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Design of Automotive Product Seat Lifting Aids in Minimizing MSD Complaints using AHOQ Method (Case Study: Final Line of Automotive Industry Assembly Process)

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ABSTRACT

Along with the times, every human level and life will be upgraded automatically. Likewise, the company if it does not adjust to the times, it will be difficult to adjust. As with the production process, there will be differences from time to time. From time immemorial, doing work manually, and in the present era using technological tools. Lifting the car seat manually makes the operator complain of pain, due to the high production volume. To eliminate the complaints from these operators, a proposed tool design was made. The method used is Axiomatic House of Quality. In general, Axiomatic Design can help the product development process be more structured with a focus on design that fits the function of the product. The first step in this research is to collect input from customers. Then after getting input from the customer, it is converted into a customer attribute. Then, develop the concept by making several alternatives based on the combination table. Next, determine the design that will be used and carry out testing and coordinate with the user, namely the assembly operator. Finally, determine the specifications and final design of the tool for lifting a seat whose load exceeds the lifting standard. The results of this study are in the form of a design tool for lifting the seat which is expected to reduce complaints of pain to the operator. So that this design design makes the company a consideration for implementation.

INTRODUCTION*

The automotive industry is one of the manufacturers that contributes to the development of the country (Hamizatun, Zuki, & Azizul, 2019). Automotive is one of the most strategic, critical and largest industries (Amrina, Andalas, & Yusof, 2011). One of the most important lines in the automotive industry is the assembly line. This line combines the components needed to produce a ready-to-use product unit. The work process is done manually with a workload and the same way of working over and over again can cause injury to the muscles (Nelfiyanti, Mohamed, & Azhar, 2021).

Musculoskeletal (MSD) is a common complaint in general, especially for those who have a monotonous job (Mishra et al., 2018). MSD is a pain felt in the skeletal muscles that workers feel starting from mild to very painful (Nelfiyanti & Zuki, 2020). This is because the workload performed by the worker exceeds the ability, he has which can result in injury to the body. One of the assemblies works processes that impacts pain on the limbs is the seat assembly process which is part of the final process.

Figure 1. Describes the process of seat lifting work on the final line of the assembly process. The seat assembly process begins by lifting the seat from temporary storage that is moved into the car to be assembled. The workload required by workers during the seat transfer process is> 20. This process and workload give the impact of pain felt by workers during the work process. Workers complained of pain in the arms, back, waist, wrists

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and hands. Therefore, the focus of this research is the design of seat lifting aids in minimizing MSD complaints felt by workers. The design of the resulting tool will be simulated using solid work and mannequins to investigate the results of the application of the tool to the perceived MSD complaints.

Figure 1. The process of lifting and raft seat work into a motor product

from figure 1 it can be seen that the worker works with discomfort such as lifting the seta from the storage and putting it into the car by bending over. Therefore, this study focuses on the design of seat lifting aids in the final process in minimizing MSD complaints felt by workers. This research is conducted on the process of assembling automotive products

Materials and methodology

Quality Function Deployment (QFD)

QFD is a solution and a thought. A powerful method for making the system sustainable among divisions. Such as product planning, design manufacturing, sales (Cohen,1995). This is a powerful method even very powerful. QFD can be developed in an economic environment and based on the increasing dimensions of the mathematical matrix, by connecting several New Products Development (NPD) scopes. Its purpose is to calculate the ranking of numerical indicators and is useful for making a decision (Maritan, 2015).
Several researchers have presented their own definitions of Quality Function Deployment. If considering the environment in which QFD will be applied, for example as part of the NPD, this method needs to be linked to the Total Quality Management (TQM) method (Ghufrani, 2010). QFD is a method of continuous product improvement, the impact of organizations studying innovation and this will be a management tool to the dynamic model of process design (Govers, 2001). According to Cohen, the House of Quality (HOQ) is a framework of an approach to management design known as QFD (Cohen, 1995).

Definition of Axiomatic Design

A tool or design method that aims to define product development by a mapping technique between the functions required by the product and the design parameters. In previous research, AD can help design and develop structured, logical products, and develop HOQs that focus on design and in accordance with product functions.
One of the developers of Axiomatic Design, Professor Nam Pyo Suh MIT (Massachusetts Institute of Technology) is an effort to create design process logic. Axiomatic Design is based on two axioms of Professor Suh's development in the 1970s and 30 more effects and theorems supporting these axioms (Ghufrani, 2010).

House of Quality

The house of quality or commonly called the House of Quality (HOQ) is the first stage in the implementation of QFD. Broadly speaking, this matrix is an attempt to convert the Voice of Customers (VOC) directly to the characteristics or technical specifications of the products or services produced. Making HOQs requires excessive time and costs, moreover the product specifications are not in accordance with the Voice of Customer (VOC) (Manchulenko, 2001).

Product Definition

According to Kotler, the product has a broad understanding is anything that is offered, owned, used, even consumed to satisfy wants and needs including services, physical, people, places, organizations, and ideas. Classification of products into goods or services based on their form is goods and services. Goods are physical tangible products, because they can be seen, touched, touched, felt, held, and treated physically by others. Then services are activities, benefits, and satisfaction provided.

Product Design and Development

According to (Ulrich, 2001), product planning is carried out before the development project is formally approved, important resources are utilized before a larger project development team is formed. Product planning is an event that considers the portfolio of a project, so that organizations can participate and determine what part of what the project will do in a certain period. In planning the product, it is necessary to identify the portfolio of products to be developed and the time of introduction to the market. The planning process is carried out by considering various product development opportunities.

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EXPERIMENTAL METHOD

There are several research methods for scientific work, namely experimental methods, descriptive methods, and evaluative methods. This study uses an evaluative method. Evaluative research is a research that seeks to evaluate the process of testing the development of a product. Evaluative research is intended to measure the success of a particular program, product, or activity. The object of this research is the Final Assembling Path. The stages of the research are as follows.

Preliminary Research Stage

The preliminary research stages carried out are as follows:

1. Literature Study

Literature studies are needed to find information to support the research carried out. The literature study used comes from books, journals, articles, internet, and other libraries that support this research. So with this literature study, obtained in theory about the right method for solving the problem / topic discussed.

2. Field Study

This method is used in data collection, where the researcher is directly involved in the research project. Field studies are useful for researchers because they provide a clear picture of the object of research. The methods used in the field study in this research are questionnaires, interviews, and documentation.

Research Planning Stage

The stages of research planning carried out are as follows:

1. Identifying Problems

Problem identification is carried out based on field studies on the object of research and literature studies on the problems encountered. Field observations and interviews with work station operators at the seat installation post. Then from the literature study, a method will be chosen that can be used

used to solve problems according to the existing situation.

2. Formulate the Problem

After carefully identifying the problem, then proceed to formulate the problem according to the reality on the ground.

3. Determine Research Objectives and Benefits

The research objectives are determined based on the problem formulation that has been described. This serves to determine the limits that need to be understood in data processing and discussion analysis in research. The benefit of research is something that is obtained after the goal is achieved.

Stages of Research Implementation and Analysis

The stages of implementation are as follows:

1. Collecting data

The data collected is internal data which is obtained based on direct observation and the distribution of open questionnaires to the operators of the final lane car seat installation. Then collect external data in the form of historical data which are archives or company documents related to research.

2. Identify customer needs

From the results of the open questionnaire, it was found that several needs obtained from the respondents were then recapitulated into Customer Attribute (CA), which is a domain that accommodates needs from the user's point of view.

3. Determine specifications and targets

At this stage, determining specifications and targets begins by adding functional requirements, adding sizes of customer attributes and design parameters.

4. Develop an integration model between house of quality and axiomatic design

There are several steps in constructing the model, namely:

a. Formulate the design matrix between FR and DP.

b. Correlate between DP.

c. Added Constraints and how they relate to DP.

d. Evaluating the Axiomatic House Of Quality (AHOQ) model that has been assembled from the results of the previous stages.

5. Develop product design concept

Developing a design concept means making several design concepts according to the specifications and targets that have been determined in the integration model between the house of quality and axiomatic design, besides that, it is also assisted by finding information about the product and then making a morphology chart.

6. Choose a product concept design

In choosing a product concept, we compare several product design concepts that have been determined and then create a screening method matrix.

7. Testing the product concept

Collect direct responses to product concept descriptions to related parties on design concepts that have been selected in the previous stage.

8. Determine the final design and specifications

Establish specifications and final product concept designs and make design improvements if necessary.

9. Analysis and Discussion

Analyze the design that has been selected with the results of concept testing that have been obtained.

Conclusion and Suggestion Stage

From the results of data processing, analysis, and discussion that has been carried out, conclusions can be drawn from this research. This refers to the goals that have been set previously, as well as suggestions that will be given for further research.

In a previous study, it was found that the results of complaints from operators of installing car seats using the Nordic Body Map questionnaire.

Table 1. Nordic Body Map Questionnaire Score Recap

No	Work station	Score of questioner NBM	
		Operator 1	Operator 2
1	Seat FR RH	44	44
2	Seat FR LH	42	42
3	Seat RR RH	42	43
4	Seat RR LH	44	43

Table 2. Areas of complaints on the body

No	Complaint
1	Pain/Stiffness in the Lower Neck
2	Pain in Left Shoulder
3	Pain in Right Shoulder
4	Pain in the Left Upper Arm
5	Pain in the Upper Right Arm
6	Back Pain
7	Pain in the waist
8	Pain in the buttocks
9	Pain in the buttocks
10	Pain in Left Elbow
11	Pain in the Right Elbow
12	Pain in Left Forearm
13	Pain in the Right Forearm
14	Pain in Left Wrist
15	Pain in the Right Wrist
16	Pain in Left Hand
17	Pain in the right hand
18	Pain in Left Thigh
19	Pain in Right Thigh
20	Left Knee Pain
21	Pain in the right knee
22	Pain in Left Leg
23	Pain in the Right Leg

RESULTS AND DISCUSSION

Identification of Customer Needs

Identification of customer needs is part of the product development process, as well as stages that are related to the process of conceptualizing, concept selection, and establishing product specifications. Identification of customer needs is done to collect data where customer needs in this case are the operators of the research object. Customer attributes are a form of customer statements that were previously obtained from the results of direct observations and interviews as well as from the results of open questionnaires.

As the questions in the open questionnaire are as follows:

1. What do you think about the current state of the work process?
2. What are the advantages of the current process?
3. What are the drawbacks with the current process?
4. What are the expectations if an improvement is made?

Table 3. Recap of the questionnaire results

No	Answer	Frek
1	Working process with minimal tools	1
	Pekerjaan saat ini sangat menguras tenaga	2
	The current job is very draining	4
	Narrow mounting maneuver area	1
2	Easy installation process	2
	Can be done quickly	1
	The process is done manually or by setting yourself	3
	Little equipment	2
3	High risk of injury	5
	Lifting load exceeds standard	2
	No special tools during the process	1
4	Help ease the seat installation process	2
	There are tools that are easy to operate for the process	4
	Minimize power output	1
	Eliminate manual processes	1

However, not all of the answers to the open questionnaire were Customer Attribute (CA), because the opinions of the workers were different. The following are statements of customers who are customer attributes in this study.

Table 4. Customer Attribute

No	Customer Attribut
1	Tool to help ease the seat installation process
2	Tool Easy mobility
3	Tool to reduce the risk of muscle injury
4	Tool easy to operate
5	Tool to minimize the energy that goes out
6	Tool do not restrict movement

However, not all results from direct observations and interviews should be interpreted as customer attributes. The following is a customer statement and the result of its interpretation becomes a customer attribute. In table 4.4, tools that can ease the seat installation process are tools designed to substitute from manual lifting process to using a tool. Then the purpose of the easy mobility aid is that the tool does not interfere after the lifting process until the seat installation is complete. Auxiliary tools reduce the risk of muscle injury, namely the risk of muscle injury can be eliminated because the previous process was done manually, while after making tools, the work relies on tools. For easy-to-operate tools, it is intended that the tools during the seat handling process do not cause more effort or effort for a process. Furthermore, the tool that minimizes the energy that comes out is because the previous process was a manual process, so the designed tool is not required to spend more energy due to the mobility process of the tool. The last point is that the tool does not restrict movement, this means that the operators are not hindered by their porosity after using the tool.

Assign Specifications and Target

At this stage it explains what a product should do. In determining the specifications and targets, this research is then carried out to determine the Functional requirements, determine constraints, determine design parameters, and develop an integration design of House of Quality and Axiomatic Design.

1. Determination of Functional Requirements

After recapitulating the customer attribute data, the next stage is the creation of functional requirements. From the customer attribute data, it is then simplified to produce several functions as parameters.

Table 5. Functional Requirement

Customer Attributes	Functional Requirement
Tool able to minimize the energy that goes out	1. Tool ease seat lifting
Tools to reduce the risk of muscle injury	
Tool Easy mobility	2. Easy to move
Tool do not restrict movement	
Tools to help ease the seat installation process	3. Easy to operate
Tools easy to operate	

Of the three FRs must be fulfilled and each function is separate from the others. Each functional requirement can be measured its success. And if there are doubts from the three functional requirements, it is necessary to clarify the desired design objectives as functional requirements. For this it can be explained as follows:

FR_1 : Tool to ease seat lift

$FR_{1\ 1}$: The weight lifted is not excessive

2. Determination of Constraints

At the stage of determining the constraints is the most important stage because of its function as a control. In this study, set constraints, namely FR_1 , a tool to relieve seat lift. Based on interviews with the seat installation operator, it was agreed that the maximum load of this tool can lift 50kg.

3. Determine the Design Parameters

After the constraints are set, the next step is to determine the Design Parameters (DP). The purpose of Design Parameters is to represent variables that meet the Functional Requirements (FR).

Table 6. Design Parameter

No	FR	No	DP
$FR_{1\ 1}$	The weight lifted is not excessive	$DP_{1\ 1}$	Lifter
FR_2	Easy to move tools	DP_2	Rail
FR_3	Tools easy to operate	DP_3	Clamp System

$DP_{1\ 1}$ to meet $FR_{1\ 1}$ requires a tool that can lift the seat but work safety is maintained. The DP_2 complies with the FR_2 criteria, because by using the rail, it does not cause limitations in the movement of the operators when carrying out the

process. DP_3 is an element that meets FR_3 , the tool is easy to operate by using a clamp system. Due to the clamp system, the process is simple, only to lock the seat during the lifting process.

Develop an integration model between House of Quality and Axiomatic Design

The AHOQ method is a method that describes the Voice of Customer (VOC) systematically in design development by referring to the functional needs of the customer. The purpose of requirements is to be independent from one another and to allow design changes without affecting other needs.

a. Formulate the design matrix between FR and DP

The design matrix serves to describe the relationship between Design Parameters (DPs) and Functional Requirements (FRs). The identification of the relationship is to ensure that there is no deviation from the function. Therefore, the methodology used is the Axiomatic Design model methodology.

Table 7. Design matrix table

FRs / DPs	DP_{11}	DP_2	DP_3
FR_{11}	1	0	0
FR_2	0	1	0
FR_3	0	0	1

b. Correlation between Design Parameters (DP)

In the HOQ model, the correlation matrix is useful for describing the relationship between technical requirements in a model. However, the AHOQ model is used to better know the dependencies between DPs, if there is a dependency, it is important to determine the positive dependency or negative dependency.

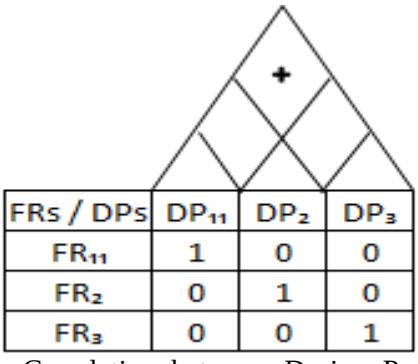

Figure 2. Correlation between Design Parameters (DP)

The correlation in Figure 2 is a positive dependency between the lifter ($DP_{1\ 1}$) and the clamp system (DP_3).

c. Adding constraints and their relationship to DP

At this stage CAs or constraints are applied to the model to determine the effect of constraints on Design Parameters. Constraints on the tool is lifting weight of 50kg, this does not show any effect on the rail (DP_2) and clamp system (DP_3). Constraints only have an effect on the lifter ($DP_{1\ 1}$), but the effect is acceptable. So, the $DP_{1\ 1}$ that is the lifter must be able to lift a load of 50kg.

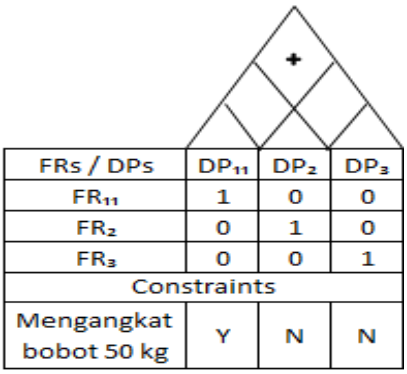

Figure 3. Constraints

c. Evaluating Axiomatic House Of Quality (AHOQ)

This evaluation stage is used to ensure that every customer need has been met in the design to be made. In the final model, it can be seen that the model does not need improvement in the design model, and this is evidenced by:

- The design matrix is an uncoupled design matrix or an ideal matrix, because FRs only have 1 relationship, namely with DPs.
- Design Parameters correlation is a positive dependency, where the dependence between DPs has a positive effect.
- Constraints do not affect DP in existing models.

Develop product design concepts

Table 8. *Morphology Chart*

No	FR	Alternative Concept		
		1	2	3
1	The weight lifted is not excessive	Lifter	Hoist	Hoist
2	Easy to move tools	Rail	Wheel	Conveyor
3	Tools easy to operate	Clamp System	Electric	Electric

It can be seen in the design morphology chart. There are 3 alternative concepts to be defined as the main concepts of the ideal tool and implemented.

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Choosing a Product Design Concept

Determination of the main concept through a selection process by considering customer needs and comparing the strengths and weaknesses of each available concept. The selection of this concept will use the screening method to select and determine the design that will be continued to the next stage. The criteria are used as a benchmark for selecting the conceptualized design.

Table 9. Screening Method

No	FR	Alternative Concept		
		1	2	3
1	Tools to ease the work	+	0	0
2	Tools can be operated easily	+	0	+
3	Tools to speed up work	0	-	-
4	Tools to maintain the quality of work	+	0	0
Count +		3	0	1
Count -		0	1	1
Count 0		1	4	2
Final score		3	-4	-3
Rank		1	3	2
Continue		Yes	No	No

After selecting the three concepts, one concept is then set to be realized as a tool. This selection stage has several assessment criteria, including the criteria for a positive value (+) which means better, for 0 it means the same as, then negative (-) means bad. The resulting values are then summed to get the continuation of each alternative concept. The assessment is obtained by discussing with the operator and the head of the related work station. So that we get a design concept that will be continued to the next stage.

Testing Product Concept

Concept design testing has not been carried out in actual in this study, because the tools are still in the process of being manufactured. However, testing the concept design was replaced by a brainstorming method involving operators and leaders at the relevant work stations. The following brainstorming questionnaire is used to validate customer attributes on the design.

Table 10. Brainstorming Questionnaire

No	**Question**	**Answer**		
		Yes	**No**	**No**
1	Do the tools ease the seat installation process?	√		
2	Are the mobility aids easy?	√		
3	Do assistive devices reduce the risk of muscle injury?	√		
4	Are the tools easy to operate?	√		
5	Does the tool minimize the energy that goes out?	√		
6	Do assistive devices not restrict movement?	√		
7	Is the assistive device sufficient for a maximum load of 50 kg?	√		

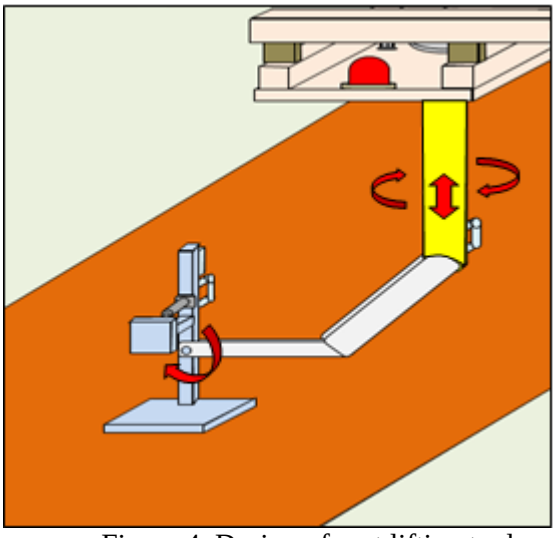

Figure 4. Design of seat lifting tools

When viewing the design of the tool, the operator and the head of the related work station learn how the design of the tool works before making and implementing it. After discussing and the results are getting the shortcomings of the design of the tool and repairs must be made. Improvements to the design of the tool, namely the up and down balancer hanger. Because according to the customer, the hanger has a rotating way of working, so it must be separated by working up and down. This can result in the life of the tool not being able to last long.

Determining the Final Design Specification

At this stage, as is known, the concept design has been improved and meets the criteria required by the customer. The design of the tool has also been agreed to be made and implemented in the seat installation path.

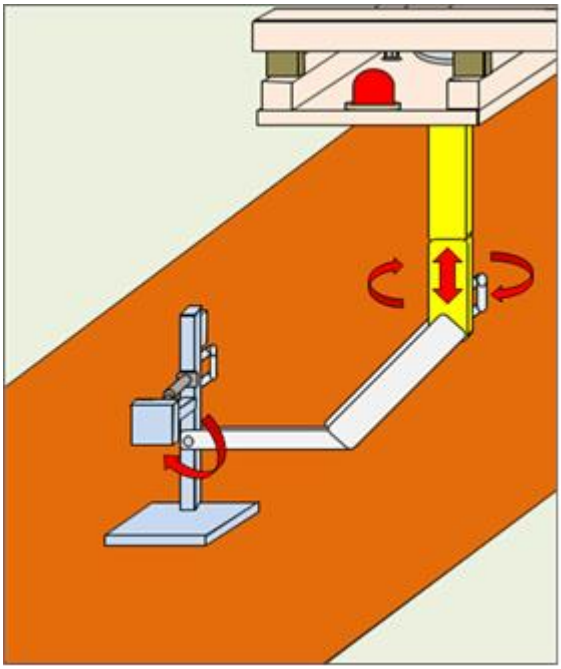

Figure 5. Design of tools after repair

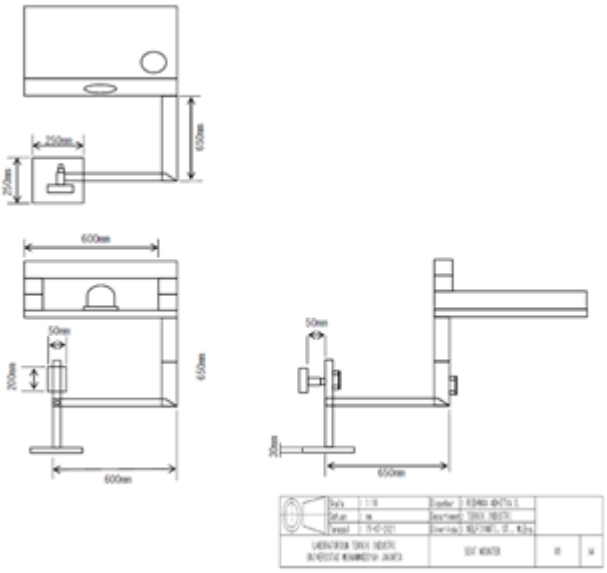

Figure 6. Final design of the tool

CONCLUSION

The conclusions that can be drawn from this research are: The design of the tool based on customer attributes can lift a maximum load of 50 kg. So that complaints of pain caused by manual processes are no longer an obstacle for operators to install seats on the Final route. The design of the tool uses a lifter system, for mobility using a rail mounted on top, and using a clamp system to clamp the seat during the assembly process.

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