Design improvement of pallet in automotive industry

To cite this article: A Bakhtiar and S A Puspitasari 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1072** 012056

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Abstract. In automotive manufacturing industry, supplies of different parts are required to construct products. Products are manufactured as per a company's production targets, and in the effort to do so, some that are sent from suppliers must arrive on time and accordingly. The process of delivery incorporates the use of shuttles where parts are packed into pallets and then sent to warehouses. High demand yields high production that implies high trucking costs. The more pallets used in the transport of goods, the more shuttles are used and the higher the trucking costs. Based on observations of problems, the low effectiveness of the transporting process of goods, among others, is factored by the less than maximum pallet design giving rise to unused spaces within shuttles upon shipment.

1. Introduction

In a supply chain, the pallet becomes a very vital supporting equipment. The role of pallet is much related to warehousing, inventory management and trucking. By definition pallet is a means to transport products or goods, in a large enough amount and in a manner that the products can be clearly classified into types of product. The product or goods are arranged vertically or horizontally depending on the warehousing system used. The pallet has several sizes and types that can be adjusted based on the trucking transportation system and product capacity.

The need for pallets increases as production capacity increases. There are several challenges or course of actions that must be taken when a company possesses its own stocks of pallets, namely (i) the need to supply wood and other supporting materials to maintain the existing pallets, (ii) overseeing of pallets damage that may give rise to claims from vendors, (iii) provision of a warehouse space to store damaged pallets and excess stock, and (iv) human resources that are not specifically trained in handling wood pallets or pallet racks.

An automotive company normally carries very complex process flow, where each workstation requires specific goods or parts compatible for that segment of work, implying the need for supplied goods from a variety of suppliers. In the present case, suppliers do not directly send goods or products to the corresponding company, but rather goods are first delivered into a warehouse. Suppliers are sectored according to geographical area into a Distribution Centre (DC) not far from the company. In the shipment process to the DC, cross docking is carried out where goods or products are stored from the suppliers and then sent to the automobile company. Suppliers transports products or parts in pallets, either in the form of racks, wood pallets, or boxes, according to the specified category of request. The pallets are then loaded into shuttles or trucks that are assigned to several supplier locations.

Cross docking, to some degree, allows savings in logistics and moving costs of products. Nonetheless, avoidable cases of improvidence practices in the transport process as goods are shipped in low or non-optimal quantities, in addition to imbalances that may occur within the pallet loads. In practice, there are only a small number of pallets sent because pallet stacking cannot be carried out, so the shipping process is not optimal with large logistics costs. From this, the researcher will choose the best method to redesign the pallet in order to maximize the quantity and great efficiency in order to reduce logistics costs. Design itself is an activity that results in planning from designing, building and engineering for better innovation. The method that will be discussed and then chosen for product design is the House of Quality, TRIZ, Kano, and DFMEA methods.

2. Literature Review

Based on the introduction above regarding product design, here are some methods available for pallet product design.

2.1. Quality Function Deployment (QFD)

How to prioritize needs and desires as desired by consumers is the understanding of Quality Function Deployment (QFD). The purpose of the QFD principle is to ensure that the needs and desires of customers can be met in the process of reducing a product. Therefore, QFD stems from the voice of the customer (VOC = Voice of Customer) so that it is often referred to as customer-driven product development or customer focused design. The first goal of QFD is to always avoid marketing missed products that fall into the market due to losing competition. And the next goal is to increase the rate and efficiency and the product development process.

Overall benefits of QFD according to [1], namely (i) product design prioritizes the needs and desires of consumers so that it is more easily understood, (ii) analysing the company's performance against its competitors, (iii) concentrate the overall design effort so that it will reduce the time of the product planning process, (iv) reduce the frequency of changes in the design so as to reduce costs, (v) encourage teamwork in making decisions.

There are several deficiencies in the implementation of QFD, which are difficult to distinguish between the different and conflicting needs of consumers, it is difficult to meet the needs of different consumers groups or segments, so it usually takes a long time.

2.1.1. House of Quality (HOQ)

House of Quality (HOQ) is part of the Quality Function Deployment (QFD) which defines consumer desires through consumer opinions, which are then given priority and interpret them into measurable specifications (engineering requirements) and set targets according to existing needs. QFD is also a tool used to determine problems that need to be resolved appropriately, where HOQ is used to build information and documentation acquisition.

There are two aspects that must be clear in HOQ according to [2]. First, specification of dimensions that can support the product. Size is a necessity in conceptualizing a product, where the size requires a goal value that helps in measuring performance, the value can be specific. Second, the point of view of the functional needs of users or consumers.

This aspect is one of the supporting aspects of the consolidation of a product. This is because during the process of determining product specifications, it must be more comfortable to use than the previous concept and fulfill the fundamental needs of its use: (i) Identifying user needs into product attributes to find out how the user's or consumer's opinion of a product is generally the consumer states his opinion the most important thing is to identify the consumer's desire to avoid misinterpretation. (ii) Determine the relative importance of attributes by giving an average weight to each attribute using a priority scale based on questionnaire and interview data for (HOQ). (iii) Evaluate the attributes of existing products to analyze satisfaction ratings on existing products and respondents have used to assess each statement of needs on a scale of 1 to 5. (iv) Making a matrix of relationships between attributes and product characteristics. (v) Identifying the relationship between product attributes and technical characteristics to provide a score making it easier for the design team to identify the characteristics that most influence customer satisfaction. (vi) Identifying relevant interactions from the results of this stage will be placed on HOQ. (vii) Determine the picture to be achieved satisfying the desires of consumers and improving their products beyond existing competing products. Tools of HOQ are presented in Figure 1.

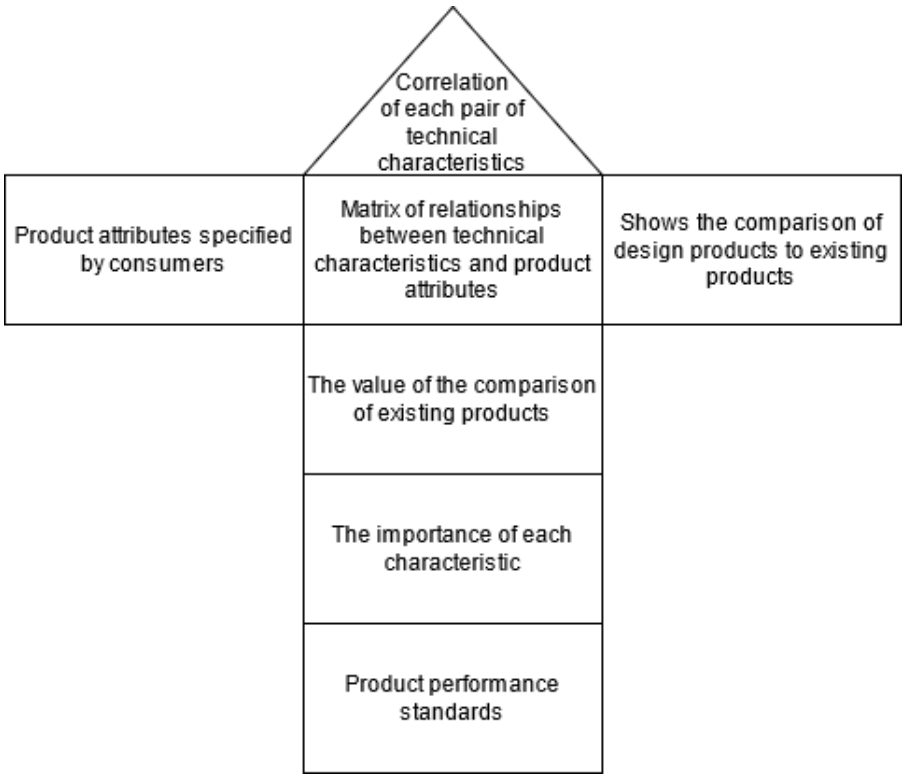

Figure 1. House of Quality tools [3].

2.2. Kano model

The model that can be used to classify product or service attributes based on the level of customer needs is also called the Kano model. Where the canoe model helps in increasing the level of expectation and satisfaction of its customers.

Mapping consumer choices is a way to understand the service attributes that are expected and chosen by customers to get satisfaction. The canoe method can do reference mapping so that an acceptable understanding and influence consumers will be able to save a lot of expenditure and energy for the product provider so that it can determine a good strategy for maximum results [4].

There are several advantages of classifying customer voices with canoe diagrams, namely (i) prioritizing needs for future development, (ii) can identify critical customer requirements that have a large impact on customer satisfaction, (iii) can get exchange value if customers have. There are different needs that cannot be met at the same time it can minimize the impact on customer satisfaction.

According to [5] there are several classifications of product and service attributes in the canoe model, namely there are six categories: One dimensional, then the second must be, then attractive, indifferent, reverse, and questionable. Where asking this clarification is done by paired questionnaires with questions that are functional and dysfunctional. Then the results are reclassified using the Kano evaluation table is presented in Table 1.

2.3. Theory of Inventive Problem Solving (TRIZ)

One method to help solve problems based on data and logic, thus accelerating the team to solve problems creatively is the definition of the Theory of Inventive Problem Solving (TRIZ) method. Where the purpose of TRIZ is asked to be able to solve problems creatively in which there is an ideal design, contradiction and innovation process.

This contradiction is a conflict where if one parameter causes other parameters to change or decrease. Where the main purpose of TRIZ is to find the ideal or perfect solution, in which there are 4 aspects, namely perfection, function, contradiction and the use of resources.

In conducting problem solving, TRIZ has 4 steps and this can be applied in the design of pallet products, namely (i) Specific Problems, which define and analyze problems in the innovation process. (ii) General Problem, analyzing the cause and effect that existed at the beginning of the problem which will then be translated into 39 parameters. (iii) General Solution, here improving and worsing features which are then incorporated into the TRIZ contradiction matrix with 40 principles to find solutions. (iv) Specific Solution, an analysis of the application of principles chosen based on priority. Section of contradiction matrix is presented in Figure 2.

The advantages of TRIZ in contradiction can be resolved by the application of innovative solutions. There are 3 basic principles, namely according to [3] (i) ideal design is the goal, (ii) contradiction helps to solve problems, (iii) the innovation process can be configured systematic.

As the definition, the aim of Triz is to solve problems creatively. The basic concept itself consists of contradictions, ideal designs, and innovation processes. Contradiction means opposition. This usually occurs when we make an increase in one parameter, but cause the other parameters to go down. The contradiction itself is divided into 2, namely technical and physical contradictions.

Table 1. Kano evaluation table [5].

		Dysfunctional form of the question				
Customer needs		**1.I like this feature omitted**	**2. I need this feature omitted**	**3. I am neutral about this feature**	**4. I can live with omitting this feature**	**5. I dislike omitting this feature**
Functional form of the question	1. I like this feature included	Q	A	A	A	O
	2. I need this feature included	R	I	I	I	M
	3. I am neutral about this feature	R	I	I	I	M
	4. I can live with including this feature	R	I	I	I	M
	5. I dislike including this feature	R	R	R	R	Q

Notes: A – Attractive need; O – One dimensional need; M- Must be need; I – Indifferent; R – Reverse; Q - Questionable

Worsening Feature → / Improving Feature ↓		Weight of Moving Object	Weight of Stationary Object	Length of Moving Object	Length of Stationary Object	Area of Moving Object	Area of Stationary Object	Volume of Moving Object	Volume of Stationary Object	Speed	Speed
		1	2	3	4	5	6	7	8	9	39
1	Weight of Moving Object	–	–	15,8, 29,34	–	29,17, 38,34	–	29,2, 40,28	–	2,8, 15,38	35,3, 24,37
2	Weight of Stationary Object	–	–	–	10,1, 29,35	–	35,30, 13,2	–	5,35, 14,2	–	1,28, 15,35
3	Length of Moving Object	8,15, 29,34	–	–	–	15,17, 4	–	7,17, 4,35	–	13,4, 8	14,4, 28,29
4	Length of Stationary Object	–	35,28, 40,29	–	–	–	17,7, 10,40	–	35,8, 2,14	–	30,14, 7,26
5	Area of Moving Object	2,17, 29,4	Area of	14,15, 18,4	–	–	–	7,14, 17,4	–	29,30, 4,34	10,26, 34,2
6	Area of Stationary Object	–	30,2, 14,18	–	26,7, 9,39	–	–	–	–	–	10,15, 17,7
7	Volume of Moving Object	2,26 29,40	–	1,7,4, 35	–	1,7,4, 17	–	–	–	29,4, 38,34	10,6, 2,34
8	Volume of Stationary Object	–	35,10 19,14	19,14	35,8, 2,14	–	–	–	–	–	35,37, 10,2
9	Speed	2,28, 13,38	–	13,14 8	–	29,30, 34	–	7,29, 34	–	–	–
10											
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38											
39	Productivity										

Figure 2. Section of contradiction matrix [3].

2.4. Design Failure Mode Effects Analysis (DFMEA)

DFMEA stands for Design Failure Mode Effects Analysis. This methodology helps identify potential failures in product design at the development stage. In most cases, engineers use this as a procedure to explore possible design failures in real-world situations or uses. Matrix DFMEA is presented in Figure 3.

DFMEA is an analysis of failure models that can occur due to product design. DFMEA is almost the same as PFMEA (Process Design Failure Mode Effects Analysis). The difference is that PFMEA is for process analysis, whereas DFMEA is more focused on product design. The output from DFMEA is used for PFMEA analysis. The relationship between these two documents is very important to be able to produce products according to the initial design. For example, failure mode in DFMEA and failure mode in PFMEA can produce the same potential effects. In this case, the effect of design failure mode must be shown on the potential effect and severity value of DFMEA and PFMEA.

Indeed, not all elements in DFMEA will be seen directly related to elements in PFMEA, because the focus is different. Information from each column is not always the same. For example, the potential design failure mode is not the same as the potential process failure mode, the potential village cause is not the same as the potential process cause. But by comparing the entire contents, we can get the connection. For example the relationship in terms of special characteristics in DFMEA and PFMEA.

The steps to design a product design using DFMEA's Design Failure Mode Effects Analysis are: (i) Design Review. To help ensure all team members are familiar with the product and its design, identifying each of the main components of the design. (ii) Review Potential Failure. Review existing documentation and data for instructions. Consider potential failure modes for each component and interface. (iii) List of Potential Failure Effects. There is more than one effect for each failure. The effect is directly related to the ability of certain components to perform the intended function. (iv) Assign Severity. Determine the severity rating for each effect that has been identified. Severity is an estimate of how serious the effect will be. Severity rating is based on a relative scale ranging from 1 to 10. Rating "10" means the effect has a very high severity level that leads to danger without warning and vice versa. (v) Assign Occurrence. Event rating is based on how often the cause of failure is likely to occur. So it is necessary to know the potential causes to rank the events because, as the severity ranking is driven by effects, the ranking of events is a function of the causes. Severity rating is on a relative scale from 1 to 10. Occurrence rating of "10" means the appearance of failure mode is very high, it happens all the time and vice versa. (vi) Assign Detection. Detection rating is based on the possibility of failure will be detected before the customer finds it. To assign a detection rating consider the design or control associated with an existing product for each failure mode and then assign a detection rating to each control. The detection rating of "1" means the possibility of detecting failure is almost certain and vice versa. (vii) Calculating RPN. RPN gives us a relative risk rating. The higher the RPN, the higher the potential risk. Calculate RPN for each mode and failure effect. The RPN formula is RPN = Severity x Occurrence x Detection.

Each of the three relative ranking scales ranging from 1 to 10, the RPN will always be between 1 and 1000. (viii) Developing an Action Plan. Taking action means reducing the RPN. RPN can be reduced by decreasing one of the three ranks (severity, occurrence, or detection) individually or in combination with each other. (ix) Taking Action. Implementing identified improvements such as outlining what steps are needed to implement the solution, then responsibilities and target completion dates for the specific actions to be taken are identified. (x) Recalculate the Resulting RPN. Re-evaluate each potential failure once repairs are made and determine the impact on the RPN.

Prototype Pre-launch Production FMEA Number:					Key Contact / Phone						Date (Orig.)	Revision Date / Rev. Level					
Part Number / Revision Level:					Core Team:						Plant Approval / Date						
Part Name / Description:											Customer Engineering Approval (if required)						
Device Code:				Plant Code:	Supplier / Plant:						Customer Quality Approval (if required)						
													Action Results				
Part Number	Number and Description of Operation	Process Function	Potential Failure Mode	Potential Effect of Failure	Y/N	SEV	Potential Cause(s) Mechanism(s) o Failure	OCC	Current Controls Detection / Prevention	DET	RPN	Recommended Action	Responsible & Completion Date	Action Take	SEV	OCC	DET	PRN

Figure 3. Matrix DFMEA [6].

3. Method Analysis

Based on the background, the automotive company needs to design a pallet product so that it can increase the effectiveness and efficiency of cross docking activities, namely by using a shuttle to carry pallets containing parts needed by automotive companies, in order to reduce the cost down the company wants.

Here are the advantages and disadvantages of each method are presented in Table 2.

Table 2. Advantages and disadvantages of the method.

Methods	Advantages	Disadvantages
QFD	- According to the wants and needs of consumers, - Quality improvement, Consumer satisfaction, - Reduction of costs, profits, - Time to market - Comparison of existing products	- It's hard to distinguish between conflicting needs, - Difficult to meet all segments, - Long time - Large questionnaire
TRIZ	- Knowing contradictions, ideal design, systematic, technological principles - Includes many categories	- Not focus on one segment - Too many variables
DFMEA	- Knowing the product failure, - Know the level of risk of severity, incidence and detection, - Priority of action, - Customer satisfaction, - Reducing time and costs, - Failure control	- Different focus, - Long time - Design shoes
KANO	- Easy to understand product specifications according to needs - Easy to determine the priority product attributes into specifications - Easily differentiate and compete with other products	- Only presents classification results not quantitative values - Only the results of the selection of the level of customer satisfaction without explanation.

The QFD method cannot be chosen because QFD uses a questionnaire from the customer, thereby increasing the effectiveness and time efficiency of a product, but in the case of pallets, the company does not need the customer's voice to get the desired pallet design according to the customer's voice, so what is needed is between suppliers and companies only.

The TRIZ method has advantages because it covers a broad scope with many basic principles and has contradictions, which all have in designing product designs but in the case of pallet to 40 these basic principles are too broad and not specific. While the canoe method has the advantage of knowing how well the attributes are to satisfy consumers, but also the disadvantages that canoes have because they are less able to capture all the voices of consumers.

The chosen method is the FMEA method which is then continued with DFMEA. So that in this FMEA, the product can be analyzed for the failure rate and the level of risk that exists in the product, then it will be continued with DFMEA which is to find failures in product design after finding a failure of the process.

The main purpose of DFMEA is to uncover potential product design failures. A basic review of DFMEA is carried out using a product scheme, DFMEA helps analyze potential product design failures at the design and development level. In addition, this methodology will reduce production costs and also the possibility of failure in product launches.

Steps that can be taken in designing the pallet using the DFMEA method are: (i) design review, (ii) reviewing the potential failure, (iii) list of potential failure effects, (iv) setting the severity, (v) setting the occurrence, (vi) setting the detection, (vii) calculate RPN, (viii) develop an action plan, (ix) take action, (x) recalculate the resulting RPN.

4. Conclusion

Based on the discussion in this review literature, the researcher concludes several research results, that: The method chosen in designing the pallet design uses the DFMEA method. DFMEA is a document that

continues to grow. All updates and changes to the product development cycle are made for the product or process. This change can and often is used to recognize new failure modes.

DFMEA indicates the likelihood of failure, the severity of the risk, existing controls, recommendations and improvements after the recommended action. The main objective of both is to reduce or avoid major product and production deviations. This methodology can reduce design or operating costs too. Furthermore, some failures might not be reduced at FMEA. This failure can be transferred to DFMEA to take the control needed for pallet product upgrades.

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