# Design of Smart System For Fruit Packinghouse Management in Supply Chain


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***Abstract*—Packinghouse management is an integration of a series of business processes and good handling practices. Many previous studies have discussed using technology and methods in each business process at the packinghouse but have not been integrated and are still focused on data input, data processing, and reporting. This research proposes the design of technology and computational integration in a business process called the Smart System for Fruit Packinghouse Management (SPHM) with the aim of accurate fruit classification, product selection, and delivery model to be sent appropriately, selection of appropriate packaging, stock optimization, reduce costs, increase sales and profits, and customer loyalty. This system consists of four sub-systems are Smart Logistic System, Smart Indexing System, Smart Packaging System, and Smart Storage System. Integration of technology and computing proposed are RFID, Computer Vision, Vis / NIR, IoT, WSN, AHP, GA, Topsis, RNN, LS-SVM, ABC, HOG, SPA, CARS, SVM, SVR, Fuzzy Logic Control, Time Series Analysis Techniques, and MLFANN.**



***Keywords— Fruit Packinghouse, Smart Logistic System, Smart Indexing System, Smart Packaging System, Smart Storage System***


## I. INTRODUCTION

The growing level of consumer awareness of the quality and nutritional value of fruit [1], traders must prioritize the needs of consumers. The fruit has a relatively short shelf-life problem so that during postharvest there is a decrease in quality and damage [2] reaching 20% to 50% during distribution to consumers [3]. Good handling practices of fruit products have the same role as good agricultural practices, which aims to provide products with optimal quality when they reach customers. Good handling practices have several different stages according to the characteristics of the fruit. Good handling practices generally include pre-cooling, cleaning and disinfecting, sorting and grading, packaging, storing, and transporting. Good handling practices play an essential role in maintaining quality and extending shelf-life [4]. The fruiting cycle starts to harvest until the consumer goes through several stages, are harvest, packinghouse, transport, warehouse, and point of sale/retailer [5]. Good handling practices will affect quality degradation [6], early good handling practices is mostly in the packinghouse so it is important to do good management to increase the economic value of the product and maintain trust of consumer.

There have been many research results that discuss the use of technology and methods of the stage of good handling practices starting pre-cooling [7][8], cleaning and disinfecting [9][10], sorting and grading [11][12][13], packaging [14][15], storage [16][17], and transportation [18][19]. However, the data and the system have not been integrated, so they cannot provide accurate recommendations in sales. This study developed the design of Smart System for Packinghouse Management (SPHM) by integrating data and artificial intelligence technology to improve accuracy and reliability. The designed SPHM model is shown in figure 1.

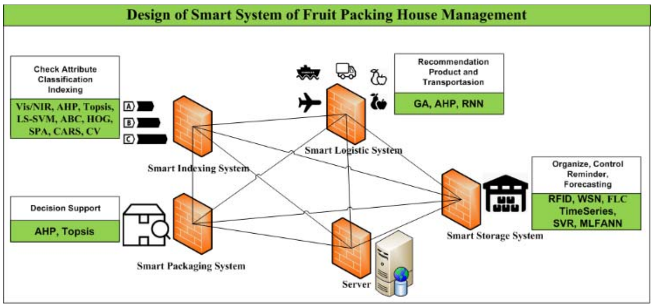


Fig. 1. Design of SPHM Proposed

## II. METHOD

In this study, developing a new discourse related to the Smart System of Packinghouse Management. The contributing methods are 1) describing the implementation of technology in business processes, 2) proposing a computational model for optimal business processes, and 3) integrating each business process in sub-systems so that intelligent systems are formed. The method used come from external research that has been done previously.

SPHM consists of 4 sub-systems are 1) Smart Logistic System to make the best product delivery recommendations. 2) Smart Indexing System for making product classification and indexing. 3) Smart Packaging System to make decision support in packaging selection. And 4) Smart Storage System to labeling and organize product placement, control storage space, a reminder when there is excess and expired stock, and demand forecasting.

## III. RESULT AND ANALYSIS

In this section, we provide analysis and discussion about technology and computational design in each SPHM sub-system.

### 3.1. Smart Logistic System

Smart Logistic System (SLS) is a sub-system that functions as a controller of the delivery process from storage to consumers. Figure 2 shows the work area of SLS. Factors to consider in developing SLS are fruit data that has been classified by the Smart Indexing System (SIS), data on the number of requests from consumers, and transportation model data related to shipping costs and delivery times. This SLS will provide shipping recommendations tailored to the product code and shipping mode. SLS can do computing to provide the most efficient shipping costs and optimal quality predictions when the product arrives at its destination. SLS does not only focus on the optimal quality of fruit products when it reaches its destination but also measures the level of consumer satisfaction based on the suitability of fruit product maturity index when it arrives and on-time delivery. Data on customer satisfaction is quite important because it is used as input for computing in predictions.

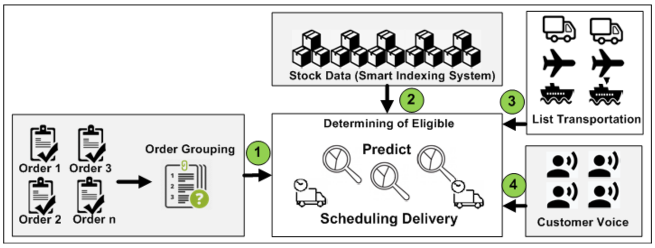


Fig. 2. Smart Logistic Workflow

The SLS work process as shown in figure 2, consists of 4 processes are 1) grouping orders, 2) determining the fruit products to be sent, 3) determining the mode of transportation, and 4) processing customer satisfaction data. To get a combination of orders, products, and transportation to obtain a list of recommended product delivery options with optimal results can use a combination of the Genetic Algorithm (GA) and Analytical Hierarchy Process (AHP). In the initial individual formed, the reproduction process is carried out, are crossover, mutation, fitness value calculation, and the process is done by calculating the accuracy results. Then the results of these recommendations and consumer assessment data are processed to provide the best shipping predictions by applying the Recurrent Neural Network (RNN). GA is a heuristic technique that can find a solution quickly enough [20] and AHP is a method for making an alternative sequence of decisions and choosing the best alternative with several criteria [21]. RNN can be used to predict time-series data with non-linear data [22].

### 3.2. Smart Indexing System

Smart Indexing System (SIS) is a sub-system that is in good handling practices in sorting and grading. SIS will provide an assessment index based on maturity and market. Maturity index correlates with fruit shelf-life and the market index correlates with sales objectives are exports and domestic. Figure 3 shows the work area of SIS. Factors to consider in developing SLS are external fruit attributes including color, shape, volume, bruising, rot and surface defects [23], internal attributes include Soluble Solid Content (SSC), Titratable Acidity (TA), firmness, Total Soluble Solids ( TTS), dry matter, aroma, meat rot and internal defects [24], [25] and classification data that is adjusted to the characteristics of consumers, products and markets.

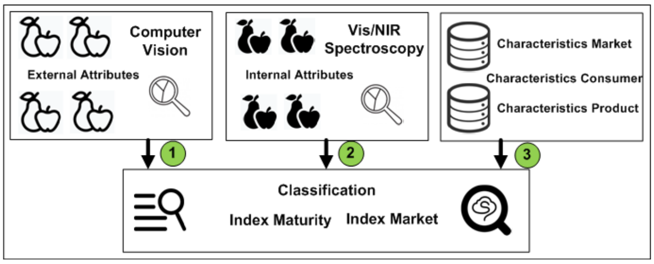


Fig. 3. Smart Indexing Workflow

The SIS work process as in Figure 3 consists of 3 processes, namely 1) examination of external attributes, 2) examination of internal attributes, and 3) classification based on attributes of market data, consumer characteristics, and products. The classification will also determine products for the export market and the domestic market. In testing external attributes using computer vision technology and internal testing using Vis / NIR spectroscopy technology. Challenges in internal and external detection are physical variability, biological variability, detection of the whole surface, discrimination between defects and stem and shells, detection of invisible defects [26]. For this reason, it is necessary to use computational methods and algorithms with strong features. In feature extraction, variable selection and wavelength and building models can use the Least Squares Support Vector Machine (LS-SVM) [27] [28], Artificial Bee Colony (ABC) algorithm [12], Histogram of Oriented Gradients (HOG) [ 29] [30], Sequential Projection Algorithm (SPA), Competitive Adaptive Reweighted Sampling (CARS), Squares Support Vector Machine (SVM) [31] [32], Artificial Neural Network (ANN) [33] [34].

The characteristics of consumers, products, and market needs are quite varied. Some consumers need products with a long shelf life, some are mature enough, and others. Data processing from 3 processes to be classified based on the maturity index and market index can use AHP and preference order techniques based on the similarity of ideal solutions (TOPSIS). The combination of AHP and Topsis methods was chosen because the AHP method has advantages based on a pairwise comparison matrix and performs consistency analysis. While the Topsis method can solve decision making practices, because the concept is simple and easy to understand, the calculation is efficient and can measure the relative performance of decision alternatives [35] [36].

### 3.3. Smart Packaging System

Smart Packaging System (SPS) as decision support related to the choice of product packaging. The primary function of packaging is to protect against damage during storage and distribution [37]. Packaging selection is also an efficient handling unit, an easy-to-store storage unit, protects the quality and reduces waste, provides service and sales motivation, reduces transportation and marketing costs, and allows new distribution methods. There are various types of packaging from materials, indicator labels, vacuum, active packaging to the use of gas or Modified Atmosphere Packaging (Map) [15] [38]. The strategy of using packaging will be related to cost, the effectiveness of the packaging in reducing mechanical damage, efficiency in maintaining fruit quality, demand from consumers, and policies of the destination country. SPS processes data from SIS, the level of customer satisfaction from SLS, and packaging related data. The combination of AHP and Topsis methods can be used to produce the best decision.

### 3.4. Smart Storage System

Smart Storage System (SSS) is used to manage packaged fruit products. Figure 4 shows the work area of the SSS consisting of 5 areas, are 1) data labeling and organizing products, 2) storage space controllers, and 3) data access, 4) reminder stock excess and close to expired, and 5) demand forecasting. RFID based data collection to facilitate organizing storage. This avoids misplacement because the fruit has different optimal temperature characteristics and wrong product retrieval [39]. To maintain the storage environment using temperature sensors, humidity, and light sensors to prevent bacterial growth [40] with Fuzzy Logic Control (FLC) based on Wireless Sensor Network (WSN) because it has the properties of self-organizing, self-configuring, self-diagnosing, and self-healing [41]. Data visibility is a necessity for smart storage because interested parties and consumers want to find what they want immediately. To avoid overstock and expired, the reminder system can recommend solutions related to policies with third parties, such as juice producers. SSS is expected to be able to optimize stock, reduce costs, increase sales and profits, and customer loyalty requires demand forecasting [42].

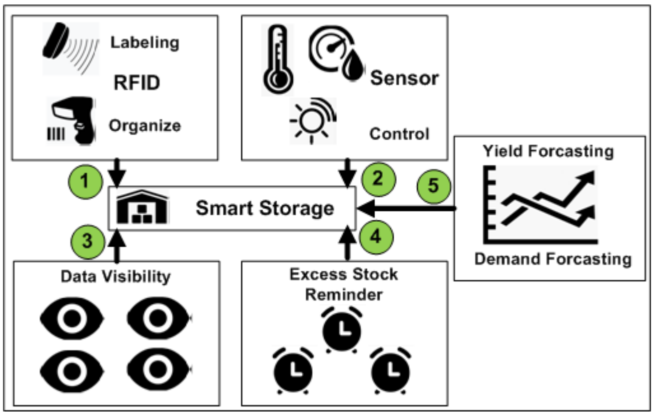


Fig. 4. Smart Storage Workflow

In determining the placement of products at the store location can use the Topsis algorithm. Topsis to process space availability with information on temperature and humidity data. Many factors affect sales, from weather to social media influencers, machine learning and predictive analytics are needed for demand and supply forecasting. To improve the model built using historical data analysis and interpretation with a combination of vector support regression algorithm, time series analysis techniques, and deep learning models. Forecasting results will be reliable because of changes in trends and seasonal products from fruit. In time series analysis techniques by collecting historical data, analyzing features, and utilizing models to predict the future. SVR algorithm for the problem of prediction of continuous variables as a regression method that maintains all major properties as well as classification problems [43]. The deep learning model uses a multilayer feedforward artificial neural network (MLFANN). MLFANN is trained by decreasing stochastic gradients using backpropagation. Gradient descent algorithm to update the weights so as to minimize the error squared between the network output value and the target and each weight is adjusted to the value of its contribution to the error [44].

## IV. Conclusion

In this study we propose the integration of four sub-systems of smart system for Fruit Packinghouse Management. The design of the proposal is based on the latest research studies. The SPHM consists of 4 sub-systems, are 1) SLS uses the GA, AHP and RNN algorithms to make the best product delivery recommendations, 2) SIS uses CV, Vis / NIR, AHP, LS-SVM, ABC, HOG, SPA, CARS, SVM, ANN and Topsis to make product classification and indexing, 3) SPS uses AHP and Topsis to make decision support in packaging selection. And 4) SSS uses a combination of RFID, WSN, sensors, FLC, and Topsis to organize and control storage and time series analysis techniques, SVM, and deep learning models for demand and supply forecasting. For further studies, prototypes can be developed with portable and mobile-based devices and implementation in packinghouses.

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