Determination of Technical Specifications for a Digital QR Code System Using Axiomatic House of Quality for Error Prevention

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Abstract

This study aims to determine the technical specifications of a digital QR Code system for the weighing process of practical spice powder recipes using Axiomatic House of Quality to prevent human error. User requirements data were collected from 25 respondents and validated through a Focus Group Discussion (FGD) involving 9 technical experts. The results identified 14 Customer Attributes (CA), which were subsequently translated into 14 Design Parameters (DP). Design matrix analysis indicated that the system is categorized as an uncoupled design, where each Functional Requirement corresponds to a specific DP, thus maintaining the independence of functions and design parameters. The resulting technical specifications are practical and applicable, covering hardware components, user interface, alarms, data storage systems, and material detection mechanisms. Therefore, the designed digital QR Code system can prevent weighing errors caused by human error and enhance product quality from the consumer's perspective.

Keywords: *QR Code, Axiomatic House of Quality, Functional Requirements, Design Parameters, Human Error Prevention.*

1. Introduction.

In an era of increasingly competitive globalisation, technological innovation is a key pillar determining the success of the manufacturing industry. Developments in digital technology, automation, and information system integration are driving a significant transformation for companies in producing quality products [1]. Product quality is a fundamental factor that cannot be ignored. Improving quality through the implementation of standards, process control, and the use of modern technology can reduce production defects, reduce failure costs, and ensure quality consistency [2]. High-quality products not only increase customer satisfaction and loyalty but also serve as a benchmark for a company's credibility in the market [3]. Achieving the product quality expected by consumers is inseparable from how a company implements the product design and development process. This stage is crucial because it determines the extent to which the resulting product can meet consumer needs while being efficient in production [4]. Product design and development based on innovative technology enables the creation of more precise, flexible, and market-oriented designs. On the other hand, integrating quality principles from the conceptual design stage (quality by design) will ensure that products are not only innovative but also meet expected quality standards [5].

Design conceptualisation is a crucial part of the product design development process for companies. Furthermore, the concepts contained in Axiomatic Design provide a framework that can assist company professionals in their application to engineering design projects [6]. The design process involves complex decision-making. Decision-makers must frequently analyse combinations of various criteria. Axiomatic Design (AD) is the design of complex engineering systems involving multidimensional and multi-criteria constraints, thus providing optimal design schemes that accelerate project completion and substantially reduce trial costs [7]. Each design alternative has different characteristics, technical capacities, and costs. Given that many decision-makers evaluate more than one criterion, the difficulty of producing an optimal decision that is accepted by all decision-makers varies [8]. A careful process of exploring customer needs in the Axiomatic design process is a must to define product demands precisely[9]. Axiomatic House of Quality (AHOQ) is a method that integrates the Axiomatic Design approach with Quality Function Deployment (QFD) to translate customer needs into technical specifications during the product design process [10]. Axiomatic design enables the identification and solution of complex original system problems through a hierarchical structure, the creation of a design matrix, and ultimately, the production of solutions [7]. This approach improves the systematic and scientific aspects of the design process by combining hierarchical structuring and providing theoretical and methodological support for system design, ultimately resulting in improved design quality [11].

PT. XYZ, as a processed food manufacturer, faces issues related to errors in the use of raw materials during the recipe weighing process. Although the company has implemented quality standards such as ISO 9001, incidents caused by human error still occur and may result in material losses or consumer claims. This situation underscores the need for a digital system capable of preventing errors from the early stages of production through automatic detection mechanisms and real-time alerts.

Research on the Axiomatic House of Quality (AHoQ) has been extensively conducted by scholars in the context of product quality improvement and system design. Ishak [9].as well as Siagian [10] employed AHoQ to enhance product quality based on customer requirements. Mohamad [12] even combined the AHoQ approach with the MEAD method to analyze macro-ergonomic aspects in work system design. Other studies, such as those by[13] and [14], also demonstrated the consistent application of AHoQ in the context of manufacturing industries and production systems. Similarly, research by [15], [16] and [17], highlighted the use of AHoQ in mapping customer needs and translating them into technical parameters. However, overall research still focuses primarily on ergonomics or mechanical product design without integrating digital systems for error prevention. Specific applications of digital QR Code systems for error prevention in production processes are still limited. This highlights a research gap that could contribute significantly to the development of more reliable, efficient, and consumer-oriented production systems.

This study aims to determine the technical specifications of a digital QR Code system for the weighing process of practical spice powder recipes. The specification determination is conducted using the Axiomatic House of Quality method, allowing user requirements to be systematically translated into precise technical parameters. With this approach, the system is expected to prevent weighing errors caused by human error while simultaneously enhancing product quality from the consumer's perspective.

2. Method

According to [14], several terms are commonly used in understanding Axiomatic Design, namely: (1) Customer Attribute (CA), the domain that encompasses the desires and needs from the user's perspective; (2) Functional Requirement (FR), the domain that defines the functions of a targeted design or product; and (3) Design Parameter (DP), the domain that represents the manifestation of the FR, describing how the functions in the FR domain are realized.

This study employs the Axiomatic House of Quality approach (Figure 1) to determine the technical specifications of a digital QR Code system for the weighing process of practical spice powder recipes, with a focus on error prevention. This method was chosen for its ability to translate user requirements into clear and measurable technical parameters.

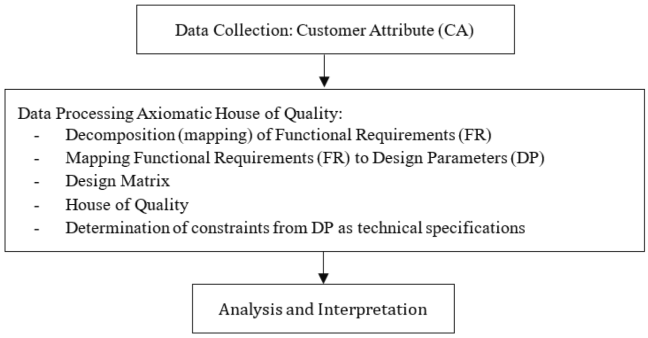

Figure 1. Research Methodology Stages

User requirement data were collected through a Customer Attribute (CA) questionnaire from 25 respondents, consisting of 3 Managers, 5 Foremen/Assistant Foremen, 5 Group Leaders, and 12 Operators/Production Staff. The questionnaire aimed to identify relevant customer attributes for determining the technical specifications of the digital QR Code system in the recipe weighing process.

Data processing was conducted through a Focus Group Discussion (FGD) involving 9 technical experts: 1 Operations Manager, 1 Operations Foreman, 1 Maintenance Foreman, 1 Quality Control Foreman, 1 Maintenance Group Leader, 1 Quality Control Group Leader, 1 Engineering Staff, and 2 software and hardware vendor experts. The FGD aimed to validate the mapping of Functional Requirements (FR) to Design Parameters (DP) and ensure that the resulting technical specifications were realistic and practically applicable in the field.

The analysis was conducted following the stages of Axiomatic House of Quality as follows: (a) Decomposition of Functional Requirements (FR): identifying user needs and breaking them down into specific functions; (b) Mapping FR to Design Parameters (DP): translating each FR into appropriate technical design parameters; (c) Creating the Design Matrix: analyzing the relationship between FR and DP; (d) Analysis House of Quality and (e) Determining Constraints and Technical Specifications: establishing the final limitations and technical specifications for the mapped design parameters.

Using this approach, the study produced systematic, measurable, and practical technical specifications that can serve as a guideline for designing a digital QR Code system to prevent errors in the weighing process of practical spice powder recipes.

3. Results and Discussion

In this section, the research results using the Axiomatic House of Quality method are presented in several tables along with their discussion.

Table 1. Decomposition of Customer Attributes (CA) into Functional Requirements (FR)

No.	Customer Attribute	No.	Functional Requirement
CA1	Clear Monitor	FR1	Provides clear and easily visible information to the user
CA2	Scanner Available	FR2	Provides a tool to transfer label data into the computer
CA3	Visual Alarm Available	FR3	Provides alarm information in the form of light
CA4	Audio Alarm Available	FR4	Provides alarm information in the form of sound
CA5	Data Recording Available	FR5	Provides a record of the recipe weighing process
CA6	Clear Recipe Guide	FR6	Provides clear guidance for recipe weighing
CA7	Clear QR Code Label	FR7	Facilitates the scanning of material labels
CA8	Complete Weighing Scales	FR8	Provides complete and adequate weighing equipment
CA9	Spare Scanner Available	FR9	Provides a spare scanner in case of malfunction

CA10	ID Level Access	FR10	Provides user identification and access levels for authorization
CA11	Ergonomic Weighing Sequence	FR11	Provides a comfortable and ergonomic material weighing sequence
CA12	Scanner Storage Available	FR12	Provides an easily accessible and secure scanner storage
CA13	Material Type Error Detection	FR13	Provides automatic detection of material type errors
CA14	Material Quantity Error Detection	FR14	Provides automatic detection of errors in material weighing quantity

Based on Table 1, the results were obtained from a Focus Group Discussion (FGD) involving 9 technical experts, namely: 1 Operations Manager, 1 Operations Foreman, 1 Maintenance Foreman, 1 Quality Control Foreman, 1 Maintenance Group Leader, 1 Quality Control Group Leader, 1 Engineering Staff, and 2 vendor experts specializing in Software and Hardware. From this activity, 14 types of Functional Requirements (FR) were identified, namely FR1 to FR14.

Table 2. Mapping of Functional Requirements (FR) to Design Parameters (DP)

No.	Functional Requirement	No.	Design Parameter
FR1	Provides clear and easily visible information to the user	DP1	Screen/Monitor Size
FR2	Provides a tool to transfer label data into the computer	DP2	Scanner Type
FR3	Provides alarm information in the form of light	DP3	Alarm Light Type
FR4	Provides alarm information in the form of sound	DP4	Alarm Speaker Type
FR5	Provides a record of the recipe weighing process	DP5	Data Storage and Recording System (software & hardware)
FR6	Provides clear guidance for recipe weighing	DP6	Recipe Interface and Interactive Guide System
FR7	Facilitates the scanning of material labels	DP7	QR Code Label Print Quality and Adhesion
FR8	Provides complete and adequate weighing equipment	DP8	Complete Weighing Scales Quantity
FR9	Provides a spare scanner in case of malfunction	DP9	Spare Scanner Quantity
FR10	Provides user identification and access levels for authorization	DP10	User Login System with Authorization Levels (password)
FR11	Provides a comfortable and ergonomic material weighing sequence	DP11	Material Layout or Ergonomic Workflow
FR12	Provides an easily accessible and secure scanner storage	DP12	Scanner Storage Location and Dedicated Storage Design
FR13	Provides automatic detection of material type errors	DP13	Material Type Detection System (material code)
FR14	Provides automatic detection of errors in material weighing quantity	DP14	Target Weight Compliance Detection System for Each Material Type

Based on Table 2, the results were obtained from a Focus Group Discussion (FGD) involving 9 technical experts, namely: 1 Operations Manager, 1 Operations Foreman, 1 Maintenance Foreman, 1 Quality Control Foreman, 1 Maintenance Group Leader, 1 Quality Control Group Leader, 1 Engineering Staff, and 2 vendor experts specializing in Software and Hardware. From this activity, 14 types of Design Parameters (DP) were identified, namely DP1 to DP14.

Table 3. Design Matrix

FR\DP	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9	DP10	DP11	DP12	DP13	DP14
FR1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
FR2	0	1	0	0	0	0	0	0	0	0	0	0	0	0

FR3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
FR4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
FR5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
FR6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
FR7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
FR8	0	0	0	0	0	0	0	1	0	0	0	0	0	0
FR9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
FR10	0	0	0	0	0	0	0	0	0	1	0	0	0	0
FR11	0	0	0	0	0	0	0	0	0	0	1	0	0	0
FR12	0	0	0	0	0	0	0	0	0	0	0	1	0	0
FR13	0	0	0	0	0	0	0	0	0	0	0	0	1	0
FR14	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Based on Table 3, each Functional Requirement (FR) corresponds to only one specific Design Parameter (DP). This condition indicates that the design falls into the category of an uncoupled design, which is considered the most ideal form. In this type of design, the design matrix is diagonal, which is the main characteristic of an uncoupled design. Since the number of DPs is equal to the number of FRs, each functional requirement has a clear and independent physical solution, allowing the process to proceed to the detailed design stage more effectively.

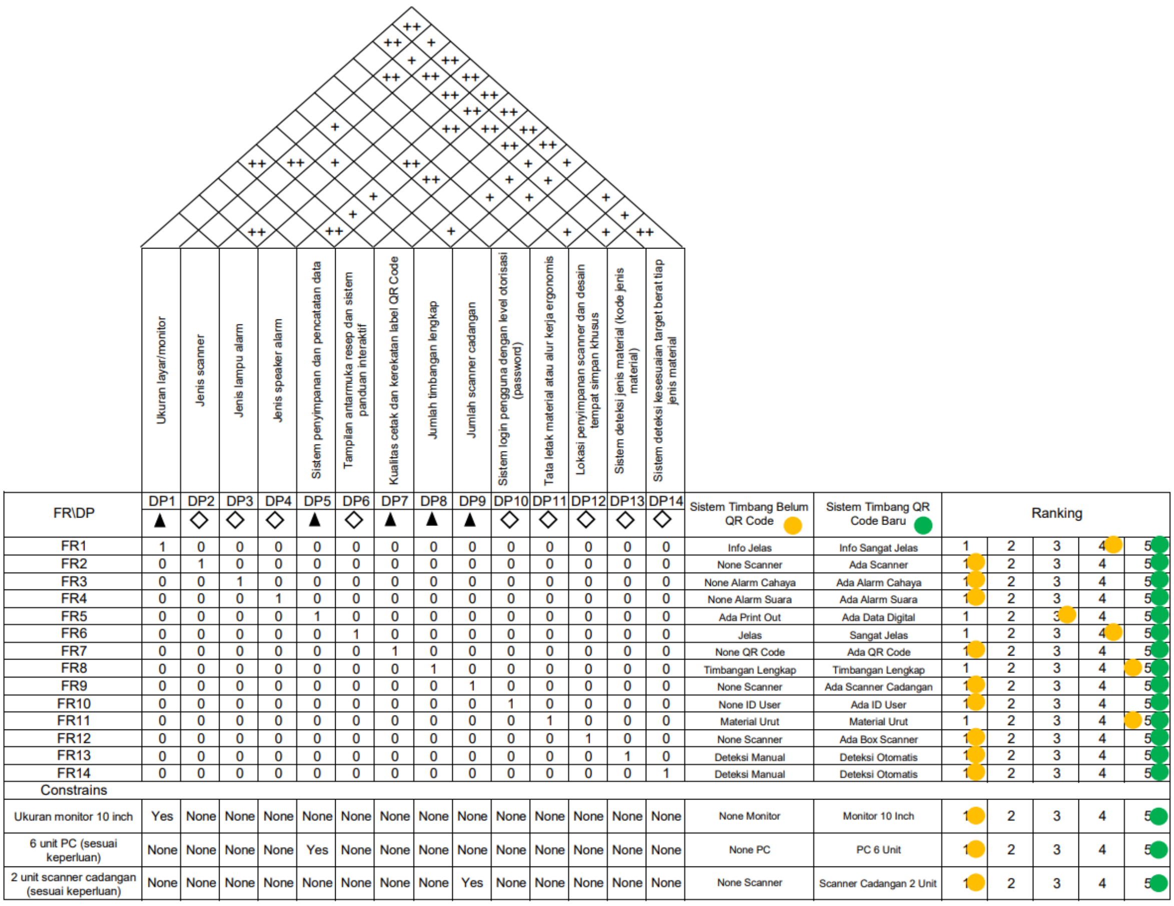

Figure 1. House of Quality

Based on Figure 1. House of Quality, the results of the Focus Group Discussion (FGD) involving nine technical experts, each identified Design Parameter (DP) was further analyzed to establish clear and applicable technical constraints. For example, DP1 regarding the monitor was translated into a minimum size constraint of 10 inches to ensure information is easily visible, while DP2 regarding the scanner specified the use of a dedicated QR Code scanner to ensure scanning accuracy. Visual and audio alarms (DP3 & DP4) were adjusted according to red, yellow, and green lights and a buzzer alarm, while the data storage and recording system (DP5) was set up with 6 PCs according to operational needs. The recipe guide interface (DP6) was implemented through an interactive interface, and the QR Code label quality (DP7) was ensured to be clear and adhesive. The number of weighing scales and spare scanners (DP8 & DP9) was set according to requirements, the user login system with authorization levels (DP10) ensured security, the material layout and scanner storage location (DP11 & DP12) were designed ergonomically, and the material type and weight detection system (DP13 & DP14) ensured accurate compliance in the weighing process.

Figure 2. QR Code System to Prevent Recipe or Material Errors

The mapping of DPs to constraints, validated through the FGD, ensures that the technical specifications of the digital QR Code system meet functional requirements, can be practically applied in the field, and prevent human errors, in accordance with the principles of Axiomatic House of Quality.

4. Conclusion

This study successfully determined the technical specifications of a digital QR Code system for the weighing process of spice powder recipes using the Axiomatic House of Quality method. Based on the analysis results, each Functional Requirement (FR) has a specific corresponding Design Parameter (DP), classifying the system design as an uncoupled design, which is ideal for maintaining the independence between functional requirements and technical parameters. The stage of mapping DPs to constraints, validated through a Focus Group Discussion (FGD) with nine technical experts, produced clear and practically applicable specifications, including monitor size, scanner type, visual and audio alarms, data storage system, recipe guide interface, label quality, number of weighing scales and spare scanners, user login system with authorization levels, ergonomic layout, and material type and weight detection systems. Accordingly, the designed system is capable of preventing weighing errors due to human error and improving product quality from the consumer's perspective.

Future research is recommended to test the implementation of the digital QR Code system in practice to assess its effectiveness in reducing human errors. In addition, integration with real-time monitoring systems or risk analysis could strengthen quality control and serve as a reference for similar studies in the manufacturing industry.

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