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Design of Warehouse Management System for Fresh Product in Supply Chain Network

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ABSTRACT

Warehouse management has an important role in maintaining product quality. Moreover, warehouses that handle fresh products are perishable and have a limited shelf life. therefore it is necessary to design smart warehouse management so that products can be accepted by customers with optimal quality. The supply chain network (SCN) is a model used to reduce costs and time efficiency. Previous research generally discusses the use of RFID, WSN and genetic algorithms for monitoring and decision making of products in supply chains and warehouses but does not focus on fresh products and warehouse management with the SCN model. The design a smart warehouse management system (SWMS), by integrating WSN, RFID and hybrid genetic algorithms (GA) with a combination of Analytical Hierarchy Process (AHP) for increased accuracy and optimization. For tracking and monitoring fresh products using Radio Frequency Identification (RFID) technology, temperature sensors, humidity sensors, and ultrasonic sensors. The SWMS design consists of 4 sub-systems: Smart Logistic, Adaptive Warehouse Inventory, Smart Forecasting System, and Smart Decision Support System.

Key words : RFID, WSN, Warehouse, Fresh Product

1. INTRODUCTION

Warehouse management has an important role in maintaining product quality. Moreover, warehouses that handle fresh produce, which is sensitive to temperature and shelf life require more complex systems to be more efficient and accurate and need to be built an environmental monitoring system for humidity, temperature, air, and light [1]. Shelf life is a safe time for perishable products so that it still fulfills physical, chemical and microbiological characteristics [2]. Temperature is one of the parameters to control the freshness and quality of products, especially perishable products [3]. For perishable products to have an optimal shelf life, proper handling is needed starting from packing, storage, and distribution [4]. The warehouse of fresh products accommodates various types of fruits and vegetables with different temperature and humidity requirements so that the storage is adjusted to its characteristics [5]. To provide fresh products with optimal quality to customers is needed the supply chain network (SCN) is a model to reduce costs and time efficiency [6][7][8]. SCN manages the flow of information from production to consumption to adjust customer needs [9]. SCN model activities are shown in figure 1.

There are several problems in the management of warehouse fresh products, first is the process of ordering products that are adjusted to the trend and the number of requests and delivery to the warehouse following capacity of the pallet space for fresh product characteristics. Second is the placement of fresh products in locations with suitable temperatures. Strategies to maintain product quality and safety by monitoring temperature conditions during storage in warehouses, through mapping of appropriate locations [10]. Errors in the placement and taking of fresh products due to inaccurate inventory [11]. Humans can cause errors in the process of placing and sending [12]. Third is the prediction of requests from customers so that it can reduce product damage due to too long storage, and wrong estimation of delivery time [13]. The fourth is the product data collection so that issue is the product with the least shelf life. Temperature monitoring, shelf life visibility, and least shelf life first out stock strategy are important in the logistics of perishable products and to reduce economic and quality losses [14]. The fifth is communication between policyholders between warehouses, this is due to the involvement of many warehouses in SCN.

RFID is one of automatic identification and data capture technologies [15]. RFID utilizes radio waves to transmit, identify, track, sort, and confirm various objects [16][17]. compared to barcodes, RFID has waterproof properties, has a magnetic scratch-resistant protective layer, is heat-resistant, durable, able to transmit long-distance and short data transmission, data encryption, and has a greater memory capacity [18]. RFID consists of two components, tag, and reader. Based on the RFID category is divided into two, namely RFID with an active RFID power supply/tag and without a passive power / RFID tag [19]. Wireless sensor networks (WSN) have been widely used in research because of their good flexibility and lower costs compared to cable installations [20][21][22]. WSN is a system consisting of transceivers, sensors, microcontrollers, and power sources. WSN has the characteristics of self-organizing, self-configuring, self-diagnosing, and self-healing. These properties are an advantage of WSN that did not exist in previous technologies [23][24][25]. RFID and WSN have been widely applied in research. WSN can provide environmental information, with integration with RFID can be applied to a wider function and lower costs compared to the existing warehouse management system [26]. Literature studies related to RFID and WSN for monitoring and tracking the quality of agricultural products have been carried out to reduce food product degradation strategies [27][28]. Genetic Algorithm (GA) is a method for optimization based on the concept of biological evolution from Darwin's theory [29]. GA uses random search techniques with natural selection mechanisms and natural genetics. GA can find the optimal solution in a complex multidimensional search that has many parameters. GA was successfully applied in various fields to solve many optimization problems [30][31][32].

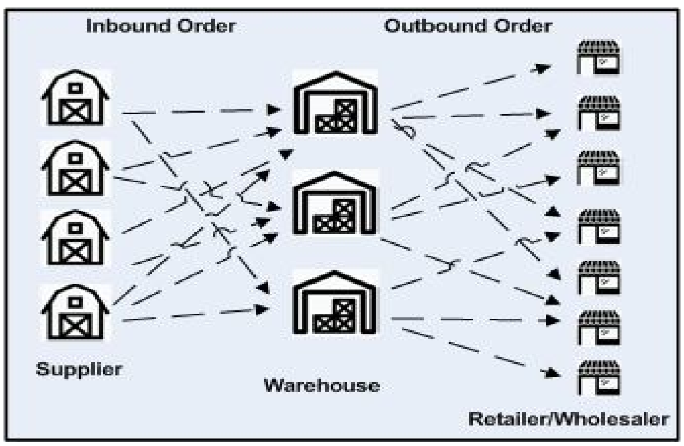

Figure 1: The three level supply chain network

Research related to warehousing and supply chain has so far discussed the use of RFID and WSN for perishable products even though it does not focus on fresh products [33][34][35][36][37]. Research on decision support systems with genetic algorithms in warehouse management addresses layout and location allocation problems [38][39], order picking problems [40], optimization of item placement [41], production and distribution problems with multi factories for the same quality products [42]. But there has been no research that addresses the optimization of warehouse management with RFID and WSN using Algortima Genetics in SCN.

In this paper, we designed a smart warehouse management system (SWMS) by implementing WSN, RFID, and genetic algorithms to solve problems. By proposing architecture and SWMS design consists of 4 sub-systems: Smart Logistics, Adaptive Warehouse Inventory, Smart Forecasting System, and Smart Decision Support System. The relationship of the sub-system is shown in figure 2.

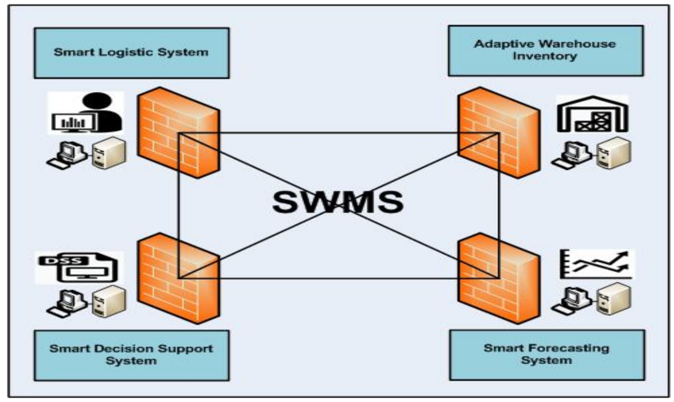

Figure 2: Smart Warehouse Management System Proposed

2. RESEARCH METHOD

This research contributed to the development of Smart Warehouse Management System (SWMS) with a combination of RFID, WSN, GA and AH technology. The contributions include designing network architecture and work systems and application integration models in the sub-systems, (1) Smart Logistic with a combination of genetic algorithms and AHP for optimizing product shipping to customers and orders to suppliers, (2) Adaptive Warehouse Inventory for data collection and product management fresh in the warehouse, (3) Smart Forecasting System to predict customer requests and orders to suppliers, (4) Smart Decision Support System to support decisions and communication between managerial level in each warehouse.

3. THE ARCHITECTURE OF PROPOSED SYSTEM

The proposed architectural system for warehouse management of fresh products, as shown in Figure 3. It is assumed there are many warehouse locations with the following work systems. First, the fresh product comes from the supplier, then the product is sorted and packed and then put in a box. Products and boxes will be affixed with RFID tags. The box will be placed on the pallet according to the RFID tag data. Determination of the location of pallets and decision making products on the box using the Smart Logistics system based on GA and AHP processing. Products that have a shelf life of zero or have expired are prioritized for sales to juice beverage manufacturers. The warehouse has a location mapping based on the characteristics and types of products with different temperature and humidity values. In each pallet installed temperature sensors, humidity sensors and ultrasonic sensors to detect storage capacity.

Sensors collect temperature, humidity and altitude data and then aggregate and acquire data. The gateway forwards to the local server system for processing before sending it to the cloud. Due to the large amount of sensor data and can use up bandwidth, an analysis is performed first to reduce the burden on the data center. Merging data from several warehouses will be processed deeper into the data center by using data mining so that it can produce an accurate and optimal decision system.

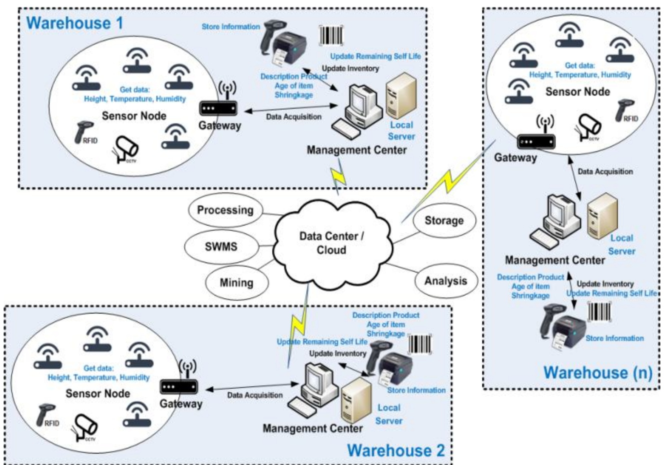

Figure 3: The SWMS Topology and Architecture

4. SWMS DESIGN

Developing a SWMS using the 3-tier concept, as in Figure 4. First is the presentation layer, which is the interface for users to enter the system. The second is the business logic layer, which is responsible for processing various logical calls. SWMS logic and Management logic are the main parts of this layer. All decision making is the result of the calculation of the model built. Third is the data layer, which consists of four bases that can communicate with each other through logic management. In building SWMS using a 3-tier concept, as in Figure 4. First is the presentation layer, which is the interface for users to enter the system. The second is the business logic layer, which is responsible for processing various logical calls. SWMS logic and Management logic are the main parts of this layer. All decision making is the result of the calculation of the model built. Third is the data layer, which consists of four bases that can communicate with each other through logic management.

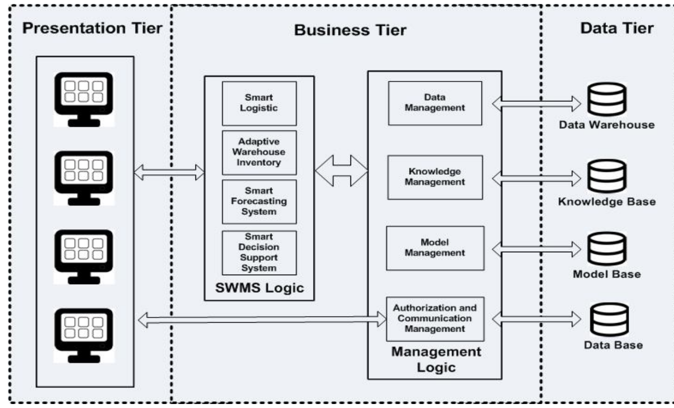

Figure 4: SWMS Application Architecture

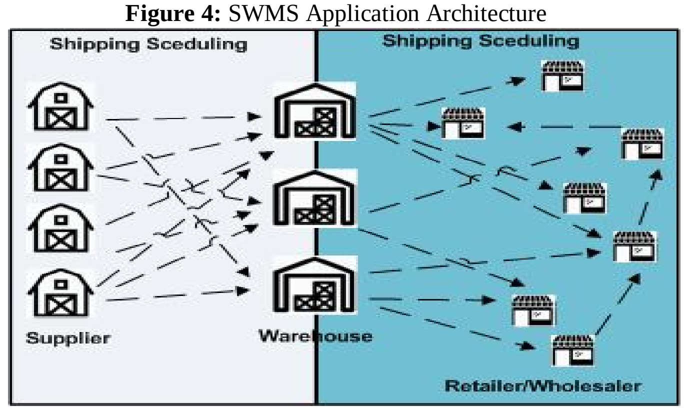

Figure 5: Smart Logistic Area

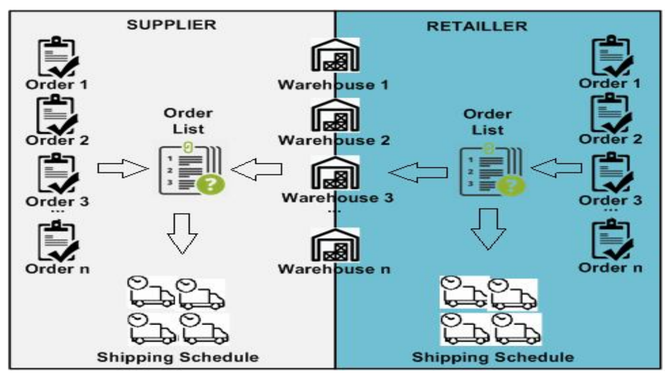

Figure 6: Smart Logistic Workflow

4.1. Smart Logistic

Smart Logistics is a subsystem for optimizing product expenditures to customers, making delivery scheduling and storing shipping data such as timeliness, product conditions and customer satisfaction. Figure 5 shows the scope of smart logistic work. To get optimal results using a combination of GA and AHP. Variables that are considered in determining the decision to release goods are customer location, warehouse location, product shelf life, customer type, shipping costs, number of orders, and delivery time. Figure 6 shows the Smart Logistic process flow, the process starts when there is an order from the customer, based on a specific time rule policy, all orders will be carried out by the system to determine the delivery schedule and transportation as well as the selected product code including box code, pallet code, and warehouse code. This system optimizes so that customers get fresh products with optimal quality and minimal costs, such as the problem description in Figure 7. The notation and mathematical model of the problem can be formulated (1).

K =\{1,2,3, .. n1\}, set of fresh produce, indexed by k
L =\{1,2,3, .. n2\}, set of Warehouses, indexed by l
M =\{1,2,3, .. n3\}, set of retailers, indexed by m
N =\{1,2,3, .. n4\}, set of transportation, indexed by n
SL_m = Shelf life of fresh produce m ∈ K
SC_{nm} = Shipping cost m ∈L,N
LS_{lm} = Lead time shipping

$$\text{Min}\sum_{m=1}^{n1} SL_m + \sum_{n=1}^{n3} \min_{l=1:n2}\{SC_m * LS_{lm}\} \qquad (1)$$

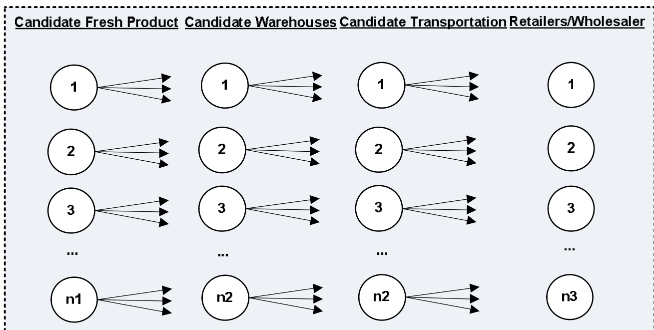

Figure 7: Problem Description

GA can only produce one solution but can be improved by a combination of other algorithms. Enhanced GA can obtain more than one solution, GA has three main operators, namely selection, crossover, and mutation. GA and AHP are applied to analyze logistical distribution location problems, GA to obtain some optimal solutions on economic factors and AHP to evaluate solutions [43]. This research proposes hybrid GA with an AHP combination. AHP is used to find the most important criteria which will then be processed by GA to obtain an optimal solution. The proposed hybrid GA-AHP algorithm is shown in figures 8.

Pseudocode of hybrid GA-AHP

While *(the solution does not optimal)* **do**
Select *the fittest P(t) among P(t) for next-generation*;
Select *two chromosomes from the population randomly*, **then**
Crossover *the two selected chromosomes which the point of crossover is randomly selected to get new chromosomes*
Mutate *the chromosomes in the population which the point of mutation is randomly selected to avoid premature convergence*.
Rank the top five chromosomes with the AHP *to get the new population / children population C(t)*
Evaluate *the fitness of chromosome of C(t) to get the optimal current solution with the highest fitness among C(t)*
Update the current condition
If previous solution < current solution, then replace the previous solution with current condition;
Select P(t+1) from P(t) and C(t);
T= t+1;
End while;
End

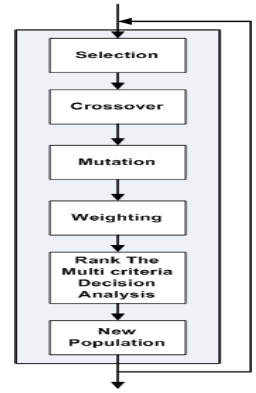

Figure 8: Propose Algorithm Hybrid GA-AHP

4.2. Adaptive Warehouse Inventory

Adaptive Warehouse Inventory (AWI) for data collection and managing fresh products in the warehouse to maintain product quality. AWI uses RFID technology, temperature sensors, humidity sensors, and ultrasonic sensors and microcontrollers. Fresh products have certain characteristics and the quality can be maintained optimally with certain temperatures and humidity. With temperature and humidity data can be used to control the engine coolant. Fuzzy Logic Control (FLC) is a technique to control using fuzzy operations. FLC on the microcontroller can be used to control the climate in the greenhouse [44][45]. Block Diagram FLC Model Proposed in figure 9. The ATmega32 microcontroller can be used at AWI as FLC communication, actuators and sensors as well as processing data for FLC. Data from the microcontroller will be used by FLC to obtain the desired environment by manipulating the actuator. AWI can manage RFID-based product, box and pallet data collection for all warehouses, components and block diagram setup proposed in Figures 10 and 11.

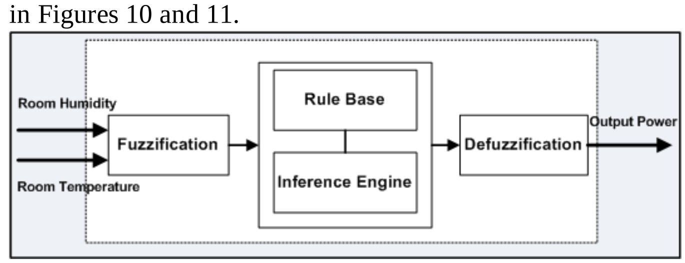

Figure 9: Block Diagram FLC Model Proposed

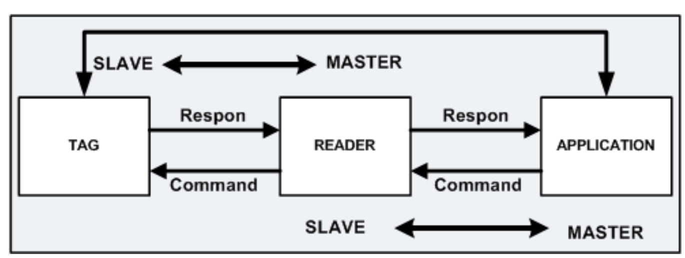

Figure 10: The Basic components of RFID

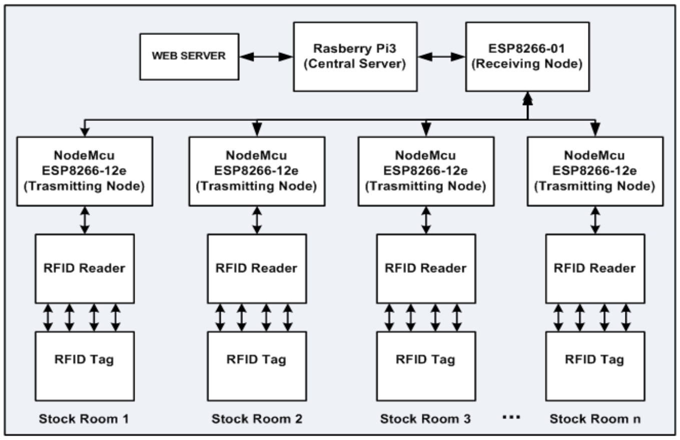

Figure 11: Block Diagram Setup Proposed

4.3. Smart Forecasting System

Smart Forecasting System (SFS) to predict customer demand and orders to suppliers so that they control stock and control. Using forecasting can reduce inventory costs, optimize stock, increase customer loyalty and increase profits. Fast Moving Consumer Goods (FMCG) is managing logistics and supply chains between producers and customers, how customers get services faster, lower costs and better [46]. FMCG with the presence of RFID technology makes improvements in efficiency, information accuracy, and speed. So that RFID is widely applied to logistics [47]. Figure 12 illustrates the scope of forecasting and the importance of management for predictions. Feedback data from Smart Logistic, RFID-based product data, availability of sensor-based storage data and inbound and outbound patterns in the warehouse are the basis for forecasting and planning.

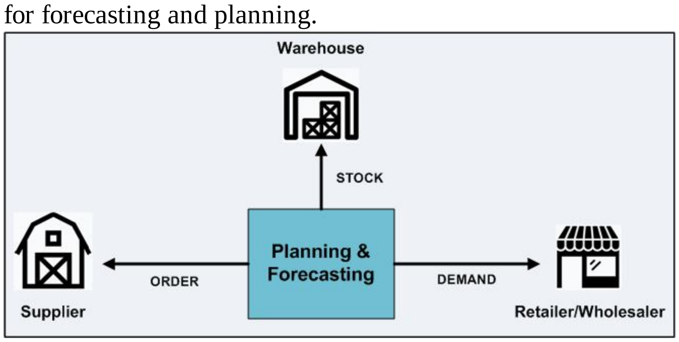

Figure 12: SFS Area

The forecasting method using an artificial intelligence approach results in better accuracy[47]. The SFS proposes using an artificial neural network (ANN) model with Least square support vector machine (LS-SVM) and Extreme Learning Machine (ELM) learning methods. This model consists of 3 layers, namely the input layer represents the factors that influence forecasting, the hidden layer which is the computational process and the output layer produces forecasting results, as in Figure 13.

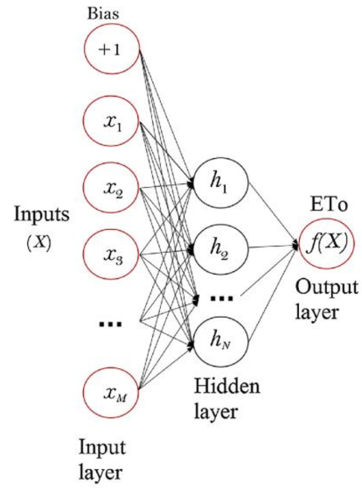

Figure 13: Structural architecture of ELM [48]

4.4. Smart Decision Support System

The consequence of applying the SCN model is communication with the warehouse manager in determining decisions that result in a long time. Therefore we need a Smart Decision Support System (SDSS) that can make it easy to unite ideas and views among members quickly and accurately. The managerial level in the presence of SDSS is helped to find the best alternative in evaluating SCN performance. Multi-Criteria Decision Making (MCDM) is a method of decision making to determine the best alternative from some alternatives based on certain criteria [49]. In developing SDSS, developing the MCDM framework with a combination of the best worst method (BWM), a new additive ratio assessment (ARAS) method and the Multiplicative Utility function. BWM has better consistency than AHP [50] and has a more efficient weight calculation [51]. ARAS method is used to solve multi-criteria problems [52]. ARAS method and Multiplicative Utility function is used for evaluation and ranking. SDSS can be used for decision making in evaluating suppliers, products, transportation, and retailers/wholesalers.

5. CONCLUSION

We have designed network architecture and work systems as well as SWMS integration models with 4 sub-systems: Smart Logistics, AWI, SFS, and SDSS. By combining RFID technology, WSN, GA algorithm, AHP algorithm, Fuzzy algorithm, LS-SVM, and ELM artificial neural network models, BWM forecasting models, ARAS function models and Multiplicative Utility Functions. The choice of technology and algorithm with a combination of the results of previous studies are expected to achieve the best optimization. The next research will implement and test the combination of technology and algorithm proposed.

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