ISJET

INTERNATIONAL SCIENTIFIC JOURNAL OF ENGINEERING AND TECHNOLOGY

Volume 8 No. 1 January-June 2024

ISSN 2586-8527 (Online)

Panyapiwat Institute of Management

Indexed in the Thai-Journal Citation Index (TCI 2)

INTERNATIONAL SCIENTIFIC JOURNAL OF ENGINEERING AND TECHNOLOGY (ISJET)

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PANYAPIWAT INSTITUTE OF MANAGEMENT

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INTERNATIONAL SCIENTIFIC JOURNAL OF ENGINEERING AND TECHNOLOGY (ISJET)

Volume 8 No. 1 January-June 2024 ISSN 2586-8527 (Online)

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Frequency of Publication:
Twice a year
• The first issue: January-June
• The second issue: July-December

Publication and Access Charges:
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Dear Colleagues,

I am pleased to present this new issue of the International Scientific Journal of Engineering and Technology (ISJET). This issue features a diverse collection of articles that highlight the latest advancements in engineering and technology research.

The issue opens with an article on the alternative design of a stacking-bag assistive device for facilitating the loading and unloading of objects. This article presents a case study on Sago Bags. The second article explores the development of a credit risk prediction model using feature engineering and machine learning techniques. This research has the potential to improve financial decision-making processes.

The issue also features articles on the development of a crispy spicy snack from Bhutan oyster mushroom by-product with Narok chili paste, enhanced autonomous driving using PrediNet20 with AHLR, a review of strawberry cultivation and challenges in Northern Thailand, and the design and implementation of material requirement planning in a plastic company. These articles showcase the wide range of engineering and technology research being conducted around the world.

I am confident that this issue of ISJET will be of interest to a broad audience of researchers, engineers, and practitioners. I encourage you to read the articles carefully and consider submitting your own research to future issues of the journal.

With kind regards,

Assoc. Prof. Dr. Parinya Sanguansat
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CONTENTS

Alternative Design of a Stacking-Bag Assistive Device for Facilitating Loading and Unloading of Objects – A Case Study on Sago Bags

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Received: February 7, 2024 / Revised: February 28, 2024 / Accepted: February 29, 2024

Abstract— **This study presents an alternative design for handling sago bags, focusing on creating a user-friendly platform for loading and unloading. Sago is packed in canvas bags of varying loads (15 kg, 25 kg, and 30 kg), which poses challenges due to its non-uniform distribution and can lead to stability issues during transport. The study proposes an assistive device made of durable, tough, and resistant materials such as HDPE, PP, ABS, and Polyester, offering a balance between hardness and solidity. The device's standardized size allows for easy connection and application with the forklift lever, with a simple design for easy maintenance and part replacement. The elastic properties of polymer materials enable deformation during heavy load handling, crucial for shock absorption in a stacking-like building style. Rubberized shoulder straps enhance grip and durability. The device can be folded into a compact size (109 cm × 30 cm × 10 cm) for easy stacking and storage. The handle features a rubber grip for comfort, and the side belt is made of 1.5 mm thick polyester, designed to accommodate 50% and 100% capacity. The base, 1 mm thick, is constructed from polypropylene (PP) and measures 109 × 120 cm, ensuring a robust and efficient solution.**

Index Terms— **Transportation, Pallet, P-Sling, Design and Development, Material Handling System, and Storage System**

I. Introduction

Tapioca pearls, also known as sago, are versatile ingredients used in various culinary creations, such as boba tea, sago cantaloupe, and sago vada. Made from tapioca starch, these pearls are rich in carbohydrates and calories. In tapioca pearl manufacturing, tapioca starch undergoes granulation to form spheres of different sizes, which are then meticulously sorted. Subsequently, the pearls undergo roasting and drying processes [1].

When storing tapioca pearls, use food-grade, airtight containers to maintain freshness and prevent contamination. Ensure the containers are durable and resistant to tearing, especially during transport. Store them in cool, dry places to prevent moisture absorption, which can affect their texture and quality. Properly label containers with packing and expiration dates to use the product within its shelf life. Implementing these practices optimizes the handling and storage of sago bags, improving efficiency, organization, and preservation. Securely pack and stack bags to ensure stability during transport, preventing shifting or damage. Maintain uniform weight distribution and prevent deformations by properly distributing sago within bags. Store bags in dry, well-ventilated areas to prevent moisture buildup, reducing the risk of spoilage or mold growth. Use appropriate handling equipment, like forklifts or pallet jacks, to minimize physical strain and potential bag damage. Select durable materials for bags and handling equipment to withstand transportation and storage rigors. Implement efficient storage and retrieval systems to streamline operations and minimize handling time. Regularly inspect bags for damage or deterioration, addressing issues promptly to prevent further damage. Provide training to personnel involved in handling and storing sago bags to ensure proper procedures are followed, reducing the risk of accidents or damage [2]-[7].

After conducting direct interviews with business owners, it became evident that in real-world applications, several factors require attention to ensure the efficiency, organization, and preservation of sago bags in a factory storage setting.

• *Racking System:* Implement a sturdy and well-organized racking system that allows for easy stacking and retrieval of sago bags. Adjustable shelving can accommodate bags of varying sizes, optimizing the use of vertical space. However, the cost of organizing items is perceived as high due to the materials used in their construction.

• *Categorization and Labeling:* Clearly label different sections or shelves for specific types or grades of sago bags. This makes it easier for workers to locate and retrieve the required bags quickly. Accurate details like instruction plates, manufacturing dates, and parameters need to be carefully prepared; otherwise, wrong information might confuse users.

• *Ventilation:* Ensure proper ventilation within the storage area to prevent moisture buildup. Sago bags are sensitive to humidity, and maintaining optimal conditions helps in preserving the quality of the product. High humidity or excess moisture can lead to the growth of fungi or infections later.

• *Palletization:* If applicable, consider palletizing the sago bags. Pallets provide stability, ease of handling with forklifts, and allow for proper airflow around the bags. Inserting the forklift levers into the designated slots of the pallet requires skill and stability to move items effectively.

• *Inventory Management System:* Implement a digital inventory management system to keep track of the quantity, production date, and other relevant information for each batch of sago bags. This enhances traceability and helps in managing stock levels efficiently.

• *Safety Measures:* Incorporate safety measures to prevent damage to the sago bags during storage. This may include using corner protectors, implementing guidelines for stacking height, and providing a designated area for loading and unloading.

• *Regular Inspections:* Schedule regular inspections of the storage area to identify and address any issues promptly. This proactive approach helps in maintaining the quality of the sago bags and ensures a smooth storage process.

• *Employee Training:* Train warehouse staff on proper handling procedures to minimize the risk of damage to the sago bags during storage and retrieval.

• *Climate Control:* If feasible, consider implementing climate control measures to regulate temperature and humidity, especially in areas prone to extreme weather conditions.

• *Quality Control Checks:* Conduct periodic quality control checks on stored sago bags to identify any signs of deterioration or damage. Prompt action can prevent the spread of issues and maintain the overall quality of the stored products.

Once these aspects have been addressed, the engineering team can establish an efficient and organized product storage system for sago bags in a factory storage environment.

II. Research Background

To achieve the objective of this study, which focuses on identifying an effective approach for managing loads during transportation and organizing stacked sago bags, various factors will be considered. These include the types of sago available in the industry, waste management, user-friendliness, ergonomic considerations, relevant research findings from similar case studies, and the overall performance within the context of the sago bag supply chain.

A. Food waste and Sustainability

In recent years, there has been a heightened focus on food waste at local, national, and international levels, driven by concerns about the environment, social implications, economic impacts, and climate change effects. Statistics reveal that roughly one-third of the world's food, equivalent to about 1.3 billion tons annually, goes to waste [8]. This significant level of food wastage poses profound consequences, contributing to environmental, economic, and social challenges, including food insecurity and the exacerbation of global warming [9]. The growing awareness of the environmental impact of food-processing waste has prompted a need to explore using this waste for livestock feed, considering its feasibility, safety, and sustainability. This research addresses the urgent issue of reducing food waste and enhancing sustainability by repurposing waste as livestock feed, highlighting the potential to convert waste into a valuable resource in agriculture. Additionally, food waste, rich in carbohydrates, proteins, and lipids, offers significant potential for biotransformation into valuable compounds. This underscores the opportunity for sustainable bioconversion methods, including the use of immobilized enzymes, to convert food waste into high-value products. Such approaches align with the broader goals of the bioeconomy, addressing environmental challenges and leveraging economic opportunities associated with food waste [10], [11].

B. Tapioca Pearl in Food Industries

Tapioca pearls or sago, are extensively used in bubble tea, desserts, and snacks, showcasing their versatility in the food industry [12]-[16]. These pearls, appreciated for their unique texture and flavor-absorbing capabilities, are popular in diverse culinary applications. Sago is derived from wet tapioca starch, obtained after extracting excess water in sedimentation tanks. Marketed as small globules or pearls, sago is valued for its easy digestibility, high carbohydrate content, and a size range from 2 to 4.5 mm [17], [18]. Its consumption offers a rapid energy boost, making it particularly beneficial for swift patient recovery. When cooked, sago undergoes a transformation from an opaque white to a translucent, soft, and spongy consistency [19]. However, caution is advised due to its high heat sensitivity; frying may cause sago to become sticky and gluey, making separation nearly impossible.

C. Sago Byproducts: Exploring Tapioca's Secondary Outputs

Numerous case studies and examples illustrate the creation of innovative food products from substandard or byproduct materials. A notable instance is the utilization of tapioca byproducts to produce bio-sugar [20]. Their research delves into the enzymatic saccharification of tapioca processing waste, resulting in biosugar generation through immobilization technology. By addressing the conversion of processing waste into valuable biosugars, this study exemplifies the potential for sustainable use of agricultural byproducts. Enzymatic processes present a promising pathway for enhancing the value of waste materials, contributing to resource efficiency. Emerging food processing technologies can significantly contribute to transforming defective tapioca pearls into desirable products. Introducing an innovative sensor that uses purple sweet potato tapioca pearls to monitor shrimp freshness is intriguing [21]. The tapioca pearls are a key component in creating a pH sensor for this purpose. This creative use of tapioca pearls in developing a freshness monitoring sensor demonstrates the adaptability of traditional ingredients for modern food quality assessment.

D. Forces Applied on Vertically Stacked Sago Bags

This section will discuss the forces exerted on vertically stacked sago bags, with all data sourced and summarized from manufacturers in the sago field. The key considerations can be articulated through the following statements.

When vertically stacking sago bags, various forces come into play, influencing the stack's stability and integrity. The primary force is *gravity*, with each bag exerting a downward force on the one below, accumulating as the stack grows. Friction between adjacent bags contributes to lateral stability, preventing horizontal shifts. *Compression forces* result from the weight of the entire stack pressing down, necessitating consideration of compressive strength. Internal shear forces may occur due to uneven loading or shifting contents. *Dynamic forces*, stemming from handling and transportation, can impact the stack, emphasizing the need for reinforcement. *Environmental factors*, such as moisture and temperature, affect bag material properties. The structural design and strength of the bags are pivotal, and the stacking configuration influences force distribution. Understanding and managing these forces is critical for preventing collapse, ensuring safe handling and storage, and preserving the quality of both the sago bags and their contents. Regular assessments and adjustments in stacking practices may be necessary based on specific bag characteristics and usage conditions.

Detailed discussions on each type of force will be provided in the subsequent section.

III. Research Concepts

To investigate alternative designs for creating a supporting device or method to transport stacked sago bags with varying weights (15, 25, and 30 kg), it is essential to consider the concepts and fundamental principles of force distribution, as well as the design and properties of both 'P-Sling and Pallet'. Additionally, customer satisfaction and analysis should be taken into account.

A. Eight Types of Forces

When sago bags are vertically stacked, eight types of forces come into play, impacting the stability and integrity of the stack. The details of key considerations and discussions regarding the forces applied to vertically stacked sago bags are explained in the following statements.

- *Gravity*

  Downward Force: The primary force acting on the stacked sago bags is gravity. Each bag exerts a downward force on the bag below it, accumulating as the stack grows taller. The force applied depends on the weight of the individual bags and the number of bags in the stack.

- *Friction*

  Lateral Force: Friction between adjacent bags plays a role in maintaining the stability of the stack. Adequate friction prevents bags from sliding or shifting horizontally, contributing to the overall structural integrity of the stack.

- *Compression*

  Vertical Force: As more bags are added to the stack, the lower bags experience compressive forces. This compression is a result of the weight of the entire stack pressing down on the bags at the bottom. It is important to consider the compressive strength of the bags and the potential for deformation.

- *Shear Forces*

  Internal Forces: Shear forces within the bags may occur due to uneven loading or shifting of contents. Properly securing the bags and evenly distributing the load helps minimize shear forces and prevents internal structural damage [22].

- *Dynamic Forces*

  Impact Forces: During handling or transportation, dynamic forces may be applied to the stack. These forces can result from sudden starts, stops, or vibrations. Strengthening the bags and optimizing the stacking pattern can mitigate the impact of dynamic forces.

- *Environmental Factors*

  Moisture and Temperature: Environmental conditions, such as moisture and temperature fluctuations, can affect the bags' material properties.

Wet or weakened bags may alter the forces involved, emphasizing the importance of proper storage conditions.

- *Structural Design*

Bag Strength: The design and strength of the sago bags significantly influence the forces they can withstand. Using bags with adequate structural integrity is essential for maintaining stability when stacked vertically.

- *Stacking Configuration*

Alignment and Symmetry: The arrangement and symmetry of the stack impact the distribution of forces. A well-aligned and symmetrical stack helps evenly distribute the load, minimizing the risk of uneven forces [23].

Fig. 1 illustrates the load applied to the heavy bag during manual carrying for stacking purposes. The force distribution results in the deformation of the sago bag shape and may cause fatigue in workers.

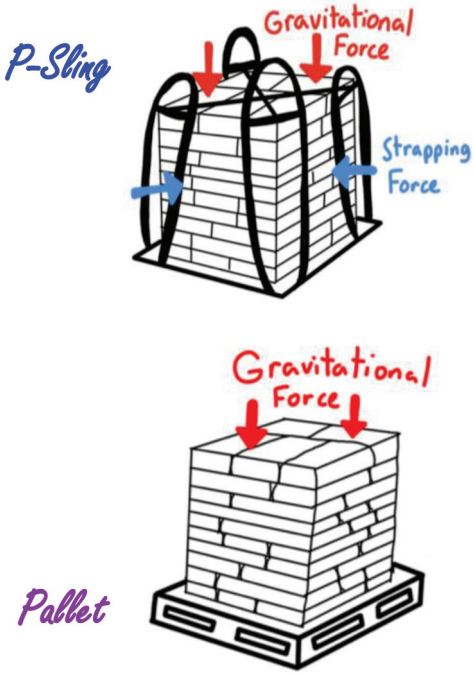


Fig. 1. The load applied to the heavy bag during carrying by forklift.

Moreover, human labor is required for putting the sago bag to the 'P-Sling' or 'Pallet' one by one where the weight of the bag is varied in the range 15 kg, 25 kg, and 30 kg [24].

The proper ways to support worker's health during carrying heavy bag, these are the tips. When lowering the bag, it is important to follow these steps to ensure safety and proper handling (Fig. 2):

1. Avoid unloading the bag directly from the shoulder to floor level.
2. Use an intermediate platform or seek assistance from a co-worker.
3. Stand close to the platform.
4. Place one foot in front of the platform.
5. Bend hips and knees while keeping the back straight.
6. Gently ease the bag off the shoulder and place it upright on the platform.
7. Pull the bag slightly over the edge of the platform.
8. Stand close to the platform with the bag touching the chest.
9. Clasp the bag against the body with one hand, while the other hand holds the bottom of the bag.
10. Step back.
11. Bend hips and knees, maintaining a straight back.
12. Carefully ease the bag onto the floor.

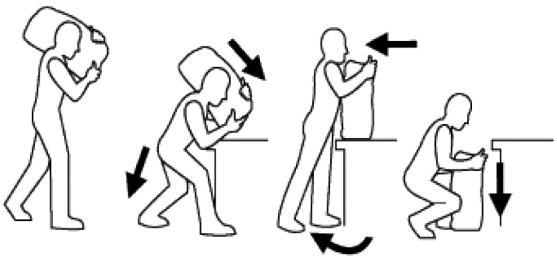


Fig. 2. Carrying Platform for Ensuring Safety and Proper Handling [25]

Understanding and carefully managing these forces are crucial for preventing stack collapse, ensuring the safety of handling and storage, and preserving the quality of the sago bags and their contents. Regular assessments and adjustments in stacking practices may be necessary based on the specific characteristics of the sago bags and the conditions of use.

B. Requirements for 'P-Sling' to Carry Stacking Sago Bags

Through interviews with target customers who have encountered issues with managing sago-stacked bags, some express the need for 'P-Sling' for carrying, while others prefer 'Pallet' for its rigid base. To address the pros and cons of each carrying method, it is crucial to uncover and analyze the specific requirements for both. The findings can illuminate a promising direction in the design stage for creating an alternative platform for carrying heavy loads.

For the first method, 'P-Sling', what customers require and expect from P-Sling to carry sago bags with varying weights (15 to 30 kg each) that are subsequently stacked up vertically includes:

- *Load Capacity*

Ensuring the P-Sling can effectively and safely handle sago bags ranging from 15 to 30 kg.

- *Durability*

Expecting robust construction and materials to withstand the weight and potential stresses during lifting and stacking.

- *Adjustability*

Capability to accommodate different bag weights with adjustable features for versatile use.

- *Secure Fastening*

Reliable mechanisms for securing bags during lifting and preventing any unintended shifts.

- *Ease of Use*

Design features that facilitate easy and efficient loading, unloading, and stacking of sago bags.

- *Safety Measures*

Implementation of safety features to prevent accidents or damages during handling.

- *Compatibility*

Compatibility with the specific dimensions and characteristics of sago bags for optimal performance.

- *Longevity*

Long-lasting performance and resistance to wear and tear for extended use.

- *Stacking Stability*

Ensuring that the P-Sling contributes to the stability of vertically stacked sago bags.

- *User-Friendly Design*

A design that considers the ease of use and ergonomics for operators involved in the handling process.

C. Requirements for 'Pallet' to Carry Stacking Sago Bags

In the case of the second method, 'Pallet', customer expectations and requirements for the effective use of Pallet" to transport vertically stacked sago bags with varying weights (15 to 30 kg each) involve:

- *Load Capacity*

Adequate strength and load-bearing capacity to support the weight of stacked sago bags.

- *Durability*

Long-lasting and robust construction to withstand the rigors of handling and transportation.

- *Dimensional Compatibility*

Proper sizing to accommodate the dimensions of sago bags for secure stacking.

- *Stability*

Ensuring stability during stacking and transportation to prevent tilting or collapsing.

- *Material Selection*

The critical decision-making process of choosing materials suitable for the storage and transportation conditions of sago bags. Although wood and plastic are widely favored for pallet construction due to their popularity, it is essential to acknowledge that they may have inferior strength when compared to metal, which is typically crafted on-demand or in customized styles.

- *Ease of Handling*

Design features that facilitate easy loading, unloading, and movement of stacked bags.

- *Stacking Uniformity*

Providing a uniform surface to ensure even stacking of sago bags.

- *Compatibility with Handling Equipment*

Integration with handling equipment like forklifts for efficient transportation.

- *Environmental Considerations*

Resistance to environmental factors such as moisture, ensuring durability over time.

- *Cost-Effectiveness*

Balancing performance with cost considerations for practical and economic use.

D. The Overall Sequences Required for Creating Analternative Design of a Stacking-Bag Assistive Device

To establish a systematic platform for the proposed research, four main topics (sequences) (Fig. 3) are necessary to accomplish the task. The subsequent section will provide detailed information on each of these topics. The design process begins with a thorough Customer Satisfaction Analysis, aimed at understanding customer needs and translating them into essential engineering design factors.

The design process begins with a thorough Customer Satisfaction Analysis, aimed at understanding customer needs and translating them into essential engineering design factors. This analysis lays the foundation for the Conceptual Design, which involves drafting the desired product design. The next step, System Level Design, classifies the drafted design into main and sub-components, ensuring a structured approach. Detailed Design follows, specifying key findings and requirements for each component based on customer needs. This process ensures that customer requirements are systematically analyzed to align with functional requirements. Finally, the Testing and Refinement stage, illustrated through case studies, focuses on considering material properties required for components like the 'Pallet' and 'P-Sling', ensuring the product meets quality standards and customer expectations.

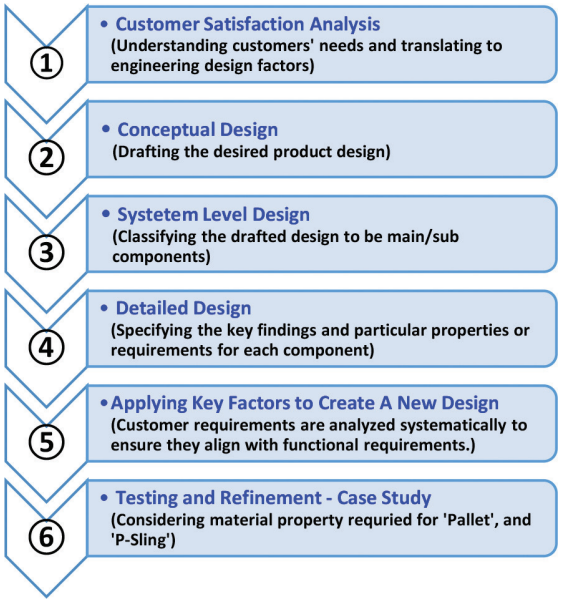


Fig.3. The summarized flowchart for the overall sequences of the research

IV. Customer Satisfaction Analysis

In this study, the chosen technique for considering and extracting customers' requirements to design and assess their satisfaction is Quality Function Deployment (QFD). Quality Function Deployment (QFD) is a systematic product development methodology that originated in Japan. It serves as a tool to translate customer needs and expectations into specific engineering characteristics and actions throughout the product design and manufacturing process. QFD involves cross-functional collaboration, ensuring that the entire organization aligns with customer requirements. It utilizes matrices known as "houses of quality" to visually represent relationships between customer needs, engineering characteristics, and various stages of product development. The aim is to enhance customer satisfaction and product quality by integrating the voice of the customer into every phase of the design and production lifecycle [26]-[28].

The key objective: Optimizing sago-stacking bag holder/carrier solutions for varied weights (15, 25, and 30 kg) through "Pallet and P-sling styles".

The key tools: To establish design guidelines for effectively holding and carrying sago-stacking bags with varying weights (15, 25, and 30 kg) through both "Pallet and P-sling styles", the following approach is recommended:

Approach I: Customer's Requirement Exploration

Step 1: Define the target user group.

Step 2: Identify customer needs through questionnaires, interviews, and experiments.

Step 3: Conduct a competitive analysis of competitor products from the customer's perspective.

Approach II. Customer's Priorities and Engineering Characteristics (ECs) Evaluation

Step 1: Prioritize customer expectations related to the sago carrying method through "Pallet or P-sling", focusing on factors like ergonomic comfort, strain prevention, and ensuring a secure and gentle grip during the lifting and transportation process.

Step 2: Consider additional factors, including lightweight design, with careful attention based on priority ratings.

Step 3: Evaluate engineering characteristics (ECs) with the highest relative weight, focusing on material type, error rate during carrying (failure rate), shape of the entire frame of stacked bags during transportation, and cost of both 'Pallet' and 'P-sling'. Additionally, consider user perceptions and experiences by applying their '5 senses', incorporating sensory feedback such as touch, sight, hearing, smell, and taste, to enhance the overall design and usability of the sago carrying method.

Step 4: Distinguish between ECs requiring experimentation (material type, shape, and size) and those derived through questionnaires or reasoning (surface area, holder construction, and function).

The key considerations of this approach are about when considering carrying by forklift, ergonomic comfort is indeed a relevant factor. While forklift operators may not directly carry the loads manually, their comfort and well-being play a crucial role in ensuring efficient and safe material handling. This involves aspects such as providing a comfortable seat and ergonomic controls for the operator, minimizing vibrations and shocks during operation, optimizing visibility to reduce strained body positions, designing a spacious and accessible cabin, implementing noise reduction measures, and, if applicable, offering climate control features for comfort during varying weather conditions. Ensuring ergonomic considerations in these areas contributes to increased productivity, safety, and overall job satisfaction for forklift operators.

Approach III: Design and Development Considerations

Step 1: Account for user preferences, storage positions, and specific needs or discomfort in the sago-stacking bag holder/carrier design.

Step 2: Encourage users to try different holders/carriers or seek professional advice for personalized solutions.

Step 3: Address concerns about time consumption and potential price increases by presenting an alternative approach.

Step 4: Suggest that target users rely on searching information about the product of interest to compare the pros and cons of relevant products available in the market. Utilize commercial or social platforms for acquiring information to make informed decisions.

This systematic approach ensures that the design process for sago-stacking bag holder/carrier solutions considers customer expectations, aligns with engineering characteristics, and offers diverse options catering to individual preferences and needs.

V. Conceptual Design Stage

To propose an appropriate assistive platform for stacking sago bags, examining the components and design features of both 'P-Sling' and 'Pallet' is essential. The design team has systematically extracted key design requirements from both handling styles. The subsequent sub-sections provide detailed insights into the components and design features.

A. The Components and Design Features of P-Sling

The P-Sling, designed for efficient handling of sago-stacking bags, typically comprises sturdy yet flexible materials. Its components include adjustable straps that can securely hold bags of various sizes and weights, allowing for versatility in accommodating different loads. The straps are often made from durable materials to ensure strength and longevity. The design incorporates ergonomic considerations, featuring padded sections or handles for comfortable gripping during lifting and carrying. Additionally, P-Sling may incorporate reinforced stitching or load-bearing points to enhance its overall durability and reliability in supporting heavy loads. To ensure ease of use, the P-Sling design may include quick-release mechanisms or adjustable buckles, enabling swift and secure attachment and detachment of bags. This user-friendly design contributes to efficient loading and unloading processes. Illustated in Fig. 4 is the design of the 'P-Sling'.

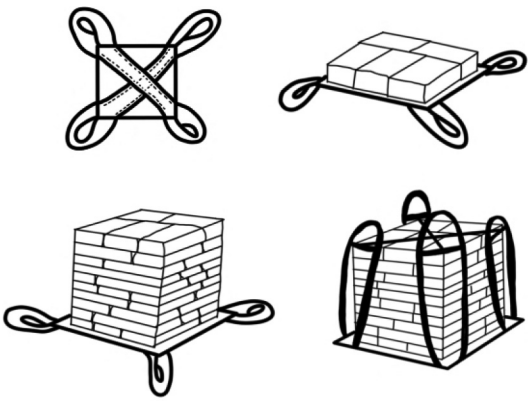


Fig.4. The components and design features of 'P-Sling' available in the market

The key points: The P-Sling is engineered with a focus on durability, versatility, and user comfort, making it a practical and efficient tool for handling sago-stacking bags of varying weights and sizes.

B. The Components and Design Features of a Pallet

Pallet is designed for the efficient handling of sago-stacking bags, encompass several key aspects. Pallets are typically crafted from materials like *wood, plastic,* or *metal*, ensuring robustness and sufficient load-bearing capacity.

Their size and dimensions vary to accommodate diverse bag sizes and weights, while the inclusion of deckboards and stringers ensures even weight distribution and stability during transportation and storage. *Load-bearing capacity* is a crucial consideration, with pallets engineered to support specific weight limits without compromising structural integrity. *Durability and longevity* are inherent in pallet design, achieved through material choices and construction techniques such as heat or chemical treatment. Accessibility from all four sides facilitates ease of handling with forklifts or pallet jacks. *Stackability* is a notable feature, optimizing storage space in warehouses and during transportation. Some designs may also incorporate safety features like anti-slip surfaces or rounded edges to enhance workplace safety during handling operations.

The key points: Pallets are thoughtfully designed to provide durability, standardization, and operational efficiency in the handling and storage of sago-stacking bags within a supply chain context. Illustated in Fig. 5 is the design of the 'Pallet'.

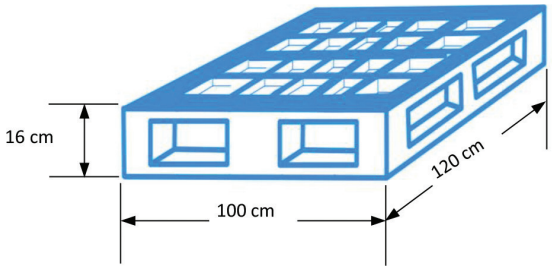


Fig.5. The components and design features of 'Pallet' available in the market

C. Design Analysis

The use of soft containers as 'P-sling' design can help reduce labor costs, provided that the enterprise has [29]:

- Devices for loading (unloading) containers.
- Loading devices for supplying containers for loading (unloading) and transportation means.
- Temporary storage sites and warehouses for filled containers.

All the benefits of soft containers can be realized if the container is appropriately chosen based on the type of cargo and if handling rules are adhered to. When selecting soft containers, various factors are taken into account, depending on the properties of the transported cargo, logistical chain, and customer

requirements. Therefore, it is recommended to consult the technical services of the manufacturer when choosing the type of soft container.

Illustrated in Fig. 6 are the Dos and Don'ts for applying soft containers.

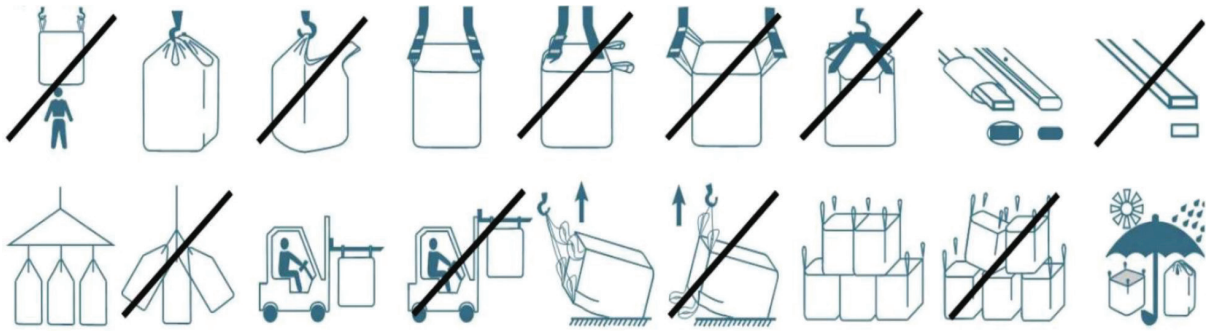


Fig. 6. The Dos and Don'ts for applying soft containers [29]. Instructions for use - Big bag user manual.

However, choosing 'P-Sling' as a solution for managing stacked items, which is itself easy to store with minimal space requirements, comes with certain limitations outlined in the standard soft container guidelines. It is specified that soft materials such as 'P-Sling' cannot be employed for the following materials:

- Liquids (special containers are designated for them)
- Substances containing concentrated corrosive acids and alkalis.
- Substances of hazard class I (explosive, strong poisons)
- Radioactive materials
- Materials with temperatures exceeding 120°C
- Lump and piece materials with a size larger than 250 mm with sharp edges

D. Pros and Cons of P-Sling and Pallet

The design team carefully weighs the pros and cons of this style as a pivotal consideration for design and development purposes. The durability of P-Sling and Plastic Pallets can vary based on factors such as material quality, usage conditions, and maintenance.

- *P-Sling Durability*

P-Slings are often made from durable materials like woven fabric or synthetic materials. Durability can be influenced by the material thickness, stitching quality, and load capacity. Regular inspection and proper maintenance contribute to extended durability.

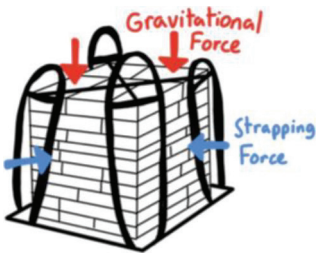
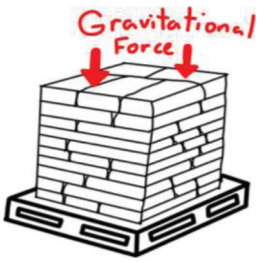
- *Plastic Pallet Durability*

Plastic pallets are known for their durability and resistance to weather, chemicals, and pests. Durability is affected by the type of plastic used (e.g., HDPE, PP), design, and load-bearing capacity. Plastic pallets are generally resistant to rotting, molding, and other environmental factors.

- *Comparing the Two*

P-Slings are lightweight and flexible but may be more prone to wear and tear, especially when subjected to sharp objects or rough handling. Plastic pallets are sturdy and robust, suitable for heavier loads, and provide better protection against external elements. However, there is a high chance of collapse. The key points: To consider the specific use case, load requirements, and environmental conditions when choosing between P-Sling and Plastic Pallets for stacking and transporting sago bags. Regular maintenance and adherence to usage guidelines contribute significantly to the longevity of both options. Furthermore, the comparison between 'P-Sling' and 'Pallet' is detailed in Table I.

TABLE I
THE SUMMARIZED COMPARISON BETWEEN "P-SLING AND PALLET"

Addressed Issues		P-Sling	Plastic Pallet
Model design			
Cost (THB)		200 ($5.63)*	1000 ($28.17)*
Weight (kg)		~ 1.55	~14
Size (WxLxH)		1.09 m x1.2 m x 1.43 m	1 m x 1.2 m x 0.16 m
Capacity	(25-kg bag)	50 bags	50 bags
	(30-kg bag)	45 bags	45 bags
	(15-kg bag)	80 bags	80 bags
Key points		Simple to transport and count / Convenient storage / Equipped with handles / Stability with full capacity during transportation / Still requires manual positioning of the sling handle into the forklift lever even with full capacity	Accessible and easy to pick up with a forklift / Easy counting and organization of stacked products in storage / Requires storage space / Base area with gaps or meshes are prone to fracturing over prolonged use
The material used for constructing		Woven fabric or Synthetic	HDPE, PP, or ABS
Durability		Better	Worse / Easy to Break

*Exchange rate - 02 January 2024 - 34.4143 THB per 1 USD [30]. Exchange Rates. Retrieved from https://www.bot.or.th/en/statistics/exchange-rate.html)

E. Key Components for Design

Sago or tapioca pearls, versatile ingredients found in a variety of foods and beverages, are crafted from tapioca starch, derived from the cassava root. Known for their spherical shape and diameters ranging from 1 to 10mm, sago pearls offer flexibility to suit different preferences. While typically white, they can be found in various colors. Sago boasts a firm texture and the ability to absorb water. When boiled, their color transforms to transparency, and the texture becomes soft and springy. Commonly used in dishes like sago cantaloupe, sago vada, and sago pudding, the drying process involves sago with a moisture content around 37% entering a rotary drum dryer. It progresses across the drum's length, from drum number 1 (located on top) down to drum number 5 (at the bottom), covering a total drying length of 30 meters. The drying time is approximately 2 hours, subject to variations based on the initial moisture content and drying temperature.

To explore the fundamental concept of the sago-making process, the essential steps for accomplishing the task are succinctly outlined in Fig. 7. The obtained information can guide the design team in developing a deeper understanding of the behavior of sago prior to the initial design stage. Furthermore, specific criteria are established for creating an alternative design for a sago-stacking bag assistive device, supporting Quality Function Deployment (QFD) to align customer requirements with engineering characteristics for the detailed design stage.

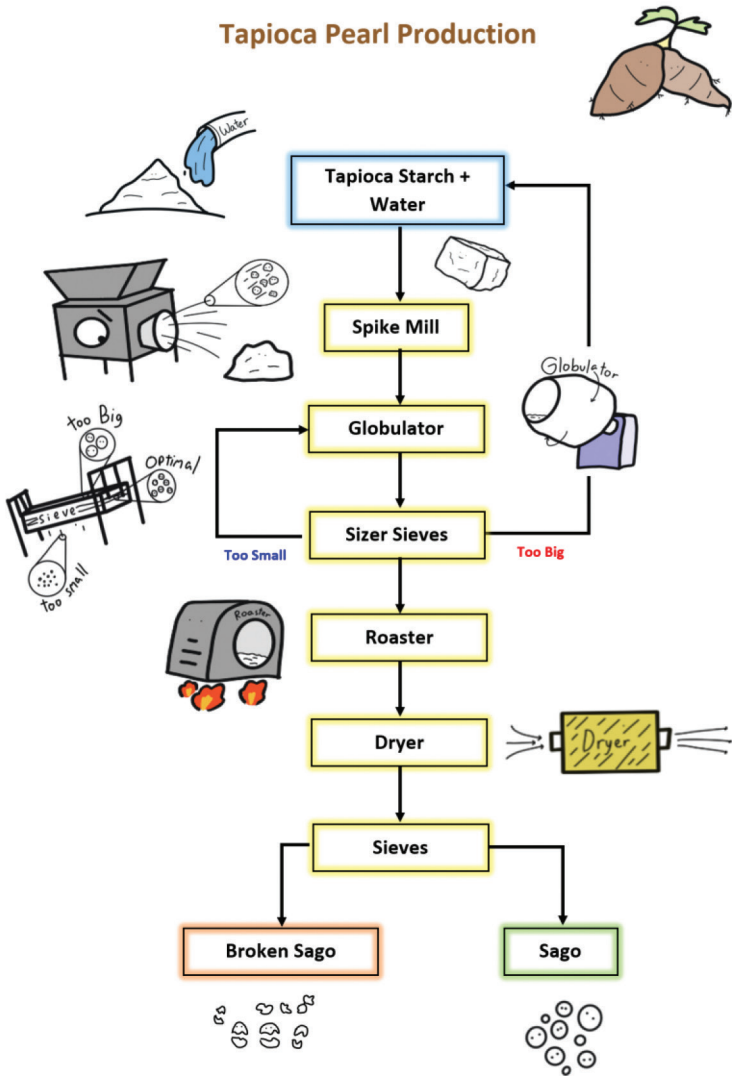


Fig. 7. The steps required for accomplishing task

VI. System Level Design

System level design involves defining the main components and subcomponents of a system. Main components are the major parts or modules of the system, while subcomponents are smaller units that contribute to the functionality of the main components. This process also includes specifying how these components interact with each other and with external systems, as well as defining the data flow and interfaces between components. Overall, system level design aims to create a structured framework that guides the detailed design and implementation of the system. Three main components are listed; handle, body, and base as shown in Fig. 8.

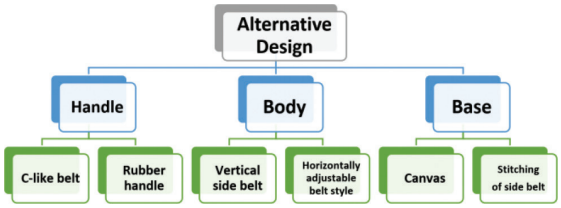


Fig. 8. Main components and sub-components

VII. Detailed Design

Based on the insights garnered from business owners consistently employing pallets and P-Sling for material handling, the design teams have compiled a comparative analysis between these two methods. This effort aims to support the concept of redesigning a supportive apparatus for the efficient handling, loading, and unloading of heavy objects, specifically within the realm of stacked-bag platforms.

Comparing the level of support between P-Sling and Pallet involves assessing several factors. P-Sling provides a flexible and adaptable support system, allowing for a degree of contouring to the load. It is particularly effective for irregularly shaped or fragile items, providing more customized support. On the other hand, Pallets offer a rigid and standardized support structure. They are suitable for uniform and sturdy loads, providing consistent support across the entire base.

In terms of versatility, P-Sling may excel in accommodating varying load sizes and shapes due to its adjustable nature. Pallets, while efficient for standardized loads, might face limitations with irregularly shaped or smaller items.

Portability is another aspect to consider. P-Sling, being more lightweight and flexible, may offer easier transportation and storage. Pallets, while sturdy, can be bulkier and may require more space.

The guidelines for developing an alternative design are illustrated in Fig. 9. These guidelines outline the characteristics and requirements necessary to support the design stage and facilitate comparison with existing design platforms. These include considerations of appearance, performance, functionality, and usability characteristics.

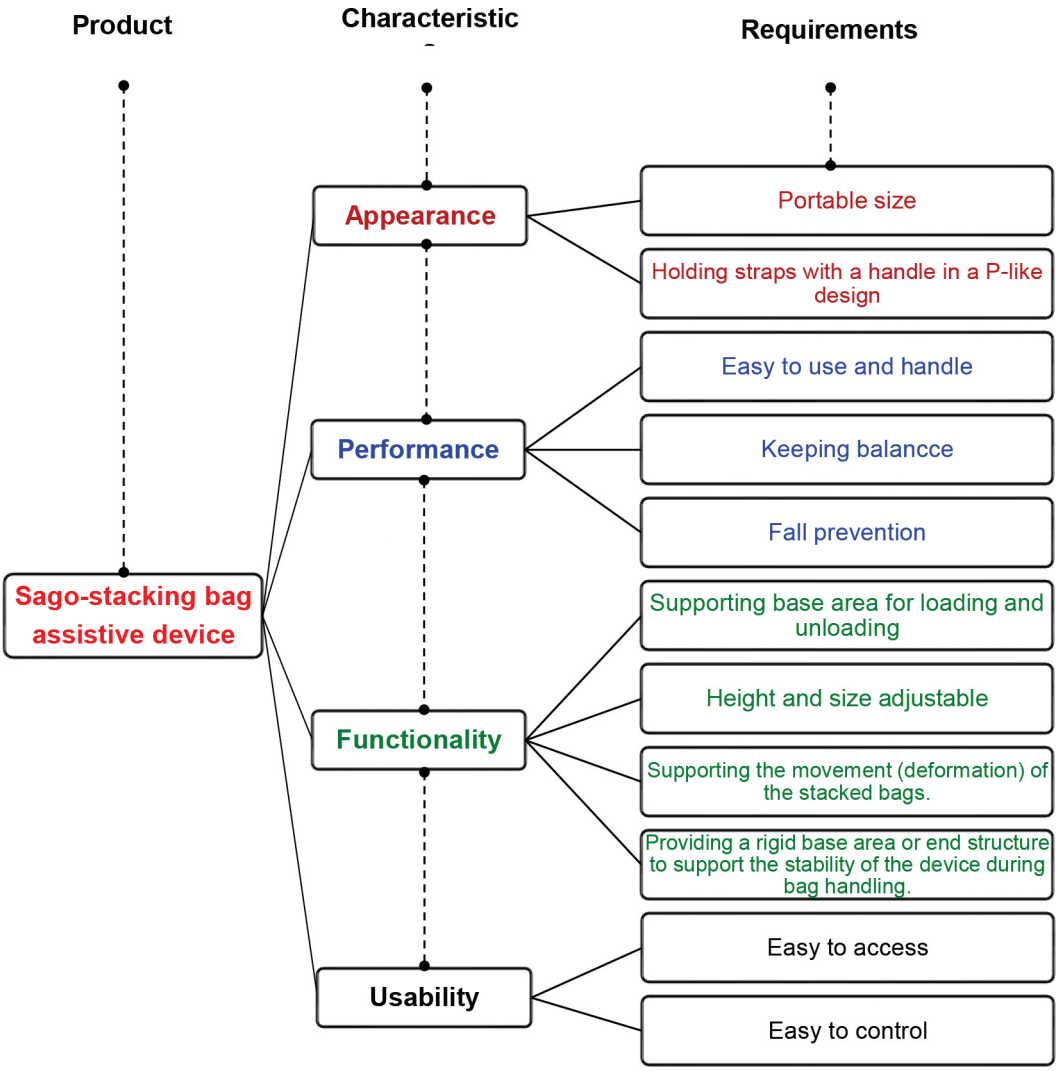


Fig. 9. Guidelines for creating an alternative design

The choice between P-Sling and Pallet depends on the specific requirements of the load, considering factors such as shape, size, and fragility. It is essential to weigh the benefits of flexibility and customization against the stability and standardization offered by each method to determine the most suitable level of support for the given application.

VIII. Applying Key Factors to Create a New Design

According to Fig. 9, which outlines specific requirements for developing the sago stacking bag assistive device, these requirements will serve as guidelines for selecting the appropriate design. Key factors addressed include the height of holding or carrying by the forklift, size of the bag, type of handling mechanism, and type of material. These factors are crucial for supporting the conceptual design of the assistive device, considering six main stages (Fig. 10). Subsequent subsections will explore the details of each consideration.

Step 1: Issue Identification and Target Group Definition

In the initial phase, the design team outlines key concerns related to stacking sago bags, formulating a set of questionnaires. Simultaneously, the target group is specified, consisting of manufacturers or business owners involved in sago production and packaging. The identified problem revolves around disorganized bag stacking on the floor, leading to challenges in management and loading onto containers, resulting in inefficiencies.

Step 2: Customer Needs Identification

The second step involves extracting needs from the target customers. The design team aims to create a preliminary design for an assistive carrying device or method that streamlines the transportation of stacked sago bags, considering cost as a primary factor. The utilization of the "House of Quality (HoQ)" is planned to unveil conceptual design needs, with a thorough analysis of competitors.

Step 3: Market Research on Related Products

In the third step, the team delves into researching related products like P-Sling and pallets. Feedback, comments, and cost considerations are documented and analyzed as part of a marketing survey. This phase may involve online searches through internet engines for comprehensive insights.

Steps 4 and 5: Component Listing and Design Refinement

The fourth and fifth steps entail listing the main and sub-components of the drafted design, all while keeping the target users' requirements in mind. Leveraging insights from the HoQ, the specifics of product characteristics, including appearance, performance, functionality, and usability of the developed sago-carrying device, are meticulously mapped out (refer to Fig. 9).

Step 6: Material Selection Guidelines

In the final step, material suggestions for crafting the assistive carrying device are provided as guidelines. This aims to steer customers toward selecting materials that ensure strength, durability, ease of use, and minimal human labor. The overarching goal is to facilitate informed decision-making in the material selection process.

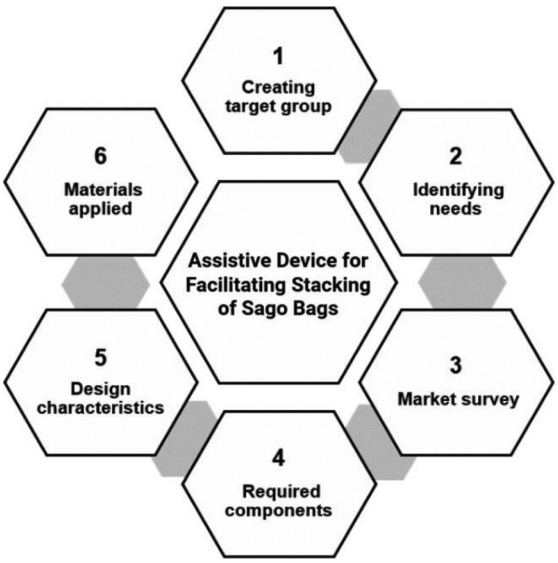


Fig. 10. Six stages required for accomplishing the proposed research

A. Customer Requirements Versus Engineering Requirements

The Quality Function Deployment (QFD) serves as a crucial tool in this study, aiding researchers in identifying essential engineering factors for the alternative design of a stacking-bag assistive device The engineering specifications, categorized by the researchers' perspectives, may display some subjective design aspects in product characteristics [31]-[40].

The House of Quality (HoQ) method is employed to establish the relationship between customer requirements and engineering specifications. To construct the HoQ, the team initiates by asking, "What do customers want?" The translated answers are then listed in the first row (engineering attributes) and the first column (customer requirements) of the house.

Illustrated in Fig. 11 is about "House of Quality for the desired product" to indicate that the House of Quality is a tool used to analyze and define the desired product's quality characteristics based on customer requirements.

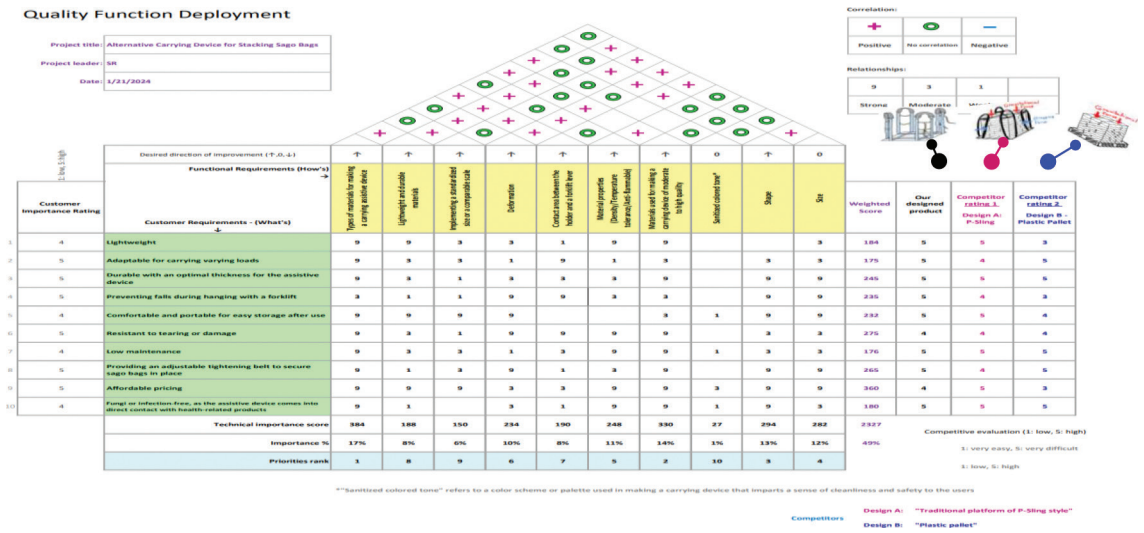


Fig. 11. House of quality with relationship matrix between customer requirement and design characteristics

Table III provides a list of product characteristics along with their definitions, while Table IV outlines the corresponding engineering attributes or requirements. The interviews conducted with the target customers have been extracted and analyzed based on the design team's perceptions and experiences in product design and development (PDD). This analysis informed the creation of a graphical 2D sketch for a proposed assistive device (Fig. 12) designed to support stacked sago bags with various loads.

In the HoQ diagram, the relationships between customer requirements (Whats) and engineering specifications (Hows) are represented on a four-scale level:

- 9 for a strong relationship
- 3 for a moderate relationship
- 1 for a weak relationship
- None for no relationship

For "customer requirements", questionnaire results guide the design team in understanding the direction and trend for the new product. In this study, the walking assistive device is expected to be light, portable, feature-rich, aesthetically pleasing, of high quality, and priced acceptably.

For "engineering attributes", the top five specifications—size, weight, comfort, price, and durability—are selected after team brainstorming. These specifications reflect the manufacturer's viewpoint regarding product design and characteristics.

In the HoQ, interrelationships between engineering attributes are divided into five levels with symbols: strong positive correlation (+), no correlation (O), and negative correlation (—).

Simply saying that, the correlation between "size" and "weight" is analyzed to be a "strong positive correlation", as larger carry-assistive device sizes are expected to result in higher weights. This correlation is symbolized in the correlating matrix.

Conversely, there is a "strong negative correlation" between "ease-to-carry" and "weight," signifying that an increase in weight may lead to decreased ease of carrying (—).

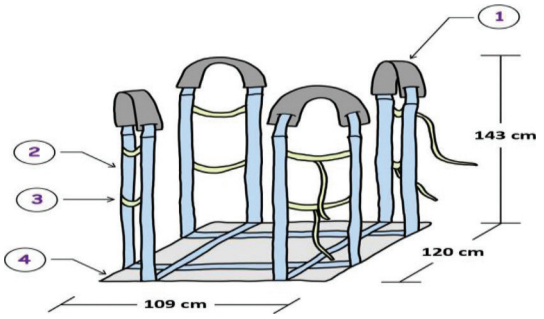


Fig. 12. Illustration for the alternative design

TABLE II
MAIN COMPONENTS OF THE ALTERNATIVE DESIGN

No.	Components	Descriptions
①	Handle	Rubber handle
②	Side belt	*Material:* Polyster *Thickness:* 1.5 mm
③	Horizontally adjustable belt style	Designed for 50% and 100% capacity
④	Base	*Material:* Polypropylene (PP) *Thickness:* 1 mm *Size:* 109 x 120 cm

TABLE III
PRODUCT CHARACTERISTICS AND THEIR DEFINITIONS

Engineering Requirements	Definitions
Types of materials for making a carrying assistive device	Materials must offer durability, toughness, and resistance to temperature, moisture, and chemicals while supporting diverse loads. The options include HDPE, PP, ABS, and Polyester.
Lightweight and durable materials	Polymers materials are the choice. Not super hard and solid as metals.
Implementing a standardized size or a comparable scale	The assistive device is designed with a standardized size around the contact area necessary for connection and application with the forklift lever. Using commercially available materials and a simple design facilitates easy maintenance for users, allowing them to find and replace parts with commercial spare parts readily.
Deformation	Polymer materials are the preferred choice, offering a balance between hardness and solidity that differs from the super-hard and solid nature of metals. Additionally, the elastic properties of these polymers allow for the deformation of the entire shape freely during the handling of heavy loads. This flexibility is crucial, especially in a stacking-like building style, where there are no supportive belts, as seen in pallets, to be compromise shock absorption.
Contact area between the holder and a forklift lever	The supportive-shoulder straps with rubber is applied around the contacting area between handle belt and a forklift lever.
Material properties (Density/ Temperature tolerance/ Anti-flammable)	Rubberized supportive shoulder straps are utilized around the contact area between the handle belt and a forklift lever.
Materials used for making a carrying device of moderate to high quality	The materials are of industrial-grade quality, robust enough to withstand various forces encountered during transportation and storage.
Sanitized colored tone	Clean and clear color tones, following a hygienic style, are carefully considered to enhance the presentation of health-related products.
Shape	Compact and easily accessible design, ensuring neatness both in storage and when suspended from a forklift lever.
Size	The assistive device can be conveniently folded into a compact size of 109cm x 30cm x 10cm. Its design allows for easy stacking without the risk of failure or disorderliness during loading, unloading, or retrieval for use.

TABLE IV
ENGINEERING REQUIREMENTS AND THEIR DEFINITIONS

Product Characteristics	Definitions
Lightweight	The proposed product features a lightweight and durable synthetic material capable of supporting the stacking of sago bags weighing between 1,200 and 1,350 kg.
Adaptable for carrying varying loads	The suggested product features an adjustable horizontal belt designed to support the carrying of stacked sago bags, accommodating a range from 20 bags (each weighing 30 kg) to 80 bags (each weighing 15 kg).
Durable with an optimal thickness for the assistive device	The thickness of the supportive device can provide to handle the stacking sago bags to the maximum weighting as 1350 kg.
Preventing falls during hanging with a forklift	The length of the handle on the designed device is determined by the distance between the topmost area of the stacked sago bags and the forklift lever, which is approximately 45-50 cm. This length is carefully chosen to prevent any swinging moment that could potentially tip the forklift during transportation.
Comfortable and portable for easy storage after use	The compact size of the assistive device allows for easy folding and storage, ensuring a neat and organized feel when unpacked for use.
Resistant to tearing or damage	The materials used for making assistive device provide less sensitive to the environment temperature in the cargo or working space. The proper thickness and medium-to-high standards of synthetic or composite materials are provided.
Low maintenance	The materials utilized in the device are resistant to humidity and can be easily cleaned with fresh water. The design is rooted in universal and minimalistic concepts, prioritizing ease of access and user-friendliness.
Providing an adjustable tightening belt to secure sago bags in place	All stacked bags are securely located and positioned in place during transportation.
Affordable pricing	Based on the appropriate thickness and the medium-to-high standards of synthetic materials, the expected price range is between 200 to 400 THB (5.8 to 11.6 USD).
Fungi or infection-free, as the assistive device comes into direct contact with health-related products	The material used in the device is inorganic, thus it does not promote the growth of fungal or microbial organism. This will mean a lower chance of product spoilage stemming from direct contact with the device.

IX. Material Property Consideration

In order to determine the suitable material conditions for creating a prototype, it is essential to study the thermal expansion characteristics of the materials in the preliminary stage. Given that the sago factory involves temperatures ranging from 130-200 °C, and the storage or loading/unloading areas are in close proximity to hot chambers or roasters, understanding the expansion or shrinkage of the carrying device becomes crucial.

For the initial material selection phase, 'Pallet' with various material types, offering rigid and straight planar contacting areas that come into contact with the sago bags, is chosen as the case study for calculating 'Thermal Expansion'.

Case Study I: Pallet with Metal Materials

In the sago factory studied in this proposed research, the metal materials commonly used for making pallets include [41]:

Aluminum: Aluminum pallets are lightweight and resistant to corrosion. They are often used in situations where weight is a critical factor or in industries where corrosion resistance is essential.

Stainless Steel: Stainless steel pallets offer corrosion resistance and durability. They are suitable for applications where cleanliness and hygiene are important, such as in the food or pharmaceutical industries.

Steel: Steel pallets are known for their strength and durability. They are suitable for heavy loads and can withstand harsh environments.

Table V presents the thermal expansion coefficients for three types of materials: aluminum, stainless steel, and steel [41].

TABLE V
Thermal Expansion – Metals

Material	Expansion Coefficient
Aluminum	22.5 x 10^{-6}/ °C
Stainless Steel	17.3 x 10^{-6}/ °C
Steel	11.65 x 10^{-6}/ °C

The design team perceives that the most suitable material for supporting stacked sago bags is 'steel' due to its lower thermal expansion coefficient, approximately 11.65 x 10^{-6}/ °C, compared to other materials. Given an original length of 1 meter, a linear thermal expansion coefficient for steel of approximately 11.65 x 10^{-6}/ o C, an inside temperature of 32 °C, and an outside temperature of 42 °C, the thermal expansion can be calculated using the formula.

$$\boldsymbol{l = l_0[1+\gamma\Delta T]} \quad \text{Eq.1}$$

$\boldsymbol{\Delta T}$ = T- T_0
$\boldsymbol{\gamma}$ = The linear thermal expansion coefficient
$\boldsymbol{l}$ = Length of the material after facing heat
$\boldsymbol{l_0}$ = Original length of the material

Therefore,

$\boldsymbol{l}$ = (1)[1+(11.65 x 10^{-6} /C°)(10 C°)]
= 1.0001165 m.

The material experiences an expansion of approximately 0.0001165 meters from its original length. This expansion can provide insights into the durability of materials like metal, which may be compromised when subjected to sudden and significant temperature changes between the interior and exterior of a factory or storage space due to weather, seasons, and climate variations. Such fluctuations can directly impact the material's durability and stability during transportation. Although metal is inherently tough, it is susceptible to issues such as rusting and deformation with distorted shapes. These factors increase the risk of sago bags, arranged in a stacking style, falling down due to uneven surfaces.

Case Study II: P-Sling with Polymer Material

If the device used for supporting stacked sago bags, formed in a 'P-Sling style', is made of polymer, it is essential to consider the thermal expansion coefficient and tensile strength values. The required information for popular polymers such as polyester and polypropylene can be found in Table VI [41] for thermal expansion coefficients and Table VII for tensile strength values [42], [43].

TABLE VI
Thermal Expansion – Polymers

Material	Expansion Coefficient
Polyester	124 x 10^{-6}/ °C
Polypropylene	81 x 10^{-6}/ °C

TABLE VII
Tensile Strength – Polymers

Material	Expansion Coefficient
Polyester	50 - 150 MPa
Polypropylene	25 - 40 MPa

From Tables VI and VII, the obtained data suggest insights into the flexibility of polymers. 'Polyester' appears to be stronger and more flexible, capable of withstanding pulling (stretching) under high temperatures or temperature fluctuations, which is crucial in environments like a sago factory with pervasive heat. Thus, the belt areas should be considered as 'Polyester-style', since the belt needs to be carried with a forklift lever while containing 1,200 to 1,350 kg of the sago bags.

X. Discussion of The Proposed Design

This study explores an alternative approach to create a user-friendly platform for loading and unloading bags containing a natural product, with sago as the focal point in this case. Changing from powdered starch to a fine-spherical shape, sago is carefully packed into canvas bags with varying loads, including 15-kg, 25-kg, and 30-kg sizes. The non-uniform pattern created by the distribution of sago particles within the bag poses challenges in maintaining a stable structure during transport, leading to deformation based on the carrier's movements. The chosen materials for the assistive device must possess qualities such as durability, toughness, and resistance to temperature, moisture, and chemicals, making options like HDPE, PP, ABS, and Polyester suitable. These polymer materials offer a balance between hardness and solidity, differentiating from the super-hard and solid nature of metals. The standardized size of the device facilitates easy connection and application with the forklift lever, and its simple design, utilizing commercially available materials, ensures easy maintenance and part replacement with readily available spare parts. The elastic properties of polymer materials allow for the deformation of the entire shape during the handling of heavy loads, crucial in a stacking-like building style where shock absorption is vital. Rubberized supportive shoulder straps are applied around the contact area between the handle belt and a forklift lever. The industrial-grade quality materials ensure robustness to withstand various forces during transportation and storage. Consideration of clean and clear color tones enhances the presentation of health-related products. The compact and easily accessible design ensures neatness in both storage and when suspended from a forklift lever. The device can be conveniently folded into a compact size of 109cm x 30cm x 10cm, allowing for easy stacking without the risk of failure or disorderliness during loading, unloading, or retrieval for use. For the proposed design, the handle features a rubber handle for comfortable grip. The side belt is made of polyester with a thickness of 1.5 mm. The horizontally adjustable belt style is designed to accommodate 50% and 100% capacity. The base is constructed from polypropylene (PP) with a thickness of 1 mm and has dimensions of 109 x 120 cm.

XI. Conclusion

The user experience is essential in the development of the assistive device. The handle's rubber grip ensures comfort during operation, while the side belt, made of 1.5 mm thick polyester, accommodates 50% and 100% capacity with its horizontally adjustable design. The base, constructed from 1 mm thick polypropylene (PP), measures 109 x 120 cm, offering durability and stability. The device can be conveniently folded into a compact size of 109cm x 30cm x 10cm for easy stacking and storage. Rubberized shoulder straps enhance grip and durability. The device's standardized size allows for easy connection and application with the forklift lever, with a simple design for easy maintenance and part replacement. Polymer materials' elastic properties enable deformation during heavy load handling, crucial for shock absorption in a stacking-like building style. The assistive device is designed to provide a robust and efficient solution for handling sago bags, addressing challenges in stability and transport associated with their non-uniform distribution.

IX. Limitation and Recommendation

The study's scope and limitations focus on sizes, weights, and particle sizes, delineated by examining tapioca pearls within the size range of 1 to 2.5 mm. These pearls are exclusively produced from tapioca starch and undergo processes limited to granulation, roasting, and drying. The weight is standardized as 1000 particles equaling 0.929 g, offering insights into the density and volume of each particle. The study considers the capacities for filling sago bags, which range from 15 kg to 30 kg.

The existing body of literature extensively explores the transformative utilization of factory waste to create innovative products, as evidenced by numerous articles available on the internet. However, upon thorough investigation, it is evident that none of these studies have specifically investigated the potential of repurposing defective tapioca pearls. This research gap highlights the unique and unexplored opportunity to contribute to the field by examining the viability and novel applications of defective tapioca pearls in the creation of innovative products, setting this research apart from the existing body of knowledge in the domain. In tapioca pearl factories, defective pearls in terms of size and color are routinely discarded, typically sold as animal feed, a practice that does not generate significant financial returns for the industry. The further study should explore innovative applications for these rejected small tapioca pearls, intending to increase their market value compared to their non-defective counterparts. By identifying new uses for these pearls, the goal is to enhance their value and contribute to increased revenues for tapioca pearl manufacturers.

The research goals should include investigating potential applications for defective tapioca pearls as a novel product. To efficiently transform rejected products into valuable by-products, there is a departure from the prevailing practice of selling them as animal feed, with careful consideration of food-grade material standards. This shift towards developing a new product from the defective tapioca pearls not only ensures

increased value but also expands the product offerings of tapioca pearl factories.

Moreover, unwanted-sized sago particles can serve as an alternative material to support the item inside the container or box during transportation, similar to bubble wrap or synthetic supportive plates. Using rubber as a supportive material for the handle ensures the longevity of the main polyester handle by absorbing friction during the transportation process. This, in turn, reduces the frequency of product replacement, making it more cost-effective.

Acknowledgement

The authors express our gratitude to the Sago Factory in Rayong province for generously sharing valuable information and resources regarding the material handling platform, along with key insights crucial for the design stage.

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Credit Risk Prediction Model Using Feature Engineering and Machine Learning Techniques

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Received: June 19, 2023/ Revised: July 18, 2023/ Accepted: July 19, 2023

***Abstract*— Credit scoring is a crucial step in the risk management process of the financial industry and commercial banks. The objective of this research is the development of a credit risk prediction model using feature engineering and machine learning techniques. This research was used to test the algorithm with a peer-to-peer (P2P) lending dataset and measure performance with classification accuracy. The experiment in this research found the XGB algorithm provided the most effective classification accuracy of 88.94%, which is better than other classifiers. Therefore, the proposed research framework of this research, working with feature engineering, feature selection, and machine learning techniques, is suitable and effective for credit scoring problem analysis.**

***Index Term*—Credit Scoring, Feature Engineering, Machine Learning**

I. Introduction

Peer-to-peer (P2P) lending is a novel financial system that leverages an internet-based platform to enable direct lending between borrowers and lenders, bypassing traditional financial intermediaries such as banks. The P2P network lending sector has experienced substantial expansion in recent times, primarily attributed to the progress made in big data and Internet finance. The proliferation of peer-to-peer lending platforms on the Internet is indicative of the industry's advancement. Peer-to-peer (P2P) lending is an online financial service that facilitates direct connections between individual investors and loan borrowers, thereby bypassing the involvement of commercial banks as intermediaries. Small and medium-sized businesses, as well as individuals in need of loans, now have this type of lending as a significant option. Lending Club, the world's largest online financial platform for borrowers and investors, has processed loans for over 3 million borrowers and attracted investments totaling more than $50 billion. By utilizing the power of the Internet, Lending Club has developed a marketplace that offers cheaper costs and higher investment returns than traditional commercial banks. The innovative methodology employed has facilitated the attainment of accessibility and simplicity in the borrowing and investing processes for all individuals. Peer-to-peer lending is a suitable match for the present economic progress of the nation, presenting noteworthy prospects. Nonetheless, it poses specific obstacles and potential hazards. The primary financial risks associated with peer-to-peer (P2P) lending are attributed to inadequate liquidity of funds, credit risks that arise due to information asymmetry, operational risks, and legal risks that result from incomplete laws and regulations in the domain of Internet finance. In contrast to conventional finance, online financial risks exhibit more intricate features. The virtual and technical aspects of Internet technology give rise to supplementary risks that surpass those encountered in traditional finance. Internet-based financial risks have a tendency to manifest abruptly and spread rapidly, with a higher potential for causing significant harm while being less manageable. As a result, the concept of risk aversion has emerged as a significant and crucial subject of discourse among investors, policymakers, scholars, and financial professionals. The presence of these risks significantly increases the probability of borrowers defaulting, thereby exposing P2P lending to credit risks that may arise from such defaults. The expansion of P2P lending platforms as well as investor profitability are both negatively impacted by loan defaults. As a result, loan evaluation has been extensively researched by scholars from both domestic and international backgrounds. The present assessment constitutes a valuable instrument for peer-to-peer (P2P) platforms to evaluate and manage credit risks. Peer-to-peer lending platforms commonly employ a credit scorecard as a basis for constructing their loan assessment framework, which is customized to meet their particular business needs. The utilization of a credit scorecard has the potential to expeditiously allocate a credit score to individual loans.

However, its efficacy in accurately distinguishing between borrowers who are prone to default and those who are not is limited [1]-[4].

As big data technology has grown and matured, risk management systems in the financial sector increasingly rely on machine learning and artificial neural networks. The utilization of Support Vector Machines (SVM), Artificial Neural Networks (ANN), and Deep Neural Networks (DNNs) is prevalent in the prediction of stock prices and their movements, demonstrating their efficacy in forecasting financial time series. Additionally, researchers have found that the Random Forest technique exhibits superior performance compared to alternative methods in the context of loan assessment for peer-to-peer lending [3]. Building on previous research, this study uses the Random Forest algorithm to create a loan default prediction model utilizing data from Lending Club loans in the first quarter of 2019. Furthermore, four distinct methodologies are utilized and contrasted with Random Forest in subsequent evaluations. The results of our study hold great importance, as they aid in improving the loan evaluation process and promoting the sustainable growth of peer-to-peer lending [4]-[6]. The next sections of this document are categorized into five distinct parts. Section 2 provides a concise overview of the existing literature pertaining to loan evaluation and credit risk assessment. Section 3 goes through the specifics of the Lending Club and machine learning. Section 4 then discusses the experiments and their outcomes. In conclusion, Section 5 provides a summary of the preceding sections.

II. Literature Review

Presently, the primary emphasis of research on P2P platforms, both domestically and internationally, centers on loan defaults and the evaluation of credit risk, utilizing machine learning techniques. Serrano-Cinca and colleagues investigated default variables using Lending Club loan sample data, a single-factor mean test, and survival analysis [7]. Yao et al. utilized advanced-support vector regression (SVR) methodologies to forecast default loss for corporate bonds, exhibiting superior performance of SVR variants in comparison to alternative techniques [8]. Malekipirbazari and Aksakalli have proposed a method of classification based on Random Forest to identify P2P borrowing customers who possess high-quality attributes. Upon comparison with several machine learning techniques, the findings revealed that the Random Forest approach exhibited a significantly superior performance in distinguishing creditworthy borrowers when compared to FICO credit scores and LC grades. Emekter and colleagues used a logistic regression (LR) model to predict Lending Club borrowers' default likelihood, finding that credit grade, debt-to-income ratio, FICO score, and revolving line utilization were key [9]. Bagherpour used a huge dataset to forecast loan defaults using KNN, SVM, Random Forest, and Sand Factorization Machines (FM) algorithms [10]. The authors Byanjankar et al. [11] introduced a credit-scoring framework that employs artificial neural networks (ANNs) to categorise peer-to-peer (P2P) loans into two groups, namely default and non-default, and demonstrated its efficacy in identifying default applications. In their study, Cao et al. [12] conducted a comparative analysis of the efficacy of eight classification techniques, namely LDA, LR, DT, SVM, RF, GBDT, MLP, and XGBoost, using datasets sourced from Kaggle. Using accuracy, area under the curve of ROC, and logistic loss, the XGBoost model performed better. Kvamme et al. employed convolutional neural networks (CNNs) to forecast loan defaults, utilizing time series data pertaining to customer transactions across diverse accounts and cards. The study conducted by the researchers indicated that the CNN model exhibited superior performance compared to the Random Forest classifier [13]. In their study, Kim et al. introduced a novel approach that integrated label propagation, transduction support vector machine (TSVM), and Dempster-Shafer theory to effectively forecast defaults in social lending through the utilization of unlabeled data [14].

The field of credit risk assessment has witnessed the emergence of diverse methodologies and models. The trust spiral model was first proposed by Tang et al. and was utilized to investigate credit risk in the lending association between small businesses and banks [15]. Moradi and Mokhatab Rafiei devised an adaptive network-based fuzzy inference system by subjecting it to training with monthly data extracted from a customer profile dataset. Subsequently, a follow-up evaluation was carried out utilizing recently established variables and their corresponding regulations within a fuzzy inference mechanism. The outcome of this process led to the development of a month roster of unfavorable clients and a flexible framework for evaluating credit hazard [16]. Brown et al. conducted actual investigations and discovered that Random Forest and Gradient Boosting classifiers performed remarkably well in credit scoring, particularly when dealing with severe class imbalances within the datasets [17]. Li conducted a qualitative analysis to determine the likelihood of loan defaults among lending club borrowers. Loan purpose, income, residence address, and work seniority were considered in this analysis. A logistic regression model was then used to construct credit scores and forecast borrower default [18]. Zhang et al. used Multiple Instance Learning (MIL) to create a novel credit scoring model that included sociodemographic and loan application information, as well as the applicants' transaction history [19]. In order to estimate credit card survival

models, Djeundje and Crook employed Generalised Additive Models (GAMs) with cubic B-splines, showing that GAMs performed better than other techniques in terms of increasing prediction accuracy [20]. Chen et al. Predicting default risk on peer-to-peer lending imbalanced datasets. The objective of this research is to utilize not only several machine learning schemes for predicting the default risk of P2P lending but also re-sampling and cost-sensitive mechanisms to process imbalanced datasets [21]. Masmoudi and colleagues utilized a discrete Bayesian network that incorporated a latent variable to construct a model for loan subscribers exhibiting default payment behavior. The objective of this model is to assess the credit risk associated with loan subscribers and group them into clusters [22]. Papouskova and Hajek created a two-stage consumer credit risk model utilizing heterogeneous ensemble learning. This model predicted credit scoring and default exposure using class-imbalanced ensemble learning and regression ensemble approaches [23]. Ma et al. and Coser et al. used LightGBM, XGBoost, Logistic Regression, and Random Forest to create a set of prediction models for estimating the likelihood of loan default among clients [24]-[25]. Finally, Cho et al. suggested an instance-based entropy fuzzy support vector machine categorization investment choice model for the P2P lending market [26]. Although there has been a large amount of research focused on forecasting loan defaults in the Lending Club, our study attempts to add to the existing body of work that employs the Random Forest approach [27].

III. Research Framework

The data were subjected to data cleaning and feature engineering in order to facilitate the extraction of characteristics and model training. The research framework comprises seven distinct steps, including data cleaning and elimination of features redundant, feature engineering, handling of missing data and scaling, oversampling, feature selection, splitting a dataset into training and testing, and machine learning techniques shown in Fig. 1.

A. Dataset

The dataset used for this study comprises publicly available peer-to-peer lending data sourced from the lending club. This dataset includes all the data gathered by the platform during the lending procedure. The primary components comprise the personal particulars of the borrower, the intended use of the loan, the individual's credit background, their current debt status, and additional relevant factors. Therefore, we used the loan dataset period from January 2007 to December 2016, corresponding to a total of 396,031 loans with 151 features each. We have used loan status as the reference label for default, where fully paid means the applicant has fully paid the loan (the principal and the interest rate), and Charged-off means the applicant has not paid the installments in due time for a long period of time and has defaulted on the loan.

B. Data Cleaning

The P2P lending datasets generally have many features, many of which are empty for most records, to help extract characteristics and train algorithms. We cleaned the data using feature engineering. This was a five-step process that comprised deleting superfluous features, converting features, dealing with missing data and scaling, and performing feature selection. First, we deleted irrelevant details like the borrower's lending club membership ID. We removed non-analyzable descriptive elements like loan purpose paragraphs. Furthermore, we eliminated characteristics that were excessively unvarying, exhibiting a homogeneity of over 99% in the data, for instance, application classifications that were primarily composed of personal loans. In addition, features that were acquired after loan approval, such as the repayment date of the previous loan, were excluded. Credit features identified by lending club and those with an excessive number of missing values, where more than 99 percent of the data was lacking, were also eliminated.

C. Feature Engineering

Because the majority of the data consisted of categorical variables, which are unsuitable for model training, the data had to be converted into numerical representations. The initial reference label is denoted as the default loan status. The category labeled charged off was assigned a value of 0, while the category labeled fully paid was assigned a value of 1. The variable employee length denotes the duration of an individual's employment in terms of years. We converted this sequential property into ordered integers using ordinal encoding. We awarded a numerical value of 10 to those who had worked for more than ten years, a value of 0 to those who had worked for less than one year, and the corresponding numerical values to those who had worked for one to ten years. The third variable pertains to the rate of revolving credit utilization, expressed as a percentage. The decimal form was obtained through conversion. It appears to be a historical time stamp for the earliest credit history. Utilize an apply function to extract the year from the given feature, followed by converting it into a numeric feature. Regarding the remaining category features, such as loan purpose and housing ownership, which lack a sequential relationship, we employed one-hot encoding to transform them. This entailed creating independent binary features for each category, with a binary value of either 0 or 1.

D. Feature Scaling and Handling Missing Values

Because there were some missing values in the dataset, it was important to address this issue before proceeding with the model training. Given that the "N/A" value signifies the absence of a default record in the past, it is imperative that this information is not disregarded. The logical way to fill in the value was to set a second feature that shows if the missing value in the first feature is present; the missing value in the first feature was filled in with values that don't typically occur. Assuming the data were normal-distributed, we filled in the average of other attributes without missing values. Moreover, in the context of employing machine learning algorithms that use the mean square error as the loss function, it is noteworthy that the magnitude of the features can significantly impact the predictive efficacy of the model. This is due to the model's propensity to exhibit sensitivity towards features that possess substantial scales. As a result, before training the model, we standardized the data to ensure that each feature only had a proportional impact on the prediction outcome. Feature scaling is the process of normalizing the range of features in a dataset. Real-world datasets often contain features that vary in degrees of magnitude, range, and units. Therefore, in order for machine learning models to interpret these features on the same scale, we need to perform feature scaling. In this research, we use MinMaxScaler for feature scaling.

E. Feature Selection

In the past, reducing the dimensionality of the data involved using an extraction method for features. The new feature is a projection of the previous one when using this type of procedure, such as principal component analysis. However, a feature extraction method removes the original features and may not have empirical meanings, making it unsuitable for business applications [26]. As a result, we must do feature selection, giving precedence to features that are highly related to the aim and deleting irrelevant features to lower the complexity of learning. In this research, we used Pearson's correlation to analyze the significance of the features. Pearson's correlation coefficient is the test statistic that measures the statistical relationship, or association, between two continuous variables. It gives information about the magnitude of the association, or correlation, as well as the direction of the relationship. We used the Feature Elimination approach to identify features that had the strongest association with the target variable and then removed them one by one to achieve the initial dimensionality reduction, with the independent variable decreasing from 151 to 26, as shown in Fig. 1to Fig. 2. Here is the information on this particular data set, shown in Table I.

F. Oversampling

The task of imbalanced classification pertains to the construction of predictive models for classification datasets that exhibit a significant disparity in the number of instances between the classes. The issue of working with imbalanced datasets is that most machine learning algorithms will disregard, and so perform poorly on, the minority class, despite the fact that performance on the minority class is generally the most essential. Oversample the minority class to correct skewed datasets. The simplest method is to duplicate minority class examples, which don't provide any new information to the model. Alternatively, novel instances can be generated through the amalgamation of pre-existing exemplars. The Synthetic Minority Oversampling Technique (SMOTE) is a form of data augmentation that is used to address imbalanced class distribution, specifically for the minority class [21].

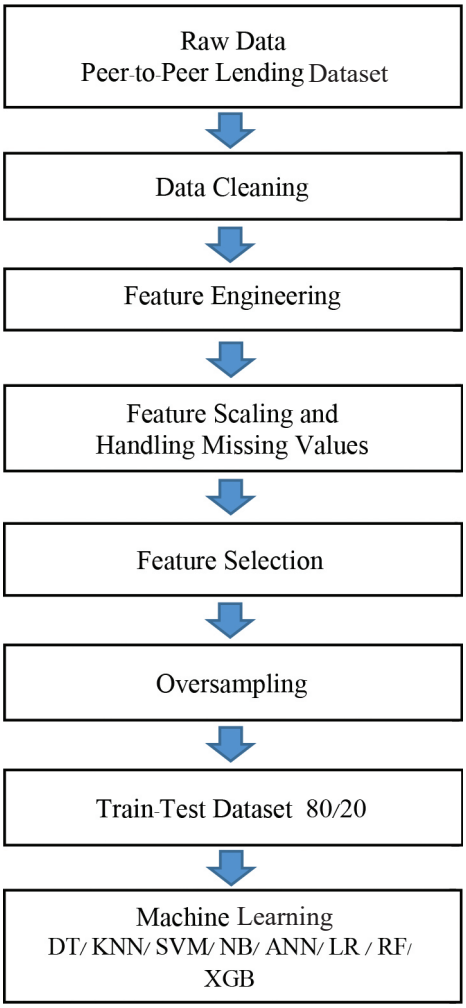

Fig. 1. Research framework

Fig. 2. Person correlation of features

TABLE I
RESULTS OF FEATURE SELECTION

Loan Stat New	Description
Loan Amnt	The loan amount requested by the borrower is indicated in the listed amount. If the credit department decides to decrease the loan amount at any given time, this change will be reflected in this value.
Term	The loan duration is denoted by the number of payments, which is measured in months and can be either 36 or 60.
Int Rate	Interest Rate on the loan
Installment	The borrower is responsible for a monthly payment that is due when the loan is initiated.
Grade	Loan grade
Sub_Grade	Loan subgrade
emp_title	The occupation or job position provided by the borrower during the loan application process.
Emp_Length	The duration of employment is stated in years. The available options range from 0 to 10, with 0 representing less than one year and 10 indicating ten or more years of employment.
Home_Ownership	The borrower's residential property ownership status is indicated during registration or obtained from the credit report.
Annual_Inc	The annual income was disclosed by the borrower during the registration process.
Verification_Status	It indicates whether the borrower's income was verified by LC, not verified, or if the source of income was verified.
Issue_D	The month in which the loan was financed.
Loan_Status	Current status of the loan
Purpose	A classification is provided by the borrower regarding their loan request.
Title	The description or title of the loan provided by the borrower.
Zip_Code	The initial three digits of the zip code are given by the borrower in the loan application.
Addr_State	The state is mentioned by the borrower in the loan application.
Dti	The ratio is derived by dividing the borrower's total monthly debt payments, excluding mortgage and the requested LC loan, by the borrower's self-reported monthly income.
Earliest_Cr_Line	The month when the borrower initially established their reported credit line.
Open_Acc	The count of active credit lines in the borrower's credit file.
Pub_Rec	The count of negative public records associated with the borrower.
Revol_Bal	It refers to the overall balance of revolving credit accounts.
Revol_Util	The percentage of revolving credit utilized by the borrower, indicates the amount of credit they are currently using compared to the total available revolving credit.
Total_Acc	The overall count of credit lines currently present in the borrower's credit file.
Initial_List_Status	The initial status is assigned to the loan listing. It can have one of two values: W or F.
Application_Type	It indicates whether the loan application is made by an individual or involves a joint application with two co-borrowers.
Mort_Acc	It represents the count of mortgage accounts.
Pub_Rec_Bankruptcies	It represents the count of bankruptcies listed in public records.

IV. Experiments and Results

We performed experiments using a collection of peer-to-peer lending datasets obtained from the lending club website. We implemented all algorithms in Python using the scikit-learn library. To evaluate the performance of our network, we calculate four metrics: accuracy, precision, recall, and F-measure, TP = the number of true positives, FP = the number of false positives, TN = the number of true negatives, FN = the number of false negatives, P = the number of positives in ground truth, N = the number of negatives in ground truth [28]-[30]. Classification effectiveness is usually measured by accuracy, precision, and recall. Precision is the proportion of true positive examples labeled positive by the system that was truly positive and recall is the proportion of true positive examples that were labeled positive by the system. The F-measure function which combines precision and recall is computed as:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$$

$$F-measure = \frac{2\times Precision\times Recall}{Precision+Recall}$$

We tested all algorithms using the validation test set of 20%. The results in terms of accuracy, precision, recall, and F-measure is the averaged values calculated across all cross-validation experiments reported in Table II to Table III and Fig. 3 to Fig. 4.

TABLE II
Traditional Framework Performance Comparisons %

List	Accuracy	Precision	Recall	F-Measure
ANN	80.60	76.5	80.60	78.49
XGB	80.60	76.24	80.60	78.36
RF	80.53	75.97	80.53	78.18
DT	70.88	71.76	70.88	71.32
NB	80.03	74.14	80.03	76.97
KNN	74.73	69.73	74.73	72.14
SVM	79.94	71.37	79.94	75.41
LR	80.31	64.49	80.31	71.54

TABLE III
Proposed Framework Performance Comparisons %

List	Accuracy	Precision	Recall	F-Measure
ANN	88.72	88.38	88.72	88.55
XGB	**88.94**	89.19	**88.94**	89.06
RF	88.89	89.52	88.89	89.20
DT	82.81	83.24	82.81	83.02
NB	86.41	85.68	86.41	86.04
KNN	85.16	84.00	85.16	84.58
SVM	88.85	**90.20**	88.85	**89.52**
LR	88.91	89.59	88.91	89.25

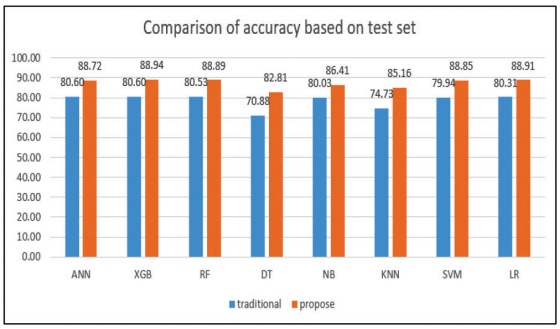

Fig. 3. Comparison of accuracy based on test set

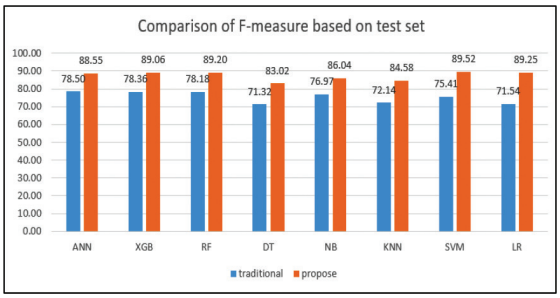

Fig. 4. Comparison of F-measure based on test set

The findings of this research showed that the proposed framework significantly outperformed the original framework in all algorithms presented in Table II to Table III and Fig. 3. The experimental results in this research found that when using the ANN algorithm, accuracy increased by 8.12%; using the XGB algorithm, accuracy increased by 8.34%; using the RF algorithm, accuracy increased by 8.36%; and using the DT algorithm, accuracy increased by 11.93%. Using the NB algorithm, accuracy increased by 6.38%; using the KNN algorithm, accuracy increased by 10.43%; using the SVM algorithm, accuracy increased by 8.91%; and using the LR algorithm, accuracy increased by 8.91%. As shown in Fig. 4, comparing F-Measure indicators, it was found that when using ANN, efficiency increased by 10.05%; using XGB, efficiency increased by 10.71%; using RF, efficiency increased by 11.02%; using DT, efficiency increased by 11.71%; using NB, efficiency increased by 9.07%; using KNN, efficiency increased by 12.43%; using SVM, efficiency increased by 14.11%; and using LR, efficiency increased by 17.71%.

The experiment of this research framework in Table III found the XGB algorithm provided the most effective classification accuracy of 88.94%, followed by the LR algorithm with an accuracy of 88.91%, the RF algorithm with an accuracy of 88.89%, the SVM algorithm with an accuracy of 88.85%, the ANN algorithm with an accuracy of 88.72%, the NB algorithm with an accuracy of 86.41, the KNN algorithm with an accuracy of 85.16%, and the DT algorithm with an accuracy of 82.81%, respectively.

The results of the experiments in this study are consistent with the findings of Cao [12] and Ma et al. [24] investigation into the performance evaluation of machine learning approaches for credit scoring. The results of this research indicate that the Boosting classifier has better performance in predictive analytics compared with the other classifier. The experimental findings from this study are also consistent with earlier research by Brown [17] and Chen [21] which involved experimental evaluations of classification algorithms for unbalanced credit-scoring datasets. The model evaluation yields consistent outcomes with high accuracy and optimal performance.

IV. Conclusion

This study tried to combine the benefits of both feature selection and feature engineering to improve the performance of the credit scoring model. The contribution of this research is to provide a framework for the development of credit scoring models using feature engineering and machine learning techniques consisting of artificial neural networks (ANN), XGBoost (XGB), random forest (RF), logistic regression (LR), and support vector machines (SVM), naive Bayes (NB), k-nearest neighbor (KNN), and decision tree (DT).

The proposed framework is tested on P2P lending datasets and measures performance with accuracy. This experiment in this research found the XGB algorithm provided the most effective classification accuracy of 88.94%. Therefore, the proposed research framework of this research, working with feature engineering, feature selection, and machine learning techniques, is suitable and effective for credit scoring problem analysis.

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Development of Crispy Spicy Snack from Bhutan Oyster Mushroom by-Product with Narok Chili Paste

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Received: July 18, 2023 / Revised: November 22, 2023/ Accepted: November 24, 2023

***Abstract*— The aim of this study is to develop a crispy spicy snack from Bhutan oyster mushroom by-product and Narok chili paste. It was rejected from the mushroom house with an evaporation system at Wat Jampee school, Suphan Buri province. The methodology of this study is the preparation of three different sizes of oyster mushroom by-products; shreded, medium, and whole mushrooms. They were then blanched in hot water, cooled in cold water, soaked in 1% Calcium Chloride (CaCl2) for 15 min., drained and dipped in batter, and deep fried at 160 °C in vegetable oil. The shred and medium size of mushrooms took 8 min. and 10 min. for the whole mushroom. It was then, baked at 90°C for 50 min. It was found that the shred and medium-sized oyster mushroom by-products had the exact overall liking at 6.90 at a slightly liking level. To select the standard recipe for Narok chili paste and the most appropriate size of mushroom by target customer for further product development. The experiment found that shredded mushrooms with Narok chili paste recipe 1 (T1S1) from six samples received the highest overall preference score of 6.10.**

As for the sensory evaluation with a 9-point Hedonic Scale found that the shredded mushroom with the first recipe chili paste got moderate overall liking (7.06), the color of the mushroom (7.09), crispiness (7.04) chili paste color (7.49), spiciness (6.90), saltiness (6.52). The consumer acceptance was 77%. Hence, the study of the development of a crispy spicy Bhutan Oyster Mushroom by-product snack from the mushroom house with an evaporation system at Wat Jampee School, Suphan Buri province, add value to the by-product until the country's economic sustainability in the future.

***Index Terms*— Oyster Mushroom, Chili Paste, Snack**

I. Introduction

Snacks can be sweet or savory. It will be processed and ready to eat immediately [1]. The main component of the snack is flour, mainly sugar and fat. There are also MSG, salt, artificial food flavors, colorings, seasoning, and little nutritional value [2].

In 2017, the total market value was as high as 35 billion baht, growing 5.3% higher than the previous year. Snack products are products with market value and there is high competition between operators in developing healthy snack products to be suitable and safe for consumers and successful in commercial distribution. Operators and related practitioners know the product development technology required, market demand, and the requirements of the Ministry of Public Health [3]. Snacks that use healthy processing methods such as baking, using natural flavors, colors, and ingredients, and local flavors such as Tom Yum flavor, basil, etc. are still in demand by consumers [4].

Wat Jampee School, Suphan Buri province crops Bhutan Oyster Mushroom with an evaporation system, which must control humidity, temperature, and water spray to adjust the environment to suit the mushrooms all the time. The mushrooms from this condition can bloom by 15-20%, more than the traditional method, this method can save energy and extend the shelf life of the mushroom lumps for longer storage time by 10-25% [5]. The school harvests mushrooms to make some dishes for students' lunch and sells as fresh. There are still some by-product mushrooms left from fresh sales that cannot be sold as fresh mushrooms because the quality does not meet the standards like mushrooms blooming too small mushroom which is often sold at low prices.

Bhutan Oyster Mushroom is the *Pleurotus eous* species which is similar in appearance to abalone and dark color. Due to the variety of properties of this mushroom, people are popular to use it to prepare dishes such as crispy fried mushroom salad, tom yum soup, mushroom salad, and mushroom chili sauce.

Accordingly, Thai people are more active in exercising and eating nutritious food and have an urgent life, the business of healthy food and beverage products tends to continue to improve. And it is also a trend that entrepreneurs pay attention to, especially healthy snack products. Because consumers pay more attention to healthy snacks. It plays an important role in the growth of the health food business. The snack market in Thailand can be considered. It is a market with potential and continuous growth.

Therefore, the purpose of this research is to develop the Bhutan Oyster Mushrooms by-product to be the crispy spicy snack. And add a new transformation with the taste of Narok chili paste to make it be a nutritious snack. So it can enter the healthy snack market. It also adds value to the Bhutan Oyster Mushrooms that are left over from sales and are of substandard quality. And the research results can also be useful to generate income for the local community and those who are interested in adding value to mushrooms as well.

II. Literature Review

A. Oyster Mushroom

Bhutan Oyster mushroom [6] has a shape and appearance similar to oyster mushrooms and is classified in the same family by the name "Bhutan Mushroom" is the name that was established in Thailand. Because this mushroom was first found in Jammu, in the foothills of the Himalayas in India. In 1975, Dr. Siripong Boonlong, Institute of Applied Science Research of Thailand Cultivated experiments in Thailand and found that Oyster mushrooms grow well in the climate of central Thailand. Later, Kasetsart University brought to experiment and culture in different mediums and conditions. It was found that Bhutanese fairy mushrooms grow well in many kinds of weather conditions, that is, when the weather is normal, the incubation takes about 20-25 days, but if it is during the winter, it takes only 15-20 days of incubation, and in the cold weather will bloom quickly. The flower color is dark. But if the summer blooms late, the flower color will fade. The picture of oyster mushroom was shown in Fig. 1 [7]. After that in 1977, the Plant Disease Research Division Department of Agriculture conducted an experiment to expand the results to farmers. Therefore, Oyster mushrooms are cultivated for commercial purposes more widely. Scientific name: Pleurotus Sajor-caju (Fr.) Sing Generic name: Phoenix mushroom, Indian oyster mushroom, Sajor-caju mushroom, Bhutan oyster mushroom.

Class : Basidiomycetes
Subclass : Holobasidiomycetidae
Order : Agaricales
Family : Tricholomataceae
Genus : Pleurotus
Species : Pulmonarius

Fig. 1. Oyster Mushrooms
Source: National Bureau of Agricultural Commodity and Food Standards (2012)

Table I shows nutrition facts of the amount of nutrients and essential amino acid that beneficial to health [8].

TABLE I
BHUTAN OYSTER MUSHROOM NUTRITION

Nutrition	Unit
Calcium	20 mg/100g
Phosphorus	760 mg/100g
Potassium	3260 mg/100g
Ferrous	124 ppm
Cadmium	0.3 ppm
Zinc	12 ppm
Copper	12.2 ppm
Plumbum	3.2 ppm
Isoleucine	78 mg/g of crude protein nitrogen
Leucine	68.1 mg/g of crude protein nitrogen
Methionine + Cysteine	62.5 mg/g of crude protein nitrogen
Phenylalanine +Tyrosine	137.8 mg/g of crude protein nitrogen
Threonine	88 mg/g of crude protein nitrogen
Tryptophan	91 mg/g of crude protein nitrogen
Valine	76.1 mg/g of crude protein nitrogen

Source: Available from: http://mdc.library.mju.ac.th/ebook/335131.pdf

B. Narok Chili Paste

Narok chili paste made from dried chilies which is generally red color and spicier than chili paste made from fresh chilies. Dried chilies are used as a seasoning ingredient. Some chili pastes may contain water as an ingredient, texture will be semi-liquid. Chili pastes made from dried chilies such as Ta Daeng Chili Paste, Ong Chili Paste, Galangal Chili Paste, Laab Chili Paste, Narok Chili Paste, etc. The standard chili paste recipe compose with fresh chili, garlic, shrimp paste, dried shrimp, palm sugar, lime juice, and fish sauce which can be applied with other type of chili paste [9]. Narok chili paste is adapted from the standard recipe but has strongly hot and spicy taste. Using Bird chili will give the most spiciness. Thai pepper looks like large chili seeds, dark red color, moderately spicy, strong aromatic, and little seeds. Narok chili paste is nutritious. Because it contains many herbs such as chili, shallots, garlic, etc. These ingredients could find in local area. [10].

C. Frying

Frying means cooking food by using vegetable oil or animal fat. It acts as a carrier for heat exchange and helps lubricate food from sticking to the pan. Frying temperatures is in the range of 170-210°C. The fried food has different unique characteristics such as crispness, color, smell, flavor, and texture. Frying is divided into 2 categories, namely deep frying and shallow frying.

Firstly, deep frying is the basic method of food preparation to get the desired sensory characteristics in terms of flavor, golden brown and crispy texture. The process of deep-frying involves immersing food in hot oil. The temperature of the surface rises rapidly. The oil on the surface is cooled. This oil will seep into the food by convection. This method was used in the research product with palm oil.

Secondly, shallow frying is a frying process by using less oil which is suitable for household frying or frying some foods that do not require uniformity of color such as roti and burgers. The quality of fried food depends on the type of oil used. The frying oil must be appropriate quality. Because the frying oil is a carrier to transfer heat to the food and cook the food.

The factors affect the quality of fried food such as food moisture, oxygen, type of oil, temperature and time of frying, package and storage those are effect on product texture, color, shelf-life, preference, and acceptance score [11].

D. Drying

Drying is the heating to cook the food. To expel water from food to the least amount remaining. The dried food will have water or moisture content about 2 to 3 percent, less water activity (aw) in the food to prolong the shelf life. Because it inhibits the growth of microorganisms and reduced enzyme activity. Drying is divided into two processes, the first process is natural drying that is the lowest cost and easiest process by sun drying but the dried product is low quality and temperature is uncontrollable. Secondly, drying by dryer with convection or conduction. The process will give the good product quality and can control the temperature. This experiment choose the second drying method after frying to reduce product moisture that impact to shelf-life and produce browning from maillard reaction to create product color properly [12].

III. Materials and Method

Materials and methods were divided into three parts: population and samples size, sensory assessment, and methodology respectively. This research is mainly experimental and survey research in the last part of the research. To explore the consumer acceptance of the crispy spicy Bhutan oyster mushroom snack from mushroom by-product to increase the value and remain from distribution to be able to be used.

A. Population and Sample size

Population, general consumers who eat crispy mushroom products and Narok chili paste in Bangkok and its vicinity, aged 19 years and above. The sampling method was randomly selected by purposive sampling method in 3 groups as follows:

First group, thirty untrained sensory participants were randomly selected by convenience sampling as in-house panels [13] into two replications for studying of the optimal size of crispy Bhutan oyster mushrooms.

Second group, thirty untrained sensory participants were randomly selected by convenience sampling as in-house panels [13] into two replications for studying of the preferences and adequacy of crispy spicy Bhutan oyster mushroom products.

Thirdly, one hundred untrained sensory participants were randomly selected by convenience sampling as in-house panels [13] into two replications for studying of consumers' preferences and acceptance of the developed crispy spicy Bhutan oyster mushroom snack.

B. Sensory Assessment

The research instrument for collecting this research data, consist of three assessment. Firstly, the sensory assessment of the crispy Bhutan oyster mushrooms which is divided into three parts; demography, sensory tests by a preference rating (9-Point Hedonic Scale) and a product-developed adequacy test (Just About Right: JAR) and recommendation respectively.

Secondary, the sensory assessment of the crispy spicy Bhutan oyster mushroom which is divided

into three parts; demography, sensory tests by a preference rating (9-Point Hedonic Scale) and a product-developed adequacy test (Just About Right: JAR) and recommendation respectively.

Thirdly, the sensory assessment of preference and acceptance of the developed crispy spicy Bhutan oyster mushroom snack which is divided into three parts; demography, sensory tests by a preference and acceptance rating (9-Point Hedonic Scale) and recommendation respectively by one hundred participants.

C. Methodology

The preliminary preparation of Crispy spicy Bhutan oyster mushrooms, Harvesting mushrooms by collecting them from planting bag then selected the rejected mushrooms which have a flaw such as defect cap and over blooming cap to the develop to be snack. Mushrooms were washed and drained. After that prepared by cutting into different sizes as shown in Fig. 2:

T1: stem size 4x0.2 cm and cap size 1x3 cm (shredded mushroom)

T2: stem size 4x1 cm and cap size 2x3 cm (medium-sized mushroom)

T3: stem size 4x1 cm and cap diameter 3 cm (whole mushroom)

Fig. 2. Cutting size of mushroom (T1) shredded mushroom, (T2) medium-sized mushroom, and (T3) whole mushroom

They were blanched in boiling water for 10 seconds, cooled with ice-cold water and drained. All of them were immersed in calcium chloride solution at a concentration of 1% (weight/volume) to reduce browning reaction for 15 minutes and drained on a sieve [14].

The prep mushrooms were dipped in wheat flour and deep-fry at 160°C, 8 min for sample T1 and T2, 10 min for T3 then rest on a wire rack to drain the oil. Frying is the processing method to improve and preserve the product quality by elimination of pathogenic microorganisms, enzyme and reduction of food moisture to prolong shelf-life.The all fried mushrooms were dried in a hot air oven at 90 °C for 50 minutes in order to reduce the moisture content and excess oil of the mushrooms [15]. After the process, all crispy mushrooms were analyzed on physical qualities such as moisture content and sensory test by thirty untrained sensory participants aged 19 years and above. Thirty untrained sensory participants were randomly assigned sampling to use in-house panels [13] into two replications to select the optimal size.

The experiment was prepared for Narok chili paste by roasting chili and pounding with the rest of ingredients then braising and seasoning. Next, mixed with dried shrimp and stirred in low heat until they were dried and well combined to be powder. Narok chili paste was divided into 3 recipes as the following table II and the picture of Narok chili paste Recipe were shown in Fig. 3.

First recipe [16] was prepared by roasting dried chili peppers, dried chilli and pounded fried shallots, fried garlic thoroughly. After that braised old galangal, tamarind paste, fish sauce and palm sugar until homogeneous on low heat. Then stirred well with dried shrimp powder until well combined. Second recipe [17] was prepared by pounding fried shallots, fried garlic, tamarind paste, dried chili, dried shrimp paste and dried shrimp powder, seasoning with fish sauce. Stirring the pounding mixture until well combined.

Third recipe [18] was prepared by roasting dried chili with dried cayenne pepper then blended with fried shallots and fried garlic thoroughly. Added dried shrimp powder in the mixture on the pan by stirring on low heat and seasoning with salt and sugar.

TABLE II
SHRIMP NAROK CHILI PASTE RECIPE

Ingredient	Recipe		
	1	2	3
Dried shrimp powder (g)	150	90	75
Dried chili (g)	15	40	30
Dried Cayenne pepper (g)	10	-	-
Fried Shallots (g)	35	90	63
Fried garlic (g)	50	15	150
Old Galanga (g)	10	-	-
Tamarind paste (g)	15	30	75
Fish sauce (g)	30	45	75
Palm sugar (g)	25	-	-
Dried shrimp paste (g)	-	10	10
Sugar	-	-	-

Fig. 3. The Narok chili paste recipe 1, 2, and 3 from left to right

The final step, mix the Narok chili paste and fried mushrooms by a ratio of 1:3 by weight for every treatment to assess the sensory of preferences and adequacy of crispy spicy Bhutan oyster mushroom products by factorial in balance incomplete block (BIB) design to get the best product by thirty participants. Then adjust the experiment according to the interpretation of the net score. After developing product, the product was assessed the sensory of preferences and adequacy by one hundred participants.

All experimental data were analyzed by Analysis of Variance (ANOVA). Significantly different means were separated according to the method of Duncan's New Multiple Rang Test (DMRT) according to the procedure described in [19].

At the end of the experiment, the developed product was analyzed color with CLE (L*a*b*) system by Spectrophotometer. The meaning of L* parameter is the lightness value between 0-100, a* is the red shade for positive value and green shade for negative value, b* is the yellow shade for positive value and blue shade for negative value. Moreover, moisture content analysis was analyzed with infrared radiation by moisture analyzerand the nutritional and chemical properties by AOAC (2019) method.

IV. Result and Discussion

A. Bhutan Oyster Mushroom Size

The results of color showed that all 3 samples were significantly different ($P<0.05$) (Table III).

The sample T3 got the highest value of the lightness parameter (L*) at 58.16, and sample T1 got the highest redness value (a*) at 5.01 and (b*) yellowness value at 12.56. In this research, mushrooms have less brown color and moisture after processing which conform to a previous study that reported that blanching before processing eliminates Polyphenol oxidase that can reduce oxidation reaction in mushrooms [14]. Moreover, immersion in a calcium chloride solution can dehydrate the mushrooms. That effect on color and moisture content from different sizes, the sample T3 (whole mushrooms) got the highest percentage of moisture content because the bigger surface area can absorbed more moisture while sample T1 (shredded mushrooms) got the least moisture content at 1.47 %.

TABLE III
The Analysis of Color and Moisture

Sample	L*	a*	b*	Moisture (%)
T1	57.08±1.46	5.01±1.04	12.56±0.88	1.47±0.21
T2	51.44±0.66	3.70±1.12	9.59±1.90	2.01±0.18
T3	58.16±1.81	2.94±0.91	8.9±3.42	2.53±0.25

Data are shown as average ± standard deviation
Note:T1= shredded mushrooms, T2 = medium-sized mushrooms, T3 = whole mushrooms

From the preference test, thirty consumers was attracting by the shredded (T1) and medium-sized (T2) that got the similar scores and were not significantly different ($P>0.05$) as shown in Table IV and Fig. 4. Therefore, they were the selected appropriately size for further study [20].

TABLE IV
THE PREFERENCE SCORE

Sample	Average Liking Score					
	Appearance	Color	Flavor	Crispiness	Texture	Overall
T1	7.23±1.19[a]	6.97±1.33[a]	6.83±0.95[a]	6.33±1.45[a]	6.37±1.19[a]	6.90±0.92[a]
T2	6.83±1.23[a]	7.00±1.11[a]	6.87±1.07[a]	6.93±1.36[a]	6.63±1.47[a]	6.90±0.85[a]
T3	6.87±1.07[a]	6.37±0.99[b]	6.37±1.27[a]	5.23±1.27[b]	5.07±1.05[b]	4.97±1.19[b]

Data are shown as average ± standard deviation
[a,b,c] The means followed by same letter are significantly different in the same column ($p<0.05$)
Note: T1= shredded mushrooms, T2 = medium-sized mushrooms, and T3 = whole mushrooms

Fig. 4. Sample T1= shredded mushrooms, T2 = medium-sized mushrooms, and T3 = whole mushrooms

B. Consumer Preference and Adequacy Score of Product

According to the results of the preference and adequacy test of shredded mushrooms (T1) and medium-sized mushrooms (T2) with 3 types of chili paste which were Narok chili paste Recipe 1 (S1), Recipe 2 (S2) and Recipe 3 (S3) as shown in Table V. To select the standard recipe for Narok chili paste and the most appropriate size of mushroom. It was tested by 100 persons of target consumers according to the procedure described in [13]. It was found that the shredded mushrooms with Narok chili paste Recipe 1 (T1S1) received the highest overall score of 6.10. In addition, other factors are still higher than other samples. For the adequacy value was in range of 60-90%. Spiciness and saltiness of the product were 60 and 63% when considering the net score on both sides, it was less than 20%. Therefore, shredded mushrooms were selected with Narok chili paste Recipe 1 (T1S1) for further product development.

TABLE V
THE PREFERENCE SCORE OF 6 SAMPLES OF CRISPY BHUTAN OYSTER MUSHROOMS

Sample	Average Liking Score					
	Crispy Mushroom Color	Crispiness	Chili Paste Color	Spiciness	Saltiness	Overall
T1S1	6.47[a]±1.76	7.10[a]±1.21	7.17[a]±1.18	6.10[a]±1.88	6.03[a]±1.40	6.10[a]±1.97
T1S2	5.57[ab] ±1.76	6.30[abc]±1.24	4.43[d]±2.10	5.47[a]±1.68	4.67[bc]±1.67	5.10[a]±1.85
T1S3	6.23[ab]±1.31	6.97[ab]±1.13	6.17[b]±1.70	5.53[a]±1.99	5.37[ab]±1.92	5.73[a]±2.05
T2S1	6.47[a]±1.74	5.23[cd]±2.50	7.00[ab]±1.41	5.90[a]±2.09	5.43[ab]±2.11	5.53[a]±2.08
T2S2	6.47[a]±1.22	5.13[d]±2.70	6.20[b]±1.96	5.90[a]±1.88	5.60[ab]±2.27	5.53[a]±2.30
T2S3	5.33[b]±2.29	5.97[bcd]±2.50	4.60[c]±1.87	5.17[a]±1.80	4.27[c]±1.67	5.10[a]±1.47

Data are shown as average ± standard deviation
[a,b,c] The means followed by same letter are significantly different in the same column ($p<0.05$)
Note: T1= shredded mushrooms, T2 = medium-sized mushrooms with Narok chili paste, S1 = Recipe 1 , S2= Recipe 2, and S3= Recipe 3

C. Consumer Preference and Acceptance

The 100 target consumers rated their overall preference and acceptance score at a moderate level, 7.06 as shown in Table VI and 77% as shown in Table VII which is the highest score. From the data can interpret that consumers are willing to buy the final product (Fig. 5).

TABLE VI
THE AVERAGE PREFERENCE SCORE

Characteristic	Score
Mushroom color	7.09±1.31
Mushroom crispiness	7.04±1.52
Chili paste color	7.49±1.02
Spiciness	6.90±1.28
Saltiness	6.52±1.58
Overall	7.06±1.25

Data are shown as average ± standard deviation

TABLE VII
THE PERCENTAGE OF ACCEPTANCE TEST

Acceptance	Percentage (%)
Accept	77
Not accept	12
Hesitant	11
Total	100

Fig. 5. The final product.

The analysis test in nutrition and chemistry of crispy spicy Bhutan Oyster mushroom with Narok chili paste by AOAC (2019) method was considered under the local standard of seasoning mushroom product (TISI 303/2008) [21], found that the product got the measurement value of the water activity at 0.33, yeast and mold < 10 colonies per grams which is lower than 0.6 and 100 colonies which are the important parameters for shelf-life and food safety as shown in Table VIII.

TABLE VIII
THE ANALYSIS REPORT OF THE PRODUCT

Qualification	Score	TISI 303/2008
a_w	0.332	0.6
Moisture (%)	4.50	-
Ash (%)	2.57	-
Fiber (%)	6.21	-
Total fat (%)	40.31	-
Protein (%)	8.07	-
Carbohydrate (%)	44.55	-
Total energy (kcal/100g.)	573.27	-
Peroxide value (mEq peroxide/kg.)	4.22	<30
Yeast and Mold (CFU/g.)	<10	<100

V. CONCLUSION

Developing the product from local mushroom by-product with Narok chili paste by added value and transformation process to make the maximized benefit from agricultural waste and transformed the chili paste into snack. In conclusion, the shredded mushrooms are the most appropriate size that was blanched to eliminate oxidation enzyme, dehydrated with calcium chloride solution before processing, deep-frying at 160°C, 8 min., and drying 90 °C. All the processes improved the product quality, color, water activity to prolong the storage of the product and also the average preferences score in all aspects was high at 7.06. Further studies should be conducted, especially in the protein extraction from mushroom by-products to be an application in plant-based meat or future food.

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Enhanced Autonomous Driving: PrediNet20 with AHLR for Improved Performance

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Received: October 20, 2023/ Revised: February 2, 2024/ Accepted: February 14, 2024

***Abstract*—In the continually evolving field of autonomous driving, enhancing model prediction accuracy and addressing noisy data remain pivotal challenges. This study introduces PrediNet20, a customized end-to-end Convolutional Neural Network (CNN) designed for the Donkey Car platform. PrediNet20 aims to alleviate the limitations of current deep learning models by improving accuracy in predicting throttle and steering angles, crucial components in autonomous driving systems. At the core of this enhancement is the introduction of AHLR, a novel adaptive loss function that enhances model training and generalization. It dynamically adjusts the loss based on the prediction error, facilitating a smooth transition from quadratic to linear loss. Coupled with the application of L1 regularization, it aids in reducing overfitting, potentially enhancing the model's resistance to data noise and outliers. Preliminary experiments using real driving data indicate that compared to existing models, PrediNet20 demonstrates approximately a 33.3% improvement in convergence speed, a 37.5% improvement in stability, a 10% improvement in robustness, and a 50% improvement in generalization. PrediNet20 offers higher accuracy and faster convergence, marking a significant step forward in the development of more reliable autonomous driving systems.**

***Index Terms*—End-to-end, Autonomous Driving, Deep Learning, Predinet20, AHLR**

I. Introduction

End-to-end-based autonomous driving has been recognized as the future of automated driving [1], promising to revolutionize the way we perceive and engage with transportation. Rapid advances in artificial intelligence and machine learning have revolutionized and laid the foundation for safer and more trustworthy autonomous driving systems. However, improving model prediction accuracy, handling noisy data, and avoiding training overfitting remain very critical issues. Thus, there is a need to continuously develop and improve the relevant models and algorithms that would produce a more rationalized autonomous driving system [2]. Among these models and algorithms within the autonomous driving system, improvements in deep learning neural networks and loss functions usually yield better results in terms of decision rationalization for autonomous vehicles.

Deep learning, as a pivotal subset of machine learning, has emerged as a crucial tool in the development of autonomous driving systems, particularly excelling in handling high-dimensional data and intricate nonlinear relationships [3], [4]. In the realm of autonomous driving, Convolutional Neural Networks (CNNs) have been extensively employed for tasks such as target detection, semantic segmentation, and end-to-end driving. Despite achieving certain successes, these models still exhibit limitations in performance and reliability when predicting throttle and steering wheel angle values from images generated in autonomous driving experiments.

Current models often grapple with overfitting issues and struggle to handle anomalies and noise in training data, potentially compromising the model's generalization ability and performance in real-world scenarios. To address these challenges, this study introduces a novel CNN-based deep learning network architecture, namely PrediNet20, tailored specifically for the Donkey Car autonomous driving platform. This model leverages meticulously designed convolutional layers combined with LeakyReLUs and filter regularization to efficiently capture spatial features of input images [5], [6]. PrediNet20 aims to overcome the performance and reliability limitations of current models, with a particular focus on enhancing the robustness of the model against anomalies and noise to improve performance in practical scenarios.

Adaptive loss function, AHLR is one of the most important key innovations in our proposed PrediNet20. This function dynamically adjusts the loss according to the magnitude of the prediction error, transitioning from quadratic to linear loss [7]-[8]. This innovation, coupled with the addition

of L1 regularization, effectively handles outliers and prevents overfitting [9].

The rest of this paper is organized as follows: The Current state of research as well as the related loss functions and deep neural networks will be explained in the related work section; the Methodology section will focus on the proposed deep neural network structure and the proposed loss function; the Experiment section will discuss the experimental setup, data collection, evaluation metrics, and experimental results. Finally, the Conclusion section will summarize our work and future research directions.

II. Related Works

A. Deep Learning in Autonomous Driving

Deep learning, as an important branch in the field of artificial intelligence, has been widely applied and developed in the field of autonomous driving. Automatic driving systems need to deal with massive amounts of high-dimensional data, and process and understand various complex non-linear relationships, which is exactly the area in which deep learning excels. Through deep learning, the automatic driving system can learn and extract key information from a large amount of driving data, to realize autonomous decision-making and control. Among various deep learning models, the application of Convolutional Neural Networks (CNNs) in autonomous driving is particularly important. CNNs have excellent image recognition capabilities and are able to extract useful features from raw images [10], [11], which are crucial for tasks such as scene understanding and object recognition in autonomous driving. For example, CNNs can be used to detect other vehicles, pedestrians, traffic signs, etc., on the road, as well as to understand road conditions and driving environments as shown in Fig. 1.

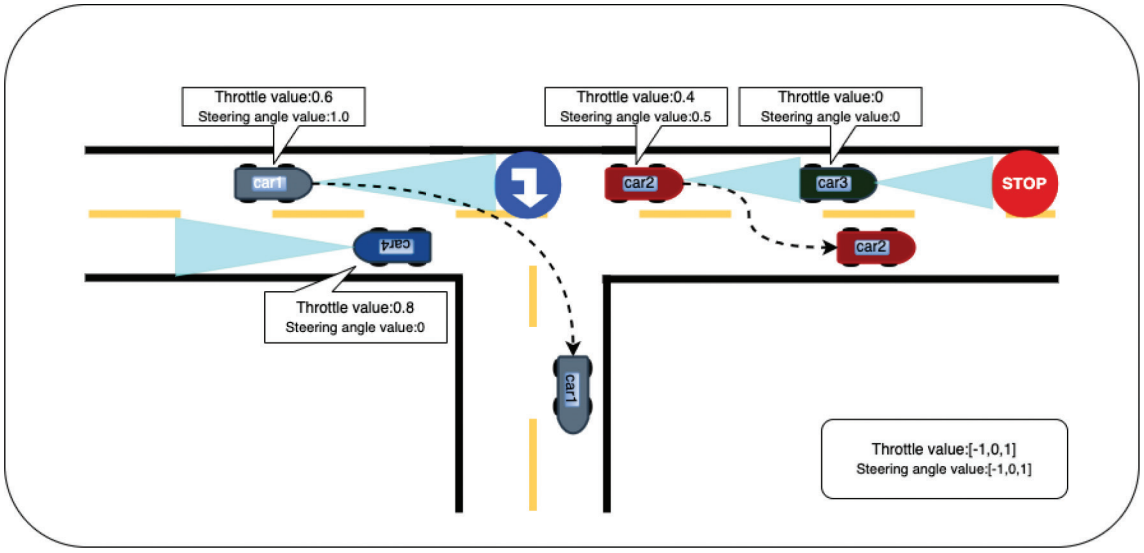

Fig. 1. The road environment of an autonomous vehicle in a real driving situation, which contains multi-task driving situations such as road tracking, road sign recognition, and object avoidance.

Moreover, CNNs are commonly employed in end-to-end autonomous driving to predict maneuvers like throttle control and steering from raw sensor data, such as camera images. This method bypasses traditional feature extraction and rules-based programming, enabling the system to adapt to diverse driving conditions from human inputs [12]-[14].

Although great developments have been achieved in the application of deep learning and CNNs in autonomous driving. There are still some challenges and problems. For example, how to deal with outliers and noise, how to prevent overfitting, and how to improve the accuracy of prediction. Therefore, this work will introduce our newly developed PrediNet20 model and the AHLR function to further improve the performance of autonomous driving systems.

B. Research and Limitations of End-to-end and Deep Learning Models

End-to-end modeling is an important approach in autonomous driving research. Such models predict driving operations, such as throttle control and steering angle, directly from raw sensor data (for example, camera images), eliminating the need for traditional manual feature extraction and programming rules, thus enabling autonomous driving systems to effectively adapt to various complex driving environments. Among them, the NVIDIA PilotNet [1] model is a representative work of end-to-end autonomous driving models.

PilotNet is a convolutional neural network-based model that predicts steering angles directly from images acquired by a single front-facing camera.

This model is trained with a large number of on-road driving data and is able to learn many complex driving rules and patterns. Similar models have been developed, such as DroNet, which is designed to safely drive a drone through the streets of a city. DroNet produces two outputs for each single input image: A steering angle to keep the drone navigating while avoiding obstacles, and a collision probability sensor to let the UAV recognize dangerous situations and promptly react to these situations [15]. Another example is DeepPicar, a low-cost autonomous car platform that uses the same network architecture as PilotNet and can drive itself in real-time using a web camera and a Raspberry Pi 3 quad-core platform. An end-to-end Deep Neural Network for autonomous driving is suitable for embedded platforms, such as Raspberry Pi 4B or Jetson Nano.

Although end-to-end models have shown excellent performance in some scenarios, they have also revealed some problems and limitations in practical applications. First, such models are prone to overfitting problems, for example, the model performs well on training data but the performance degrades on unseen data. Second, end-to-end models are weak at handling noise and outliers. For example, if the training data contains incorrect driving maneuvers or noisy data due to sensor errors, the model may learn incorrect driving behaviors. This poses a challenge to the safety and reliability of autonomous driving systems.

A variety of deep neural network architectures are widely used in the field of autonomous driving. These include, but are not limited to, Keras Linear (Linear), Keras Categorical, Keras RNN (LSTM), Keras 3D (3D), and so on. Each of these architectures has its own characteristics and applicable scenarios. For example, Linear architecture is relatively simple and less computationally demanding, making it suitable for simpler tasks [16]. 3D networks outperform their predecessors in terms of network depth and performance, but they are more computationally costly. 3D and LSTM are novel innovations in CNN structure, instead of using 2D convolution, as most other models do, 3D uses cross-layer 3D convolution. LSTM uses long short-term memory networks that use a series of images for autopilot rather than relying solely on individual frames [17]-[20]. Our proposed PrediNet20 integrates the advantages of the above models and makes some innovations to better adapt to autonomous driving tasks.

Therefore, how to solve these problems of end-to-end models and improve the robustness and generalization ability of the models is an important issue in current autonomous driving research. In this work, we will introduce our newly developed PrediNet20 model and adaptive Huber loss function with regularization, which are aimed at solving the above problems and improving the performance of autonomous driving systems.

C. Application of Loss Functions

Mean Square Error (MSE) [21] and Mean Absolute Error (MAE) [22], [23] are frequently employed loss functions in the context of autonomous driving tasks, as documented in the literature. Nonetheless, it is imperative to acknowledge that these metrics exhibit distinct advantages and drawbacks, necessitating careful consideration in their selection for specific modeling scenarios.

MSE, as a commonly employed loss function, possesses the characteristic of heightened sensitivity to outliers. This attribute arises from its inherent property of magnifying each conceivable error, thereby rendering it susceptible to undue influence by data points that exhibit substantial deviations. Consequently, the utilization of MSE may result in models exhibiting overfitting tendencies when confronted with datasets containing outliers of considerable magnitude.

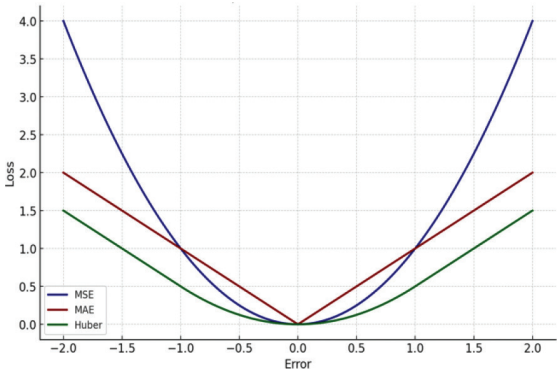

Fig. 2. Comparison of loss functions

In contrast, MAE, as an alternative loss function, adopts a more equitable approach by ascribing equal weights to all errors within the dataset. This equitable treatment of errors translates into robust insensitivity to outliers, making MAE a suitable choice for scenarios where data anomalies are prevalent. However, it is worth noting that this very attribute of MAE, while beneficial in mitigating the influence of outliers, may inadvertently hinder a model's capacity to effectively discriminate among errors of varying magnitudes. Consequently, the modeling framework might exhibit reduced precision in distinguishing and addressing errors of different sizes.

Fig. 2 illustrates the mean square error (MSE, dark blue line), the mean absolute error (MAE, dark red line), and the Huber loss function (dark green line) [24] as a function of error. It can be observed that the Huber loss function behaves similarly to the MSE when the error is less than a set threshold (set to 1.0 in this figure) and it is identical to the MAE when the error is greater than the threshold. It behaves like an MSE when the error is less than a set threshold, and an MAE when the error is greater than the threshold, which makes the Huber loss function neither overly sensitive to outliers nor neglecting large errors, and thus outperforms both the MSE and the MAE.

The Huber loss function, known for its effectiveness in handling outliers, faces several limitations that necessitate critical analysis. One prominent drawback is the need for manually specifying a threshold, a parameter with a substantial impact on model performance. The absence of a standardized method for threshold determination poses a significant challenge. Moreover, the Huber loss function lacks adaptability, lacking the intrinsic ability to autonomously adjust sensitivity to varying error magnitudes. In comparison to loss functions with built-in regularization components like L1 and L2 regularization [25], Huber loss may exhibit weaker capabilities in mitigating model overfitting. To address these issues, our research proposes an innovative adaptive Huber loss function. This approach aims to eliminate the manual threshold selection requirement by introducing a dynamic mechanism that tunes the threshold based on data characteristics. The adaptive Huber loss function will autonomously modulate sensitivity to errors, accommodating variations in error magnitudes within the dataset. Additionally, it will incorporate regularization elements inspired by successful techniques like L1 and L2 regularization [26], thereby enhancing its ability to counteract model overfitting. This critical analysis underscores the rationale behind adopting a new approach in our study.

D. Applications of Regularization and Activation Functions

Overfitting is a common and thorny problem in the training of deep learning models. When a model overfits the training data, it performs poorly on unseen test data, thus affecting the ability for model generalization. To address this problem, regularization techniques were developed. Regularization prevents the model from overfitting the training data by adding a penalty term to the loss function, thus limiting the complexity of the model. Common regularization techniques include L1 regularization and L2 regularization, both of which prevent overfitting to a certain extent and improve model performance on unknown data. Normally, data augmentation strategies can also be used to improve model performance on unseen data, However, it is worth noting that while regularization techniques provide valuable tools for addressing overfitting, they may not fully address the challenges posed by inherent noise or limited training datasets.

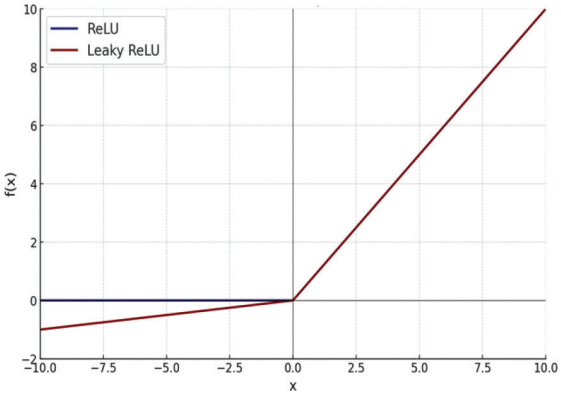

Fig. 3. ReLU vs Leaky ReLU

Like regularization, the activation function is an important component in deep learning models. The activation function determines the output of each node in the network and thus affects the output of the entire network. Different types of activation functions have different properties and affect model performance. For example, the Sigmoid and Tanh functions are able to map the inputs to a fixed range but are prone to the problem of vanishing gradients when the input values are large or small. The ReLU function [27] solves this problem but then suffers from the problem of zero gradients when the inputs have negative values. LeakyReLU [28] and Parametric ReLU, by allowing a certain number of outputs for inputs with negative values, thus solving the aforementioned problems of ReLU. For autonomous driving tasks, choosing the appropriate activation function is a very important aspect, because the choice directly affects the predictive ability and stability of the mode.

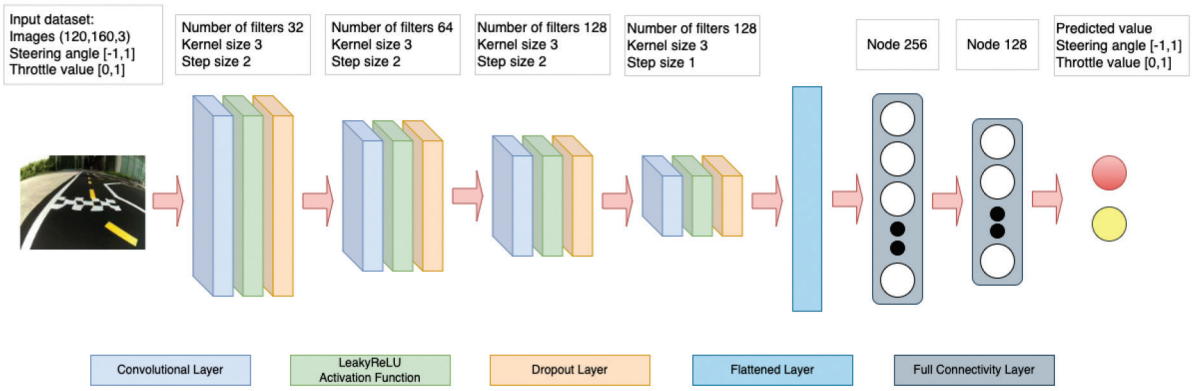

Fig. 4. A schematic diagram of the network stucture of PrediNet20

Fig. 3 shows ReLU function (dark blue line) has an output of 0 when the input value is negative and an output equal to the input value when the input value is positive. In contrast, the Leaky ReLU function (dark red line) allows for some negative output when the input value is negative, with a slope determined by the parameter alpha (in this Fig., alpha is set to 0.1). This design allows Leaky ReLU to maintain a certain gradient when the input value is negative, thus solving the problem of ReLU gradient vanishing in negative intervals.

In this work, we will use LeakyReLU as an activation function in our PrediNet20 model and incorporate a filter regularization technique to improve the performance of the model on the task of predicting throttle and steering angles. We also introduce an adaptive Huber loss function with regularization to further improve the training and generalization capabilities of the model.

III. Methodology

A. Predinet20: A New Deep Learning Model

Although existing research has provided good results in terms of accuracy, model overfitting, and robustness in predicting steering angle values and throttle values for autonomous vehicles, we have carefully constructed and implemented a deep learning-based end-to-end driving model designed to solve the above problems. We propose a novel network model architecture for PrediNet20 and a novel loss function, AHLR, which further improves the accuracy and robustness of the predicted values of the model. The model architecture is shown in the Fig. 4 above. Our method innovates and improves on this using the linear model as our baseline model. The advantages and details of our method are explained in the following section.

1) Strengths and flexibility of the Model

The structure of our model consists of a core layer of convolutional neural networks and a linear output layer. This architecture has many advantages. First, convolutional neural networks outperform traditional machine learning models in image processing. This is because the convolutional layers are able to effectively extract localized features in an image, and they are able to capture more complex and abstract features as the number of layers increases. In addition, convolutional neural networks reduce the number of parameters in the model through weight sharing and pooling operations, which reduces the risk of overfitting.

Second, the linear output layer allows the model to directly predict continuous driving commands rather than discrete categories. This is critical for end-to-end driving because driving operations are typically continuous rather than discrete. For example, the steering angle of the steering wheel, the control signals for the gas pedal, and the brake, all of which are continuous values. Thus, by directly predicting these continuous driving commands, our model can avoid complex intermediate steps such as feature engineering and rule design in traditional approaches.

Moreover, our model is highly flexible. By simply changing the value of *numOutputs*, our model can easily adapt to different numbers of outputs. This is very useful for handling different driving tasks. For example, if we only need to predict the steering angle of the steering wheel, then we can set *numOutputs* to 1; if we need to predict both the steering angle of the steering wheel and the control signal of the throttle, then we can set *numOutputs* to 2; and so on.

2) Design of our Deep Neural Network Model

Our model design is divided into two core phases: the feature extraction phase and the feature mapping phase. More details of these phases are explained below.

In the feature extraction phase, we use the powerful ability of the convolutional neural network to extract representative features from the input image. Through this phase, we can transform the original image information into more refined information that better reflects the main characteristics of the image.

For the feature mapping phase, we employ a fully connected layer coupled with a linear activation function. We transformed the extracted features from the prior phase into anticipated driving operations. These operations encompass steering wheel adjustments, throttle control, and brake application, among others. Through the processing of this phase, our model is poised to predict subsequent driving actions directly based on the input images.

Feature extraction phase. In the feature extraction phase, we use four convolutional layers, each followed by a LeakyReLU activation function and a Dropout layer. All convolutional layers use a 3x3 filter and a step size of 2. This means that the filter slides over the input image in steps of 2 pixels, which gradually reduces the dimensions of the feature map. The mathematical definition of the convolution operation is:

$$Y_{i,j,k} = \sum_{m,n} X_{i+m-1,j+n-1,k} \cdot W_{m,n,k} + b_k$$

where $Y_{i,j,k}$ denotes the elements of the output feature map, $W_{m,n,k}$ denotes the elements of the input feature map, $W_{m,n,k}$ denotes the elements of the convolution kernel, and b_k denotes the bias term.

We chose LeakyReLU as the activation function because it solves the "dead ReLU" problem of the ReLU activation function. When "dead ReLU" happens during the training process, a part of the neurons may never be activated, resulting in the corresponding parameters not being updated. The

Dropout layer is a regularization technique that randomly sets the outputs of some neurons to 0 during training, thus preventing the model from overfitting.

Feature mapping phase. We use two fully connected layers, each followed by a LeakyReLU activation function and a dropout layer. The goal of the fully connected layers is to integrate the local image features into global features so that the model can understand the entire image. The mathematical definition of a fully connected layer is:

$$Y = XW + b$$

where Y denotes the output, X denotes the input, W denotes the weight matrix, and b denotes the bias vector.

We then use a fully connected layer and a linear activation function for each expected output (for example, control signals for steering wheel steering, throttle, and brake). The goal of the linear activation function is to directly output the predicted driving commands without introducing additional nonlinearities. The linear activation function is mathematically defined as:

$$f(x) = x$$

where $f(x)$ denotes the output of the function and x denotes the input of the function.

B. AHLR: A Novel Loss Function

To make our loss function capable of dynamically adjusting the threshold according to the data characteristics of the adaptive ability and reduce the overfitting problem of the model, a novel AHLR loss function is proposed. The details of this function are explained below.

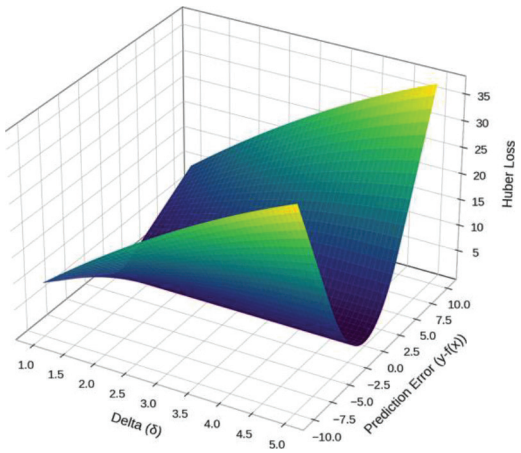

Fig. 5. 3D image of the AHLR function

The AHLR is a loss function designed to enhance the performance and generalization ability of deep learning models in regression tasks. The loss function improves Huber Loss with a regularization penalty term by dynamically adjusting the threshold δ and introducing regularization, allowing the model to better handle outliers and control complexity, resulting in better performance in applications such as autonomous driving. The Fig. 5, this 3D image demonstrates how the AHLR function varies with δ (represented on the x-axis) and prediction error (represented on the y-axis). As δ increases, the function exhibits greater tolerance when dealing with larger prediction errors. In the following sections, we will gradually define the details of how the Huber loss function is improved to the Adaptive Huber loss function and finally improved to our novel AHLR loss function.

1) Mathematical Derivation of AHLR

We begin with the foundational Huber loss function, a classical loss function tailored for handling outliers by merging the features of both squared error loss and absolute error loss. Given a constant δ', the Huber loss function, which operates on the actual value y and the predicted value $f(x)$, is defined as:

$$\text{If } |y - f(x)| \le \delta',$$

$$L_{(HL)(y,f(x))} = \frac{\left(y - f(x)\right)^2}{2}$$

Otherwise,

$$L_{(HL)(y,f(x))} = \delta'|y - f(x)| - \frac{\delta'^2}{2}$$

To enhance the Huber loss function, we introduce the Adaptive Huber Loss (AHL). This is achieved by substituting the constant δ' with a learnable parameter δ as illustrated below:

$$\text{If } |y - f(x)| \le \delta',$$

$$L_{(AHL)(y,f(x))} = \frac{\left(y - f(x)\right)^2}{2}$$

Otherwise,

$$L_{(AHL)(y,f(x))} = \delta\,|y - f(x)| - \frac{\delta^2}{2}$$

To combat potential overfitting associated with the Adaptive Huber loss function, an L1 regularization term is integrated. Specifically, the regularization penalty, penalty(δ) = sgn(δ), is added to the AHL. The combined loss function, AHLR, is presented below:

$$L_{(AHLR)(y,f(x))} = L_{(AHL)(y,f(x))} + \lambda \times sgn(\delta)$$

where λ denotes the weight of the regularization term.

To optimize the AHLR, we use gradient descent to find the minimum of the loss function. An essential phase involves computing the gradient of the loss function concerning the model parameters. The gradients with respect to the model parameters and the threshold are detailed below:

$$\frac{\partial(L_{AHLR})}{\partial\theta} = \frac{\partial(L_{AHLR})}{\partial f(x)} \times \frac{\partial f(x)}{\partial\theta}$$

$$\text{If } |y - f(x)| \le \delta',$$

$$\frac{\partial(L_{AHLR})}{\partial\delta} = 0$$

Otherwise,

$$\frac{\partial(L_{AHLR})}{\partial\delta} = |y - f(x)| - \delta + \lambda \times sgn(\delta)$$

Next, using gradient descent, we optimize and iteratively refine the model parameters θ and the associated thresholds δ. The mathematical methodologies for updating θ and δ are encapsulated below:

$$\theta_{(t+1)} = \theta_t - \frac{\alpha(\partial L_A HLR)}{(\partial \theta)}$$

$$\delta_{t+1} = \delta_t - \beta \frac{\partial L_{AHLR}}{\partial \delta}$$

Here, and represent the learning rates, which can be determined empirically or through cross-validation.

The model training process involves iteratively updating parameters using gradient descent to minimize the AHLR, thereby obtaining optimal parameters. In each iteration, the loss function and its gradient are computed based on the predictions of the model and the actual values. This iterative process persists until the model performance aligns with the preset stopping criterion or achieves the preordained maximum iteration count.

2) Advantages of Regularized Penalty Terms

Firstly, it is known that Huber Loss is a loss function commonly used in regression tasks to balance the characteristics of mean squared error (MSE) and absolute error (MAE). Compared to MSE and MAE, Huber Loss is more robust to outliers because it imposes a linear penalty for large errors and a quadratic penalty for small errors.

To enhance the regression performance of the model using Adaptive Huber Loss, we introduce a regularization penalty term to control the threshold. This technique not only manages the model complexity but also prevents overfitting by adding extra terms to the loss function. In this paper, we modify the Adaptive Huber Loss to obtain AHLR and explore its potential advantages, demonstrating the effectiveness of regularization in reducing the risk of overfitting and controlling the complexity of the model.

The regularization penalty term is used to constrain the complexity of the model to avoid overfitting. It is an additional term in the loss function that penalizes the parameter size of the model. In AHLR, we introduce a regularization penalty term $\lambda \times sgn(\delta)$ in addition to the Adaptive Huber Loss, where λ is the regularization factor and $sgn(\delta)$ indicates the sign of. The regularization penalty term is used to limit the range of values for δ so that it will not be too large or too small.

Based on the mechanism of action of AHLR regularization penalty term, we summarize the following advantages:

Robustness: through the properties of Huber Loss and Adaptive Huber Loss, AHLR is able to better handle outliers, which improves the robustness of the model to data noise and enhancesthe robust driving ability of autonomous driving cars.

Generalization ability: Model overfitting can be effectively prevented by introducing a regularization penalty term, which can improve the generalization ability of the model on unseen data.

Adaptive: AHLR can achieve more flexible model fitting by dynamically adjusting the threshold so that this loss function can be applied to data distributions of different tasks, which can effectively accomplish multi-task autopilot.

IV. Experiments and Result

In this section, we introduce the experimental setup and results with our proposed AHLR loss function and the PrediNet20 neural network structure. We utilize Donkey Car, a small open-source autonomous driving platform, to collect a dataset comprising driving images along with their corresponding steering and throttle values. We conduct comprehensive experiments on the Donkey Car platform and present the evaluation results for the PrediNet20 model with the AHLR loss function.

A. Experimental Setup

This section describes the construction of the driving platform, the training and validation process, and the evaluation metrics used.

In this experiment, we chose the Donkey Car open-source platform as the base platform for our experiments. The Fig. 6 shows the design of our experimental platform. We selected this platform because its flexibility and extensibility allow us to more accurately simulate real-world automotive kinematics. Nonetheless, we made some key adjustments to the platform to better fit our experimental needs.

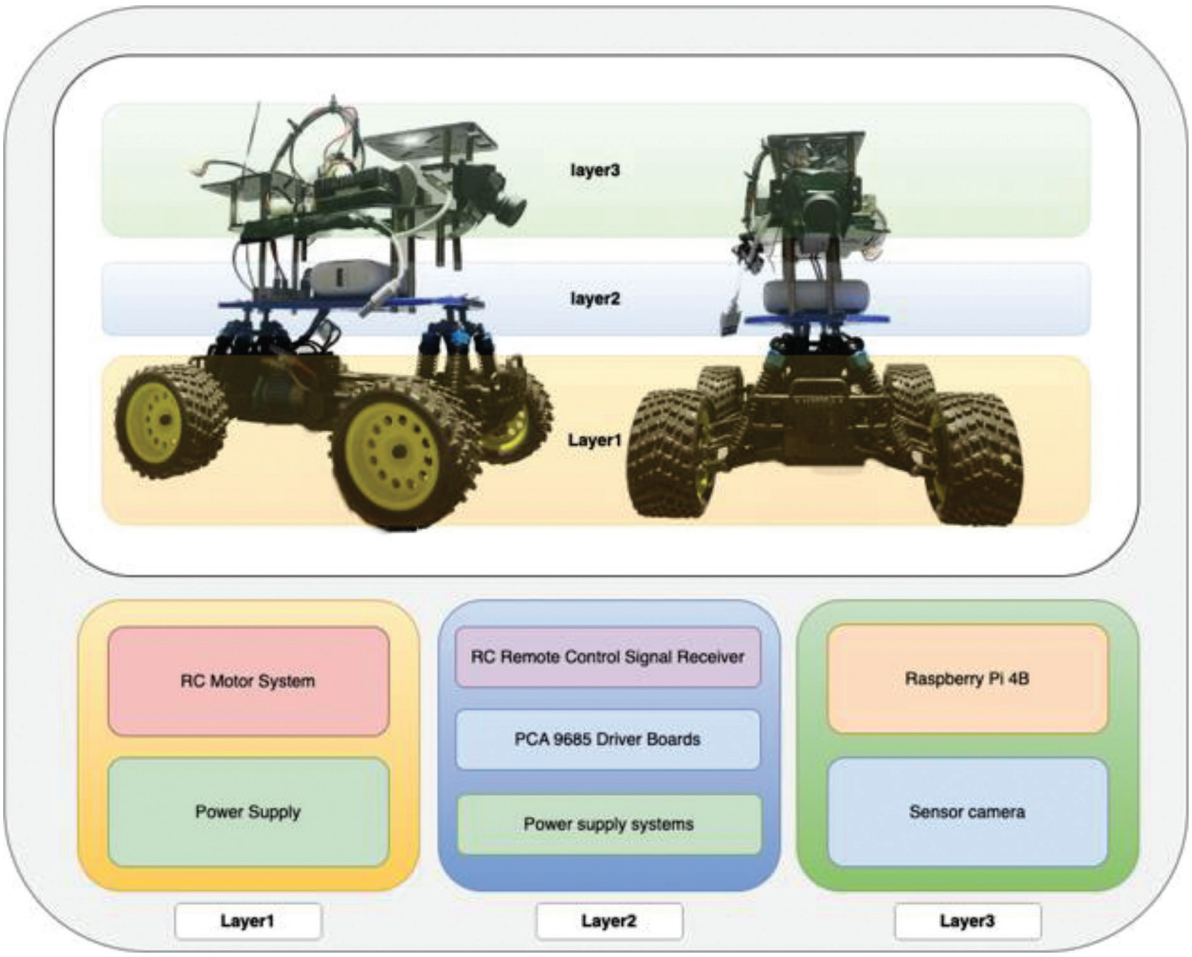

Fig. 6. The experimental platform we built based on Donkey Car open-source autonomous driving platform, which implements a layered design.

We also build the training of the model and the inference environment for the model. Table I presents a detailed configuration of the software and hardware utilized for the experiments in this work.

TABLE I
SOFTWARE AND HARDWARE CONFIGURATIONS

Category	Details
CPU	Intel Core i7-9700KF @ 3.60GHz
GPU	NVIDIA GeForce RTX 2060
RAM	16GB DDR4 @ 3200MHz
OS	Windows 10 Professional
Language	Python 3.8
Framework	TensorFlow-gpu 2.2
Libraries	OpenCV 4.5, Numpy 1.21

After building the experimental platform based on Donkey Car, we designed and constructed a 3m x 6m lane map site, as shown in Fig. 7. This was because the ratio of our experimental platform to a real car is 1:16, aiming to maximize the simulation of driving on real roads. We also applied multiple road signs and road markings. The data we collected includes images of dimensions 120 x 160 x 3, steering angle values, throttle values, and other configurations in JSON format associated with the images. During the training process, we categorized the collected data based on different human commands, namely Left, Straight, Right, No Action, and Accelerate. The variety of these actions indicates that the data is well-suited for multitasking driving.

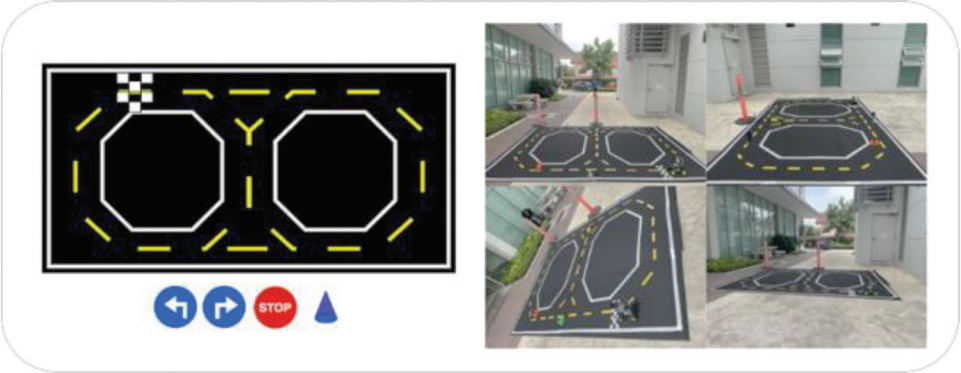

Fig. 7.The schematic diagram of the lane map site built to simulate a real driving scenario and the actual pictures taken during the experiment, as well as the markers (such as left and right turn signs, stop signs, obstacles, etc.).

1) Training and Validation

For the training and validation, the data is split into two parts: One is used for training and validation. Therefore, each model is validated on unseen data. An essential component of our training methodology is the optimizer we use. For this work, we chose the Adam optimizer for model optimization due to its robust performance in various deep-learning tasks.

The Adam optimizer is an adaptive learning rate optimization method that combines the advantages of two well-known optimization algorithms: Momentum and RMSProp. Momentum uses previous gradients to accelerate the Stochastic Gradient Descent (SGD) by adding a fraction of the previous update to the current one. RMSProp, on the other hand, adjusts the learning rate based on the recent magnitudes of the gradients.

The mathematics of Adam combines these methods to provide the benefits of both. It is mathematically defined as follows:

$$m_t = \beta^1 m_t^{-1} + (1 - \beta^1) g_t$$
$$v_t = \beta^2 v_t^{-1} + (1 - \beta^2) g_t^2$$
$$\hat{m}_t = m_t / (1 - \beta_1^t)$$
$$\hat{v}_t = v_t / (1 - \beta_2^t)$$
$$\theta = \theta - \eta \hat{m}_t / \sqrt{(\hat{v}_t)} + \varepsilon$$

Where:

- θ denotes the parameters of the model.
- η is the learning rate.
- g_t denotes the gradient at time step t.
- m_t and v_t are the moving averages of the gradients and their squared values, respectively.
- $\hat{m}_t$ and $\hat{v}_t$ are the bias-corrected first and second-moment estimates.
- β_1 and β_2 are hyper-parameters that control the decay rates of these moving averages.
- ε is a small constant added to prevent division by zero.

For our experiments, typical values for the hyperparameters are $\beta_1 = 0.9$, $\beta_2 = 0.999$, and $\varepsilon = 10^{-7}$. The learning rate η is set adaptively during the training process. We initialize both m and v as zero vectors, ensuring they are of the same shape as the gradients.

The selection of the Adam optimizer was based on its proven efficiency in various tasks, especially in deep learning scenarios where the data is abundant, and the model complexity is high.

We will go on to verify the performance of our model and the generalization ability of the model in the next sections to determine whether the model can handle a variety of different driving scenarios and tasks.

2) Evaluation Metrics

To highlight the superiority of our PrediNet20 model combined with the AHLR loss function over Linear, LSTM, and 3D models, we evaluated its performance based on Quick Convergence, Stability, Robustness, Expressiveness, and Generalization ability.

Quick Convergence

Quick convergence is crucial in model training, indicating the models' capability to achieve optimal performance in fewer iterations. We define the rate of quick convergence as the average decrease in loss per epoch, given by:

$$\text{Quick Convergence} = \frac{\text{Initial Loss} - \text{Final Loss}}{\text{Number of Epochs}}$$

A higher value indicates faster convergence to the optimal solution

Stability

Stability during training signifies the models' resistance to oscillations and fluctuations throughout the learning process. We measure stability as:

$$\text{Stability} = (\text{MaxLoss} - \text{MinLoss}) - |\ \text{MeanLoss} - \text{MinLoss}\ |$$

A smaller value of this metric indicates greater stability in the learning dynamics.

Robustness

Robustness measures the models' resilience to input noise and outliers. It is computed as:

$$\text{Robustness} = \frac{\text{Max Loss} - \text{Min Loss}}{\text{Min Loss}}$$

A higher robustness score indicates the models' enhanced capability to handle unexpected data variations.

Expressiveness

Expressiveness gauges the models' capacity to capture the inherent complexity and diversity of the data. We evaluate this by observing the models' ability to identify primary features. We visualize the feature extraction by extracting a feature map from the models' first filter, as shown in Fig. 8. PrediNet20 outperforms the Linear model in this regard. Furthermore, real-world driving tests using the Donkey Car on our custom lane maps showed that the Donkey Car excels in tasks like road tracking, road sign recognition, and obstacle avoidance compared to other models and loss functions.

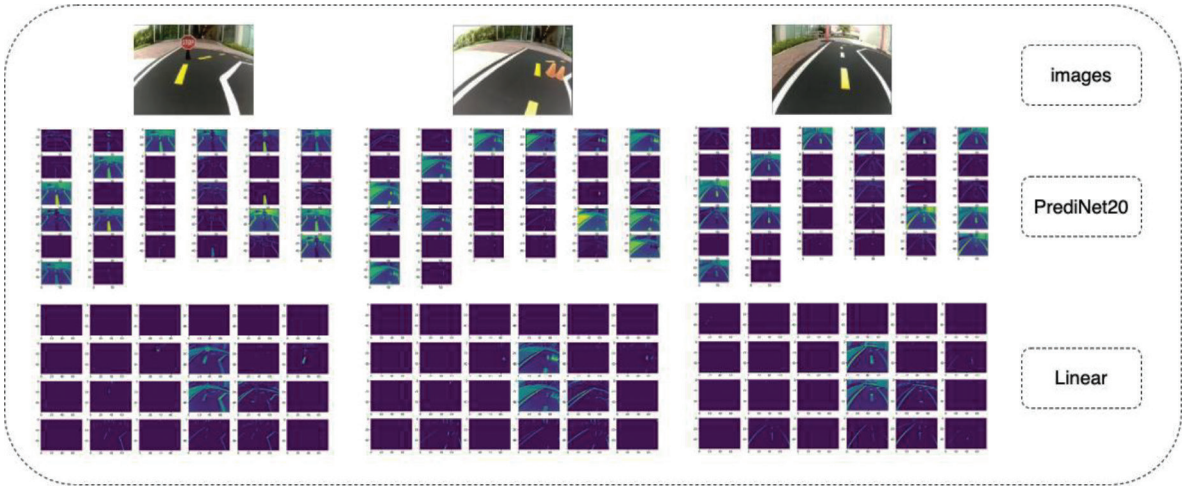

Fig. 8. The feature map of the provided image for the first filter in the convolutional layer of the PrediNet20 model and the Linear model.

Generalization Ability

Generalization ability evaluates the models' performance on unseen data, which is vital for its practical applicability. It is defined as:

Grneralization Ability = | Training Loss-Max Loss |

A smaller generalization ability value suggests that the model is more adept at handling data it hasn't been trained on, underscoring its practical significance.

B. Traning Process

For real-world autonomous driving scenarios, this work meticulously designed a series of intricate experiments to gather data for model training and evaluation. We constructed an autonomous vehicle based on the Donkey Car platform and placed it within a specially fabricated 3m x 6m lane environment shown in Fig. 7 to ensure consistency and controllability of the experimental conditions. Within this setting, we meticulously documented key data, including images, steering angle values, and throttle values, aiming to capture the various dynamic changes throughout the autonomous driving process.

Although a large amount of raw data has been accumulated, the presence of noise, anomalies, and inconsistencies may adversely affect the training and generalization capabilities of the model. To address these challenges, we performed data cleaning. Thus, the operations of reducing noise, correcting anomalies, and harmonizing inconsistencies are effectively performed. We thus enhance the integrity, consistency, and reliability of the dataset to ensure that it is ready for robust model training.

Finally, we systematically divide the entire data into training, validation, and testing sets for model training, hyperparameter tuning, and final performance evaluation. We adopt an 80%-20% division strategy, where 80% of the data is used for training, and the remaining 20% is evenly distributed for validation.

As for the loss function, a novel loss function AHLR is introduced in this experiment. AHLR combines the advantages of the traditional Huber loss and further improves the robustness and generalization ability of the model by introducing an adaptive mechanism and regularization.

The model was trained using batch gradient descent. During training, we not only monitored the performance on the training set but also closely followed the loss trend on the validation set. This approach allowed us to stop training in time when the performance on the validation set stopped improving and saved the models that performed best on the validation set.

C. Experimental Result and Discussions

In order to improve our efficiency in evaluating PrediNet20, we first trained the performance of different loss functions with different batch sizes and compared the loss values according to their size and discrete values. As shown in Fig. 9, different combinations of loss functions with batch sizes produce different results. By analyzing Fig. 9 in-depth,

we determined that all models and loss functions performed best with a batch size of 64, having lower loss values and dispersion.

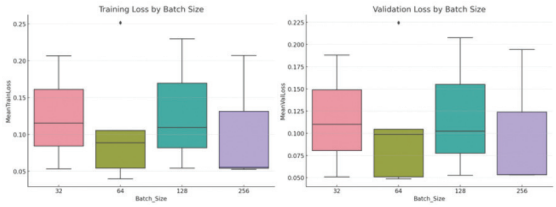

Fig. 9. The comparison of the different loss functions for the trained models with different batcg sizes.

After choosing the optimal batch size, we combined these four models with our proposed loss function and two existing loss functions and we trained Linear, PrediNet20, LSTM, and 3D with a Batch Size of 64 and a combination of MSE, MAE, and AHLR loss functions, and plotted subplots of training loss values and validation loss values for each model separately to further compare the training performance of PrediNet20 with the three existing models.

Fig. 10 shows that PrediNet20 demonstrates excellent fitting ability under multiple loss functions. Compared to other models, PrediNet20 achieves lower loss values early in training and higher stability of the validation loss, indicating its ability to generalize to the data. We have listed the data from the training logs in a table as shown in Table II. We can view the specific values, based on which we can better analyze the training performance of PrediNet20 and AHLR. Below is our analysis.

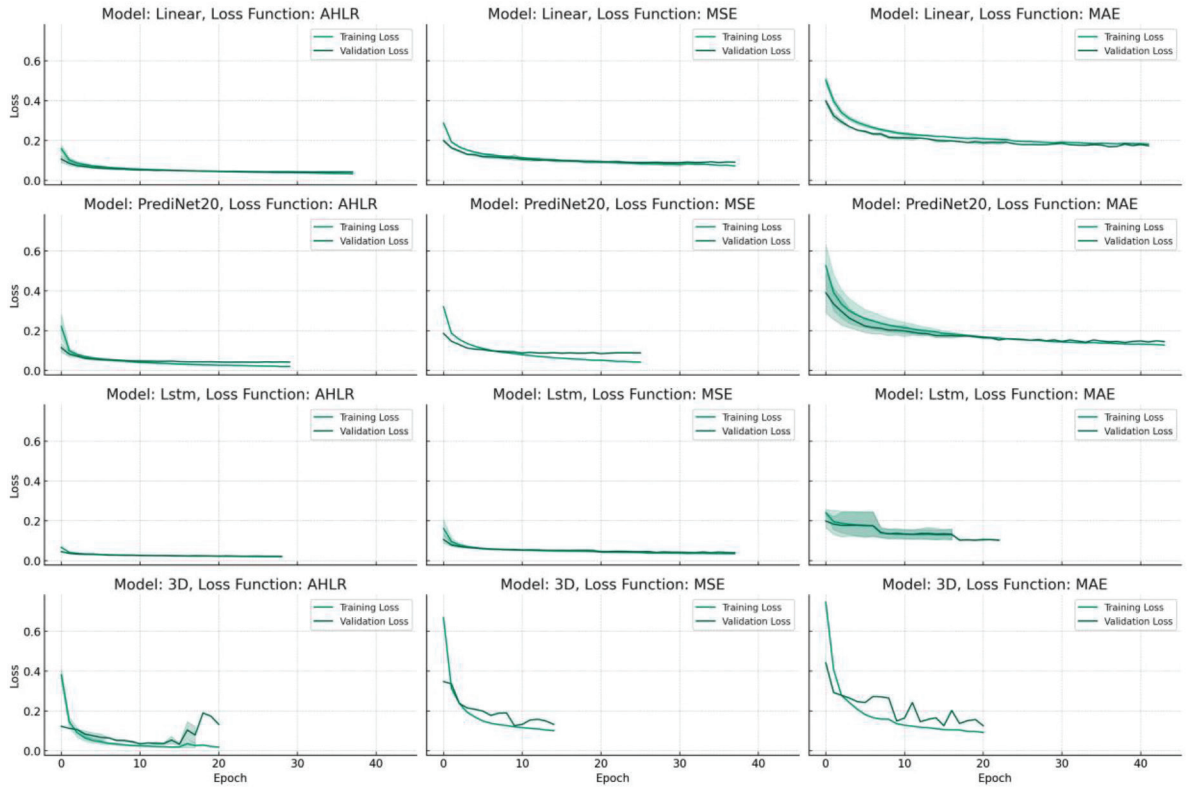

Fig. 10. The trend of training loss and validation loss for each model and loss function combination. Each subfigure represents a different model and loss function combination.

TABLE II
THE PERFORMANCE OF FOUR DIFFERENT MODEL TYPES (3D, LSTM, PREDINET 20, AND LINEAR) WITH THREE DIFFERENT LOSS FUNCTION (AHLR, MAE, AND MSE)

Model Type	Loss Function	Epochs	Training Loss	Max Loss	Min Loss	Mean Loss
3D	AHLR	18	0.0147	0.3485	0.0147	0.0510
3D	MAE	21	0.0923	0.7467	0.0923	0.1849
3D	MSE	15	0.1012	0.6686	0.1012	0.1861
LSTM	AHLR	29	0.0205	0.0633	0.0205	0.0274
LSTM	MAE	7	0.2472	0.2582	0.2472	0.2496
LSTM	MSE	26	0.0419	0.1476	0.0416	0.0553
PrediNet20	AHLR	30	0.0201	0.1588	0.0192	0.0399
PrediNet20	MAE	22	0.1655	0.4206	0.1655	0.2066
PrediNet20	MSE	26	0.0420	0.3195	0.0420	0.0888
Linear	AHLR	38	0.0325	0.1880	0.0324	0.0554
Linear	MAE	42	0.1818	0.5209	0.1818	0.2298
Linear	MSE	34	0.0838	0.2931	0.0838	0.1153

For the 3D model, we observe that a training loss of 0.0147 is achieved under 18 periods when using the AHLR loss function, with maximum and minimum losses of 0.3485 and 0.0147, respectively, and an average loss of 0.0510. This suggests that the AHLR may provide superior performance under this model type when compared to the MAE and MSE.

Compared to the 3D model, the LSTM model had a training loss of 0.0205, a maximum loss of 0.0633, a minimum loss of 0.0205, and an average loss of 0.0274 for 29 epochs under AHLR. These data suggest that the LSTM model may have achieved more consistent performance when using AHLR.

The performance of the Linear model varies under different loss functions. For example, using the AHLR loss function, the model has a training loss of 0.0325, a maximum loss of 0.1880, a minimum loss of 0.0324, and an average loss of 0.0554 under 38 epochs. The performance of the linear model under MAE and MSE varies significantly from that under AHLR relative to the other models.

Of particular note, the PrediNet20 model demonstrates excellent performance when using the AHLR loss function. Under 30 epochs, the training loss reached 0.0201, the maximum loss was 0.1588, the minimum loss was 0.0192, and the average loss was 0.0399. These values highlight the superiority of the PrediNet20 model in terms of consistency and efficiency compared to other combinations of models and loss functions.

Fig. 11 is based on the stability and superiority of the training loss values and validation loss values in the above table. The training loss value box plots and validation loss value box plots provide a visualization of the median, quartiles, and outliers of the training loss. By looking at the box plots, we notice that the loss distribution of PrediNet20 is more compact and the median is lower in most cases. This suggests that the training of PrediNet20 is more stable with less fluctuation in loss values. It also shows the compactness of the loss distribution, further confirming the stability of its training.

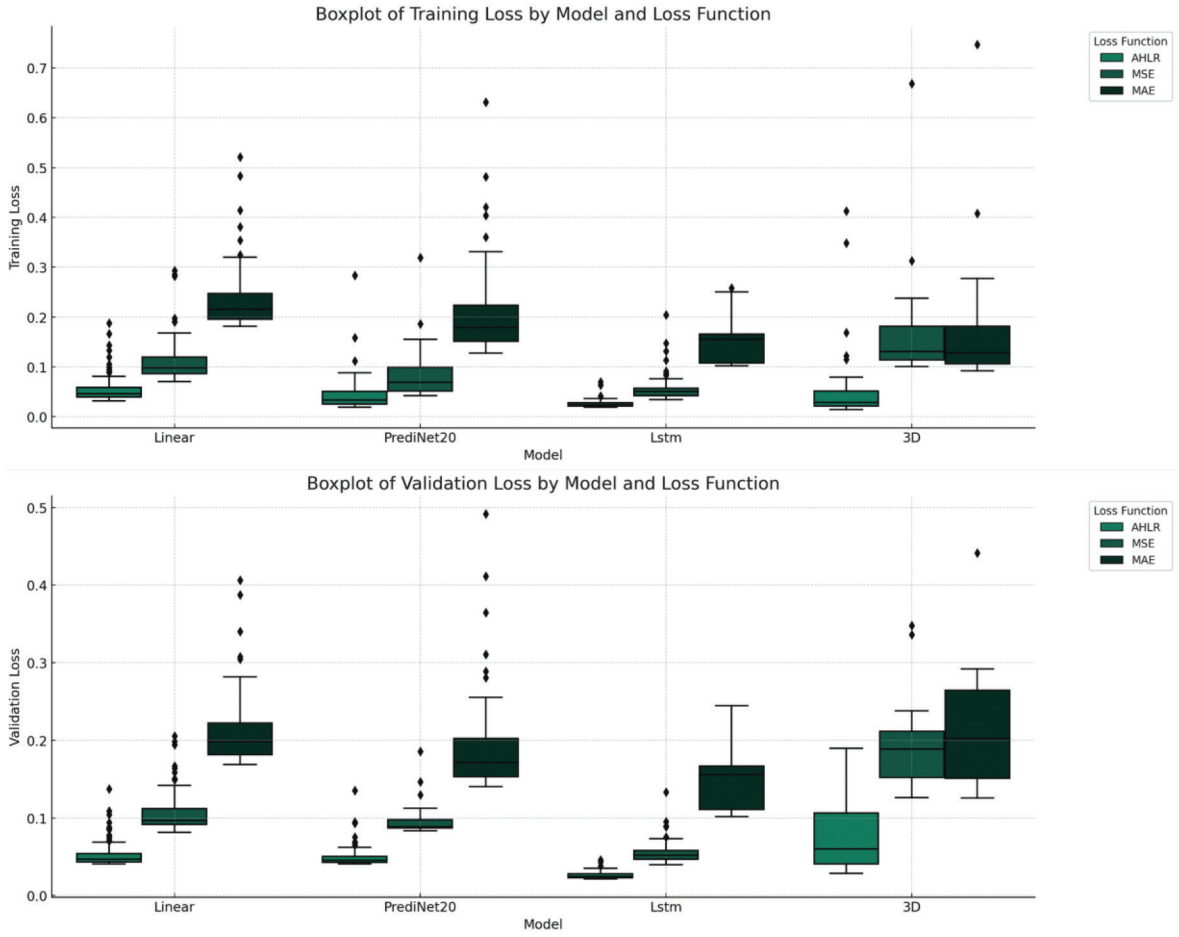

Fig.11. The distribution of training loss and validation loss values for different models and loss function.

Based on our customized evaluation metrics combined with Table II for substitution calculations. Combined with the needs of our autonomous driving task, we set thresholds for each of the four evaluation directions, where Convergence Speed > 0.002, we consider the convergence speed to be fast; where Stability > 0.07 we consider the stability to be high; where Robustness > 5 we consider the robustness to be good; where Generalization < 0.2 we consider the generalization ability to be good. Since the selection of thresholds is a balancing process based on the task requirements, the above thresholds are set based on the specific task requirements of our design experiments. Based on the thresholds we chose, we will plot the following Table III to compare our PrediNet20 model using the same loss function AHLR with other models.

TABLE III
MULTIFACETED PERFORMANCE COMPARISON OF DIFFERENT MODELS WITH THE SAME LOSS FUNCTION

	PrediNet20	**Linear**	**LSTM**	**3D**
Quick Conv	0.004	0.003	0.001	0.001
Stability	0.05	0.08	0.06	0.08
Robustness	6.0	5.5	4.5	5.5
Expressiveness	Better	Average	-	-
Generalization	0.10	0.15	0.25	0.25

This comprehensive evaluation provides insights into the strengths of the PrediNet20 model and the AHLR loss function in handling various aspects of autonomous driving tasks. Compared to other models and loss functions, PrediNet20 and AHLR exhibit better performance in terms of speed, stability, robustness, expressiveness, and generalization ability.

V. Conclusion

In this study, we introduce a novel Convolutional Neural Network (CNN) named PrediNet20, specifically designed for end-to-end autonomous driving on the Donkey Car platform. Our research aims to address existing model limitations by enhancing the predictive capabilities of throttle and steering angle, thus improving overall autonomous driving system performance. To achieve this objective, we propose an innovative loss function, AHLR, designed to enhance the training and generalization capabilities of the model. AHLR dynamically adjusts the loss function based on the magnitude of prediction errors, ensuring a seamless transition from quadratic to linear loss. Additionally, it incorporates L1 regularization to promote model sparsity and mitigate the risk of overfitting.

Simultaneously, we acknowledge the efforts of other researchers in similar domains. For instance, the study conducted by Li Y and Qu J [5] modified the loss function based on Mean Squared Error (MSE), yet did not consider the potential performance enhancement achievable through the use of an adaptive loss function. Our research distinguishes itself by innovatively introducing AHLR, resulting in elevated levels of performance and generalization.

Extensive experiments confirm that PrediNet20 exhibits superior performance and faster convergence compared to existing models. The experimental results validate the accuracy and reliability of PrediNet20 in predicting throttle and steering angles, providing an efficient solution for end-to-end autonomous driving.

Our research findings underscore the potential advantages of PrediNet20 and AHLR in autonomous driving applications. These innovative technologies contribute not only to improving the safety and stability of autonomous driving systems but also lay a robust foundation for achieving truly intelligent autonomous driving. Furthermore, our work provides valuable references and guidance for advancing the application and development of autonomous driving technologies in real-world scenarios.

However, we also recognize certain limitations in PrediNet20 and AHLR, particularly in optimizing for specific driving scenarios and adapting to different environments. To comprehensively address these issues, further research is recommended. Additionally, explanatory and confirmatory analysis of the consistency and divergence with past research contributions by other scholars would provide a more nuanced understanding of our research's position, reinforcing the rationale behind our adoption of a novel approach.

Acknowledgment

In this work, the first and the last authors contributed equally, each accounting for 50% of the total contributions.

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Strawberry History, Cultivation and Problems in the Northern Area of Thailand: A Review

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Received: April 15, 2024 / Revised: May 23, 2024 / Accepted: May 24, 2024

***Abstract*— This review explores the history, cultivation practices, and challenges faced in strawberry production in the northern region of Thailand. Historically, strawberries were introduced to Thailand in the mid-20th century, with substantial development occurring in the 1960s through initiatives by His Majesty King Rama IX. These initiatives aimed to diversify agricultural outputs, replace opium cultivation, and improve the living standards of hill tribes in the northern area. The cultivation of strawberries in northern Thailand, particularly in provinces like Chiang Mai and Chiang Rai, has become significant due to the region's suitable temperate climate and elevation. The first strawberry varieties (Pharachatan numbers 13, 16, and 20) were successfully grown by 1972 and introduced to local growers as a replacement crop. Despite the favorable conditions, strawberry cultivation in northern Thailand encounters several challenges. These include pest infestations, diseases such as anthracnose, powdery mildew, botrytis, and issues related to soil fertility and water management. Furthermore, climate change poses a growing threat, with increasing temperatures and erratic weather patterns impacting production cycles. The Royal Project, Kasetsart University, and the private sector have introduced newer cultivars; Number 329 (Yael), Pharachatan numbers 50 (B5), 60 (Rosa Linda × Tochiotome), 70 (Toyonoka), 72 (Tochiotome), and 80 (hybrid) to replace the older varieties due to their many advantages. This study examines these challenges in detail and discusses potential strategies for mitigating their impact, emphasizing the importance of research, extension services, and sustainable agricultural practices in ensuring the future viability of strawberry farming in this region.**

***Index Terms*—Strawberry, Agriculture, Northern Thailand**

I. Introduction

Strawberry (*Fragaria × ananassa*) is a small plant of the genus *Fragaria* in the rose family. *Fragaria* comes from the word "Fragrance", meaning "great smell" which corresponds to the important characteristic of strawberry fruit. In the field of genetics, strawberry is an octoploid hybrid species with 56 chromosomes in nucleus of somatic cell which derives from accidentally crosses of two octoploid wild species (*fragaria virginiana* and *fragaria chiloesis*) in Brittany of France during the late 17th century [1]. Different varieties of strawberries were bred by other countries afterward, which were suitable for the local environment. Many varieties are constantly being bred and released to temperate and subtropical legions. Nowadays, this plant can be grown almost anywhere in the world except for the polar and desert regions. Strawberry plants are photoperiodic in flower induction and divided according to their response to daylight length into two groups: June-bearing and Ever-bearing. June-bearing strawberry is a group of short- day plants that have reproductive and vegetative states at different periods. Short-day length and low temperature in winter turn June-bearing strawberry to reproductive state by stimulating flower formation. The plant produces all their fruit in late winter to spring. After reproductive state, June-bearing strawberry divert their energy into growing and produce daughter plant. Ever-bearing or Day-neutral strawberry is a group of plants that have reproductive and vegetative at the same time. The plant is not seasonally sensitive. Fruit of ever-bearing is smaller than fruit of June-bearing as they expend energy into growing fruit far longer and do not offer as much energy towards producing runners and spreading. Although, photoperiodism is the main factor for flowering, strawberry flowering also requires other factors as well. Common factors such as temperature, fertility, and nutrient intake, including other environmental factors also affect the flowering of strawberries. The fruit of strawberry

is widely appreciated for its unique flavor and has become one of the most popular fruits around the world due to its delicious taste, sweet aroma and high nutritional value. The production of strawberry is 8th in the rank of 2021 world gross production value of fruit. It is classified as one of the high-value agricultural products [2] and commonly consumed both as fresh fruit and as processed fruit [3]. The vitamins, minerals, and antioxidants in strawberry provide important health benefits [4]-[6]. Antioxidant compounds in strawberries protect cells and tissues in the body by neutralizing unstable molecules known as free radicals. Strawberries are low-glycemic foods. It has little effect on blood sugar. Furthermore, the polyphenols in strawberries enhance insulin sensitivity in non-diabetic adults. This is an option to control or lower glucose levels.

The fruit of the strawberry is also used in the food processing industry for products such as fruit juice, yogurt, sour milk, and jam. Moreover, strawberries are used in cosmetics. Strawberry-based cosmetic treatments protect the skin from harmful ultraviolet A radiation, especially when used in combination with coenzyme Q_{10} [7].

Strawberry cultivation in Thailand has a rich history that dates back to 1960 when His Majesty King Rama IX initiated the practice (Fig.1). The goal was to introduce strawberries cultivation to hill tribes in the northern region of the country [8].

Fig.1. His Majesty King Rama IX visited the people at Doi Ang Khang, Fang, Chiang Mai.
(Source; http://www.psproject.org/?page_id=9731 *The Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects*)

This initiative aimed to provide an alternative source of income for the hill tribes, who were often engaged in illegal activities like opium cultivation and drug trafficking. By introducing high-value crops such as strawberries, the government hoped to shift their focus towards legitimate and sustainable agricultural practices. However, despite the efforts to promote strawberry cultivation, the quality and quantity of the products fell short of cultivar standards. This could be due to inadequate cultivation methods or techniques. To address this issue, it is essential to combine traditional Thai farming knowledge of soil, water, and climate with advanced production technologies and improved crop management practices, as seen in the rapid growth of the strawberry industry in other countries like USA (Fig. 2), China (Fig. 3) or Japan (Fig. 4). Those countries have the advantage of being able to understand the plant, management and the use of labor-saving equipment because these countries have learned to cultivate strawberries for a long time.

Fig. 2. Strawberry cultivation in California, USA

Fig. 3. Strawberry stereoscopic cultivation in Shandong, China (Source; http://www.xinhuanet.com/english/2018_12/10/c_137662200_4.htm)

Fig. 4. Strawberry cultivation in Tokushima, Japan

Proper strawberry cultivation must come from integrating the traditional cultivation with foreign innovations. At present, the government, Universities and some companies have brought in foreign innovations without understanding, causing the cultivation to be inefficient or unworthy use of resources (not worth the yield). Linking Thai traditional cultivation with foreign innovation is an important development approach. Developing of cultivation systems for non-native crops such as strawberry or ice plant [9] can push these growers to become High-Value-Agricultural-Product (HVAP) producers faster because there are few competitors.

II. History of Strawberry in Thailand

There is no clear evidence of when Thai people first became aware of strawberries. The oldest historical evidence discovered is a royal letter from His Majesty King Rama V to the queen while he was traveling in Europe (Geneva, Switzerland) on 22 May 1897. Parts of the royal letter mention the fruit called strawberry, the same size of a lychee fruit and delicious [10]. However, there is no evidence that he brought it back to be planted in the country. Later, His Majesty King Rama IX was aware of the domestic problem of narcotics (opium), which is the main crop of the hill tribes in the north, and wanted to solve the problem. He sought out plants that were suitable for the cold weather and had high value for the hill tribes to plant instead. Early attempts at cultivation were largely experimental, but significant progress was made in the 1960s when the Thai government, in collaboration with private enterprises, launched initiatives to diversify agricultural production. King Rama IX had Luang Samanawakit to study their growth at the Chitralada Royal Villa, Dusit Palace [11]. Nine years later, the Royal Project Foundation was established to improve living standards of the hill tribe in the northern area of Thailand by using cash crops to replace opium cultivation. In 1972, first 3 cultivars (Cambridge Favorite, Tioga, and Sequoia) were successfully growth in northern part of Thailand and introduced to local grower in the name of Pharachatan number 13, 16, and 20 respectively. Pharachatan number 16 was the most adaptable and became the main cultivar until 1991.

During that, three cultivars of Aiko, Pajaro, and Douglas were introduced and trialed but were not successful. The Royal Project began to succeed in the next attempt (May 1986) for importing Japanese varieties such as Nyoho, Toyonoka, and Aiberry were a valid option [11]. After that, the Royal Project and Kasetsart University have brought in newer cultivars; Number 329 (Yael), Pharachatan number 50 (B5), 60 (Rosa Linda × Tochiotome), 70 (Toyonoka), 72 (Tochiotome), and 80 to replace the older due to their many advantages [12]. Pharachatan number 80 is the main variety of Thailand from 2007 and still in the great demand until now. This variety is June-bearing strawberry which requests short day condition with low temperature to initiated flower bud. Pipattanawong (2000) reported that the cultivation of strawberries in northern Thailand, particularly in provinces like Chiang Mai and Chiang Rai, has become significant due to the region's suitable temperate climate and elevation. Over the decades, strawberries have evolved from a novel crop to a commercially viable product, gaining popularity among local farmers and consumers alike. At present, strawberries are the fruit with the highest price-per-unit of all economic fruits of Thailand [14].

III. Characteristics of Each Variety

A. Pharachatan Number 13 or Cambridge Favorite

A facultative short-day plant which is an early variety imported for testing by the Royal Project Foundation in 1969, which can adapt well to the environment of Chiang Mai province. It has small fruit sizes and soft in texture [15].

Fig. 5. Image of Pharachatan number 13
(Photo by Barry Proctor)

B. Pharachatan Number 16 or Tioga

This variety imported from America for experimental cultivation. A facultative short-day plant which adapts well with the environment of Chiang Mai province, full sun, very well drained soil. However, the harvesting period is short. The fruit is large (depending on the weather conditions). The flesh is quite hard, sour taste with light to dark red in color. Fruit is suitable for processed in the food industry because the pole comes off easily. [8].

Fig. 6. Image of Pharachatan number 16
(Photo by the Seed Collection Pty. Ltd.)

C. Pharachatan Number 20 or Sequoia

A facultative short-day plant which has a sweet taste and is suitable for cultivation in highland areas. However, it is not very popular because the fruit's

flesh is very soft and the skin is thin, making it unsuitable for processing in the food industry [8].

Fig. 7. Image of Pharachatan number 20
(Photo by Putteringinthegarden)

D. Strawberry Number 329 or Yael

A short-day plant which was imported from Israel by Mr. Pramote Raksarat, Director-General of the Department of Agricultural Extension, in 2001. The skin and flesh inside are bright red and quite hard. The aroma and taste are quite sweet. When fully ripe, it can be stored for a long time. The fruit of this strawberry variety is very suitable for shipping and processing [8], [16], [17].

Fig. 8. Image of Strawberry number 329
(Photo by Phetchaburi Agricultural Research and Development Center)

E. Pharachatan Number 50 or B5

It is a variety that grows well in temperature conditions of 15-28 Celsius. Fruit is sweet, fragrant, and medium in size with dark red. The core of the fruit is mostly hollow. The texture is quite hard. Pharachatan number 50 is a variety that was created for His Majesty King Bhumibol Adulyadej in his 50 years celebrating of accession to the throne. [8].

Fig. 9. Image of Pharachatan number 50
(Photo by The Royal Project Foundation)

F. Pharachatan Number 60

A facultative short-day plant which is the first hybrid variety to be successful, is a cross between Rosa Linda [18] and Tochiotome. The fruit is large, with an average weight of 10-15 grams. The taste is sweet. The skin and flesh inside are bright red [8].

Fig. 10. Image of Pharachatan number 60
(Photo by Phetchaburi Agricultural Research and Development Center)

G. Pharachatan Number 70 or Toyonoka

A facultative short-day plant which is a variety imported from Japan. It's famous for its deep red color, sweet flavor, and juicy texture. It was first developed in the 1980s in Miyagi Prefecture and quickly became one of Japan's most popular strawberry varieties. In Thailand, this variety produces high yields. The fruit is large and has a spherical or conical shape, sweet taste. The skin and flesh are red with hard texture which makes it convenient for transportation and storage. Pharachatan number 70 is a variety that was created for His Majesty King Bhumibol Adulyadej in his 70 years celebrating of accession to the throne [8].

Fig. 11. Image of Pharachatan number 70
(Photo by Hanamankai)

H. Pharachatan Number 72 or Tochiotome

A facultative short-day plant which was brought from Japan by the Royal Project Foundation and given the number 72, which was named after the year His Majesty was 72 years old. The fruit has an average weight of 14 grams. The skin is dark red when ripe but the flesh is white. The flesh of Pharachatan number 72 is firmer than number 70, but less sweet [8].

Fig. 12. Image of Pharachatan number 72
(Photo by Phetchaburi Agricultural Research and Development Center)

I. Pharachatan Number 80

A facultative short-day plant which is a hybrid variety (code 01-16) from Japan that was planted and selected at Doi Pui Research Station, Chiang Mai, Thailand [19], [20]. It has the ability to adapt well to the Thai environment and is resistant to anthracnose. Healthy plants can produce high yields with average weight of 30 - 35 grams/fruit. The fruit is heart-shape, bright red skin with white flesh, juicy, and sour-sweet [8], [12], [13], [16], [19]-[22]. This variety was promoted to growers in 2007 and is popular to this day. However, the quantity and quality of their produce began to decline due to cell deterioration and unstable weather conditions.

Fig. 13. Image of Pharachatan number 80
(Photo by Phetchaburi Agricultural Research and Development Center)

J. Pharachatan Number 88

A facultative short-day plant which is a hybrid strain between the number 80 and number 60. This variety was bred to solve the problem of incomplete flower development when exposed to fluctuating temperatures by adding genetics from number 60 that was able to flower even after receiving a short period of cold. The shape, firmness, aroma and taste are similar to those of number 88. However, this variety can produce flowers continuously and has a higher yield than number 80.

Fig. 14. Image of Pharachatan number 88

IV. Propagation

Strawberries, a winter fruit that has been cultivated in Thailand, have been able to adapt and create income for grower for a long time. It can propagate both sexually and asexually methods depend on objective [23].

A. Sexually Propagation

In general, the method of sexual propagation has been used in the field of breeding [24]. The Royal Project Foundation reports that strawberry breeding has been developed using the method of cross-pollination since 1997. The first variety obtained from the strawberry breeding program was Pharachatan

number 60 and the Department of Agriculture issued a certificate of plant variety registration under the Plant Varieties Act of 1975 (R.P.2) No.276/2006 to the Royal Project Foundation on 16 September 2006 [25]. Later, the Angkhang Royal Project began a "Pharachatan number 80" breeding program by bringing hybrid seeds of "Royal Queen" from Japan to plant, test and select according to the program. This project was successful in the season of 2002 with variety code 01-16 selected. Strawberry breeding programs continue to be developed by royal projects, universities and private companies [8], [12], [13], and [21]. However, there is no strain that is more in demand than strain number 80.

B. Asexually Propagation

Field observations suggest that asexually method is suitable for commercial because it can be done quickly, at low cost, and produces new plant with the same genotype. Strawberry plants can develop stolon once they are fully grown. Stolon is an elongated, two-node, vegetative, axillary shoot, which supports the ramet (rooted rosette) until it is completely independent on its own roots [26]. In the northern area of Thailand, daughter plants in highland nurseries are propagate from April to October under the low night temperatures there induces flowering [27], [28]. Daughter plants must be planted in polyethylene bags in case production is required in lowlands. They are transplanted to extend the growing season at highland nurseries from June to October and to facilitate early December harvest. The mother plant much has approximately 4-5 branches and can produce up to 10 stolons in 60 days. Each stolon has approximately 7-10 daughter plants. Only 5 of the strongest plants should be selected for planting. Healthy mother plant can produce up to 50 daughter plants within a period [8]. In this duration, the mother plant sends energy to supply the daughter plant through the stolon and it is more susceptible to infection of microorganisms. During April to October, growers must prepare enough water for growth of strawberry because this is quite long and the water on the highlands is quite scarce. Insects such as thrip and spider mites are often infested during this period due to low-humidity and lack of rain. Using a sprinkler irrigation system along with the use of *Beauveria bassiana* can help reduce the rate of infestation. Insecticides should be used only when the infestations cannot be controlled by biological methods.

Although, currently variety (Pharachatan 80) is a hybrid cultivar that resists Anthracnose (*Colletotrichum* spp.). However, all types of plant pathogenic microorganisms have adapted to infect the plant all the time. *Colletotrichum* is also a type of fungus that is highly adaptable and can adapt to infect Pharachatan 80 in just a few years. Nowadays, *Colletotrichum* can be found on most of main planting areas (Samoneg and Fang districts) [29]. Watering should be completed early in the morning to prevent high humidity conditions during the night that suitable for fungal growth. Using *Trichoderma harzianum* is very necessary to control fungal plant diseases during this period. However, *T. harzianum* is not recommended to use when plant tissue must be taking in the tissue culture process in the aseptic technique. In this case, eliminating plant fungal diseases with fungicides is a more appropriate method.

Another big problem that is very common in growing areas is viral infections. However, the problem of virus outbreak can be resolved by removing infected plants from the area. Followed by the use of disease-free plants to replace. Currently, production sites such as the Royal Project or Doi Kham Food Products Co., Ltd. are continuously developing disease-free plant from using tissue culture (disease-free meristem). Moreover, Doi Kham Food Products Co., Ltd. has begun production and delivery to the growers who are in the promotion system of First Royal Factory as a pilot project. Another reason that limit yield of strawberry is regression. Using new-regenerate plant from meristem is the great way to eliminate this problem. Division of branch crowns is another method of propagation that can be can be used for strawberry propagation. However, it is a less popular method than daughter plants and only used in cases where the plant does not have a stolon.

V. Cultivation

A. Open Field Cultivation

Strawberries are grown as an annual crop. In Thailand, it should be planted between mid-august to mid-September for highlands, and between mid-Septembers to mid-October for lowlands [30]. Most plants cannot continue to grow when planted in conditions of excessively hot and dry weather. Choosing an appropriately area and improving the soil are the first factors that lead to success. The suitable soil for cultivation should be sandy loam and rich in organic matter [31], [32] It should be slightly acidic with pH=5.5 to 6.5 and able to retain moisture throughout the day but not become soggy because strawberry root is quite sensitive [11]-[13]. The strawberry planting bed must be approximately 30 centimeters above ground level and approximately 50 centimeters wide [8], [11]-[13]. Application of organic amendments such as leaf compost or manure with *T. harzianum* maybe use as an alternative to cover crops [8]. Planting have consistently demonstrated that the optimum is late August achieves a high yield in most cases. The planting spacing of each plant much be 25 to 30 centimeters apart [8], [11]-[13]. The stolon side must always be turned towards the inside of the plot. This planting direction will cause the flowers and

fruits to grow outward, which is the right direction for harvesting. All roots must be under the soil. Surrounding area must be firmly pressed down and careful not to create puddles as this may cause the plant to sink into the plant material after watering (Fig. 15).

Fig. 15. Strawberry plant after transplant in the field.

Covering the plot with rice straw is an option for weed control called "Mulching". The hill tribe growers cover the raised beds with dry leaves of *D. tuberculatus* before planting [27], [28]. In the first 60 days, watering should be done using a sprinkler system and started early in the morning to remove dew from the leaves. A second watering can be done if the soil is dry, but this should be completed before noon [8]. Approximately 20 days after planting, add chemical fertilizer formula 12-24-12 at a rate of 10 grams/plant. [8]. Old leaves and those with signs of disease infestation must be removed as soon as they are found because it is a habitat for plant pathogens. Removing the leaves from the plant must be done carefully and always from the outermost leaves. At least 3 leaves must be left if the plant is still small. Also, stolon must be removed to help reduce energy consumption. All plant debris must be removed from the cultivation area and water sources. Ten days after, apply chemical fertilizer formula 13-13-21 approximately 10 grams/plant and repeat 4 times, 7-10 days apart [30]. The drip irrigation system must be replaced with the sprinkler irrigation system as soon as flowers are observed. The fertilizer that is high in phosphorus and potassium (18-24-24) much apply to the plant when most of the plants have bloomed. However, fertilizers that are high in nitrogen and potassium (12-6-18) replacement must be done as soon as the plant is found to quite worn out. Foliar spraying of micronutrients such as calcium, magnesium, and boron is very important during fruit development [8]. It also helps the plants to be more resistant to adverse environmental conditions. Fertigation can be used to add nutrients to plants. However, providing fertilizer with a high concentration will cause over-vegetative growth and inhibit flower production [33].

Flowering response of Pharachatan 80, particularly their temperature-photoperiod interaction, is a complex response and relatively unknown. Daughter plants must be exposed to low temperatures to stimulate the process of flower bud formation. It requires a low temperature, 10-15 °C, for 20-30 days to induce flower budding [8], [12], [13], [16], [19]-[22]. Suitable conditions for planting strawberry is the late fall or rainy season in the northern area of Thailand. This processes called strawberry vernalization [34]-[36]. The first inflorescences can be found immediately after the plant received enough chilling unit during vernalization and the blooming usually begins from November every year (Fig. 16).

Fig. 16. Pharachatan number 80 grown at the Angkhang Royal Project Research Center While the first set of flowers is blooming.

Receptacle of strawberries will begin to significantly expand within 3-5 days after pollination has occurred. Strawberries are not berries in the botanical sense. The flesh is the tissue that develops from receptacle which soft, juicy, delicate and easily bruised [8]. The developing fruit can be seen from the central part of the flower that becomes raised and light (Fig. 17).

Fig. 17. The shape of strawberry flowers after being pollinated.

On the contrary, flowers that turn dark green to brown are those that cannot continue to develop. Postharvest pathogenic microorganisms often outbreaks during this time. The flower that have turned brown should be removed as soon as they are seen to reduce the habitat of pathogenic microorganisms. Pharachatan 80 usually have no more than 20 fruits per inflorescence with 12-20 grams per fruit [8], [12], [13], [16], [19]-[22]. Trimming the inflorescence is something that should be used in cases where there are too many flowers per inflorescence. Too many fruits per inflorescence causes the plant to not supply enough nutrients and makes all the fruits small. Moreover, too many fruits may have a negative effect on the plant and the next inflorescence.

Pharachatan 80 can provide 4-5 inflorescences during harvesting period (December to March). However, strawberry growers face the problem of

drought in March every year. This problem limits the duration of reproductive with only 3 inflorescences. Irrigation management and soil improvement are good options to solve this problem.

B. Greenhouse Cultivation

The use of greenhouses for strawberry cultivation is still not popular. This is because building a greenhouse takes a lot of investment and has relatively high production costs. The payback period may exceed a specified number of years. Strawberry greenhouses are generally found only on farms that are open for tourism. In fact, growing strawberries in greenhouses can solve problems related to environmental fluctuations, disease and insect outbreaks, lack of water, nutrient deficiency and also increase productivity. One of the projects that encourage strawberry growers to learn and practice using greenhouses is a project of the Chiang Mai Provincial Agricultural Extension Office (in Thai; โครงการยกระดับการแข่งขันในระบบธุรกิจเกษตร). This project was created through the cooperation of government agencies, private companies, and educational institutions with the objective of developing strawberry production by supported the budget for the construction of 40 greenhouses with temperature control systems to 5 groups of grower in 2019. Each greenhouse in the project is equipped with temperature, humidity and lighting controls, as well as an automatic fertilizer dispensing system. These greenhouses can be used for both seedling and fruit production in all seasons. The strawberry plants grown inside are well protected from pests and adverse environmental conditions. The Chiang Mai Provincial Agricultural Extension Office focuses on Pharachatan 80 to supply for high-end market.

The group with the highest use of greenhouses is in Fang District, where greenhouses are mainly used for seedling (daughter plant) production. This project is under the royal initiative of Her Royal Highness Princess Maha Chakri Sirindhorn (Fig. 18). The advantage of using seedlings produced in a greenhouse system is uniformity in plant size, cleanliness and vigor. The seedlings produced can be used to alleviate the problem of a shortage of seedlings in the area, where growers mostly have to wait for remaining seedlings from production sites in Samoeng District. Most important point is the cleanliness of the seedlings because it reduces the mortality rate from disease outbreaks. It also helps growers reduce the use of dangerous chemicals. However, growers are still unable to produce strawberries according to the variety's characteristics because this variety was not selected for growing in greenhouses, combined with the relatively high humidity conditions inside the greenhouse, causing incomplete pollination.

Fig. 18. Disease-free strawberry plant production site. (Uper-left; Greenhouse, Uper-right; mother plants, lower-left; the production officer gave a report to Her Royal Highness Princess Maha Chakri Sirindhorn., lower-right; Daughter plants)

The group that is most successful in strawberry producing is the Khun Chang Khian with 5 greenhouses. The growers in this group have experience in growing and selecting appropriate varieties from Korea (Seolhyang). This strawberry variety was selected in greenhouses and is able to grow well under this environment. Moreover, the growers have a deep understanding of the growth and crop requirement of this variety. Both of these reasons allow growers to use their greenhouses to their full potential. However, Growers are still not successful in this business because sales income is still lower than annual production costs. Moreover, Seolhyang fruits are not in demand of the market, causing growers to have a lot of overdue products in storage.

VI. Harvest

Fruit of Pharachatan 80 is a kind of perishable fruit and often found fungal decay [37]-[40]. This character is similar to Japanese strawberry and requires intensive pre-harvest to post-harvest management. Some of the crop losses are caused by harvesting strawberries that are too ripe. Damage can be reduced by selecting maturity stages or using appropriate harvesting indices [34]. Most strawberry farms harvest their crop when 50-75 percent of the fruit is red. The major strawberry producing region of the United States, California, has a Harvest Index of 66 percent [41]. The harvest index that the Royal Project recommends to growers is 60-80 percent [42]. However, Doi Kham Food Products Co., Ltd. has set criteria that growers who want to sale in the premium category must harvest at 90 percent [22]. This chosen maturity stage is used as a selling point with the idea that consumers will receive high quality fruit which similar to that in the field. Packaging designed to accommodate the shape of the fruit is used along with maintaining temperatures from farm to store. The damage found was considerable even though various management systems had been put in place to help. Various techniques are applied to produce such as coating the surface of produce with edible solutions. However, coating fruit that is eaten

fresh without peeling is quite risky in terms of taste. A technique that seems more likely to be applied to strawberries is plasma treatments and low temperature, as in the experiment with figs [43] or pre- and post-harvest salicylic acid treatment [44].

VII. Problem and Mitigation Strategies

A. Pest Infestations

Common pests such as aphids, spider mites, and thrips can significantly damage strawberry crops. Effective pest management requires continuous monitoring and timely interventions.

Mitigating pest infestations in strawberry cultivation requires an integrated approach combining several strategies to effectively manage and reduce pest populations while minimizing the impact on the environment and human health. Integrated Pest Management (IPM) is a holistic approach that combines biological, cultural, mechanical, and chemical methods to manage pests sustainably. This involves using natural predators or parasites to control pest populations. For instance, introducing ladybugs to control aphids or using nematodes to target soil-dwelling larvae. Moreover, crop rotation and intercropping can disrupt pest life cycles. Selecting pest-resistant strawberry varieties and practicing proper sanitation by removing plant debris can also help reduce pest habitats. The chemical pesticides should be used as a last resort, they are sometimes necessary for managing severe infestations.

B. Diseases

Strawberries are susceptible to various diseases, including anthracnose, powdery mildew, botrytis (grey mold), and verticillium wilt. These diseases can reduce yield and fruit quality if not properly managed. Mitigating diseases in strawberry cultivation requires a comprehensive approach that incorporates cultural practices, biological controls, resistant varieties, and responsible use of chemicals.

1) Cultural Practices

Crop Rotation: Rotating strawberries with non-host crops can help break the life cycle of soil-borne pathogens. Avoid planting strawberries in the same field more than once every three to four years.

Sanitation: Removing plant debris and infected plants can reduce the sources of inoculum. Keeping the field clean and free from old plant material helps minimize the spread of pathogens.

Proper Spacing and Pruning: Adequate spacing between plants improves air circulation, reducing the humidity that favors disease development. Regular pruning of excess foliage can also help. minimize the spread of pathogens.

2) Resistant Varieties

Disease-Resistant Cultivars: Planting disease-resistant strawberry varieties can significantly reduce the incidence of certain diseases.

3) Biological Control

Beneficial Microorganisms: Introducing beneficial bacteria and fungi into the soil can suppress harmful pathogens. For instance, Trichoderma spp. can be used to control root diseases, while Bacillus subtilis is effective against foliar pathogens.

Natural Predators and Parasites: Encouraging natural enemies of disease vectors (such as mites and insects that spread viruses) can help manage disease indirectly.

4) Chemical Control

Fungicides: When necessary, fungicides can be used to control fungal diseases. It's important to use them judiciously to avoid resistance development. Rotating fungicides with different modes of action can help prevent resistance.

Biorational Pesticides: Using softer chemicals like neem oil or potassium bicarbonate can be effective against diseases with minimal impact on the environment and non-target organisms.

C. Soil Fertility

Maintaining soil health is crucial for strawberry production. Issues such as soil compaction, nutrient depletion, and poor drainage can adversely affect plant growth.

Ensuring soil fertility is crucial for the successful cultivation of strawberries. Planting cover crops like legumes (e.g., clover or vetch) can fix nitrogen in the soil and improve its organic matter content. These crops can be tilled into the soil before planting strawberries to boost fertility. Before crop, inoculating soil with beneficial microbes like mycorrhizal fungi and nitrogen-fixing bacteria can enhance nutrient uptake and improve plant health. These microbes form symbiotic relationships with plant roots, aiding in nutrient absorption and disease resistance. During crop, combining organic and inorganic fertilizers can provide immediate nutrient availability while enhancing soil health in the long term. Balanced fertilization with nitrogen, phosphorus, and potassium, along with trace elements like calcium and magnesium, is crucial for optimal growth. Regular monitoring and adapting practices based on specific soil conditions and plant needs are essential for sustained soil health and fertility.

D. Climate Change

Increasing temperatures and erratic weather patterns pose a significant threat to strawberry cultivation. Changes in climate can disrupt the growing season, affect fruit quality, and increase the incidence of pests and diseases. The most common obstacle is water shortages at the end of the growing season.

Mitigating the effects of climate change on strawberry cultivation in Thailand involves a combination of adaptive agricultural practices, technological innovations, and sustainable management strategies. Collecting and storing rainwater can provide an additional water source during dry periods. This practice helps maintain soil moisture levels and supports irrigation needs. Implementing drip irrigation and other water-saving technologies ensures that water is used efficiently and reduces the stress on water resources during droughts.

E. Incompletely Vernalization

This problem often happens due to warm air moving in the growing area. It increased the percentage of aborted flowers plus malformed fruits, resulting in a significant decrease in total marketable yield. Chiang Mai University has conducted an experiment using chilling to stimulate strawberries to bloom off-season. The results of the experiment show that artificial vernalization with the temperature lower than 10 that might show earlier flowering [31]. The plants which vernalized for 1 and 2 weeks at 2 °C showed earlier flowering (21.4 and 23.1 days, respectively) than did those vernalized at 4 °C (24.9 and 25.7 days, respectively). This technique can be further developed to solve the problem of plants not flowering in winter. Moreover, it was found that the use of MSG residue solution was sprayed to create flower inflorescences in Fang district. It was found that the strawberry plants had regular flower inflorescences after spraying this solution for approximately 3-4 days. This is consistent with subjection of Chiang Mai provincial agriculture and cooperatives office [45]. Also, supported by the study on a peanut legume which shows the highest yields when treated with MSG compared to the peanut treated with pig manure, chicken manure or cattle manure [46]. Research on the effect of MSG specifically on plant flowering appears to be limited or nonexistent in scientific literature. MSG is commonly known as a flavor enhancer used in food, but its potential impact on plant physiology, including flowering, hasn't been extensively studied. The next problem encountered after the plants show their inflorescences is incomplete pollination. Strawberries already have natural pollination factors such as insect, wind and gravity. However, there are some areas where poor pollination of strawberry flowers occurs results in small and malformed berries pollination or abnormal fruit shapes [47]. The use of plant growth regulators in the Gibberellin group can increase productivity. It has been widely found in Samoeng and Fang plantations. This is consistent with reports of using 75 ppm GA3 to increase strawberry fruit weight and the number of yields per plant [48]-[51]. Another plant growth regulator that promotes complete development of strawberry fruits is auxin [52]. However, the concentration of auxin is specific to the strawberry variety and something that must be taken seriously. Problems with incomplete fertilization can be common in greenhouse. The use of pollinators can increase the fertilization rate and allow the fruit shape to develop normally. Keeping bees to raise in strawberry greenhouses is a normal procedure in Japan (Fig. 19).

Fig. 19. Example of beekeeping in a strawberry production greenhouse for use in pollination

Some strawberry growers in Thailand have brought bees into their greenhouses to help with pollination and have had success in reducing malformed berries. A survey of the plantation area revealed that Maejo University is another source of strawberry cultivation under greenhouses that use bees for pollination and are successful (Fig. 20).

Fig. 20. Experiment with raising bees in strawberry production greenhouses at Maejo University, Chiang Mai

VIII. Conclusion

Strawberries are appreciated worldwide for their unique flavor, high nutritional value, and health benefits. Thailand has a rich history of strawberry cultivation dating back to the 1960s, aiming to provide hill tribes with an alternative source of income and combat illegal activities. However, challenges such as inadequate cultivation methods hinder optimal production.

Integrating traditional Thai farming with advanced technologies is vital for improving cultivation practices. Proper soil management, pest and disease

control, and adaptation to climate change are crucial for successful strawberry cultivation. Strategies like IPM, using disease-resistant cultivars, and maintaining soil fertility play a key role in mitigating challenges. Harvesting and post-harvest management are critical to ensuring fruit quality and reducing losses. Addressing issues like incomplete vernalization, climate change impacts, and pollination challenges are important for sustainable strawberry cultivation. Adopting innovative techniques such as artificial vernalization, monitoring flower development, and enhancing pollination through growth regulators or pollinators can improve yields and minimize fruit abnormalities.

Overall, a holistic approach combining traditional knowledge with modern technologies, along with effective pest and disease management, proper soil fertility practices, and adaptation to climate challenges, is essential for successful and sustainable strawberry cultivation in the northern region of Thailand.

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The Design and Implementation of Material Requirement Planning: A Case Study of the Plastic Company

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Received: April 12, 2023/ Revised: July 17, 2023/ Accepted: August 21, 2023

***Abstract*— The Company has a problem with inventory shortages caused by insufficient materials to meet customer needs and a lack of spare components for constructing finished goods due to the shared use of spare parts. To improve inventory management, this research employs engineering principles to create a new Material Requirement Planning (MRP). It also offers planners an option that would provide an inventory that is more efficient than the current approach. The problem was analyzed with Cause and Effect (Fishbone Diagram), presented the structure of the Bill of Material (BOM), and used a spreadsheet program on the cloud (real-time) for material management Order Notification Program can be compatible with Microsoft Excel. This research uses ABC analysis of the high-order Type A products of four departments.**

The reduction in raw material shortages from November to December 2022 resulted in a 100% reduction in delivery delays across all departments and a 66.67% reduction in the cost of warehouse management compared to the average ratio in the year 2022, leading to a cost savings of 64,180 baht per year for warehouse management.

***Index Terms*—Material Requirement Planning (MRP), Inventory Control, Bill of Materials (BOM)**

I. Introduction

Material Requirement Planning management involves inventory in many companies. Operations managers have to consider this because inventory is one of the most expensive assets. It has also a high value in current assets so good inventory management is a crucial part of any company. They may have some types of inventory planning and control systems. A bank has methods to control its inventory of cash. The manufacturing company has methods used to control inventories: raw materials, work in process, and finished goods. Retailers and wholesalers are also concerned with inventory planning and control.

A. Statement of the Problems

The case study is a plastic company, the manufacturing was initially bathroom accessories and glass, showers, and seat cover equipment. The distributor sells several different sanitary ware materials products and has earned the trust of the nation's top modern trade department stores and shops.

The plastic company has Make-to-Order management by receiving orders from customers and production operations Assembling the finished product and delivery of orders. For inventory control, the staff checks the available stock level of items every day and orders by using past experiences. Sometimes does not have enough materials to meet customer needs or spare components to construct finished goods because spare parts are used together. There is a shortage of inventories. There is a shortage of inventories. The Warehouse at Plastic Company is shown in Fig. 1 to Fig. 2.

Fig. 1. Raw Materials


Fig. 2. Work in Process (WIP) Materials

In the warehouse, Staff controls the inventory of many materials based on the experience of observing. Regardless of customer order quantity.

When the staff checks stock and prepares orders for each: a product that is composed of several types and sizes, it does not operate on suitable what items should be stocked, when stock should be replenished, and how large orders should be. Sometimes out of stocks products be occurred leading to shortage costs. Customers have to wait for backorders and customers receive the product late. The number of shipping delays is shown in Fig. 3.

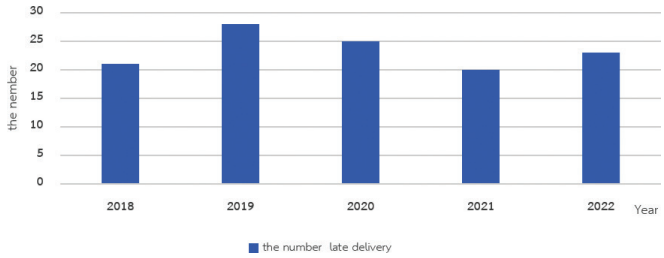


Fig. 3. The number of shipping delays

If there are insufficient spare components, the planning department will notify the manufacturing department. However, producing spare parts takes varying amounts of time depending on the specific production processes involved. As a result, shipping may be delayed, and if the delay exceeds the allotted time, the factory may incur penalties.

The shortage of goods comes from using spare parts together. Fig. 4 illustrates a comparison between the maximum order count and the average inventory each time during production. The staff places orders based on their experience, regardless of the quantity specified in customer orders.

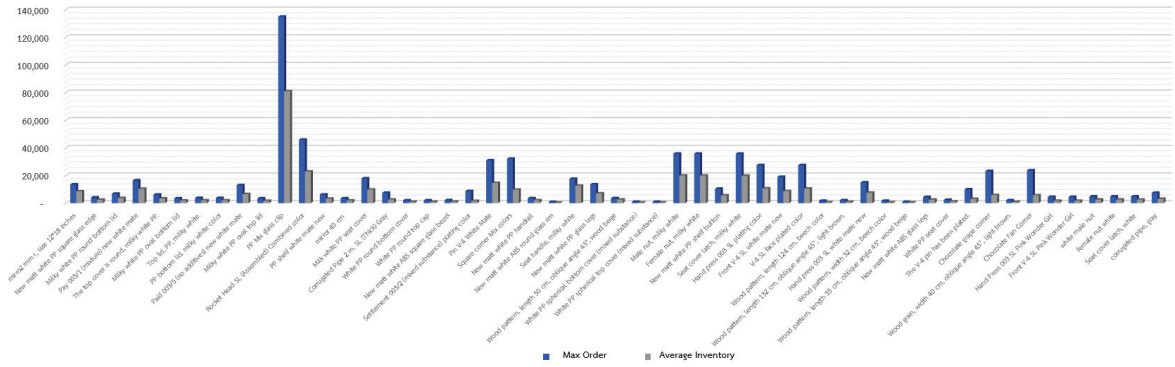


Fig. 4. Compare count maximum order with an average inventory

The researcher has an idea to assist in the creation of the production planning database system by using the spreadsheet program order notification 2022 on Google cloud to create and edit files online while collaborating with other users in real time to help decrease stock management issues and delivery delays.

B. Scope of Study

• This research examined the high-order type A products of four departments.

The data used in this research aims to assist material planning for the plastic company through the utilization of the order notification program.

• Microsoft Excel, specifically the order notification software, is employed for material management, and the associated files are uploaded onto Google sheets.

C. Objectives

• To study the causes of problems to reduce delayed delivery and the spare parts that aren't enough for production.

• To study and summarize the current practices of companies.

• To develop a new Material Requirement Planning (MRP) to remedy inventory management.

• To propose an alternative for planners who want to generate an effective inventory that is better than the existing method.

II. Literature Review

A. The Material Requirement Planning System (MRP)

MRP system attempts to determine material needs. The main purpose of the MRP is to facilitate organizational calculations to determine the required quantity of parts needed in production [1]. MRP helps to ensure that required materials like components, parts, or subcontracted items arrive at the set time for fulfilling the demand requirements of finished goods. To calculate and define the right order time and shipping time for the required parts or components needed for the production of a new product, it combines data from production schedules with data from inventory as well as the bill of materials [2].

The data were analyzed to examine the status quo and to adopt the MRP by spreadsheet on the cloud. After the MRP adoption, the company was able to determine the quantity requirement, leading to the MRP prototype creation for production as follows: inventory quantity, materials that are in the process of ordering, production schedule, and component requirement lists [3].

B. Inventory Control

Inventory is their largest asset that may cover more than 40% of the total assets, it should be properly managed and controlled. However, the managing and controlling of the inventory should have some objectives as follows:

• To raise company profitability

• To evaluate the effect of company policies on inventory levels

• To minimize the total cost of logistics activities

Nowadays, many inventory management techniques can be applied in many businesses such as Inventory carrying cost, Economic order Quantity (EOQ), ABC analysis, and the Bill of Materials (BOM) [4].

C. ABC Analysis

ABC analysis can basically be used in all areas of materials management.

It enables:

• To distinguish the essential from the inessential

• To focus on activities of high economic importance, while reducing the burden on the remaining areas by simplification measures

• to increase the efficiency of measures (e.g. cost reduction) by the possibility of targeted use

ABC analysis can be carried out weekly, monthly, quarterly, or annually as required. The more often the analysis is performed, the better the overview of the stock situation, and the faster the response to changes in stocks can be implemented [5].

D. Bill of Materials (BOM)

BOM is a detailed account used for defining, recording, and saving the final product and its makeup, contents, quantities, and structure. The BOM can be presented in many different ways, such as Explosion and Implosion [6]. This study briefly describes the different BOM structures as follows:

- Single-Level Explosion
- Indented Explosion
- Summarized Explosion
- Single-level Implosion
- Indented Implosion
- Summarized Implosion

Furthermore, BOM can also be called a Product Structure or Material List. The Furthermore, BOM is usually presented in a Level-by-Level way: Level 0 represents the finished products, Level 1 as structural components, Level 2 as the composition of the structure in Level 1, and so on as Level 3 until the list reaches the most basic components/raw materials. The tree structure of BOM is illustrated in Fig. 5 [7].

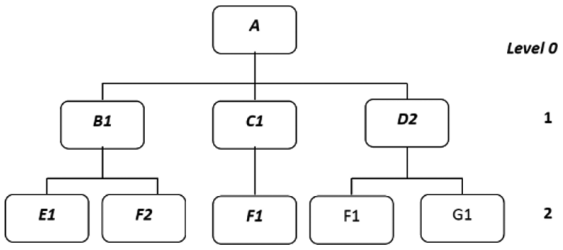


Fig. 5. Tree structure (BOM) of product A

II. Research Methodology

The steps that will be taken for research completion are as follows:

1) Study the background of the plastic company.
2) Process Analysis
   - ABC Analysis
   - Cause and effect analysis
   - The structure of the BOM
   - Calculate safety stock and re-order point
3) Design the experiments and apply them to the program.

A. Information about the Plastic Company

This research is on the design and implementation of a material requirement planning system in a plastic company. Based on requests from customers (Make-to-Order). Customers can choose from a variety of shapes and sizes for the items they want. The product can be categorized into 4 categories shown in Fig. 6.

- Nozzle
- Seat Cover
- Glass
- Wood Glass

Fig. 6. The product of the plastic company

B. Process Analysis

The first step in the process is to prepare data about statistics on transportation from the previous year to gather data on delivery delays of a plastic company. From the statistics from Table I, the amount of delay from delivery in 2022 shows a total of 22 delivery delays. Each department has similar delivery averages.

TABLE I
THE AMOUNT OF DELAY FROM DELIVERY IN 2022

Department	Number of Delays	Average
Nozzle	8	2
Seat cover	5	3.63
Glass assembly	5	2.80
Wood grain assembly	4	4
Total (Day)	**22**	**3.11**

In the second step, the researcher uses ABC analysis to select the products of each department in the Type a group and found that there were 27 types of products in the type a group as shown in Fig. 7 to Fig. 10.

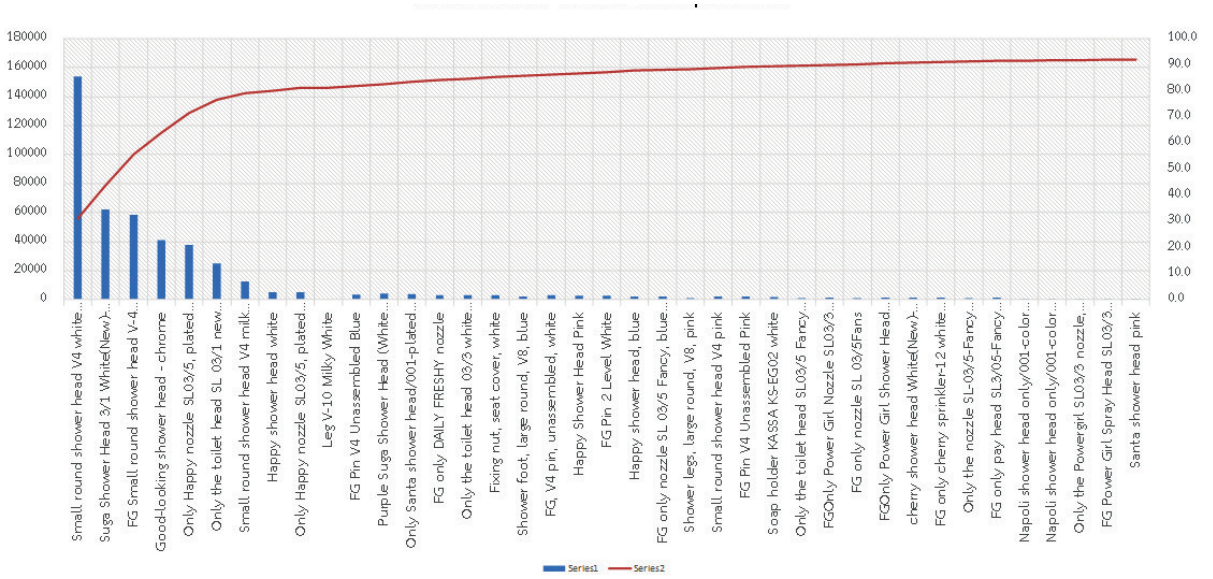


Fig. 7. Volume sales of the nozzle department (December, 2021- October, 2022)

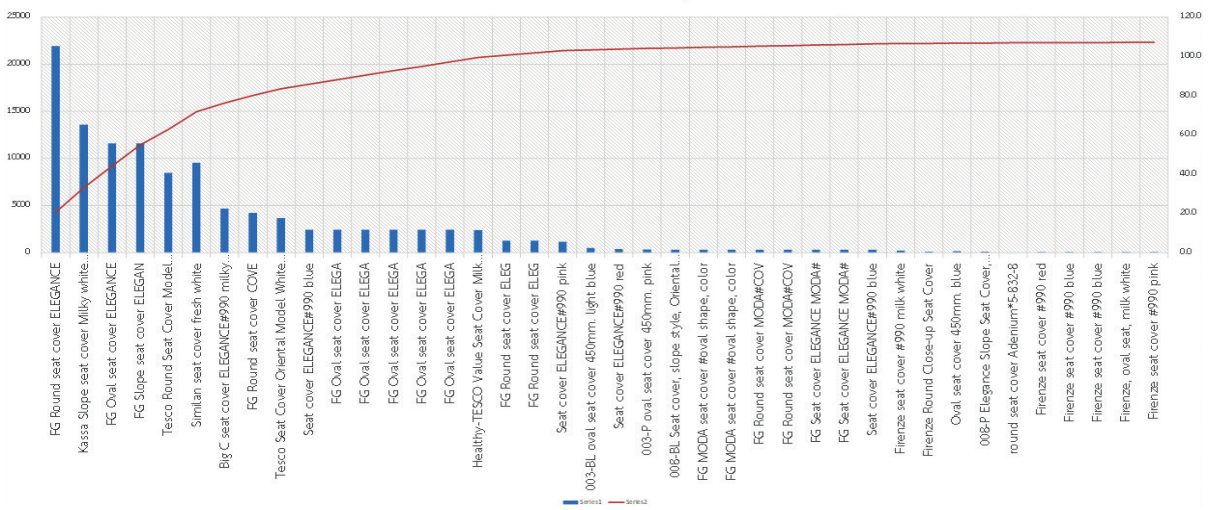


Fig. 8. Volume sales of the seat cover department (December, 2021- October, 2022)

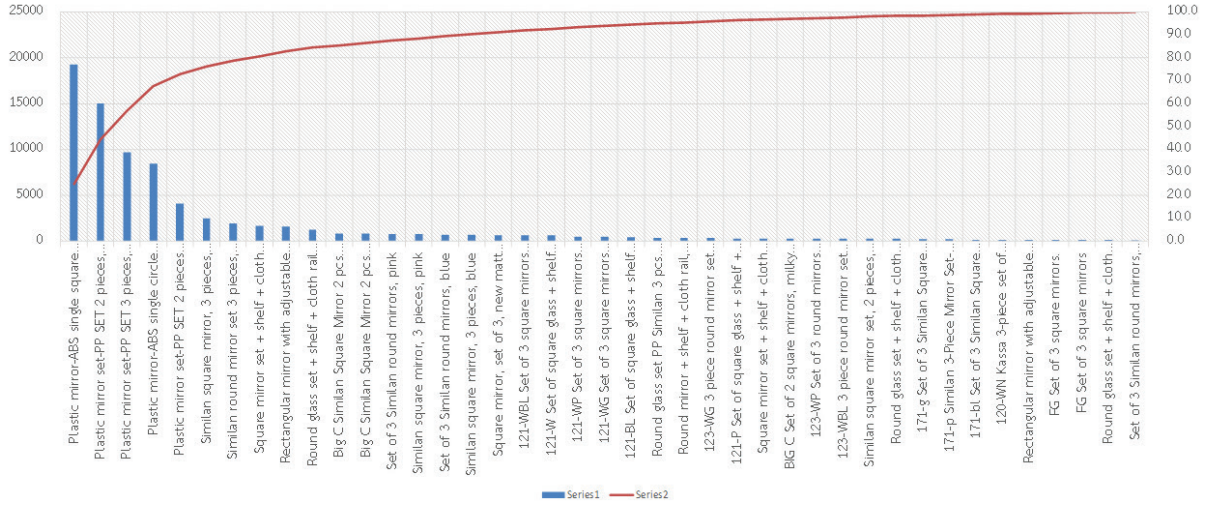


Fig. 9. Volume sales of the glass assembly department (December, 2021- October, 2022)

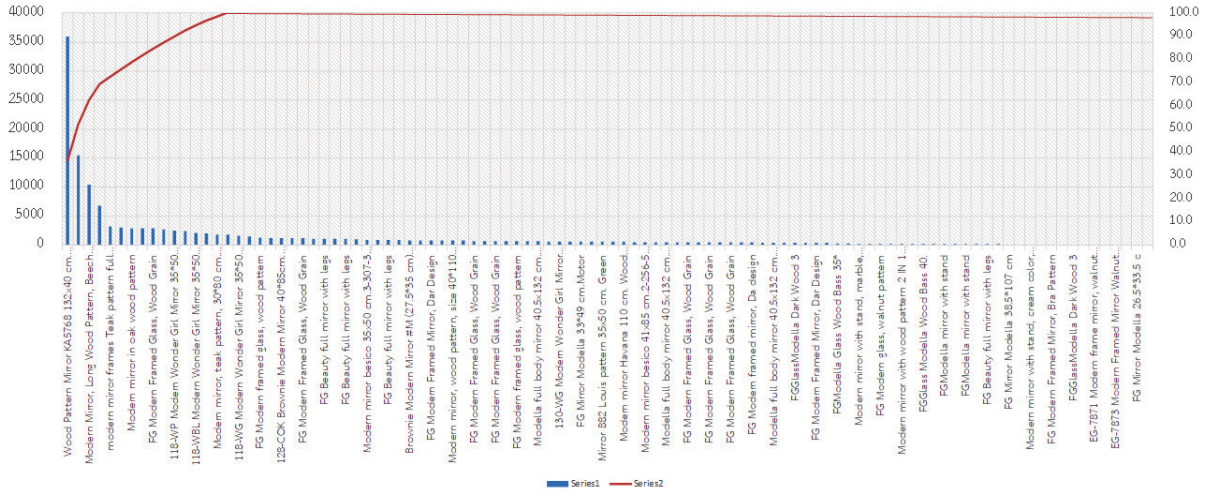


Fig. 10. Volume sales of wood glass assembly department (December, 2021- October, 2022)

According to the ABC analysis, there are 27 Type a products divided into 4 departments, as shown in Table II below.

• The nozzle department has product type 7 items and uses characters instead of N1- N7.

• The seat cover department has product type 8 items and uses characters instead of S1-S8.

• The glass assembly department has a product type 7 items and uses characters instead of G1- G7.

• The wood glass assembly department has product type 5 items and uses characters instead of W1- W5.

TABLE II
THE PRODUCTS IN TYPE A GROUP

No.	Department	Code	Character
1	Nozzle	11113050071	N1
2	Nozzle	11113030136	N2
3	Nozzle	11113060004	N3
4	Nozzle	11113040044	N4
5	Nozzle	11113030143	N5
6	Nozzle	11113030138	N6
7	Nozzle	11113050061	N7
8	Seat Cover	11115010002	S1
9	Seat Cover	11115010051	S2
10	Seat Cover	11115020001	S3
11	Seat Cover	11115010068	S4
12	Seat Cover	11115010026	S5
13	Seat Cover	11115010050	S6
14	Seat Cover	11115010061	S7
15	Seat Cover	11115010067	S8
16	Glass	11114010136	G1
17	Glass	11114010137	G2
18	Glass	11114020068	G3
19	Glass	11114020069	G4
20	Glass	11114020071	G5
21	Glass	11114010142	G6
22	Glass	11114010122	G7
23	Wood Glass	11114030063	W1
24	Wood Glass	11114030112	W2
25	Wood Glass	11114030003	W3
26	Wood Glass	11114030047	W4
27	Wood Glass	11114030057	W5
Total		**27**	

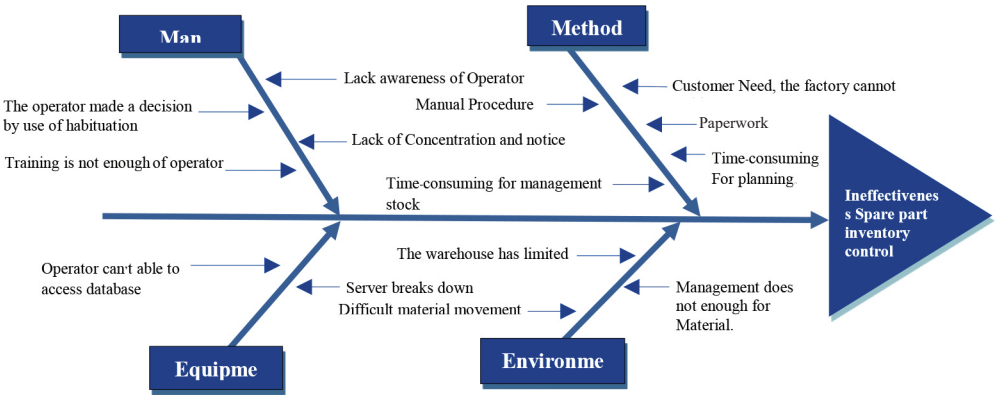


Fig. 11. Cause and effect for the ineffectiveness of the current system.

Moreover, the cause-effect diagram Ishikawa diagram fishbone diagram is an effective tool for the problem-solving process. It is used to investigate for sub-causes [8]. This step shows the analysis of cause and effect for the ineffectiveness of the current system. Fig. 11 shows a fishbone.

In the man-related cause, to investigate the spare parts required, the material planners and purchasing personnel should have high experience in doing their job. They have to know every part in detail. And they must concentrate on their work because their work involves numerical tasks. Lost concentration would make an error and result in overstock and shortage.

In the method-related cause, most of the work is paperwork. Staff use a parts list printed on paper to investigate the quantity needed for each product that is composed of several types, and sizes and use spare parts together. The Investigation task then is time-consuming since the staff has to deal with many spare parts lists and sheets of schedule. Besides time wasted on paperwork while investigating the required quantity for each part.

The equipment-related cause involves the use of printers, servers, and computers for material planning. As the spare part requirements are updated daily, any server breakdown can restrict staff members' access to the database, impeding their ability to perform their tasks effectively.

The environment-related cause relates to the limited space in the warehouse, which hampers the movement of products and pallets, leading to decreased storage efficiency.

In conclusion, the proposed system should address these identified causes that hinder the efficiency of the material planning and control system. The new system should adopt a proactive approach, focusing on appropriate methods, ease of use, minimizing human error, and facilitating the

In the next step, study the structure of the Bill of management of raw materials.

BOM can be presented as a relationship between the assembling work and the components necessary to manufacture items. The researcher has analyzed the composition of various types of products. After that, the data for 67 different materials and components were divided using code A-Z to show the data by Table III, The semi-product of 27 product types A.

TABLE III
THE SEMI-PRODUCT OF 27 PRODUCT TYPES A

Character Product	Code Semi	Character Semi Product	Amount of Used
N1	020902040051	CC	1
N2	020502030051	P	1
	020602010051	T	1
	020701020051	W	1
	029902020028	KKK	1
N3	020902040026	BB	1
N4	020502040026	Q	1
	020602010026	S	1
	020701020026	V	1
	029902020028	KKK	1
N5	020501070051	O	1
	020602010026	S	1
	020701020026	V	1
	029902020028	KKK	1
N6	020502030051	P	1
	020602010024	R	1
	020701020024	U	1
	029902020028	KKK	1
N7	020902040002	AA	1

TABLE III
THE SEMI-PRODUCT OF 27 PRODUCT TYPES A (CON.)

Character Product	Code Semi	Character Semi Product	Amount of Used
S1	021202020002	FF	1
	021201020002	CC	1
	021209020002	MM	1
	021210020002	OO	2
	021211020002	QQ	2
	021217020002	VV	2
	021217020002	VV	2
	021212020002	RR	1
S2	021207020002	JJ	1
	021208020002	KK	1
	021209020002	MM	1
	021210020002	OO	2
	021211020002	QQ	2
	021217020002	VV	2
	021212020002	RR	1
S3	021204020002	HH	1
	021205020002	II	1
	021209020002	MM	1
	021210020002	OO	2
	021211020002	QQ	2
	021217020002	VV	2
	021212020002	RR	1
S4	021202020002	FF	1
	021201020002	CC	1
	021209020002	MM	1
	021210020002	OO	2
	021211020002	QQ	2
	021217020002	VV	2
	021212020002	RR	1
S5	021202040001	GG	1
	021201040001	EE	1
	021209020001	LL	1
	021210020001	NN	2
	021211020001	PP	2
	021217020001	UU	2
	021212020002	RR	1
S6	021202020002	FF	1
	021201020002	CC	1
	021209020002	MM	1
	021210020002	OO	2
	021211020002	QQ	2
	021217020002	VV	2
	021212020002	RR	1
S7	021215020002	SS	1
	021216020002	TT	1
	021209020002	MM	1
	021210020002	OO	2
	021211020002	QQ	2
	021217020002	VV	2
	021212020002	RR	1

TABLE III
THE SEMI-PRODUCT OF 27 PRODUCT TYPES A (CON.)

Character Product	Code Semi	Character Semi Product	Amount of Used
S8	021207020002	JJ	1
	021208020002	KK	1
	021209020002	MM	1
	021210020002	OO	2
	021217020002	VV	2
	021212020002	RR	1
G1	020101010051	E	1
	020901010051	Y	2
	020408020028	N	8
	010301010001	A	1
	029903050028	MMM	1
	021212020002	RR	1
	020901010051	Y	2
	020408020028	N	8
G2	020901010051	Y	2
	020408020028	N	8
	010301010001	A	1
	029903050028	MMM	1
	021212020002	RR	1
	020901010051	Y	2
	020408020028	N	8
	010301010001	A	1
	029903050028	MMM	1
	021212020002	RR	1
	020901010051	Y	2
W1	021601120030	BBB	2
	021601230030	FFF	2
	021701040028	III	4
	021702050028	JJJ	3
	029903040028	LLL	1
	010301010004	B	1
W2	021601041150	WW	2
	021601041350	XX	2
	021701040028	III	4
	029903040028	LLL	1
	010301010001	A	1
W3	021601080020	YY	2
	021601210020	DDD	2
	021701010021	GGG	2
	021701020021	HHH	2
	021702050028	JJJ	1
	010301010004	B	1
	029903040028	LLL	1
W4	021601100021	ZZ	2
	021601150021	CCC	2
	021701040028	III	4
	029903040028	LLL	1
	010301010001	A	1
W5	021601120019	AAA	2
	021601230019	FF	2
	021701040028	III	4
	021702050028	JJJ	3
	010301010004	B	1
	029903040028	LLL	1

In addition, the researcher provides an example of the BOM structure diagram N4-N6, which can be simulated as shown in Fig. 12 to Fig. 14.

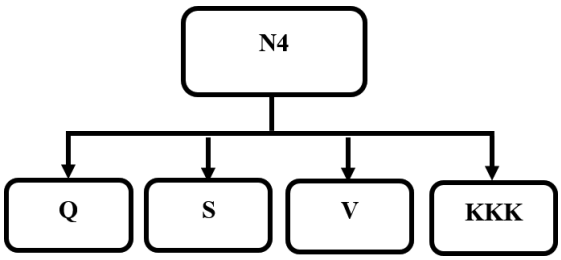


Fig 12.The structure diagram of N4

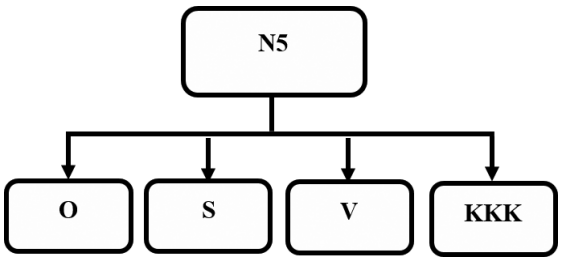


Fig. 13. The structure diagram of N5

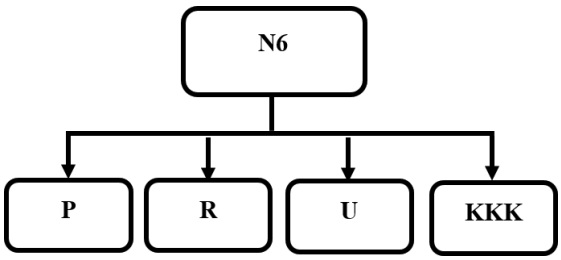


Fig 14.The structure diagram of N6

From Fig. 12 to Fig. 14, BOM diagram N4-N6 shows the use of shared parts in production, for example:

• N4 and N5 have semi-product parts S: code 020602010026, and V: code 020701020026 that share spare parts.

• N4, N5, and N6 have semi-product parts KKK: code 029902020028 shares spare parts.

Calculate safety stock and re-order point

Finally, find the safety stock and reorder point of the semi-product of 67 items. Calculated using Microsoft execs applied software using mean and maximum value methods. To feed the database into the order notifications program as shown in Fig. 15.

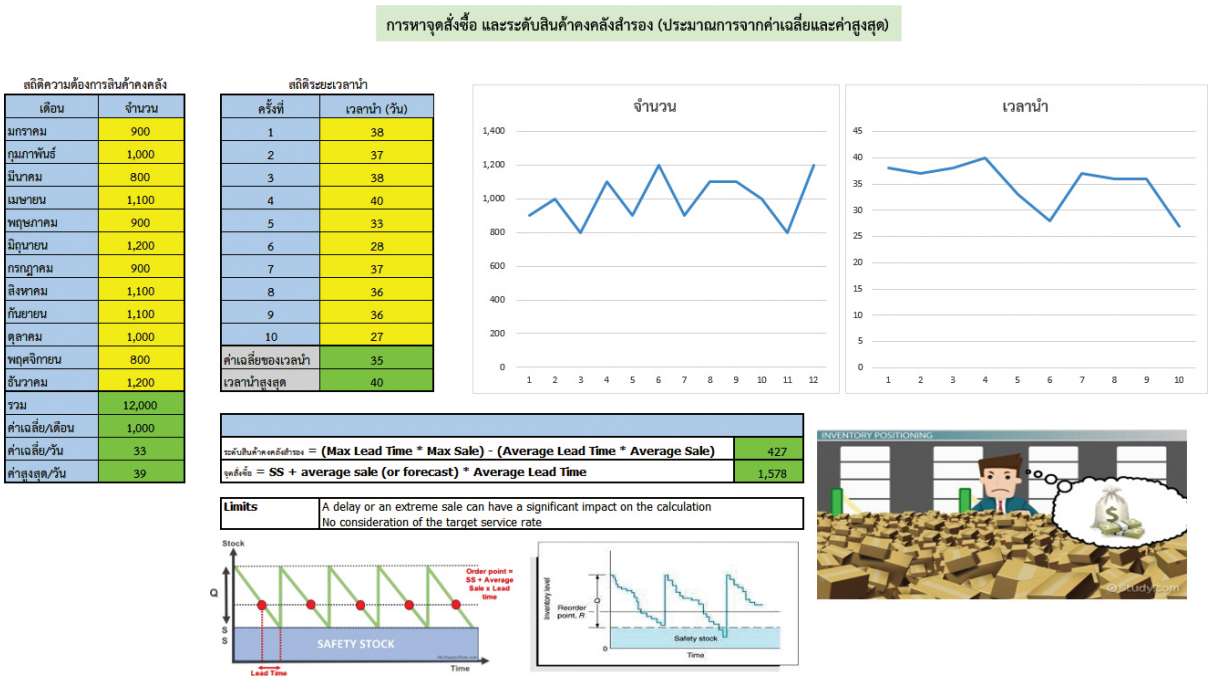


Fig. 15. Finding safety stock and reorder point

B. Design the Experiments and Apply to the Program

The order notification program can be used to determine the number of raw materials in inventory. How much can be utilized to create various commodities or products?

The order notifications program will tell you right away to make purchases to top off the stored inventory level if the raw materials are not enough to utilize in accordance with the production schedule. The software was created using the practical spreadsheet program on the cloud, which can be used conveniently and edited files online in real-time. In addition, is compatible with Microsoft Excel files the basic office program available on most computers. It consists of several worksheets.

5 Worksheets are as follows:

1) Home screen
2) Products
3) Raw materials used to assemble products
4) Bill of Materials
5) Orders

as shown in Fig. 16.

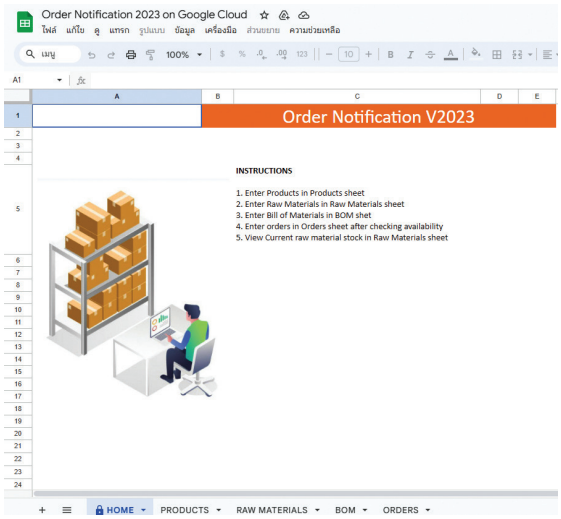


Fig. 16. Main page (Home screen)

Using the order notifications program

Open the order notifications program. Developed from google spreadsheet by entering class a product data 27 items on the product or product sheet (products) and shown in Fig. 17.

RAW MATERIALS

Enter each Raw Material in a separate row (Start from row 7)

Unique Raw Material Name	*Inventory you have when you first start using this template*	*Inventory level below which you should replenish stock*	Calculated: *Units purchased till now*	Calculated: *Units available in stock now*	Calculated: *Should we order now?*
RAW MATERIAL NAME	STARTING INVENTORY	RE-ORDER POINT	PURCHASES	AVAILABLE NOW	TO ORDER
A	488	1428	500	738	YES
B	344	770	0	344	YES
C	138	263	0	138	YES
D	86	126	0	86	YES
E	268	537	0	18	YES
F	110	234	0	110	YES
G	103	191	0	103	YES
H	86	174	0	86	YES
I	175	387	0	175	YES
J	43	95	0	-207	YES
K	43	95	0	-207	YES
L	37	79	0	37	YES
M	212	466	1000	1212	NO
N	3909	8774	1000	2909	YES

HOME | PRODUCTS | RAW MATERIALS | BOM | ORDERS

Fig. 17. Raw materials worksheets

For the system to calculate these quantities automatically when delivering order notifications, the researcher implements the software using the number of raw materials and points of purchase. Fill out the BOM sheet as shown in Fig. 18 to Fig. 19 with the list of materials used to manufacture each product.

BILL OF MATERIALS

Enter recipe for each product (Start from row 10)

See Sample below: To create Banana Berry Shake (L), we need 1 Banana, 5 Strawberries and 10 Blueberries.

BILL OF MATERIALS

Enter recipe for each product (Start from row 10)

These three calculations are needed to calculate inventory. Please do not edit.

You can ignore this data.

PRODUCT	RAW MATERIAL	UNITS	UNIT OF MEASURE	RAW MATERIAL UNITS USED TILL NOW (*Total raw material units used till now*)	AVAILABLE RAW MATERIALS NOW (*Available raw materials now*)	HOW MANY PRODUCTS CAN BE MADE? (*Units of Products that can be made*)
N1	CC	1.00	Count	1000.00	1596	1596
N2	P	1.00	Count	500.00	366	366
N2	T	1.00	Count	500.00	334	334
N2	W	1.00	Count	500.00	334	334
N2	KKK	1.00	Count	500.00	-1005	0
N3	BB	1.00	Count	1000.00	173	173
N4	Q	1.00	Count	1000.00	516	516
N4	S	1.00	Count	1000.00	944	944
N4	V	1.00	Count	1000.00	944	944
N4	KKK	1.00	Count	1000.00	-1005	0
N5	O	1.00	Count	500.00	1086	1086
N5	S	1.00	Count	500.00	944	944
N5	V	1.00	Count	500.00	944	944
N5	KKK	1.00	Count	500.00	-1005	0
N6	P	1.00	Count	800.00	366	366
N6	R	1.00	Count	800.00	295	295
N6	U	1.00	Count	800.00	295	295
N6	KKK	1.00	Count	800.00	-1005	0

Fig. 18. List of spare parts used in the production of goods

ORDERS

Enter purchase and sale orders in the below table.

If an order has multiple product items, enter them in separate rows.

Supports up to 1000 entries below.

16-Nov-2022

CHECK TODAY'S AVAILABILITY

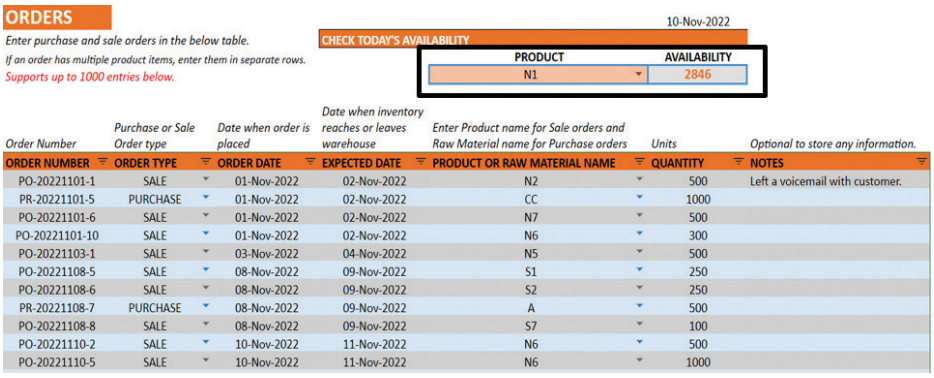
PRODUCT	AVAILABILITY
N3	173

Order Number	*Purchase or Sale Order type*	*Date when order is placed*	*Date when inventory reaches or leaves warehouse*	*Enter Product name for Sale orders and Raw Material name for Purchase orders*	*Units*	*Optional to store any information.*
ORDER NUMBER	ORDER TYPE	ORDER DATE	EXPECTED DATE	PRODUCT OR RAW MATERIAL NAME	QUANTITY	NOTES

Fig 19. The number of products that can be manufactured.

Assume that there are now 2,846 pieces of raw materials for product N1 that can be used to make items, as shown in Fig. 20.

When an order comes in 1,000 units of product N1 Fig 21. Depicts the remaining quantity of item N1 as 1,596 pieces.



ORDERS

Enter purchase and sale orders in the below table.
If an order has multiple product items, enter them in separate rows.
Supports up to 1000 entries below.

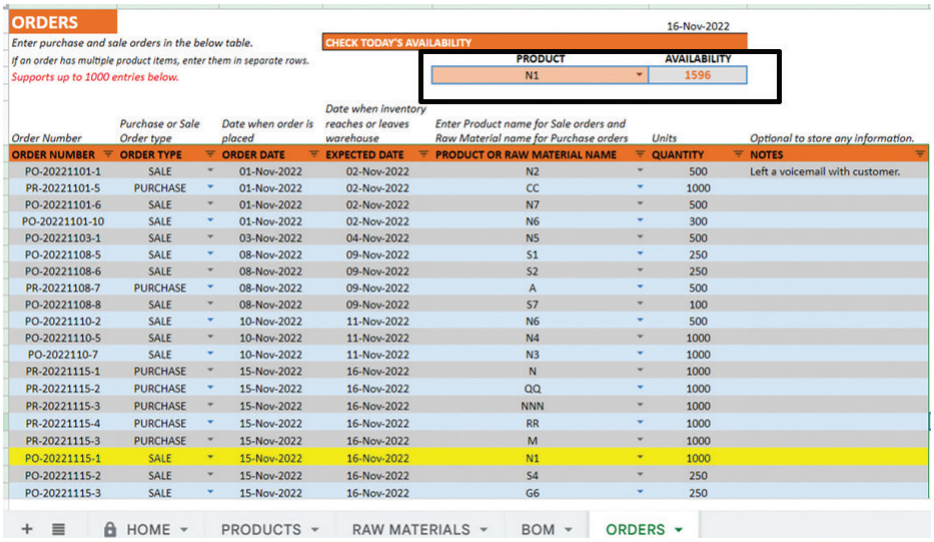
10-Nov-2022

CHECK TODAY'S AVAILABILITY

PRODUCT	AVAILABILITY
N1	2846

Order Number	*Purchase or Sale Order type*	*Date when order is placed*	*Date when inventory reaches or leaves warehouse*	*Enter Product name for Sale orders and Raw Material name for Purchase orders*	*Units*	*Optional to store any information.*
ORDER NUMBER	ORDER TYPE	ORDER DATE	EXPECTED DATE	PRODUCT OR RAW MATERIAL NAME	QUANTITY	NOTES
PO-20221101-1	SALE	01-Nov-2022	02-Nov-2022	N2	500	Left a voicemail with customer.
PR-20221101-5	PURCHASE	01-Nov-2022	02-Nov-2022	CC	1000	
PO-20221101-6	SALE	01-Nov-2022	02-Nov-2022	N7	500	
PO-20221101-10	SALE	01-Nov-2022	02-Nov-2022	N6	300	
PO-20221103-1	SALE	03-Nov-2022	04-Nov-2022	N5	500	
PO-20221108-5	SALE	08-Nov-2022	09-Nov-2022	S1	250	
PO-20221108-6	SALE	08-Nov-2022	09-Nov-2022	S2	250	
PR-20221108-7	PURCHASE	08-Nov-2022	09-Nov-2022	A	500	
PO-20221108-8	SALE	08-Nov-2022	09-Nov-2022	S7	100	
PO-20221110-2	SALE	10-Nov-2022	11-Nov-2022	N6	500	
PO-20221110-5	SALE	10-Nov-2022	11-Nov-2022	N6	1000	

Fig. 20. Checking the maximum amount of finished goods that can be produced.



ORDERS

Enter purchase and sale orders in the below table.
If an order has multiple product items, enter them in separate rows.
Supports up to 1000 entries below.

16-Nov-2022

CHECK TODAY'S AVAILABILITY

PRODUCT	AVAILABILITY
N1	1596

Order Number	*Purchase or Sale Order type*	*Date when order is placed*	*Date when inventory reaches or leaves warehouse*	*Enter Product name for Sale orders and Raw Material name for Purchase orders*	*Units*	*Optional to store any information.*
ORDER NUMBER	ORDER TYPE	ORDER DATE	EXPECTED DATE	PRODUCT OR RAW MATERIAL NAME	QUANTITY	NOTES
PO-20221101-1	SALE	01-Nov-2022	02-Nov-2022	N2	500	Left a voicemail with customer.
PR-20221101-5	PURCHASE	01-Nov-2022	02-Nov-2022	CC	1000	
PO-20221101-6	SALE	01-Nov-2022	02-Nov-2022	N7	500	
PO-20221101-10	SALE	01-Nov-2022	02-Nov-2022	N6	300	
PO-20221103-1	SALE	03-Nov-2022	04-Nov-2022	N5	500	
PO-20221108-5	SALE	08-Nov-2022	09-Nov-2022	S1	250	
PO-20221108-6	SALE	08-Nov-2022	09-Nov-2022	S2	250	
PR-20221108-7	PURCHASE	08-Nov-2022	09-Nov-2022	A	500	
PO-20221108-8	SALE	08-Nov-2022	09-Nov-2022	S7	100	
PO-20221110-2	SALE	10-Nov-2022	11-Nov-2022	N6	500	
PO-20221110-5	SALE	10-Nov-2022	11-Nov-2022	N4	1000	
PO-2022110-7	SALE	10-Nov-2022	11-Nov-2022	N3	1000	
PR-20221115-1	PURCHASE	15-Nov-2022	16-Nov-2022	N	1000	
PR-20221115-2	PURCHASE	15-Nov-2022	16-Nov-2022	QQ	1000	
PR-20221115-3	PURCHASE	15-Nov-2022	16-Nov-2022	NNN	1000	
PR-20221115-4	PURCHASE	15-Nov-2022	16-Nov-2022	RR	1000	
PR-20221115-3	PURCHASE	15-Nov-2022	16-Nov-2022	M	1000	
PO-20221115-1	SALE	15-Nov-2022	16-Nov-2022	N1	1000	
PO-20221115-2	SALE	15-Nov-2022	16-Nov-2022	S4	250	
PO-20221115-3	SALE	15-Nov-2022	16-Nov-2022	G6	250	

HOME | PRODUCTS | RAW MATERIALS | BOM | ORDERS

Fig. 21. The number of finished goods

III. Result and Discussions

Apply the inventory management method, and follow the established corrective guidelines in the process. The cause-and-effect diagram in Fig. 10 is an analysis by the researchers to identify the true origin of each problem. The processing results are focused on action planning, as stated separately in each topic. These solutions will be implemented step by step, as also shown in Fig. 22.

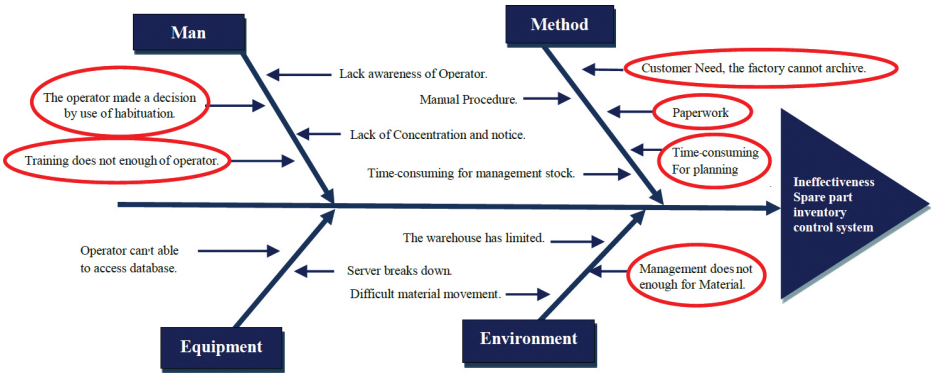


Fig. 22. Fishbone diagram

The summary of what actions to be taken in each solution topic is shown in the diagrams below. The diagrams also link those actions to the root causes they eliminate from Fig. 23.

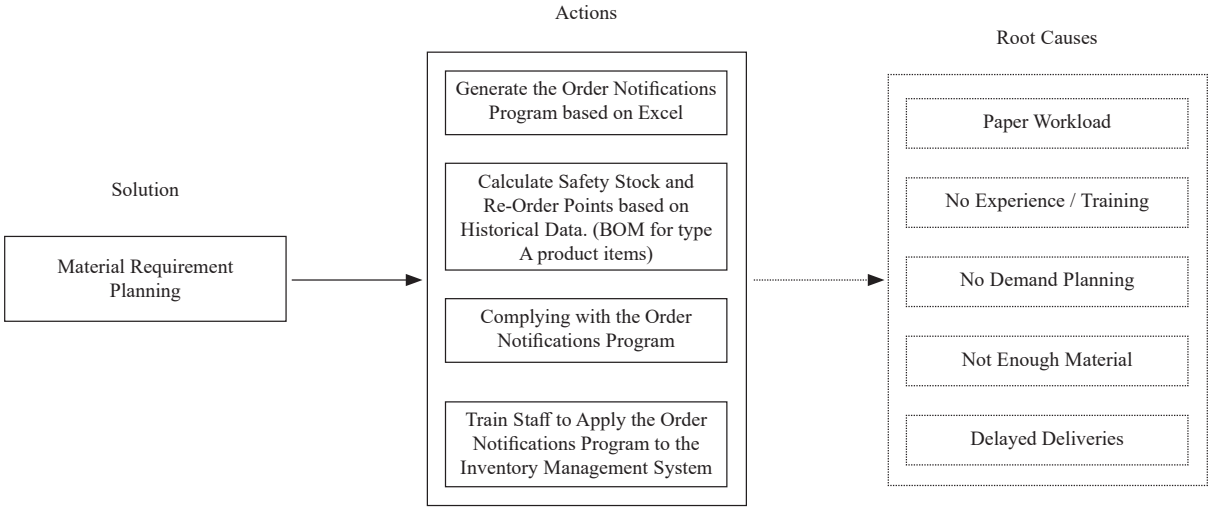


Fig. 23. Actions and eliminated root causes by material requirement planning.

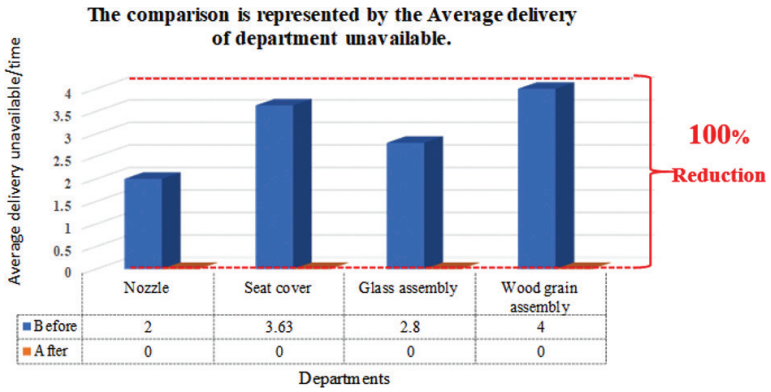


Fig. 24. Bar chart showing reduction of average unavailable delivery per time.

The implementation, results from two months (November-December 2022) reflect the success of improvement activities from the researcher. The company can use the program. The direct and indirect benefits from improvement caused a reduction in the total cost and reduced delayed delivery of the plastic company. The comparison is represented by a bar chart about delivery in Fig. 24 below.

Inventory control is an important problem for business operations in the current economy. The effectiveness of logistics can be increased with good order management. The delivery of goods to customers will be impacted if raw materials are not purchased on time or in adequate quantities. It also has an impact on the organization's brand image and reputation. Material Requirement Planning, in the opinion of the researcher, is an important and effective strategy for handling the demand for the materials required for each product and it is also useful for estimating item sales in the company based on historical sales data to help decrease delayed delivery and Increase the customers' satisfaction. It has main supporting tools such as (1) A Master Plan, giving the number of every product to be made in each period (2) A Bill of Materials, which gives structured lists of the materials needed for each product and (3) Inventory Records, show the current state of stocks, lead times, costs, etc.

Plastic company is used as a case study to be analyzed and improve its process to gain more success. This medium-sized company is located in Bangkok, It has been operating for 31 years, the problem is the ineffectiveness of the inventory control system and there aren't enough spare parts to produce finished goods. There is a shortage of inventories. It needs immediate action to edit the problem and avoid paying a penalty for delivery delays.

V. Conclusion and Suggestion

The objective of the research is the design and implementation of MRP in The Plastic Company. Researchers study the causes of problems to reduce delayed delivery and the spare parts that are not enough for production. Using the design program is the tool for planning the raw material.

It can improve save costs and increase logistics efficiency to implement the order notifications program to be applied in planning the purchase of raw materials so that inventory is available to serve customer demands in the appropriate quantity and at the right time, can be summarized as follows :

1) Reduce problems from raw material shortage

After generating the order notifications program based on Excel. The improvement caused reduced delayed delivery of the plastic company. There has been a 100% reduction in delivery delays in all departments. Higher accuracy in demand planning can prevent a shortage of raw materials. Staff can prepare adequate raw materials without overstocking them based on reasonable raw material planning.

2) Reduce the cost of warehouse management

Overall improvement after the 2 months of implementation is shown in more effectiveness. The cost of warehouse management (planning), the result has decreased by 66.67%, when compared to the average ratio in the year 2022.

3) Reduction in error

Since in the proposed system most of the work will be done by a basic program computer is user-friendly, the human error, for example, forgettable order, forgettable part, a mistake in calculation, etc. will be improved. In the current system, one material planner is responsible for a lot of spare parts, and there are thousands of parts in the list of low inventory and shortage of spare parts. They may look over some parts. Although they recognize it later, it may be too late to order. Mistakes in the calculation are unavoidable because material planning and control is a numerical task.

This research also addresses the suggestion of monitoring and control continuous improvement needs continuous monitoring and control from supervisors of all departments. The researcher suggests monthly follow-up meetings to ensure the implemented actions are effective without internal errors.

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[4] E. P. Wigner, "Theory of traveling-wave optical laser," *Phys. Rev*., vol. 134, pp. A635-A646, Dec. 1965.

[5] E. H. Miller, "A note on reflector arrays," *IEEE Trans. Antennas Propagat*., to be published.

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[20] N. Kawasaki, "Parametric study of thermal and chemical nonequilibrium nozzle flow," M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

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[22] B. Smith, "An approach to graphs of linear forms," unpublished.

[23] A. Brahms, "Representation error for real numbers in binary computer arithmetic," IEEE Computer Group Repository, Paper R-67-85.

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[25] Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

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