of the level of difficulty shown by the Equation 2.

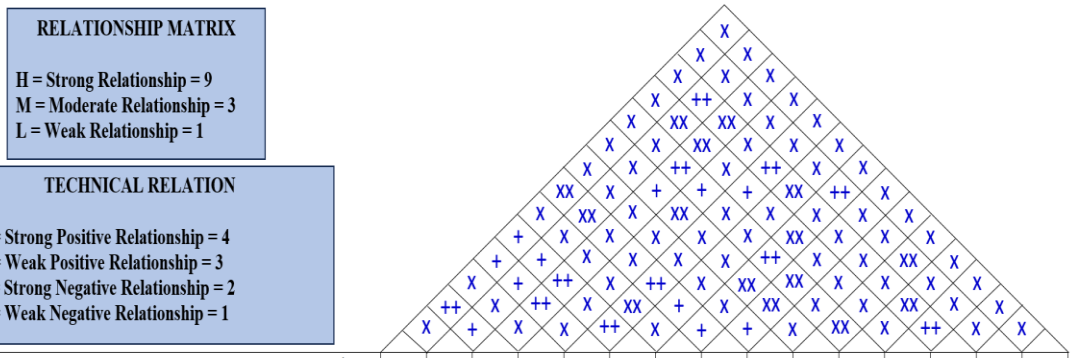
$$\text{Difficulty Rank} = \frac{\text{sum of each technical characteristic}}{\text{total sum of each technical characteristic}} \text{ x } 100\% \quad (2)$$

C. Overall Results HoQ

Based on the House of Quality diagram shown in Figure 4, the highest technical importance value is 10.37% on the technical requirement "Transfer trolley dimensions 7000 x 1500 mm". Through this matrix, the main modification and improvement priority is to increase the length of the material handling equipment by 2 meters or 2000 mm. In addition, there is the second highest requirement, which is "Handling a maximum load of 20 tons". Furthermore, there is a comparison of scores on each technical requirement by categorizing the level of difficulty that is considered the most difficult, which " Handles a maximum load of 20 tons" which is 18.86%. Followed by "Use considerable motor power" with a difficulty level of 18.29%.

3.6 Selection Design Concept

The next step is the concept selection phase which is in line with the process in the House of Quality in the QFD method. This concept selection is taken based on the previous determination, which is then scored against the criteria contained in the customer requirements. In addition, the scoring is taken using the same assessment as in the relationship matrix. The higher the score in the concept selection, the score determines the concept that will be selected. The following is a table of concept selection that will be used.



RELATIONSHIP MATRIX

H = Strong Relationship = 9
M = Moderate Relationship = 3
L = Weak Relationship = 1

TECHNICAL RELATION

++ = Strong Positive Relationship = 4
\+ = Weak Positive Relationship = 3
XX = Strong Negative Relationship = 2
X = Weak Negative Relationship = 1

		Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15				
		Direction of Improvement (↑,O,↓)	↓	↑	O	↓	O	↓	↑	O	↑	↑	↑	O	↑	O	↓				
Customer Importance	Customer Requirements (What's) ↓	Technical Requirements (How's) →	Specified use the currennt speed to increase performance	Transfer trolley dimensions 7000 x 1500 mm	Uses considerable motor power	Motors rated above or IP54	Handles a maximum load of 20 tons	Process cycle time capable of supplying 4 pieces of plate ≥ 15 tons without overloading	Selection of durable and non complex components	Using OHC wheels	Rail locations that need to be repaired in the supply area	All critical spare parts use the just in time system	The system should have easy access for routine maintenance and repairs	Main frame design using H Beam and UNP types	The structural section that need to be updated are the main frames	Using the same type of remote on the hoist crane	Buzzer mounted on the back with loud noise level.	Weighted Score	CONCEPT A	CONCEPT B	CONCEPT C
5	Performance & Speed	Expected rate of speed improvement	H	L	H	L	M	H	L	L	L	L	L	L	L	L	L	205	5	5	5
4		Desired dimensions	L	H	L	L	M	L	L	M	L	L	L	H	L	L	L	140			
3		Impact of expansion on overall	M	H	M	L	H	L	L	L	L	L	L	L	L	L	L	105			
3		Minimum motor HP	H	M	H	L	H	M	L	L	L	L	L	L	L	L	L	129			
5	Complexity	Type of drive system to be replaced	L	L	L	L	L	L	H	H	L	L	L	L	L	L	L	46	1	5	3
4		Convenient technical specifications of the drive system	L	L	L	L	L	M	H	H	L	L	M	L	L	H	L	195			
4		New materials or designs to be used	L	H	L	L	M	L	L	L	L	L	L	H	H	L	L	155			
5		Structural parts that need to be updated	L	L	L	L	L	L	L	L	L	L	L	M	H	L	L	172			
2	Reability & Durability	Rail locations that need to be repaired	L	L	L	L	L	L	L	L	H	L	L	L	L	L	L	46	5	1	1
2		Required water resistance motor specifications	L	L	L	H	L	L	L	L	L	L	L	L	L	L	L	123			
2		Type of wireless remote desired	L	L	L	L	L	L	L	L	L	M	L	L	L	H	L	117			
5	Capacity	Desired load capacity	L	H	L	L	H	H	L	L	L	L	L	L	L	L	L	164	5	5	5
3	Easy of Maintenance	Easy to find spareparts	L	L	L	L	L	L	L	M	L	H	H	L	L	L	L	125	1	5	3
3		Easy maintenance	L	L	L	L	L	L	H	L	L	H	H	L	L	L	L	50			
2	Safety	Buzzer installation location	L	L	L	L	L	L	L	L	L	L	L	L	L	L	H	46	3	5	3
		Technical Importance Score/ Total Score	122	186	122	68	166	146	148	138	68	104	108	126	124	100	68	1794	20	26	20
		Importance (%)	6.80%	10.37%	6.80%	3.79%	9.25%	8.14%	8.25%	7.69%	3.79%	5.80%	6.02%	7.02%	6.91%	5.57%	3.79%	100%			
		Difficulty Rank	12.57%	16.00%	18.29%	9.71%	18.86%	13.14%	14.29%	14.86%	9.14%	12.00%	14.29%	12.57%	14.86%	10.29%	8.00%				
		Target	0.2 m/s	7000 x 1500 mm	≥ 3HP	IP54	≤ 20 Ton	≥ 4 Piece Plates (3 - 3.5 T)	Time Repair Less	Ø 290 mm	Continue	Continue	Continue	Grade 250	Jig Process	JUUKO	77 -98 db				

CONCEPT ASSESSMENT

5 = Positive Relation
3 = Moderate Relation
1 = Negative Relation

Figure 4. House of Quality Diagram

Table 5 Alternative Selection Concept

No.	Criteria Description	Alternate		
		Concept A	Concept B	Concept C
1.	Performance & Speed	5	5	5
2.	Complexity	1	5	3
3.	Reability & Durability	5	1	1
4.	Capacity	5	5	5
5.	Ease of Maintenance	1	5	3
6.	Safety	3	5	3
TOTAL SCORE		**20**	**26**	**20**
• **5 = Positive Relation**		**Concept A = (Fuels)**		
• **3 = Moderate Relation**		**Concept B = (Battery)**		
• **1 = Negative Relation**		**Concept C = (Grid Power)**		

Based on Table 5 results, the highest score indicates that concept B directs the selected answer. Henceforth, the selected concept will be forwarded to the next stage.

3.7 Design Product Results

Overall concept or design on the transfer trolley is still adjusting to the current handling. Following the general requirements of the QFD method, the transfer trolley has a length of 7000 mm and a width of 1500 mm. Because with the addition of the length of the transfer trolley it helps increase the safety of the plate which has a length above 6 meters during the supply process. Combining the main frame with the current frame structurally transfer trolley frame is able to support a load of 20 tons. It was chosen modifications to the main frame of the transfer trolley. Design modifications transfer trolley structure can be seen in Figure 3.

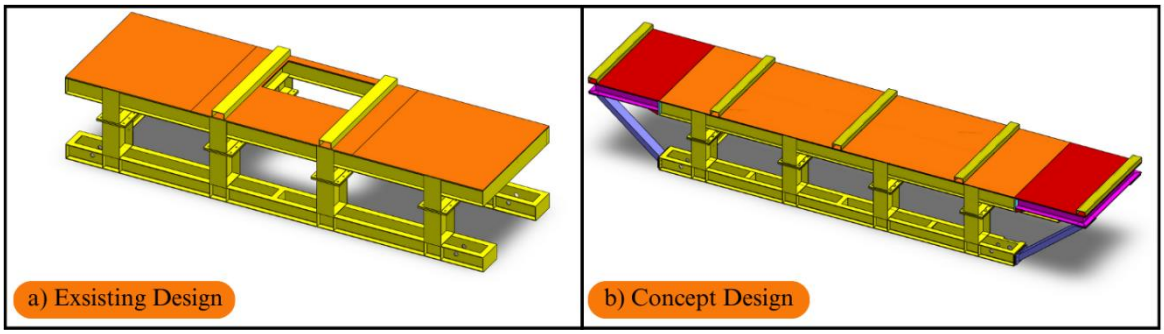


Figure 3. a) Existing Design, b) Concept Design

A. Detail Product

The following is the overall model of the material handling transfer trolley based on the modified design concept with the battery. The overall model is presented in Figure 4.

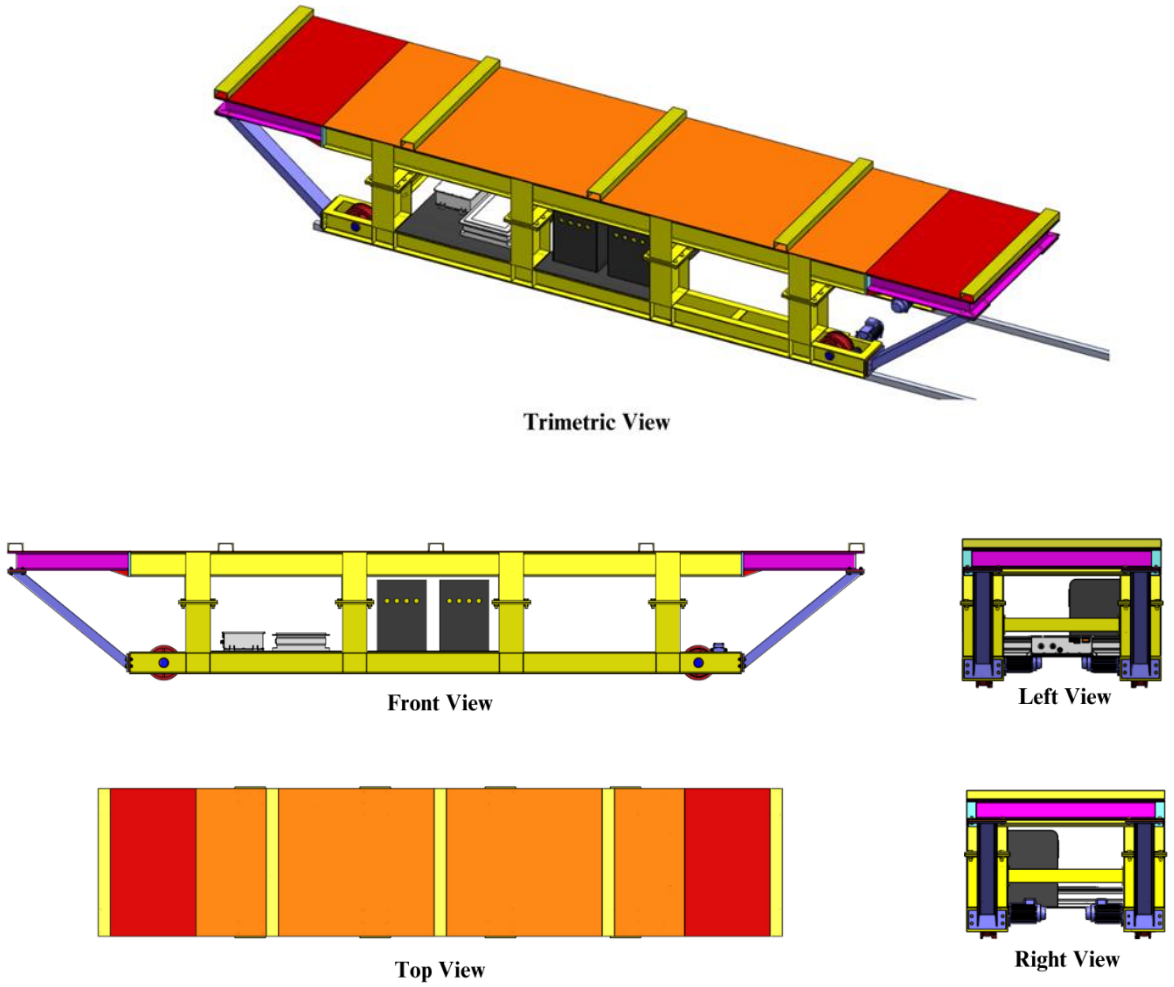


Figure 4. Whole model transfer trolley with battery concept

B. Bill of Material (BOM)

After obtaining product details on the transfer trolley, the next step is the process of determining the materials and components applied to the transfer trolley (Bill of Materials). The loaded list starts from a list of general working drawings, to a list of working drawings that will be modified. In figure 5 shows the depiction of the model as a whole (general) and the number of components contained in the transfer trolley model that can be seen in Table 6.

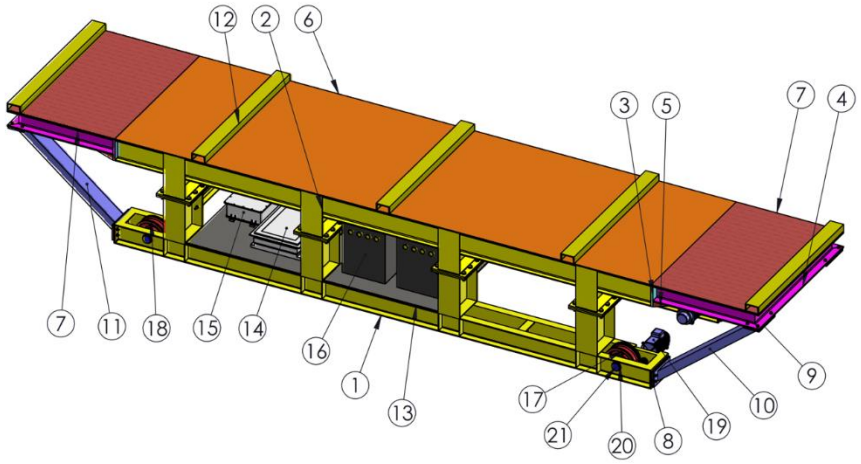


Figure 5. Component arrangement on the transfer trolley

The following is the structure of the bill of materials contained in the transfer trolley.

Table 6 Bill of Material Transfer Trolley

NO	QTY	Part Name	Part Number
1	1	Bottom Main Frame Structure	LRRY01-L1010000
2	1	Top Main Frame Structure	LRRY01-L1020000
3	4	Doubler	LRRY01-L1090000
4	2	Extension Main Frame	LRRY01-L1090000
5	8	Stiffener	LRRY01-L1050000
6	1	Top Plate	LRRY01-L1100000
7	2	Extension Plate	LRRY01-L1070000
8	4	Bottom Reinforcement Support	LRRY01-L1030000
9	4	Top Reinforcement Support	LRRY01-L1120000
10	2	Assy Front Reinforcement	LRRY01-L1130000
11	2	Assy Back Reinforcement	LRRY01-L1140000
12	5	UNP 125 X 65	LRRY01-L1080000
13	2	Additional Plate	LRRY01-L1160000
14	1	Battery Zen Slim 16	LRRY01-L2000000
15	1	Ovartech On-Board Charger 22 KW	LRRY01-L3000000
16	2	Box Control Panel	LRRY01-L4000000
17	2	Front Driven Wheel	LRRY01-L6000000
18	2	Rear Driven Wheel	LRRY01-L7000000
19	2	Electric Motor AC	LRRY01-L5000000
20	8	Double Pin	LRRY01-L1060000
21	4	Cylinder	LRRY01-L1700000
22	40	NUT M12	B-1515-81210
23	88	BOLT M12	B-1010-81250
24	48	NUT M12	B-1510-82016

4. Conclusion and Recommendations

4.1 Conclusion

Based on the objectivity of this research, especially on the improvement of the transfer trolley drive system, there are several conclusions that can be described as follows:

- Selection of alternative transfer trolley drive system concepts using the QFD method with several scoring criteria including; 1) Performance & Speed; 2) Complexity; 3) Reability & Durability; 4) Capacity; 5) Ease of Maintenance; 6) Safety. As a result, concept B was selected with the highest score which proposes a concept with a drive system from the main source of battery.

4.2 Recommendations

According to the results of research that has been done with the QFD method, there are several recommendations for continuing improvements to the material handling transfer trolley that can be used:

1. In handling the transfer trolley, modifications and developments are still needed in the electrical circuit system so that the transfer trolley can be more optimal.
2. Consider the overall investment cost that needs to be incurred to continue handling transfer trolleys with batteries.
3. It is necessary to select the type of charging that is compatible with the environment in the work area.

References

[1] AHK, "Indonesia's downstreaming policy gives its mining sector significant room for growth," Business Indonesia, 2023. https://business-indonesia.org/news/
[2] J. O. Matson and J. A. White, "Operational research and material handling," Eur. J. Oper. Res., vol. 11, no. 4, pp. 309–318, 1982, doi: 10.1016/0377-2217(82)90196-5.
[3] A. S. Deshpande, "Design and modelling of rail transfer trolley," no. 2581, pp. 322–325, 2018.
[4] A. S. Al Kharusi, D. Keloth Kaithari, M. M. Mirza, and P. S. Bhambare, "Electrically operated multipurpose trolley," IOP Conf. Ser. Mater. Sci. Eng., vol. 376, no. 1, 2018, doi: 10.1088/1757-899X/376/1/012108.
[5] ahmad D. Imami and N. Syakhira, "Sustainable environmental and optimizing industry journal," vol. 4, no. 1, pp. 100–109, 2022.
[6] A. F. Simanjorang and A. Arista, "Perancangan jig main steam di PT.Tomoe Valve Batam," J. Comasie, vol. 3, no. 3, pp. 57–63, 2020.
[7] A. Kasan and A. Yohanes, "Improvement produk hammock sleeping bag dengan metode QFD (Quality Function Deployment)," Din. Tek., vol. 10, no. 1, pp. 40–49, 2017.
[8] M. Basuki, S. Aprilyanti, A. Azhari, and E. Erwin, "Perancangan ulang alat perontok biji jagung dengan metode Quality Function Deployment," J. INTECH Tek. Ind. Univ. Serang Raya, vol. 6, no. 1, pp. 23–30, 2020, doi: 10.30656/intech.v6i1.2196.
[9] M. Ustman and D. Suwito, "Pengembangan rancangan desain mesin pencampur ragi kedelai dengan metode QFD (Quality Function Deploymet)," J. Pendidik. Tek. Mesin JPTM, vol. Volume 9, pp. 1–7, 2019.