Proposed Framework of Product Redesign Need Assessment based on Customer Requirement, Complaint and Failure Analysis

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Abstract

Rapid technological change, increasing product complexity, and relatively short marketing time are challenges of today's manufacturing businesses. New product development and introduction are required to keep the business continuity of a manufacturing company and win the competition. In an ideal world, every product would be tailored to the customer's demands. The user of a product expects a high-quality, dependable product. Customers may get a defective product and file a complaint. This unpleasant experience of product users could be utilized as feedback to improve existing product design. Identification of functional components is the essential stage of product redesign. Customer requirements are primarily used to prioritize function components, whereas complaint and failure knowledge, which are also crucial for improving product reliability, is frequently overlooked. This paper proposes an integrated framework development of need assessment in product redesign based on customer requirements, complaints, and failure analysis. Customer requirements are used in product redesign through quality function development (QFD), while failure analysis is followed by failure mode and effect analysis (FMEA). Data complaints would be arranged to follow the Kano-QFD/FMEA to be developed in an integrated manner. This proposed framework may improve the product's reliability and quality by simultaneously considering the customers' requirements, complaints, and the product's risk priority number, and therefore improving the product's market competitiveness.

Keywords
Complaint, customer requirement, FMEA, Kano-QFD, product redesign

1. Introduction

Rapid technological change, increased product complexity, and a relatively short time to market are all challenges facing the manufacturing business. As a result, new product development is required to stay competitive. After a product has been on the market for a while, it is frequently necessary to redesign it. Redesigning products is done for a variety of reasons. First, the design fails may be discovered, or customers' needs may alter (Smith, Smith and Shen, 2012). Redesigning products can also increase quality, lower prices, lengthen product life, and lower environmental impacts. Consequently, redesign is a critical aspect of the product development.

During the early design phase, a large amount of data is collected and processed to aid in the decision-making process that leads to product synthesis. Several strategies have been created to assist in collecting, organizing, analyzing, synthesizing, and displaying data utilized in the design process. Among these strategies are Failure Modes and Effect Analysis (FMEA). Kano, and Quality Function Deployment (QFD). Each one is a formal process aimed at achieving specific objectives. Customer value has been highlighted as a vital success factor in the early stages of new product development. Customer satisfaction can be affected by the quality of goods. Consumer dissatisfaction is usually shown in the form of complaint behavior.

Consumer feedback is a reflection of user satisfaction and complaints. This information is beneficial for enhancing product quality. From the early design stage to detailed engineering design, the manufacturing product design process takes into account not only customer requirements (Suef, Suparno, and Singgih, 2013; Nault et al., 2015; Shaker, Shahin, and Jahanhan, 2019) but also customer complaints (Suef, Suparno, and Singgih, 2013; Nault et al., 2015; Shaker, Shahin, and Jahanhan, 2019). Previous research have created an FMEA-Kano integration model for product development to bring customer needs and design requirements closer together, resulting in improved quality and customer satisfaction (Tuertmann et al. al., 2016; Suef, Suparno, and Singgih, 2017; Lorenzi et al., 2018). Shahin et al. (2013; 2017). Ma et al. (2016; 2019) created a QFD-FMEA integration model to identify product components that could be improved to be more reliable. Ginting et al. (2020) effectively combine the method of design for manufacturing & assembly (DFMA) model with QFD in product design and development from the planning stage through the conceptual design. The combination of QFD-DFMA, according to Chiu et al. (2011), can be utilized to reduce the quantity of material and energy used, reduce emissions, and optimize material capacity. Product design research using hybrid techniques takes an integrated approach, both conceptual design and process planning.

Along with the global competition in the manufacturing industry, research in the QFD-FMEA and DFMA area needs to be developed, considering the industry's commitment to product improvement. The QFD-FMEA approach in several recent studies is a tool for analyzing consumer needs and product failure mechanisms. Consumer needs become a significant factor in product development design, as well as in design improvement. The existence of uncertainty factors and the risk of failure in product redesign encourages the decision-making process at the early stages of design to consider failure modes and risks before implementing the strategy in the manufacturing process.

However, it is difficult to solve problems in product redesign accurately at the initial conceptual design stage, especially in fulfilling customer satisfaction which accommodates customer complaints and considering previous product failure modes. Several integrated design models have been proposed to overcome this problem. Still, efforts to integrate all three considerations in product redesign at the early conceptual planning stage have not been achieved. This research develops a proposed framework development of product redesign based on customer requirements, complaints, and failure analysis**.** The following is the structure for this article. In section two, we present a structured literature review of current research in the relevant area (see Table 2). To fill the niche we describe the research methodology and the proposed an integrated framework in section three. The following sections discuss the opportunities for future research, while the last section concludes the article.

2. Literature Review

2.1. Product Redesign

Frequently, new products are developed by redesigning existing ones. Redesigning products has become necessary in product development (Zhang, Chu, and Xue, 2019). The primary goal of product redesign is to increase customer satisfaction by enhancing the desired target qualities. As a result, identifying improved product features remains a challenging prospect in product redesign research. These enhanced product features are implemented through product redesign in response to changing client needs and satisfaction (H. Ma et al., 2019). The process of determining which components and aspects of a product should be upgraded or redesigned has been a critical field of research in recent years to increase product quality and lower production costs. Table 1 shows preliminary researches in the product redesign area in the last five years.

Table 1. Preliminary Research in Product Redesign

No.	Article	Objectives	Case Study	Tools & consideration
1	(Salim et al., 2019)	Using DFMA approach and design efficiency on two different designs	Agar wood extracting oil machines	Assembly time, total cost, number of parts, design efficiency

No.	Article	Objectives	Case Study	Tools & consideration
2	(L. Zhang, Chu, & Xue, 2019)	Identify features to be improved with manufacturing costs, redesign lead times and technical risks consideration	Smartphones	Data mining, online review, redesign index, optimization model, python
3	(Farahin, Effendi, & Radhwan, 2019)	Design improvement of Wing 2 HLK168 Drone Controller based on DFMA method	Drone controller	Catia, assembly cost & time, model Boothroyd
4	(Xin, Farizuan, Radhwan, Shayfull, & Fathullah, 2019)	Product redesign through the assembly process with consideration of manual handling time, manual insertion time, total assembly time, design efficiency through the DFMA method.	Drone Remote Control	DFMA, CAD, design efficiency
5	(H. Ma, Chu, Xue, & Chen, 2019)	Using fuzzy QFD and FMEA to improve the design of selected components in a complex products and systems.	Crawler crane	QFD, FMEA, fuzzy, directed causality relationship model
6	(Butt & Jedi, 2020)	Using DFMA methodology for manufacturing cost reduction and design efficiency	Dust filter tool	DFMA, Pugh controlled convergence
7	(El-Nounu et al., 2018)	This article examines existing design-for-assembly approaches in light of the specific issues that come with legacy product redesign.	Butterfly bracket	DFA
8	(Ahmed Mohamed Wahba El Hadad & Ahmad Humaizi Bin Hilmi, 2016)	Assembly time reduction on the Rapman 3.1 3d Printer through the DFMA approach.	Printer	DFMA, assembly time
9	(Basarir & Cem Altun, 2018)	Development of manufacturing process redesign procedures on adaptive facades with standard products.	Sunscreen panel	Reverse engineering, DFMA
10	(Harlalka, Naiju, Janardhanan, & Nielsen, 2016)	Development of product redesign concepts to reduce the number of components and manufacturing costs with DFM and CAD approaches.	Food processor	DFMA, CAD, cost modelling

2.2. Customer Requirements and Complaints

Customer requirements should be taken into account throughout the product development process to avoid producing inefficient products. Customer needs have aided in the development of new products and services by research and development (R&D). Customers' suggestions and concerns might assist you in developing new product concepts. Furthermore, considering consumer wants during new product development (NPD) can increase the number of new ideas and hence improve innovation quality. The impact of recognizing consumer needs on development activities and new products has been established in an empirical study (Joung, Jung, Ko, & Kim, 2018). As a result, recognizing consumer requirements serves as a beginning point for organizations' entire development operations, such as R&D and the launch of new products or services, to be more effective and efficient.

Previous research emphasized on customer needs that are directly related to a product's execution phase. Customer's requirements in the pre- and post-use stages of a product should also be taken into account. Consumer complaint studies have traditionally concentrated on behavioral reactions, or consumer activities that directly indicate an expression of dissatisfaction. Early in the new product development process, incorporating the customer value has been diagnosed as a vital success factor for product development. The quality of items might have an impact on customer satisfaction.

Consumer dissatisfaction is usually shown in the form of complaint behavior. Complaint behavior is defined as any possible dissatisfaction consumers feel at the time of purchase, during the consumption process, or during the possession of the item (see Figure 1). Complaint behavior theory is one of the disciplines in post-purchase consumer behavior that occurs after evaluating product and service consumption which can indicate loyalty and dissatisfaction behavior shown by complaints (Zeithaml, Bitner, & Gremler, 2009). Complaint behavior has an influence not only on customer perceptions of the product but also affects other customers such as family and friends. In addition, Ndubisi and Ling (2006) and Donoghue (2010) illustrate that complaint behavior can cause customer loss, and retaining loyal customers can reduce costs rather than attract new customers.

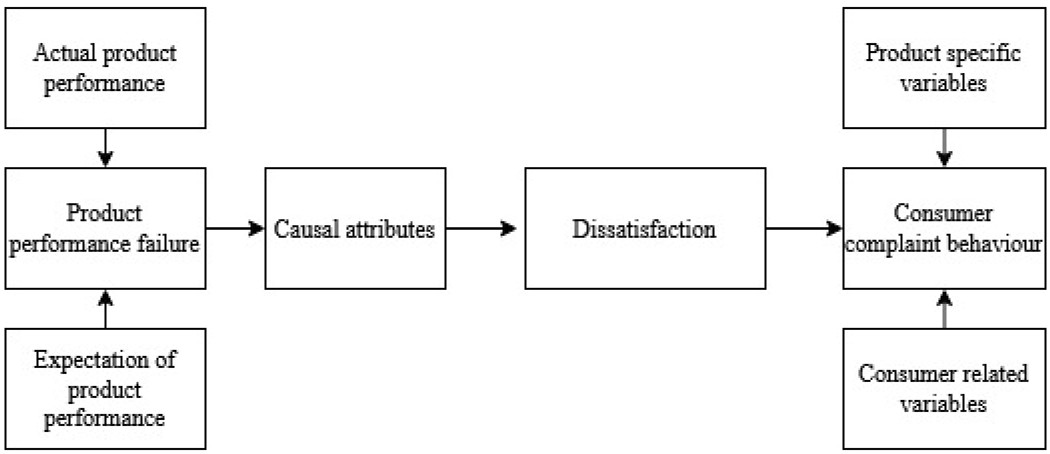

Figure 1. Dissatisfied consumers' complaint behavior concerning the performance failure (Donoghue & De Klerk, 2010)

2.3. Kano Model

Dr. Noriaki Kano established the Kano model in 1984 to classify product or service features into five categories based on how effectively companies may satisfy customer expectations. Kano model measures the relationship of satisfaction/dissatisfaction and the degree to which requirements are fulfills. Kano principles could determine any non-essential factors that can be eliminated without harming the consumer impression of the product or service, in addition to the fundamental and special requirements. Because the concepts of the basic and particular criteria are described in depth, the Kano model was adopted (Shaker, Shahin, & Jahanyan, 2019a; Singgih, Karningsih, Suef, & Dalulia, 2018). The Kano classification (see Figure 2) breaks the types of service attribute criterion into five categories:

a. Must be: Customers will be dissatisfied if product attributes operate poorly or are removed. However, boosting the performance of product attributes will not bring excessive satisfaction.
b. One-dimensional: Customer satisfaction will rise if product attribute performance is excellent. Otherwise, if product attributes perform poorly, consumer satisfaction will suffer.
c. Attractive: Customer satisfaction will grow exponentially as service attribute performance improves. However, a reduction in customer satisfaction will be accompanied by a decrease in the performance of the company's service qualities. Customers, on the other hand, will not be dissatisfied if the product attribute is not given.
d. Indifference: Customer satisfaction is influenced by these categories. The performance of the service attributes in the indifference category will have no impact on customer satisfaction.
e. Reverse: Customers are dissatisfied with the increasing performance of product attributes.

Research by Shahin et al. (2013; 2017) developed an FMEA-Kano integration model for product development to bring customer needs and design requirements closer to improving quality and customer satisfaction. Ma et al. (2016; 2019) developed a QFD-FMEA integration model to identify product components to be redesigned with higher reliability. Feedback from consumers is a representation of user satisfaction and complaints. This information is valuable in improving product quality. The manufacturing product design process is not only fulfilling customer requirements from the early design stage to the detailed engineering design (Nault, Peronato, Rey, & Andersen, 2015; Shaker, Shahin, & Jahanyan, 2019). But it also considers customers' complaints (Suef, Suparno, & Singgih, 2013; Tuertmann, Ruessmann, Schroeder, Linder, & Schmitt, 2016). Fixing products concerning customer claims or complaints is always performed incapacity of the company. It is aligned with the quality initiatives practices.

2.4. Failure Modes and Effect Analysis

Failure Modes and Effect Analysis (FMEA) is a design approach for product and system reliability studies. FMEA simplifies the process of identifying, analyzing, and systematically evaluating the impact of failures in a product or system structure (C F Liew et al., 2019). Several new model developments and practices have been integrated and tested to enhance the contribution of fuzzy FMEA, DEMATEL, the technique for order preference by similarity to ideal solution (TOPSIS), fuzzy TOPSIS, process analytic hierarchy, network artificial neural networks, grey theory, application of quality functions (QFD), and others (Ma et al., 2016; Gu, Cheng, and Qiu, 2019). Because FMEA analysis cannot use relevant information on customer requirements and technical attributes to determine the order of priority for addressing failure modes, combining QFD with FMEA can aid in the elimination of faults. Extending each phase of QFD under identical conditions provides knowledge and a basis for FMEA analysis and failure mode interpretation.

QFD is a consumer-driven strategy for the development and processing of new products in order to optimize customer satisfaction. Its main principle is to gather all consumer demands data for a product. Customer requirements should be reflected in the product's associated features, fundamental challenges, and goal values, and they should be consistent, bridging the gap between customer demand and product function. Gu (2019) gained complementary advantages by combining QFD and FMEA, taking into account the dangers of each fault model and the customer requirements of the system during the design process, allowing the fault mode to be enlarged more extensively. The importance of technical attributes is brought back into the FMEA risk assessments, and the concept of a corrective coefficient is developed, improving the accuracy of component priority orders. Moreover, the extension of each phase of QFD provides data and a framework for FMEA analysis and failure mode evaluation. However, Gu (2019) has not discussed the input of quality initiatives in detail, whether it is only consumer needs or to consider consumer claims and complaints.

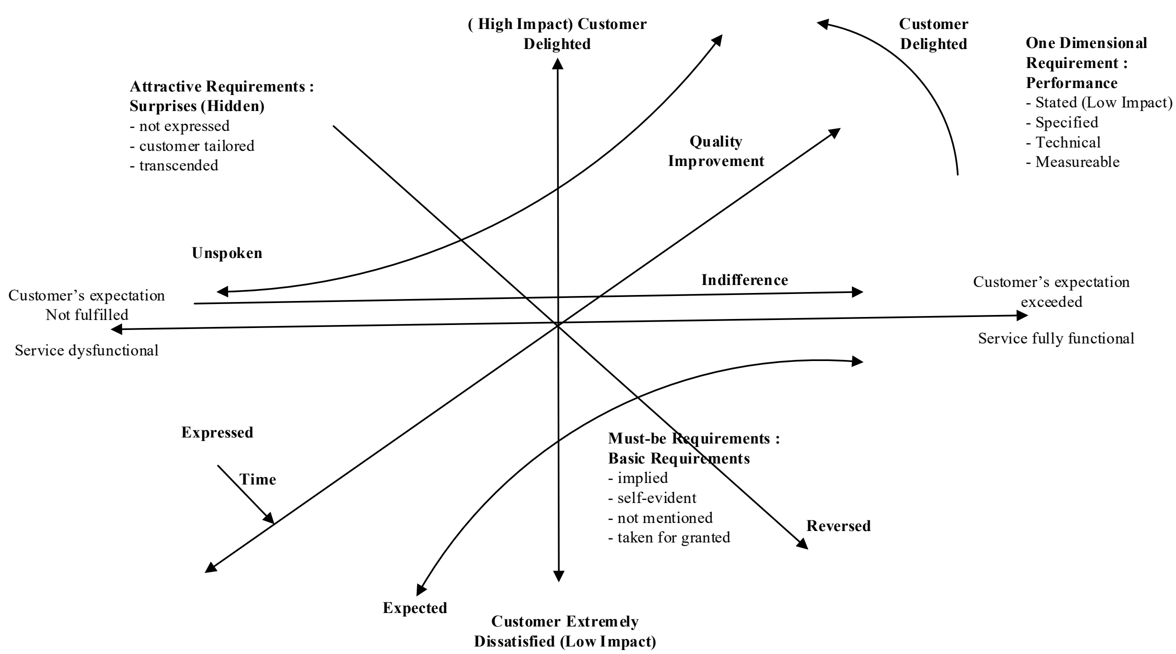

Figure 2. Model Kano (Eiríksdóttir & Thorarensen, 2013)

Chen et al. (2017) proposed fuzzy linear programming methods to resolve part fulfillment levels in order to obtain the required contribution levels of design requirements for customer satisfaction. They implemented FMEA into QFD processes, and the models handle it as a constraint. Almannai et al. (2008) develop a decision tool with the integrated approach of QFD and FMEA. QFD identified the most suitable factory automation option, and FMEA identified the equivalent risk which is handled in the production system design and implementation phases. Ma et al. (2016) employ the QFD method to determine customer requirements, whereas the FMEA method is used for reliability analysis in product redesign. Ma et al. (2019) employed fuzzy QFD-FMEA to determine the components that needed to be redesigned, taking into account consumer needs and product reliability. The method uses QFD to redesign customer requirements, while FMEA is utilized to rethink dependability.

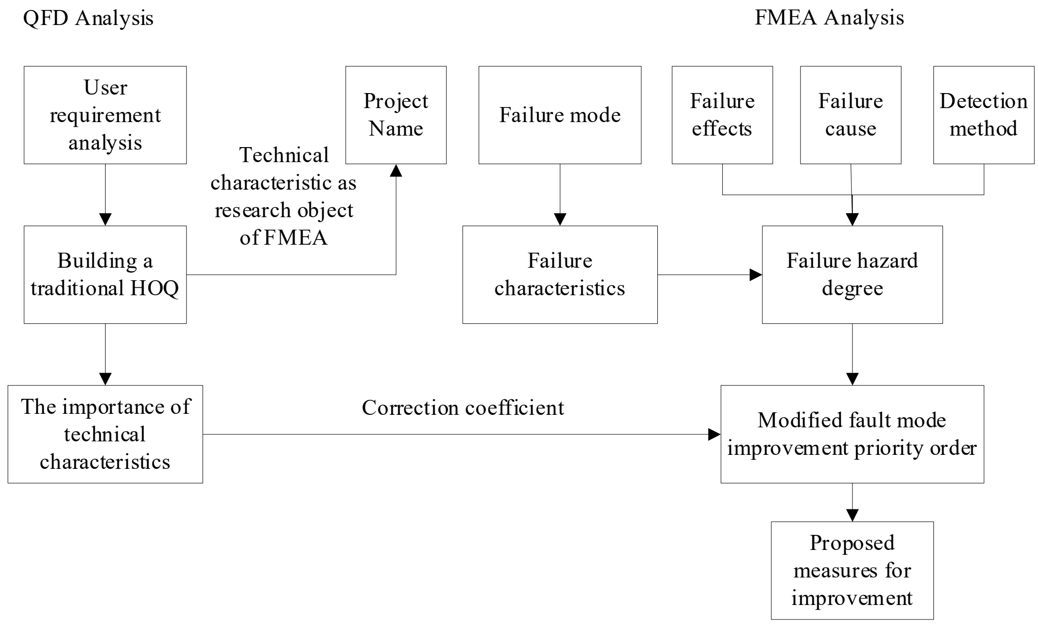

Figure 3. Basic model of integrated FMEA and QFD (Gu, 2019)

As argued at Gu et al. (2019), both FMEA and QFD are utilized for preliminary predictive analysis, Gu (2019) also ensures that the most reliable products are developed with the fewest probability of failing to fulfill customer requirements (see Figure 3). They offer excellent complementary properties and improve product reliability from several angles. Their integrated app offers fresh product pre-analysis concepts. The integration model is broken into three sections, and the first is the deployment of a quality house from customer needs to design parameter in a QFD analysis. In FMEA, failure forms, causes, and effects are also identified. The in-house deployment of quality, from design features to failure characteristics, is the third component. Figure 3 illustrates the integrated model workflow.
The concept of integration of QFD and FMEA is also used by Shaker et al (2019) and Ma (2019) in developing a product redesign concept by considering consumer needs and the risk of previous product failures. The research of Shaker et al (2019b) and Ma (2019) contributes that the product redesign process can be focused on product parts or components or sub-assemblies that have the highest risk of failure while meeting consumer demands. The compatibility and interdependent of FMEA and QFD are investigated in this study, and the integration framework of FMEA and QFD is developed with customer complaint consideration.

Table 2. Research position

Article	Objectives	Framework	Factors	Case	Tools			
					QFD	Kano	FMEA	Others
(Pullan, Bhasi, & Madhu, 2010)	This research aims to establish existing solutions to the challenge of concurrent design optimization, as well as the stages of process planning for new product development.	Reduce total time for design.	Manufacturing information (artefact, work piece, and manufacturing process sequences)	Machine tools	√			DFM
(Hu, Lin, Chang, Cheng, & Tseng, 2014)	Integration of QFD, TRIZ, and FMEA for improving product quality, lowering costs, and bearing customer expectations.	DFA	Manufacturing operation, time, cost	Control Valve	√		√	TRIZ
(H. Ma, Chu, Xue, & Chen, 2016)	Developing a framework to identify the to-be-improved components for redesign of complex products and systems, based on fuzzy QFD and FMEA approach.	Redesign Necessity Index (RNI)	RNI, customer requirements, and failure information	Crawler crane	√		√	Fuzzy
(H. Ma, Chu, Xue, & Chen, 2017)	The characteristics of function solution principles are linked to customer preferences and product failures to create a morphological matrix.	Decision making	Manufacture cost, maximum cost, CR, component function,	Drilling machine	√			Ooptimization, DFMA
(Frizziero, Francia, Donnici, Liverani, & Caligiana, 2018)	Design validation of direct open mold based on QFD and TRIZ analysis.	Hybrid Manufacturing	Industrial, Structural strength, Customization, Precision, Production Speed, Workability, Precision, Thermal, Resistance, Complex Shaping, Reliability	Open mold	√			TRIZ
(X. Zhang et al., 2019)	Quality improvement of end-of-life (EOL) product with two-phase QFD model and failure modes' feedback.	DFRem Model	Failure mode, customer needs	Automotive engine crankshaft validates	√		√	Fuzzy

Article	Objectives	Framework	Factors	Case	Tools			
					QFD	Kano	FMEA	Others
(Shaker et al., 2019a)	Developing an integrated framework for FMEA improvement	Two phase QFD-FMEA	Customer needs, risk	Blast furnace operation	√		√	
(Gu, Cheng, & Qiu, 2019)	Analyzing the compatibility and interdependent of QFD-FMEA are analyzed in order to develop an integrated framework.	Integrated model QFD-FMEA	Customer requirement, failure mode, risk, correction coefficient	diesel engine fuel	√		√	TOPSIS
(Liew, Prakash, Kamaruddin, & Ong, 2019)	Determining an operational performance for manufacturing industry with FMEA and operational performance indicator (OPI)	FODP Framework	Performance, failure, risk, efficiency	Semi-conductor			√	Simulation
(B. Ma, Ma, Li, Chu, & Liu, 2019)	Using perspective of performance degradation for redesign identification	Degradation model, Anomaly detection model	Failure, degradation, severity, abnormality	Wind turbine			√	SCADA, RNI
(H. Ma, Chu, & Li, 2019)	Considering customer requirements and failure risk for function components identification of product redesign.	Product redesign	weight, function component (FC), cost, time	Crawler crane	√		√	QFD, FMEA
This article (2021)	Developing an integrated framework to identify and determine the priority of components or parts to be repaired by considering customer requirements, user complaints and failure analysis	Product redesign need assessment	Customer requirement, failure modes, complaint	Manufacturing industry	√	√	√	Kano-QFD/ FMEA

3. Research Methodology

The primary phases of the approach used in this essay are as follows. First, a survey of the multidisciplinary literature on product creation, with failure analysis, customer requirements, and complaints taken into account. The utilization of existing theories, methods, and approaches, as well as the factors and meaning that they produce, were revealed through a literature review. Ultimately, this phase of evaluation produces a plethora of competing and contradictory ideas, interpretations, and concepts. Fulfillment of consumer needs is carried out by the company in order to achieve management effectiveness. The method widely used in measuring consumer needs for a product is Quality Function Deployment (QFD) and its integration with the Kano model.

The model developed in this study uses two basic models. The first basic model of QFD-FMEA is Gu et al (2019) and the second ones is Suef (2013). The Kano method is an effective tool in achieving this goal. Kano translates the importance of the attributes of manufactured products into the features of a product in three categories, namely must-be, one-dimensional, and attractive (Suef, Suparno, Singgih, Sukwadi, & Widawati, 2014). Quality Function Deployment (QFD) also is another alternative in correlating consumer needs and product design specifications. Reliability improvement targets complement the needs of product redesign assessments, in addition to meeting consumer needs and user complaints. User complaint data is categorized in the must-be attribute. The must-be attribute is a form of consumer need that has low satisfaction when fulfilled. However, if it is not fulfilled, consumers will feel very dissatisfied.

Second, recognition of framework, model, and patterns in seemingly random information. This step looks for suitable model within the concepts, objectives, and resumes a gap for research direction. Third, synthesis similar meanings, factors and create independent concepts, where each concept has distinctive meanings and represents close idea. Fourth, the last phase is developing an integrated framework and explaining the relationships between the derived concepts.

4. Results and Discussion

Most company redesign to create new product. The new product design with improvement from existing product means product redesign. Product redesign is a significant approach in the product development process, where the goal is to improve product designs that have better reliability and meet consumer needs (H. Ma et al., 2019). Redesign improves the quality and efficiency of the product development. The product redesign framework in this study also considers the failure modes from of existing products. FMEA is considered as an effective method to identify the form of failure of a product along with the structure of its constituent components (Prabowo et al. 2018). FMEA is part of a qualitative reliability analysis procedure. Product redesign is carried out in the product development process as an effort to evaluate products that have been marketed or used by consumers.

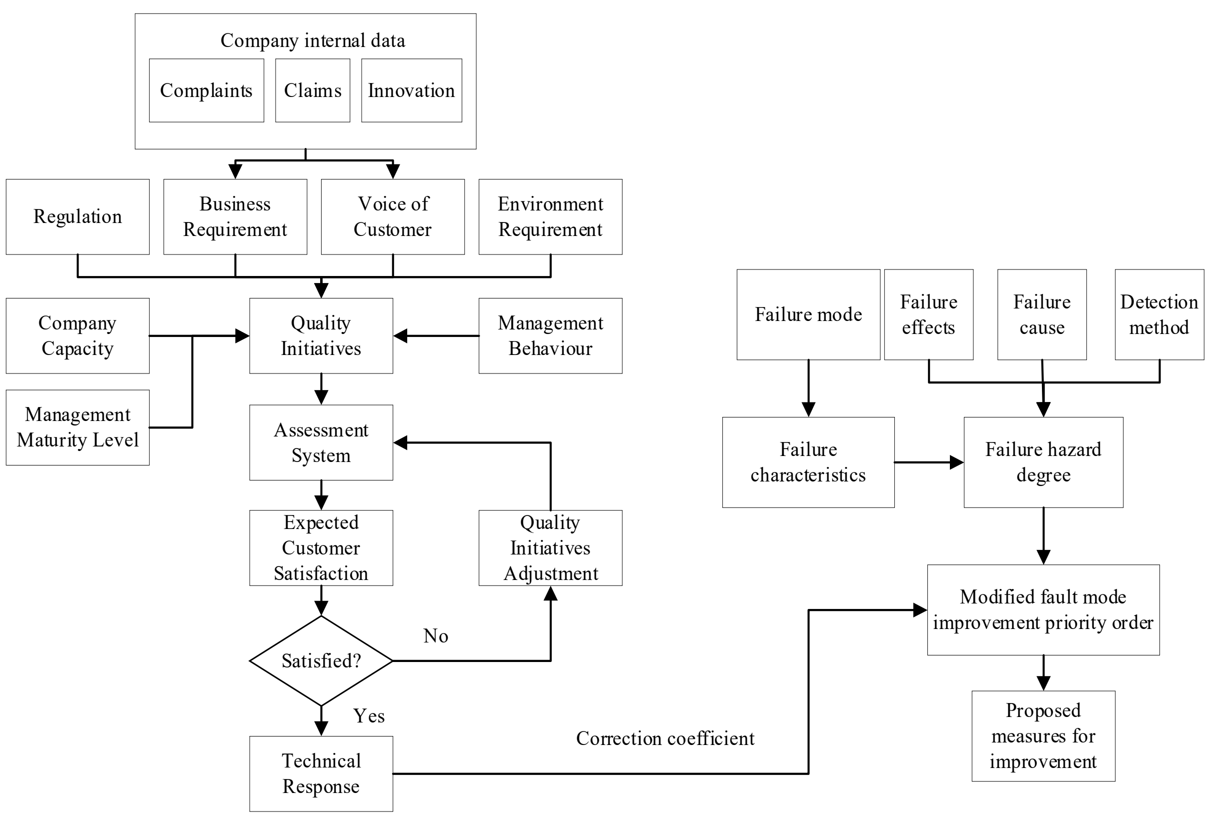

Figure 4. An integrated framework development (proposed model)

Three factors are considered in this research are consumer needs (Shahin, 2004; Ma et al., 2016; Shaker, Shahin and Jahanhan, 2019), product/component failure modes (Shahin, 2004; Ma et al., 2016; Madzík and Kormanec, 2020), and user complaints (Suef et al., 2014; Shahin, Khodadady and Shirouyehzad, 2015; Siregar, Ginting and Agnesia, 2017). This customer feedback is very valuable to be used as a basis for improving product development. The issue that continues to grow is how to use consumer feedback on product complaints and information about the nature of product failure to prioritize redesigned components. According to experts, QFD's technical response directly correlates with customer happiness. Professionals recognized that technological answers have a range of effects with the advent of the KANO technique. With reference to the customer satisfaction impact of each technical response, the QFD-Kano technique turns the voice of the customer (VOC) into technical response. Customer needs, as well as customer satisfaction and dissatisfaction rates, are required by QFD-Kano. Data from claims and complaints, as well as company efforts, must be processed so that they may be used as a backup voice of customer (VOC), taking the place of a consumer survey.

Failure modes of the finished product can be identified and analyzed by considering the product structure, constituent materials and product reliability. Companies also need information related to the form of product failure when used by consumers. Failure Mode and Effect Analysis (FMEA) is used as a problem prevention tool, to improve the fulfillment of consumer demand and to avoid things that cause customer dissatisfaction, especially at the early design stage (Shahin, 2004; Shahin et al., 2013). The contribution of this FMEA method is risk ranking or priority ranking which is calculated using severity (S), occurrence (O), and detection (D) parameters. One of the problems that arise is the interdependence between several failure modes and effects. For example, assume that the scales of the three "severity" (S), "incidence" (O) and "detection" (D) indices have the same metric and the same design level corresponds to the same value on different index scales. Therefore, the assumption is that all three indices are equally important and are likely to identify conditions with the same Risk Priority Number (RPN) but characterized by different index levels. Through the use of a simple rating method, specifically built to meet industry needs, an RPN is created for each cause of failure (Sanditya, R. et al, 2020). With a high RPN value, it will be selected as a top priority corrective action to reduce the risk of failure and become a top priority for product redesign.

Tang et al. (2021) and Shaker et al. (2019) confirmed a nonlinear relationship between failure rate and severity in RPN. Particulary, the failure frequency is disproportionate to the severity of the loss. When product failure reaches a critical point, it boadly will stimulate the customers to become dissatisfied, complaining, and waste to use the product again. FMEA consider as problem solver in short-term production technology, presenting the necessary quality to meet customer value. Therefore, when using FMEA, the research should consider the area covered by the quality must-be in the Kano model and based on customers' views on the severity of the impact of product failure.

Figure 4 depicts the integrated model's workflow. Both FMEA and Kano-QFD are used for preliminary prediction analysis in the QFD analysis process to ensure that the most reliable goods are produced with the least risk to fulfill users' needs. They improve product reliability from various angles and have strong complementarity. Their integrated solution offers a novel approach to product pre-analysis. The integration model is developing in three phase, the primary quality house deployment from complaint and user requirements to design characteristics, known as Kano-QFD analysis. Customers' requirements are more accurate when complaints are used as a customer need in product development since customers provide factual complaints. Second is FMEA, as the deployment of possible failure patterns, causes, and impacts. FMEA results the failure hazard degree as the risk priority number (RPN). The third is the secondary quality house deployment from the technical response to the modified fault mode improvement priority propose.

5. Conclusion

Manufacturing companies have focused on product redesign to stay competitive as their drive to attract more consumers and increase product complexity has grown. Product design's initial conceptual design stage is gradually improved since it substantially impacts the product's development and manufacturing stages. A comprehensive literature review is carried out to (1) identify the drawbacks of QFD, Kano, and FMEA; (2) analyze the integration between QFD, Kano, and FMEA with other product development tools; and (3) identify the gaps and opportunities for developing an integration model for product redesign need assessment. By developing this integrated framework model, apart from considering customer requirements, we propose the involvement of customer complaints and product failure modes in product redesign. This framework will perform better in product redesign because it involves product failure modes in product reliability improvement. Consideration of complaint data on consumer dissatisfaction can confirm the significance of meeting consumer needs. However, this study has some limitations in case study testing. Future research directions should implement this conceptual framework into case studies of product redesign to improve product quality for each X strategy in the manufacturing industry.

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