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Design Thinking: Visual Guidance for Quality Inspection Case Study on Cosmetic Packaging Company

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Abstract: This paper examines the occurrence of human mistake throughout the quality inspection process at a company that manufactures cosmetic packaging. Human mistake arises when the visual guidelines for quality requirements created by the inspector do not align with the expectations and requirements of the users as selectors. A design thinking method is employed to enhance the visual guide's design and successfully minimize inspection errors. The user-centred design technique involves collaboration between users and designers throughout five distinct design stages: empathize, define, ideate, prototype, and test. The enhancements made to the visual guide have resulted in a reduction in inspection mistakes by 8.3% within selectors, 36.25% between selectors, 15.8% for each selector compared to the standard, and 38.75% for all selectors compared to the standard.

INTRODUCTION

The effectiveness of a quality control system relies heavily on the human aspect, which plays a crucial part in the system's operations [1]. It is crucial to minimize or completely eliminate the occurrence of quality control failures caused by human error. Humans have a crucial part in the quality control system [2]. A study was conducted on a company that manufactures cosmetic product packaging of different sizes and with specific specifications based on client preferences, in order to acquire a deeper understanding of this significant human role. Inspection errors frequently arise inside this firm. To ensure accuracy, the quality inspection findings conducted by the selectors undergo a three-step validation process by the inspector. This process involves sampling during setup, in the process, and at the final stage. Inspections are conducted using visual means, focusing on assessing the functionality, appearance, and color of the packaging. The selector conducts a manual inspection by referring to a visual reference of quality requirements, which consists of a sample image placed in front of them. Moreover, the format of visual guidelines for quality standards differs depending on the type of products manufactured. Even for identical products produced by different users, the visual representation of quality needs may vary.

The accuracy and durability of the selector in the quality inspection process are crucial, particularly when the inspected product is moving rapidly on the conveyor and the inspection activity is conducted over an extended period of time. Despite the lengthy and rigorous quality inspection process, numerous inspection errors are actually detected, resulting in defective products surpassing the acceptable quality level (AQL) during quality control. According to the company's non-conformity report from June to December 2020, there were 364 instances of inspection errors in the printing process and 134 inspection problems in the stamping process. This inspection fault necessitates a thorough re-examination of each individual product in the entire batch. This reinspection is more time-consuming and necessitates extra selectors.

Through observations made on the manufacturing floor, it was noted that issues arose with the visual guide that served as a reference for the selection in terms of quality criteria. The selector found that the visual guide created by the inspector could not be accurately translated to meet the inspector's requirements. Incorrect inspections and defective items that pass quality control are inevitable. Inspectors have conducted multiple training sessions for selectors on following the drawing requirements, nevertheless selectors continue to make numerous inspection errors. Furthermore, inspections are conducted over an extended duration, approximately eight hours every shift, while the inspected product swiftly progresses on conveyors. Selectors experience fatigue and boredom rapidly, in addition to the frequent alteration of the visual guide based on the manufactured goods.

How do inspectors and selectors collaborate to create a visual guide of quality requirements that ensures the design matches the selector's expectations and demands, resulting in a large reduction in inspection errors? The most effective way to create joint designs between users, such as a selector and a designer, in order to achieve a visual control design that aligns with the selector's preferences, is by employing a design thinking method [5].

DESIGN THINKING AND VISUAL GUIDE FOR QUALITY INSPECTION

Selectors typically struggle to appropriately interpret visual standards for quality assessments. Leavy [6] suggests that visual assistance can be effectively comprehended and implemented when the user observes and experiences the design process of the guide. Leavy asserts that the process of creating a visual guide must be repeatedly presented. User testing is an essential component of design thinking (DT) that involves showcasing designs to users. In addition, Dobbelaer et al. [7] suggest that receiving vocal feedback from users is highly beneficial during the design development process, particularly when conducting design trials in real-world settings.

In addition, as stated by Liedtka [8], the utilization of design tools, such as the mapping of user interactions with the guide, can facilitate the collaboration between designers and users in addressing encountered challenges and identifying potential opportunities. Liedtka asserts that implementing a design thinking method not only involves finding solutions, but also involves revolutionizing the collaboration between designers and users to envision and explore novel opportunities. Cahyadi and Prananto [9] highlight the significance of engaging in conversation with diverse interdisciplinary and cross-functional teams when creating a visual guide. Enhancing the effectiveness of the design process can be achieved by enabling designers to collaborate with users, namely those who possess the data or are responsible for the process. DT can be employed as a comprehensive, innovative, and problem-solving framework. Conversely, utilizing DT for problem solving can enhance user engagement in the process of discovering answers [10].

According to Henriksen et al. [11], designers should allow design users to have access when they encounter practical challenges. The input provided by consumers will assist the designer in fostering innovative thinking to enhance the design. According to Bower [12], designers must possess context-sensitive design principles and expertise in order to create designs that are responsive to the specific demands of users. This means that design should be a reflective activity that adapts to the situation in which it is applied. According to Lee and Lim (2013), traditional design methodologies make it challenging to comprehend user desires and motivations. Users anticipate designers to comprehend their latent or unacknowledged desires and requirements. Moreover, the designer not only creates designs based on the user's wants, but also anticipates and incorporates the user's needs, ensuring that the design is highly desirable to the user. Design thinking is crucial for innovation since it effectively uncovers intricate and intangible user requirements and expeditiously devises inventive solutions for them.

Design thinking is using designer logic and approaches to match human requirements, resulting in improved value for users and the creation of new prospects. Furthermore, as stated by Bresciani [14], including the design thinking concept into the creation of a guide can enhance designers' decision-making process, ensure a more concentrated visualization, yield clear and visually appealing outcomes, and foster collaboration between users and designers. Sandorova et al. [15] suggest that creating a visual guide to quality criteria using the design thinking idea can enhance creative thinking, teamwork, and communication. Furthermore, as stated by Cleckley et al. [16], designers must possess empathy during the development process. This involves actively listening to stakeholder input regarding their expectations and aims. According to Albay and Eisma (2017), the utilization of the design thinking process can assist designers in developing designs that are innovative, engaging, visually appealing, and focused on the needs of the user.

DESIGN METHODOLOGY

A Design Thinking (DT) technique is utilized to create a visual guide that outlines the quality requirements for cosmetic product packaging. The purpose of this guide is to minimize inspection errors made by selectors. Design thinking (DT) is an innovative methodology for developing imaginative and appealing solutions [18]. The DT process consists of five stages: empathize, define, ideate, prototype, and test [19]. Empathy serves as the fundamental basis for the human-centred design process. Three methods to cultivate empathy include observing, actively engaging, and immersing oneself. Monitoring the conduct or routines of ordinary users. Interact directly with individuals to gain insight into their thought processes and the principles they prioritize. Engage in the experience by actively attempting to perceive it from the perspective of a user.

If the test results do not meet the inspector's criteria, they are redone from the beginning stage, which is empathizing. Problem identification involves conducting interviews with selectors and inspectors, as well as making field inspections to observe the production process flow, quality control procedure, and the types of faults that frequently arise. Data gathering involves the testing of MSA (Measurement System Analysis) attribute data through the use of subjective assessments and visual inspection [20]. The assessment of selector inspection proficiency was conducted in three groups, denoted as A, B, and C, each with two replications. The MSA findings are used to assess the proficiency of selectors in performing inspections. The interpretation of the MSA results involves comparing the results of each appraiser to a standard, as well as comparing the results amongst different appraisers and all appraisers collectively to the standard. In this study, the evaluator functions as a selector. Appraisers are evaluated based on the consistency of their analysis. This technique quantifies the level of consistency in the responses provided by appraisers during many replications. The appraiser versus standard comparison involves assessing each appraiser's response in relation to the standard answer, determining the percentage of deviation from accuracy. Between appraisers seeks to analyze and evaluate responses from all appraisers. The comparison between all appraisers and standard answers provides a comprehensive study of their responses. In addition, the results of the selection test were examined using a fishbone diagram to detect deviations caused by specific factors [21].

RESULTS AND DISCUSSION

Quality inspection conducted by selectors and inspectors

This case study examines an inspection system for cosmetic packaging items in the Assembly Decoration (AD) line. The system utilizes a visual guide. Following the completion of the decoration process, each product is promptly examined by the selector, who proceeds to weigh it and place it into the cardboard package, affixing the production code in the process. The decorating process involves the utilization of printing and stamping techniques. In the printing process, ink is utilized as the primary decorative material, but in the stamping process, foil is employed.

Inspectors and selectors are responsible for conducting quality inspections in AD. The selector visually examines the completed product as it emerges from the machine, swiftly tracking its movement along the conveyor. Malfunctioning products are segregated and positioned adjacent to the machine, whereas satisfactory products are enclosed within cardboard containers. The job of the selector is crucial in discerning between high-quality and faulty products. The selection process for identifying high-quality and faulty products adheres to the visual criteria established by the Defect Range Board (DRB) and Color Range Board (CRB). DRB is a visual criterion used to ascertain whether a product should be rejected or accepted based on its maximum limit. The DRB contains instances of faulty products, high-quality products, and the maximum permissible tolerance threshold. CRB serves as a visual reference for establishing the acceptable range of color variation. The DRB (Defective Rate Bound) and CRB (Critical Rate Bound) for each product are subject to variation based on the specific requirements or tolerance limits for product defects set by each customer.

The inspections conducted by the inspectors differ from those conducted by the selectors. Inspectors conduct inspections with greater specificity using a sampling plan that aligns with the inspection plan. The sample strategy, which involved evaluating the function, look, and color, was conducted on three occasions: during setup, in process, and at the end stage. Function samples will be inspected using a dyne test pen, rubbing test, and tape test. Examine the visual characteristics and hue of the sample by comparing it to the DRB-CRB. The number of samples for sampling varies based on the quantity of batches being analyzed. The AQL limit represents the uppermost threshold for the proportion of faulty items that is permissible in a given batch. Inspectors either conduct direct sampling or perform in-process sampling. The inspector examines the last samples or conducts inspections before they are sent out.

Each inspection consistently reveals faulty items in the AD line, exhibiting various forms of faults. Defects arising from the stamping and printing processes have distinct characteristics. The printing process may exhibit many defects such as scratches, black spots, material spots, thin printing, hair printing, jetting, printing blur, filthy ink, thick printing, gripping printing, and hazy printing. Conversely, the flaw in the stamping process primarily pertains to the foil. The majority of flaws in this method are untreatable due to the inability to remove the foil, similar to certain inks. The faults that can occur in the stamping process encompass slippage, hole stamps, striped stamps, jagged stamps, thick stamps, petal stamps, subordinate stamps, superior stamps, and hazy stamps.

Subsequently, the selector's capacity to conduct inspections utilizing Measurement System Analysis (MSA) attribute data is evaluated. The initial step involves choosing products to serve as test samples. Each step requires a total of 20 product samples. The sample products are categorized into two groups: those that are of high quality and those that are flawed. A total of 40 sample items were examined in the printing and stamping process, consisting of 20 products that met the required standards and 20 products that were found to be defective. Product selection is performed during machine operation. The quality supervisor validates the collected sample products to ensure that they conform to the product category and determines whether to approve or reject them. The product sample that has been categorized and validated by the quality supervisor serves as a reference or response key that will be requested by the selector. The answer key is categorized into two distinct groups: accepted and rejected answers. The last stage involves preparing DRB-CRB, an educational resource for selectors prior to conducting tests.

Conducting a test on 42 selects divided into three groups, with each group consisting of 14 individuals. The exam commences by seeking consent from the selector. The examiner elucidates the testing procedure, wherein the selector scrutinizes 40 sample items, thereafter segregating the products deemed acceptable into the accept product container, while placing the failed products in the reject product container. Prior to conducting the inspection test, it is essential to thoroughly examine the Design Reference Book (DRB) in order to comprehend the predetermined threshold for accepting the tested product. The findings of the selector test were examined using MSA.

The analysis of output is conducted by comparing the performance of individual appraisers to a standard, as well as by comparing the performance of different appraisers to each other and to the standard. The inspector establishes a minimum threshold of 85% for the pass selection standard applied to all output results. The initial analysis involves appraisers' assessment of the consistency of each selector's responses by comparing their answers in the first and second replications. According to the test results of all AD selectors, 10 out of 42 individuals (23.8%) scored above the norm, while the remaining 32 selectors (76.2%) scored below the standard. Selectors that fall below the requirement require more attention due to their propensity to produce inspection errors. The second analysis involves evaluating each appraiser's performance against a set criterion in order to ascertain the degree of truth or accuracy exhibited by each evaluator. This study not only compares the responses between the two replications, but also includes the pre-established standard replies. According to the test results of all the pickers, 97.6% of the participants (41 out of 42 people) were still below the standard. Further investigation is essential to determine the underlying causes behind the prevalence of inspection errors among numerous selectors. The final step involves doing an inter-rater reliability analysis to assess the consistency between appraisers. This analysis examines the concordance of responses among all pickers, without comparing them to the norm. The findings of the inter-rater reliability test among appraisers indicate very poor consistency. Specifically, team A demonstrates a consistency rate of 5%, team B has a consistency rate of 10%, and team C shows a consistency rate of 0%. This demonstrates that the selectors lack consistency in performing product inspections, and there is still a discrepancy in their interpretation of defective and good products among different selector teams. The final step involves comparing the evaluations of all appraisers to a standard, which reveals how each evaluator responded to the standard and determines the accuracy of their assessments. Based on the test findings, the selectors in Team A achieved a score of 5%, Team B achieved 10%, and Team C achieved 0%. The selectors' capacity to conduct inspections remains inadequate, suggesting that within a particular team, the selectors provided inconsistent responses that did not align with the prescribed replies. In other words, there is a possibility of errors occurring, where a product that is actually good is mistakenly labeled as defective, or a product that is actually defective is mistakenly labeled as being in good condition.

In addition, the fishbone diagram (Appendix 1) is used to investigate the potential underlying reasons for defective items that manage to pass inspection. After conducting extensive discussions with all selectors and inspectors, it was determined that the primary elements contributing to the issue were human error and methodologies. The approach elements encompass challenges in recognizing faulty items in accordance with DRB-CRB criteria, variations in specifications for defective products as per DRB-CRB, and distinct inspection techniques for each selector. The human factor arises from various causes, such as fatigue, particularly eye fatigue, lack of knowledge about product standards, reduced focus, and less attention to flaws, particularly in material components.

Utilize design thinking to revamp the visual inspection guide

Efforts to enhance product quality involve modifying the DRB-CRB visual inspection guides to assist selectors in accurately identifying product flaws, hence increasing the likelihood of passing inspection. The redesign of DRB-CRB was executed with a design thinking methodology [18] encompassing five distinct stages: empathize, define, ideate, prototype, and test.

Stage of empathy. The objective of this stage is to comprehensively comprehend the DRB-CRB rules from the perspective of the user [16]. The designer of the DRB-CRB guidelines employs a method of discussion and observation. They observe and inquire with selectors and examiners, who serve as users, in order to gain a comprehensive understanding of the desired DRB-CRB guidelines. At this point, a wide range of information regarding the DRB-CRB was gathered. What is the frequency of using the DRB-CRB as a reference for assessing package quality during a single shift? Is the visibility of the location and orientation of the DRB-CRB straightforward? Can the DRB-CRB guide assist in identifying various types of defects? Additionally, it requests information regarding the present visual representation of the DRB-CRB, its dimensions, and the proximity between the image and the description within the DRB-CRB. What are the users' preferences regarding the visual aesthetics of the DRB-CRB? What is the user's comprehension of the current CRB-DRB description, where should the description be positioned, and are there any recommendations for supplementary descriptions? What is the frequency at which users come across flaws that are not specified in the DRB-CRB, as well as defects that are challenging to identify? Do users frequently express skepticism and inquire about flaws to other departments?

The term "stage" refers to a distinct phase or period in a process or development. During this phase, the identified users' requirements for the DRB-CRB guidelines, which were determined in the previous empathy step, are examined to ensure clarity. Through careful observation and user inquiries, it has been determined that users, namely selectors, typically consult or take notice of the DRB-CRB guide an average of 1-3 to 3-5 times during each shift. Users rarely utilize the DRB-CRB handbook. Furthermore, it was determined that the guidelines provided by the DRB-CRB for certain items were deemed to be less beneficial or less valuable. Typically, users suggest enhancements to the DRB-CRB in order to optimize its capacity to direct inspections. One of the proposed enhancements is to modify the arrangement of the DRB-CRB guidelines, ensuring that they do not overlap in order to facilitate the differentiation of defect kinds. Additionally, it is advisable to enhance the guide's description by providing more comprehensive and lucid information in Indonesian. This will enable users to gain a more precise understanding of the many sorts of flaws. Additionally, it is advisable to optimize the positioning of the guide description in order to enhance visibility and legibility for users.

Ideation Stage. The purpose of this stage is to gather and refine a range of solution concepts derived from the suggestions or inputs provided by users in the preceding Define Stage. Potential remedies for addressing the DRB-CRB recommendations that better align with user preferences and requirements can be generated through collaborative brainstorming sessions including all key quality control stakeholders, including selectors, inspectors, and quality managers. They collectively contribute thoughts or suggestions for enhancing the design of the DRB-CRB [9]. We collected a total of 50 potential designs for the DRB-CRB. An evaluation was conducted on all of the design solution suggestions proposed by the DRB-CRB, and the most exceptional ones were chosen. Subsequently, the chosen DRB-CRB guide solutions ideas (Appendix 2) were developed into prototypes. The chosen DRB-CRB guide exhibits enhanced clarity and organization in its design. It provides supplementary information on each defect type and effectively separates the faults into distinct columns for improved visibility. Furthermore, the positioning of photos and their accompanying descriptions avoids any overlap. Using various colors and employing a high level of tolerance, words can be differentiated. For instance, the word "reject" can be highlighted in red to indicate rejection, while black can be used to signify that it is still within permissible bounds.

Development in the prototype stage. A prototype of the DRB-CRB was created to facilitate the examination of a product, based on the design solutions chosen in the previous Ideate Stage. The DRB-CRB prototype was meticulously crafted to closely resemble the selected design concept. Subsequently, the DRB-CRB prototype underwent testing, where multiple selectors utilized it as a reference to examine products that were already identified as either defective or non-defective. The products evaluated by each inspector undergo a validation process to ensure that the selector, as a user, has made the correct option based on the design concept. This prototype is just intended for testing purposes and should not be utilized on the production floor.

Testing phase. Currently, the new DRB-CRB design is being evaluated and utilized by multiple selections to facilitate the quality assessment of a product. Analyzed through Measurement System Analysis, the test findings of attribute data aimed to determine the impact of the new DRB-CRB design on both the appraiser's answer and the user's reaction. Prior to conducting the test, all users/selectors thoroughly examined the new design of the DRB-CRB. A total of six participants, picked at random from both Team A and Team B, were used as samples. The experiment was conducted twice, on separate days. Consequently, the revised design of the DRB-CRB has an impact on user feedback. The test results for the user utilizing both the old and new designs are displayed in Appendix 3. After analyzing each appraiser's performance compared to the corporate standard, it is evident that the selectors have shown significant improvement. However, two out of the six selectors have not yet met the company's criteria. The user's error rate is significantly lower compared to the prior test results. Enhancing the visual guide leads to a significant improvement in accuracy for checking, resulting in a reduction of inspection errors by 8.3% within selectors, 36.25% between selectors, and 15.8% for each selector compared to the standard. Furthermore, the examination of all appraisers compared to the standard reveals a rise in the accuracy of correct checks, with Team A achieving 45% and Team B achieving 32.5%. On average, the visual guide is capable of reducing inspection errors for all selectors compared to the standard by 38.75%. Nevertheless, the company's anticipated gain of 85% in accuracy has not been achieved, making it suboptimal.

The enhancement of the DRB-CRB design necessitates a reiteration of the five stages of design thinking, commencing with the preliminary stage, empathize. The second iteration of the design thinking process suggests enhancing the training methodology. This training not only attempts to enhance inspection skills, but also seeks to ascertain the utilization of the guide by pickers. What are the constraints or deficiencies of the guide design. How does the selector provide feedback when utilizing the guide? These recommendations can enhance the design and therefore enhance the performance of the selector in conducting inspections. Case studies are provided during the training to encourage active participation from the selectors [6]. As a result of the study's timing constraints, the suggested training has not been completely put into action. The new DRB-CRB design, developed through the utilization of case studies in training, is anticipated to enhance the proficiency of selectors in conducting inspections.

It is necessary to consistently monitor and assess the efficiency of the revised DRB-CRB design. Monitoring can be conducted with the checklist format (Appendix 4).

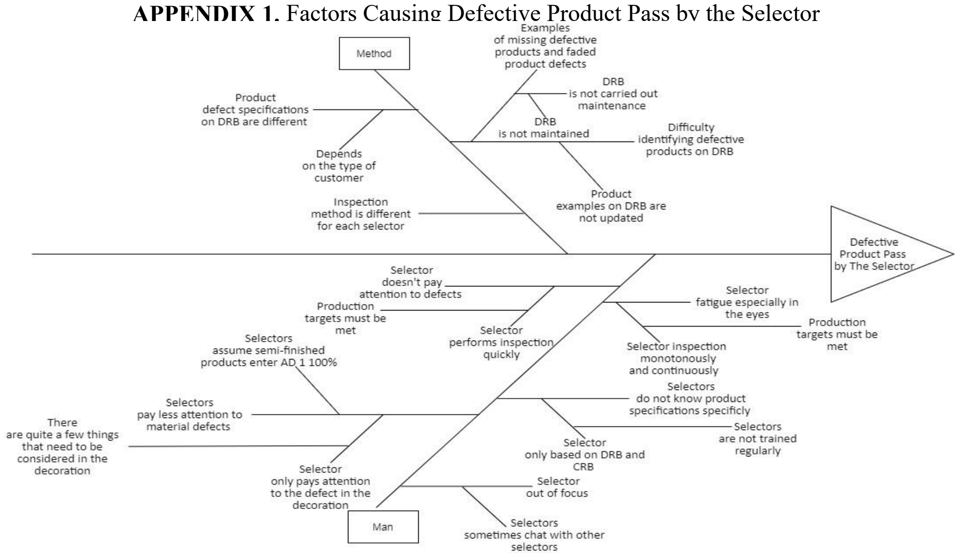
CONCLUSION

Through careful observation of the manufacturing floor, it has been noted that a significant number of defective goods are able to pass inspection. This is mostly attributed to the DRB-CRB's limited ability to effectively perceive quality control boundaries, as well as human error and the incompetence of selectors. Enhancement endeavors involve modifying the DRB-CRB in accordance with the desires and requirements of users. The redesign process is executed through collaborative efforts between designers and users, employing a Design Thinking methodology. According to the measurement system analysis, the new DRB-CRB design effectively decreases selection error, but it does not meet the company's intended level of optimization. The enhancements made to the visual guide have resulted in a reduction in inspection mistakes by 8.3% within selectors, 36.25% between selectors, 15.8% for each selector compared to the standard, and 38.75% for all selectors compared to the standard. There is a need for enhanced training to improve the pickers' capacity to apply distinct guidelines based on the products requested by clients. This training should be more engaging and distinctive from the conventional training conducted thus far. Utilizing presenting methods and case studies for training is a suggested alternative. The objective is to ascertain the specific DRB-CRB recommendations that the selectors truly require, in order to ensure their satisfaction and enthusiasm in implementing those guidelines.

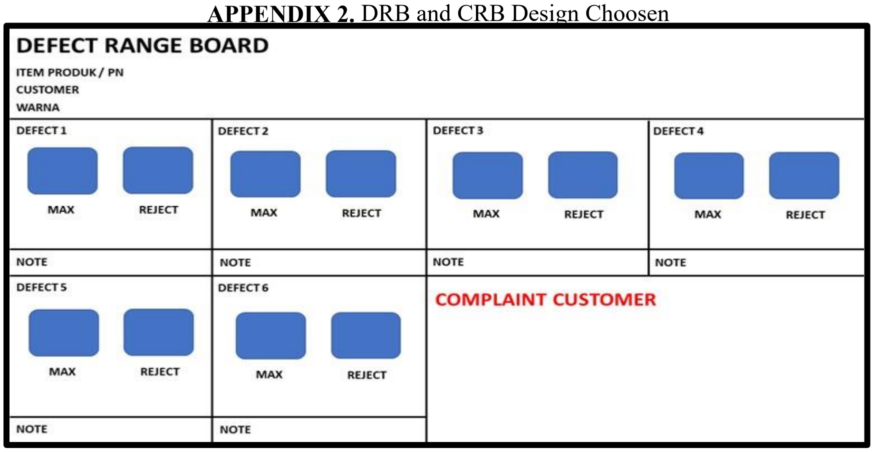
The DRB-CRB visual guide design with one DT cycle still exhibits numerous deficiencies, and the reduction in selection error falls short of the company's objectives. Another deficiency lies in the failure to observe the work behavior and routines of each selector. Enhancing the DRB-CRB design necessitates the iterative implementation of DT cycles. In order to enhance the appeal and efficacy of the DRB-CRB in minimizing inspection errors, it is imperative to explore alternative media, such as audio-visual, which can offer more comprehensive explanations, facilitate communication, and generate greater interest.

APPENDIX

APPENDIX 1. Factors Causing Defective Product Pass by the Selector



APPENDIX 2. DRB and CRB Design Choosen



APPENDIX 3. MSA Analysis for Attribute Data Before and After Improv ement

Selector	Within Appraiser (%)		Each Appraiser VS Standard (%)		Between Appraiser (%)		All Apraiser VS Standard (%)	
	Before	After	Before	After	Before	After	Before	After
Team A	85.0 87.5 80.0	100.0 87.5 92.5	77.5 72.5 55.0	90.0 80.0 87.5	35	77.5	32.5	77.5
Team B	80.0 87.5 72.5	92.5 90.0 80.0	70.0 75.0 55.0	87.5 85.0 70.0	35	65.0	33.5	65.0

APPENDIX 4. Checklist Form Example for Monitoring the DRB-CRB Effectivity

DRB-CRB Checklist			
Company Logo	**Ref no: XXXX** **Items: Product X**	***Confirmed by***	***QC Approval***

Name	Loaning		Evaluation				Need Repair?	Description	Corrective Action
	Borrow Date	Return Date	Cleanliness	Appropriateness	Product Condition	Writing Condition			

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