Model Design of Adaptive Production Planning and Inventory Control (PPIC) in the Food Industry

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ABSTRACT

Raw materials for the food processing industries include plant, animal and marine products, packaging materials, food ingredients and food chemicals. Major food companies produce large quantities of semi-processed and consumer food products in continuous-flow operations, that must be utilized. The conventional PPIC Model cannot anticipate unpredictable problems and handle disturbances occurred in their production systems effectively. Thus, the objectives of this research are to develop a PPIC Model, which is suitable for food industry, and propose Disturbance Models to increase the PPIC function in order to control disturbances occurred in the production system.

The developing PPIC models for food industry including Demand Management by Artificial Neural Network, Master Production Scheduling by Fuzzy Multi Objectives Linear Programming, Raw Material Inventory Planning by EOQp, Raw Material Inventory Control by Continuous Probabilistic Review System by Reorder Point, Material Requirement Planning for Production, Scheduling by Flow Shop Scheduling Genetic Algorithm and Distribution Routing by Travelling Salesman Problem Genetic Algorithm (TSPGA). Whereas, the Disturbances Control Model incorporating Operational Disturbances Control Model and Variance Model. The disturbances models can help in controlling the disturbances occurred and updating the % Loss Raw Material and % Loss Finished Good to adapt the PPIC System.

Keywords: Food Industry, production system, PPIC models, disturbances models, control.

1. PREFACE

1.1 Background

Food industry has become one of the largest industries in Indonesia in terms of number of companies and added value. With the increasing population number in Indonesia, the needs for food will increase accordingly. This is in line with data from the Central Bureau of Statistics (BPS) that states Indonesian population growth in 2010 was at 15.21% with percentage of average household spending for food consumption in 2009 reached 50.62% dominated by prepared foods at 12.63% (BPS, 2010). With the increasing demand of food, the opportunity for food industries will continue to grow bigger.

Production Planning and Inventory Control or abbreviated as PPIC has become one of the main activities in a production system with purpose to plan and control production input in an industry as efficient as possible to produce output according to the market demand. With input supply condition that is prone to disturbance, production activities with the level of interaction that involves many parties, to fulfill volatile fluctuations of market demand, the PPIC system of food industry will find complexities and dynamics that continue to increase. Conventional PPIC model will find it difficult to anticipate unpredictable problems or control disturbances with satisfactory results. This is because the current practical conditions have a level of complexity that tends to grow rapidly, resulting in decreasing adaptability and level of flexibility of the PPIC models.

According to Ho (1989) there are several forms of uncertainty that affect production process, which categorized into two groups: environmental uncertainty (including demand uncertainty and supply uncertainty) and the system uncertainty (uncertainty associated with the production process). Besides the literature review recommends the use of conceptual model (including safety stocks), Artificial intelligence-based models (fuzzy sets theory, neural networks and genetic algorithms) as well as analytical models (including mathematical programming) in the production planning under uncertainty [11].

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PPIC system of medium - short term consists of several subsystems or sub-functions including Demand Management, Master Production Scheduling, Material Requirement Planning and Scheduling [5]. If each subsystem is described as system building blocks, the failure of one or several subsystem blocks will result in system failure, because the unreliability of one subsystem will affect overall system reliability [9].

Considering the dynamics of market demand and the need to control disturbance in operational production system, the agroindustry with its special characteristics requires the utilization of reliable models that can support the PPIC activities.

PPIC system application development in the modern agroindustry companies today is the utilization of Enterprises Resources Planning (ERP) system. PPIC is an ERP module that is most frequently applied. PPIC system currently being developed in ERP is still limited and shows many weaknesses. In addition, ERP still needs additional decision support facilities in its planning area. Koh & Saad (2003) even suggested the underperformance of ERP in facing uncertainty [12].

1.2 Research Objectives

1. To develop a PPIC model suitable for the production system of Food Industry.
2. To perform a model design that can control disturbances in production system of Food Industry.
3. To perform PPIC model design that can control disturbances in production system of Food Industry (Adaptive PPIC Model of Food Industry).

1.3 Novelty

The output of this research contributes to the scientific enrichment of Industrial Engineering and Management, especially in the area of production system by applying models that are suitable with the uncertain conditions. The design of Adaptive PPIC Model of Food Industry is the expansion of conventional PPIC model which is an integration of reliable models of the PPIC sub functions which are also complemented with Disturbance Control model that has an adaptive function of PPIC model.

2. LITERATURE REVIEW

2.1 Food Industry

Food industry is part of the food system that includes production, processing, distribution and consumption of food products in the agroindustry. Raw materials for food industries include agricultural products, livestock, marine products, packaging materials, food flavorings and chemicals for food [4].

2.2 Production Planning and Inventory Control

Production Planning and Inventory Control (or commonly abbreviated as PPIC) is part of the production and inventory management activities. The purposes of PPIC activities is to perform production and inventory planning in utilizing resources effectively and carry out production and inventory control by making adjustment between the plan that has been made and the daily production activities. The problems that must be faced in the PPIC include: what adjustments, how many, when, who and how the adjustments should be done [3].

2.3 Inventory Planning and Control

A strategy is required to manage independent inventory demand because it is influenced by external factors. In the inventory control system, there are two systems, namely: Continuous Review System (commonly referred to as the Q system) and the Periodic Review System (often called P system) [15].

3. RESEARCH METHODOLOGY

Research will be conducted by stages in accordance with figure 1 below. Based on the identification of the characteristics of the production system needed in the food industry, a model of PPIC for Food Industry was then developed. Subsequently, the Disturbance Control Model was developed in accordance with the PPIC Food Industry model by performing the disturbance identification process that occurs in the production system of food industry.

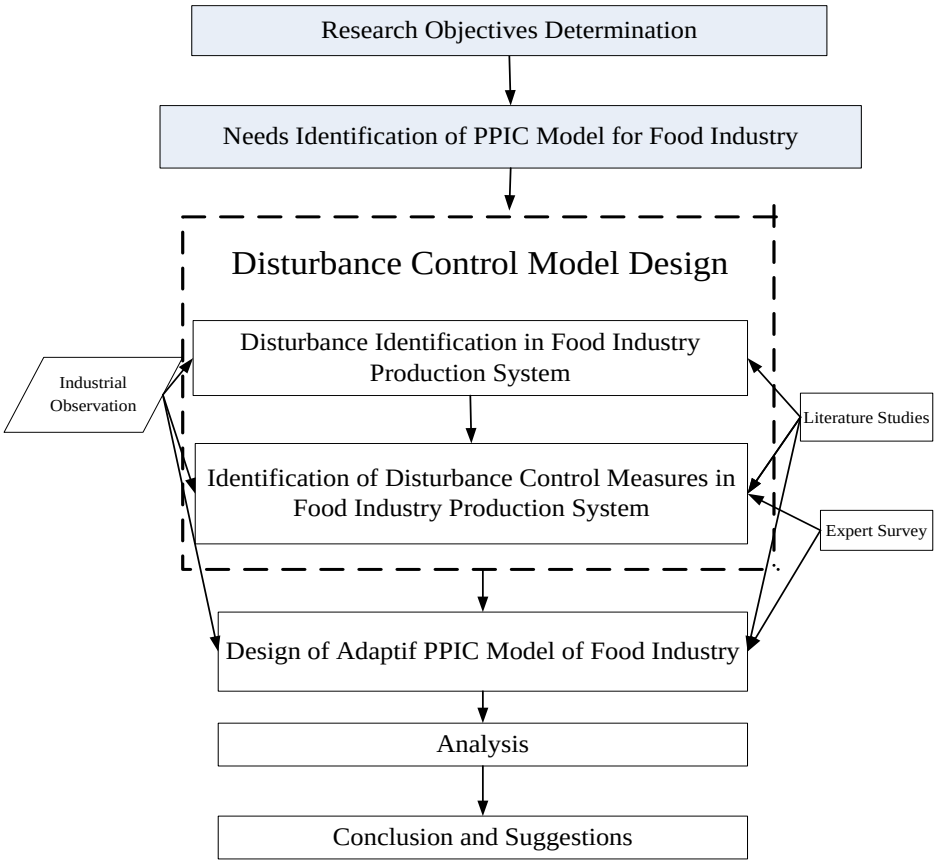

Fig 1 Research Process

4. RESULTS AND DISCUSSION

PPIC model development in this research refers to the activities of Manufacturing Resources Planning (MRP II) developed by Fogarty [5], in which the researcher determine the PPIC activities began with demand that has to be managed by the company. The company must be able to meet the demand effectively by utilizing the production inputs (supply) efficiently.

PPIC scope of activities begins with the demand management followed by planning quantity of production based on demand as well as considering the production capacity with economical production costs. The PPIC activities then proceed with planning and controlling the inventory of raw materials and finished products to meet production needs, which can minimize inventory costs as well as makespan scheduling for timely delivery of finished products to meet the customer's needs. In general, the main subfunctions in PPIC activities include: Demand Management, Master Production Scheduling, Material Requirements Planning, Scheduling and Distribution Requirements Planning that can represent the company's scope of PPIC activities.

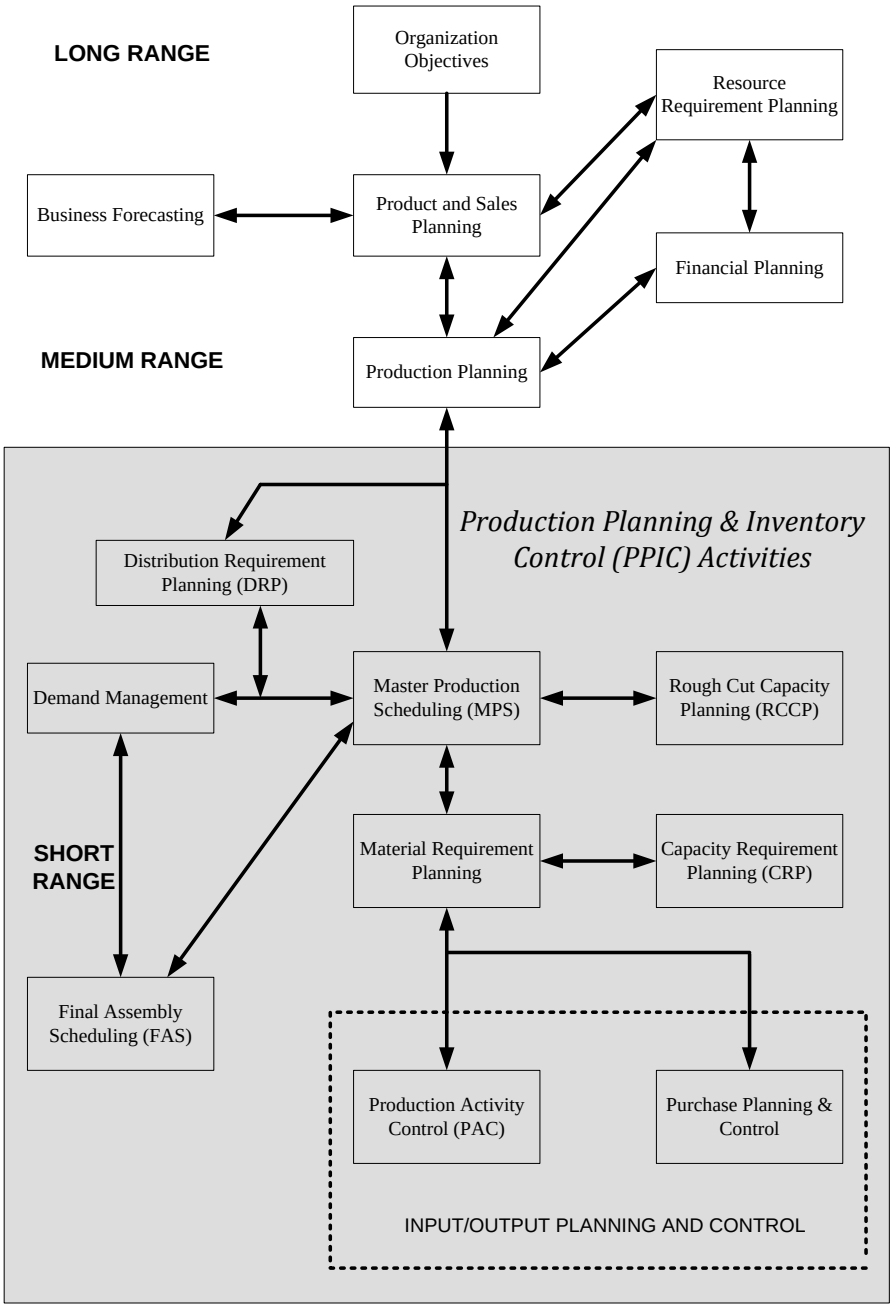

Fig 2 Production Planning & Inventory Control (PPIC) – Part of Manufacturing Resources Planning (MRP II) [5]

4.1 Development of PPIC Model for Food Industry

In general, to maintain the continuity of the business, the food industry has a goal of production systems that can minimize losses and maximize production utilization. To enhance the effectiveness of PPIC function in the food industry, PPIC submodel used must be an effective submodel and have considered the characteristics of agroindustry raw materials. In addition to support the company's goal to maintain the sustainability of the customer demand fulfillment, the company must always maintain the quality and safety level in accordance with the standards of food products that have been set.

For these needs, the food industry must be supported by a reliable suppliers who are able to cooperate under certain contract of cooperation agreements. Food industry should also consider the percentage of loss in PPIC calculations due to the occurrence of inconsistency and uncertainty.

The following are the considerations in production planning and inventory control in the food industry by taking into account the characteristics of perishable, seasonal and bulky agroindustry raw materials: [10]

1. The need of multi suppliers to maintain the continuity of raw material supply
2. The need of economical safety stock of raw materials so as not to contribute in

lowering the quality of raw materials due to storage period.

3. The need of appropriate order measurement of raw materials and according to needs.
4. The need of extra safety stock of raw materials and extra safety stock of finished products to anticipate failure in production process and increase in percentage of defective finished products due to variability problem of raw material quality that cause the high percentage of production loss.

To improve the reliability of the PPIC system run by the food industry companies, the utilization of appropriate production planning models is proposed to address the uncertainty in accordance with the journal review by Mula [11] namely:

1.Demand Management (DM) Model with performance criterion is minimizing the error, using the method of Analytical Neural Network (ANN).

ANN method has superior performance in estimating the demand based on past sales data pattern to generate an error value (eg Mean Square Error criterion) test results that are very small compared to other demand forecast methods (such as Decomposition method, Exponential Smoothing and Moving Average methods) [ ]

2.Master Production Scheduling (MPS) Model with the criteria of minimization of production costs and maximizing the utilization of production using a Fuzzy Multi-Objective Fuzzy Linear Programming model

The availability of agroindustry raw materials that are uncertain in quantity and quality as well as the possibility of internal disruption of production led to tolerance in the use of raw materials, production completion time and production costs. According to Mula, et.al. (2006), the optimization model by considering the fuzzy numbers is in accordance with the conditions of uncertainty in production planning activities. Therefore, MPS model using optimization model of Fuzzy Multi Objective Linear Programming will get a reliable result of production volume planning as a model of PPIC's decision in the food industry [16], [17].

3.Raw Material Inventory Planning (RM Inventory Planning) Model with inventory cost minimization criteria using the Material Requirements Planning (MRP) method with lot determining technique of Economic Order Quantity (EOQ) that taking into account the life of raw materials (EOQp) and the existence safety stock [7].

4.Raw Material Inventory Control (RM Inventory Control) Model is based on the Continuous Review System with criterion of size optimization of raw material order that uses the reorder point (ROP) calculation and safety stock in raw material procurement activity.

Considering the characteristics of raw materials that have a limited shelf life, PPIC if Food Industry should use the RM Inventory Planning decision model by using a Material Requirement Planning (MRP) model with lotting Development Economic Order Quantity /EOQp method which has considered the shelf life of raw materials.

Taking into account the quality of varied agroindustry raw materials, the use of models of inventory control policies is proposed: Continuous Review System Probabilistic to calculate stock opname of raw materials and finished products inventories periodically and adding safety stock of raw materials for planning the time of raw materials order with suppliers as well as determining point of order to the supplier (ROP) for the RM Inventory Control calculation.

5. Scheduling model using Flowshop-Genetic Algorithm Scheduling method [6].

6. Distribution Requirement Planning model with determination of distribution channel based on Travelling Salesman Problem-Genetic Algorithm (TSPGA) method [13]

Genetic Algorithm method is the recommended meta-heuristic method to be applied to practical issues that focus on finding the optimal parameters. Therefore, in determining the production sequence of product items in the food industry as well as the determination of distribution channels for distributors or consumers, the Genetic Algorithm method is used to achieve close to optimal output model performance.

4.2Disturbance Control Model

The definition of disturbance in this research is the Disturbances in the production

system that are issues causing the production system to become unstable due to deviations between planning and actual, hence adjustment measures are needed which aims to restore the stable production system. In accordance with the PPIC function, means the minimum deviation between plan and actual production (for the next discussion will be referred to as variance).

In production operations, in connection with the PPIC discussion in this research, there are three types of disturbances that occurred and the variances that arise due to the disturbance. In this paper there is no discussion on the relations between disturbance and variance occurred. Disturbances that are identified include:

1. Supply Disturbance, including: delays in raw material delivery due suppliers' difficulties to obtain quality raw materials for processing or production disruption at supplier factories
2. Production System Internal Disturbances (raw materials, operators, machinery/equipment, energy, policy/culture/technology/environment), including:
    a. Rejected raw materials because the condition is no longer fresh
    b. Jammed or damaged machinery that prolong the completion of production
    c. Negligence of production operator or production errors resulting in the output product does not meet the standard or reject.
    d. Power outages of more than 1 hour that causes production halt and WIP cannot be used anymore
    e. Changes in production or inventory policies that causes production target cannot be achieved.
3. Demand Disturbances, including: negative issue about product image causes significant downward trend of demand or big promotions that cause significant surge in product demand.

Variances that are identified include:

1. Variance a is a deviation between Purchase Order (PO) of product item generated by demand forecast (DM – ANN) and Actual Sales
2. Variance b is a deviation between raw material PO to supplier and actual raw material delivery from supplier.
3. Variance c is a deviation between the quantity of raw material inventory generated by MRP calculation and actual Stock Opname of raw materials.
4. Variance d is a deviation between MPS output of production plan and actual production
5. Variance e is a deviation between completion target of production of Flowshop Genetic Algorithm Scheduling output and actual production makespan.
6. Variance f is a deviation between distribution plan in accordance with RO and FO orders and actual distriution revenues
7. Variance g is a deviation between travel time of Genetic Algorithm output distribution channels and actual distribution travel time.

In general, disturbance control model consists of Operational Disturbance Control Model and Disturbance Variance Model. The Operational Disturbance Control Model is useful to to provide recommendations to control the disturbance that occurred in the operations as well as keep records of operational disturbance and concrete operational measures taken to control the disturbance. The Variance Model is useful to calculate percentage of variance and the calculation of Loss RM percentage and Loss FG percentage based on the results of variance percentage calculation. This calculation is done periodically and will update the percentage Loss RM and Loss FG that will be included as one of the summin factors in PPIC Model. With the updated percentage of Loss RM and Loss FG periodically, means the periodic PPIC adjustment process has been implemented thus it is called Adaptive PPIC model.

The Disturbance Control Model is also able to provide Follow Up recommendation for disturbance control policies by PPIC division or other non-PPIC divisions based on the recapitulation of disturbance frequency calculation, the determination of disturbance severity, determination of disturbance impact and source.

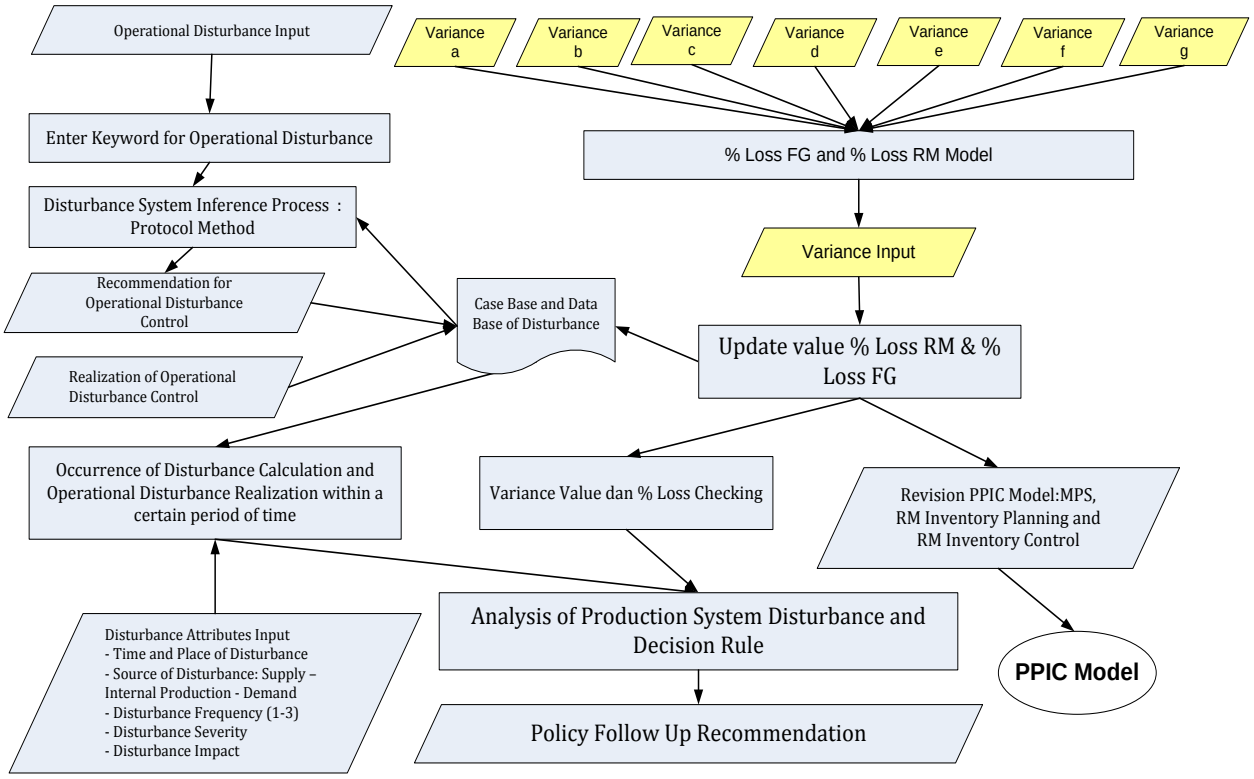

Fig 3 Disturbance Control Model

To handle the occurrence of production system disturbance, the percentage of Loss Raw Material (% Loss RM) and% Loss Finished Good (% Loss FG) calculation is conducted periodically based on the calculation of the a, b, c, d, e, f and g variances of each period. The success indicator of Adaptive PPIC function is to meet the performance criteria for each PPIC model and to minimize the percentage value of variance so that it can lower the percentage value of Loss Raw Materials and Loss FG in accordance with the target specifications of the company.

4.3 Adaptive PPIC model in Food Industry

The variability rate of raw materials in production process of food industry could potentially lead to disturbance in the internal system of production process, and later causes the execution of production does not match the production plans, so it is necessary to update the inventory system with a shift in production plans. Furthermore, the 'adjustment' of PPIC should be done immediately so as not to disturb the fulfillment of consumer demand. The frame of reference is in accordance with the following figure.

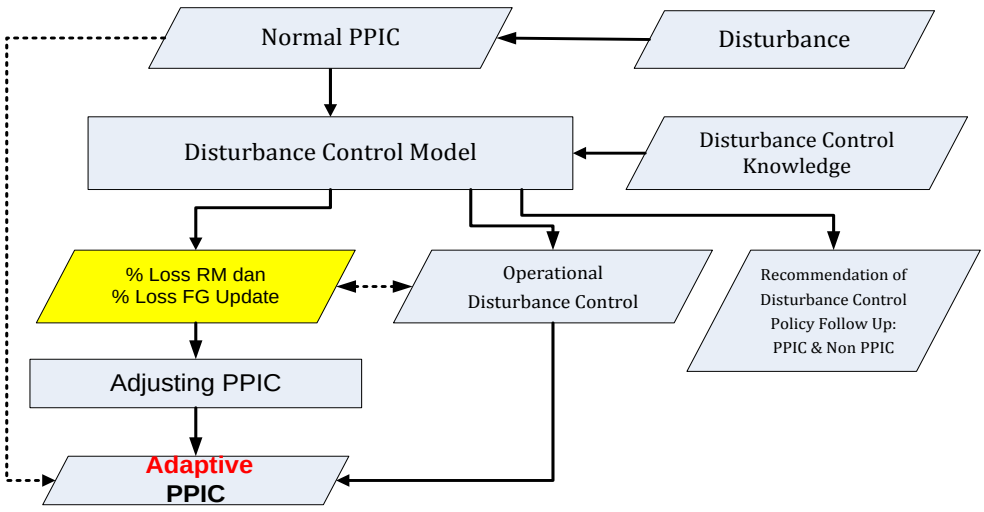

Fig 4 Adaptive PPIC Frame of Reference

The design of Adaptive PPIC model being developed is still on the conceptual stage and is developep based on operational condition of production system in food industry with characterictics as follows:

1. Food industry is a middle-upper scale industry that has applied PPIC decision model, or uses computer assisted heuristic models to support calculation.
2. Food industry produces products offered by outlets of modern market and conventional market regularly (Regular Outlet/RO) which are listing products and fixed order products.
3. The output product has a relatively short shelf life (days up to a maximum of 1 week)
4. Food industry uses agroindustry raw materials with various length of shelf life (days to months), various quality and require special method of storage to maintain their quality.

The relation of PPIC model and Variance Disturbance Model can be seen in the following table and figure. In the figure it can be seen that after PPIC is made by using the proposed model, at the end of the period (eg, daily or weekly) the variance value (a, b, c, d, e, f, g) as well as Loss FG and Loss RM percentage are calculated based on production data. The percentage values of variance a, f and g are associated with the percentagce of Loss FG, while the percentage values of variance b, c and d are associated with the percentage of Loss RM. The results of these calculations will update the value of Loss RM percentage that will be the input for the RM Inventory Planning & Controlling model and will also update the value of Loss FG percentage that will be the input to the MPS model.

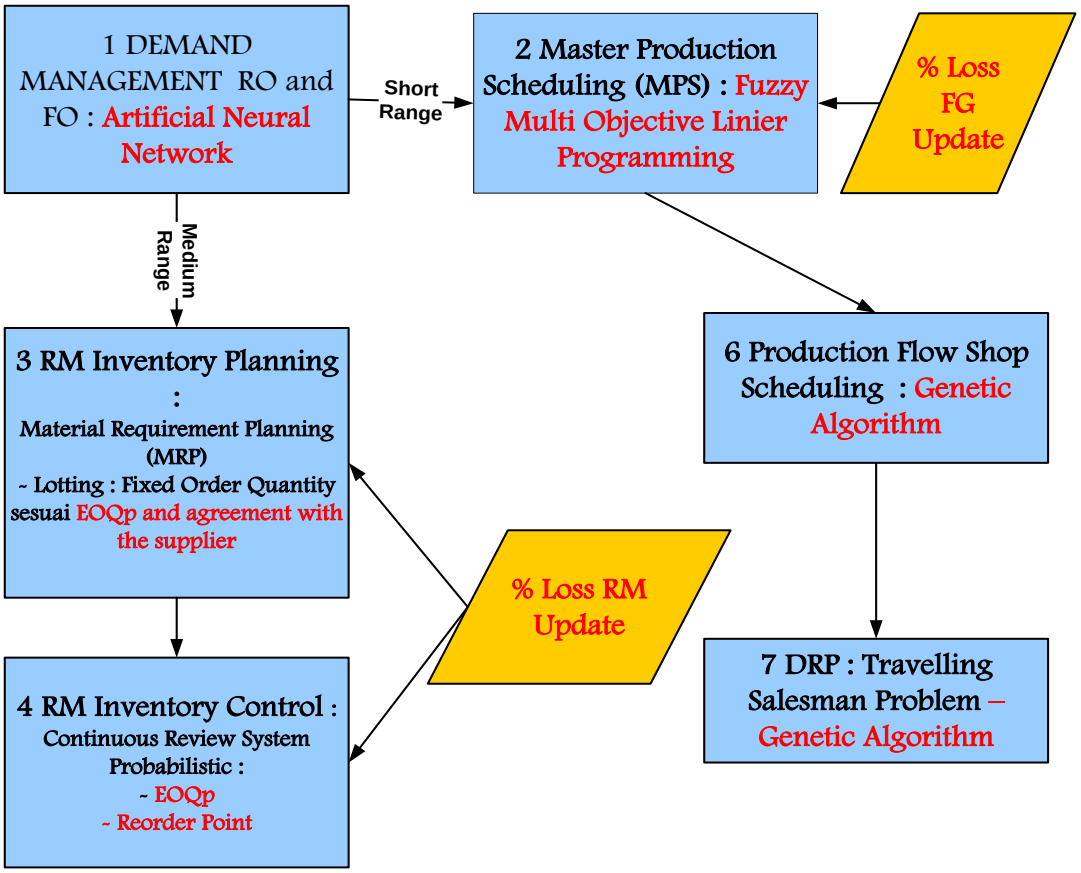

Fig 5 Relation of % Loss FG Update, % Loss RM Update and PPIC Model

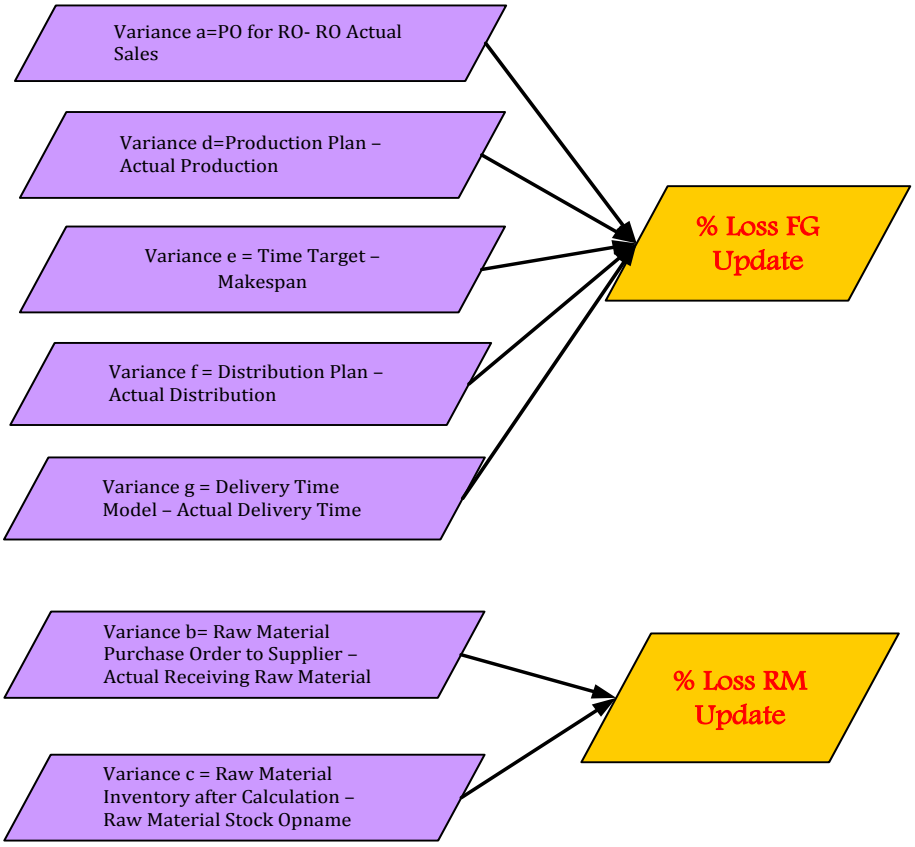

Fig 6 Correlation of Variance with % Loss FG Update and % Loss RM Update

TABLE 1
CORRELATION OF PPIC FUNCTION AND DISTURBANCE INDICATORS

Fungsi PPIC *PPIC Function*	1 DM	2 MPS	3 RM Inv Planning	4 RM Inv Controlling	6 Sequencing	7 DRP
Approach under Uncertainty	Artificial Neural Network (ANN)	Fuzzy Multi Objective Linear Programming	MRP Heuristik : Lotting EOQp	Continuous Review System : Reroder Point	Flow Shop : Genetic Algorithm	*Distribution Sequence*: Genetic Algorithm
Performance Criteria	*Error Minimizing*	*Production Cost Minimization & Production Utilization Maximization*	*Minimization of RM Inventory Cost*	*Minimization of Understock & Overstock*	*Minimization of Makespan*	*Minimization of Distribution Travel Time*
Disturbance Indicators	*Variance a*	*Variance d*	*Variance b*	*Variance c*	*Variance e*	*Variance f, g*
Adjust PPIC Model	*Add % Loss FG to MPS*		*Add % Loss RM as Safety Stock to RM Inventory Planning & Controlling*		---	---
Indicator of Controlling Achievement	↓ ↓ *Variance a*	↓ *Variance d*	↓ *Variance b*	↓ *Variance c*	↓ *Variance e*	↓ *Variance f, g*

5. CONCLUSION

The design of Adaptive PPIC Model of Food Industry has a PPIC submodel collaborated with disturbance control model suitable for the food industry. PPIC Adaptive model has an added value compared to the conventional

PPIC model due to its intelligent and adaptive PPIC sub-function that is capable to improve the food industry performance for effective and efficient production system purposes. Measured performance criteria are: minimizing the error in demand forecasts, production cost minimization, maximizing the production utilization, minimizing inventory costs of raw materials, minimizing makespan, minimizing travel time of distribution

The Adaptive PPIC of Food Industry model that has been designed conceptually should be complemented with operational model to clarify the performance improvement of the design model. Besides that to improve the effectiveness and efficiency of PPIC function, the Adaptive PPIC of Food Industry model design may also be integrated further by developing it into the Intelligent Decision Support System for Adaptive PPIC of Food Industry.

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