

THE KANBAN- RFID MODEL BASED ON CLOUD COMPUTING

Satit Kravenkit*

Received: March 07, 2018; Revised: September 18, 2018; Accepted: September 18, 2018

Abstract

The Kanban system driven by RFID technology for identifying individual products, has been developed to deliver the finished products to meet the customer's actual requirements and improve the automated production process at the manufacturer. However, the developed model focuses entirely on the IT infrastructures, thus placing a financial burden on small and medium size enterprises. To eliminate this problem, a cloud-based infrastructure for a Kanban-RFID system with low costs through reducing the waiting time to enter into the production process is proposed. The proposed Kanban-RFID model is divided mainly into 2 layers; the enterprise and cloud computing layers. In each layer, the primary functions and communications of the service components were determined so that the Kanban-RFID system could correspond directly to the mechanism of the production process and economically place it on both IT and cloud computing infrastructures. To evaluate the performance of the proposed system, rice mill manufacturing was used as a case study in order to find 2 criteria metrics. Firstly, the results evaluated through the simulation model using Arena simulation showed that the amount of waiting time spent on the operational process of the proposed model, compared with the traditional model (push system), decreased from 201.65 to 88.19 min (56.26%). This output subsequently increased the number of finished goods delivered to the customers from 615 to 651 (5.73%). Secondly, the cloud-based proposed system gained 18.27% of the break-even point at 1 year 7 months and 27.14% of the return on investment.

Keywords: Kanban, RFID technology, cloud computing, simulation model

Department of Computer and Information Science, Faculty of Applied Science and Engineering, KhonKaen University, NongKhai, 43000, Thailand. Tel. 0- 4241- 5600; Fax. 0- 4241- 5699; E-mail: satikr@kku.ac.th, satit41617590@gmail.com

** Corresponding author*

Introduction

The Kanban (Nomura and Takakuwa, 2004) which is based on lean manufacturing and was originally introduced by the Toyota Motor Corporation contributes to the increased effectiveness of the production process in manufacturing. The Kanban can be introduced into the production line within the production system, also known as just-in-time manufacturing. Conventionally, the characteristics of Kanban (Wan and Chen, 2008) are broadly divided into 3 types: Kanban card, look-see, and electronic Kanban; however, the outstanding Kanban characteristic is the card signs which represent such specific information as a piece of material's name, the description, and quantity, in order to consistently create a work flow in the production process and deliver the requested materials effectively.

The Kanban system differs completely from the traditional manufacturing strategy which employs the push system. The objective of the push system is controlled by planning with material requirements planning, so as to produce the products that meet the requirement of the customer. Meanwhile, the Kanban system adopts the pull production system where materials are processed at the upstream process point by receiving instructions from the downstream process point.

Kanban has been the subject of several case studies; Wan and Chen (2008) proposed web-based Kanban systems based on PHP and MySQL. The features effectively provide real-time tracking and monitoring of the information content compared to physical Kanban. Human errors are reduced because of the automated transactions. Naufal *et al.* (2012) proposed the installation of the Kanban system into the production process in a Malaysian factory. This study demonstrated that the time spent on the production process and the level of inventory are reduced. However, the limitation for using the Kanban system in the production process is the loss of the Kanban cards and the complication of the Kanban process; thus, an improvement for implementing the Kanban system in the automation process is highly required.

Radio frequency identification (RFID) technology is one of the innovative technologies considered efficient for the automation process. RFID is a wireless system that identifies an individual object using a radio wave (Zhu *et al.*, 2012). RFID was introduced during World War II to detect the aircraft of either allies or enemies. Subsequently, RFID was introduced into the railways and the automobile industry. More recently, RFID technology has been applied by the retailer Wal-Mart to manage the process of logistics and the supply chain (Ngai *et al.*, 2008).

The RFID system comprises 2 parts. First, the tag or label (transponder) is responsible for storing the information identifying objects of interest (Ngai *et al.*, 2008; Zhu X *et al.*, 2012). Secondly, the RFID reader is responsible for recording and reading the information within the tag. The highlight of recording and reading the data of RFID is that readers do not need to touch the tag; that is, the RFID reader makes it possible to read quickly through various surfaces such as plastic, water, and solid material.

The previous studies have proposed RFID in a variety of industries. Wang *et al.* (2008) integrated RFID into the inventory control system in a thin film transistor liquid crystal display in Taiwan. The results suggested an improvement in product inventory. To illustrate, the cost for inventory management decreased 6.19% and the turnover of inventory increased 7.6%. Jarupathirun *et al.* (2009) presented a case study the use of the e-Kanban system to reduce the operation and logistics for a parts' supplier within the automotive industry. The outcome demonstrated improvements in production lead times, financial costs, effective and efficient work processes, and reductions in waste. Furthermore, Su *et al.* (2009) presented a solution for Kanban management based on the RFID system. The system process is able to greatly enhance the circulation velocity of the Kanban system, and decrease the rate of mistakes when compared to the traditional Kanban management. Also, the results presented high accuracy and the benefit of data for the management information system.

In addition, the intelligence system integrated with RFID was proposed (Yeh *et al.*, 2011). This study retrieved the customer's shopping behavior by focusing on the product movement in and out of the shelves attached to the reader. The result indicated that the intelligence of the RFID system could analyze the customer's needs for specific products, suggest to and provide them with extra descriptions, and detail the promotion of a product. Also, Tabanlı and Ertay (2013) proposed the Kanban system integrated with RFID into the automotive belt industry. The results suggested that for production logistics the profits rate increased. Particularly, the RFID integrated into the manufacturing execution system was also proposed (Zhong *et al.*, 2013) to obtain and monitor the real-time traffic of materials through a production line. The manufacturing execution system enabled the enterprise to reduce 90% of its paper use, and the level of the inventory along the production line and the production cycle decreased by 27% and 22.6%, respectively.

Recently, an application integrating RFID technology has been designed on cloud computing. Cloud computing (Mell and Grance, 2011) is technology adopted to provide various IT services that are primarily designed to reduce cost for users. There are 3 types of cloud deployment models (Alfonso *et al.*, 2013; Singh *et al.*, 2015). First, the public cloud provided by third-party service providers offers customers the use of computational resources which are charged based on actual service usage. Secondly, the private cloud is managed within a company by creating a data center within the company for the cloud computing. Lastly, the hybrid clouds are those taking the merits and advantages of both the public and private clouds into account. The critical data and services with the control are stored in the private cloud, while trivial information is stored in the public cloud. This research focuses on the public cloud; the pricing model (Altmann and Kashef, 2014) defines the public cloud, the so-called "pay as you use" concept in which users are charged for the resources they consume, thus enabling users to achieve scalability and cost effectiveness, particularly for a variation in workload.

Although the previous works attempted to propose the Kanban integrated with the RFID system, the limitation of these previous studies remains the lack of a model approach in which Kanban integrated with RFID has been deployed in cloud computing. Thus, the limitation leads the small and medium size enterprises (SME) to directly pay the costs, especially of the IT infrastructure of the proposed system.

In this research, a model of a low cost Kanban-RFID system based on cloud computing to improve the traditional system and reduce the waiting time of the operational process is proposed. The proposed model is divided into 2 layers: the enterprise and cloud computing. In each layer, the basic function and communication of the service components are determined. In the experiment, a rice mill operation was selected and the operations were created using an Arena simulation model.

The remainder of this paper is organized as follows. In the materials and methods section, the author proposes the concept of the Kanban-RFID model and evaluates the model with determined criteria. In the results and discussion, there is an interpretation of the results of the Kanban-RFID model. Finally, there is a brief conclusion to the study.

Materials and Method

In this section, a proposal is made for the Kanban-RFID model in cloud computing by demonstrating the primary functions and communications of the service components. Then, the Kanban-RFID is implemented in the rice mill operation using the Arena computer simulation to evaluate the results.

The Proposed Cloud Based Kanban-RFID Model

The proposed Kanban-RFID model is divided into 2 layers, the enterprise and cloud computing layers, as shown in Figure 1.

In the enterprise layer, initially there is demonstrated the direction of the materials or products moving from downstream to upstream

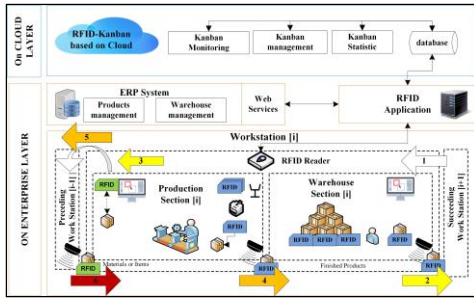


Figure 1. The proposed Kanban-RFID based on cloud computing

as do the assigned functions through a model workstation. An enterprise workstation was designed comprising 2 sub-sections: a production section and a warehouse section. The operational process of the production and warehouse sections varies according to business characteristics. It is noted that individual businesses may have different preceding and succeeding workstations before and after the present workstation [i].

The process of the communication and product movement of the Kanban-RFID model in the production line layers is assigned as follows. In the first step, the requested customer signal from succeeding workstations [i+1] is sent to the warehouse station [i] via the computer device installed with the Kanban-RFID application. Then, at the warehouse station [i], the requested orders are attached to the RFID tag so that it is read by the RFID reader prior to the delivery to the succeeding workstation [i+1], as shown in process step 2. As soon as the operational process of step 2 is completed, the signal instantly sends, via the computer device at the production workstation [i], for the replacement of the products previously delivered in the warehouse station [i], as shown in step 3. For the purpose of resource economy, before the materials are transferred to the production operation [i], the old RFID tag is removed from the material so that it can be reused as the RFID tag for new materials from the preceding workstation [i-1]. Meanwhile, after the new production [i], all the finished goods are attached to the new RFID tag. In step 4, the finished goods are transferred to the warehouse [i] through the RFID readers. Simultaneously, the

ordering items signal informs the preceding workstations or warehouse [i-1] to order the materials, as shown in step 5. In step 6, the materials attached to the RFID tag move from the workstation [i+1] to the production area [i].

With the RFID application, the data of the RFID tags from the first layer are transmitted to the RFID antenna and readers, respectively. The RFID application installed in the host within the enterprise, responsible for managing the various standards of the RFID readers and filtering the redundant RFID data which are subsequently transmitted to the cloud database (Tian *et al.*, 2013), is connected to a RFID reader. The data on the RFID tag retrieved from the workstation [i] are subject to the addition of related data available on the enterprise resource planning (ERP) system, which may include such Kanban information as the bill for the material and other specific data of certain products.

The ERP system manages the process of the business within the enterprise. Several application services under ERP have been developed to serve the requests of individual organizations. In the proposed model, the product and warehouse management services were selected because the product management service records the primary information related to the product and bill of materials (BOM) corresponding to the required data of the Kanban-RFID system. In addition, the warehouse service was selected because it contains the information related to the remaining number of products and safety stock of products, which have been previously calculated to maintain the reorder point. Such action occurs through the web services. These services enable the various applications and different platforms to connect and exchange (request and response) the required data where mere names and the argument type of the provided function are required. Eventually, the data of the RFID application are combined and sent to the Kanban-RFID in the cloud.

As far as the cloud layers are concerned, the public cloud is selected as the IT infrastructure for installing the Kanban-RFID applications and making them available in respect to the software as a service. The selected

public cloud is easy to configure and affordable, especially for the SME. Presently, the various pioneer public cloud providers such as Window Azure, Google Cloud, and Amazon Web Services provide a variety of series and different performances of the instance servers allowing the customers to deploy infrastructures quickly to meet their business requirements. It is intended that the acceptable performance specification with the low cost of the instance server will be selected as the environment system for installing the Kanban-RFID application.

For the database, 2 types are offered for the customer, either the cloud provision of a software database (standalone database) or the software database cloud-based virtual machine or VM database. The significant difference between the standalone database and VM database is that the standalone database has a better point of time restoration than the VM database. The firewall is easily configured. In addition, the standalone database provides geo-replication enabling the customer to copy data to secondary databases in the same or different data center locations. Thus, the advantages of various functions on a standalone database create a high cost per month. The VM database allows the customer to manage the setup of the database system; however, it creates a lower cost for performance, which is required in this research.

Within the Kanban-RFID application, 3 main functions are proposed, as follows. First, the Kanban monitoring product is responsible for monitoring the event and activity of the product moving from upstream to downstream through the workstations. This function enables an employee to track and trace the materials and products in real-time, and the finished goods attached to the RFID tags. Secondly, the Kanban management is responsible for configuration of the proposed system consisting of the basic functions, as follows:

(1) The items data: the basic data of materials or products must include the ID, names, and descriptions of the items or products, the level of the safety stock, and the remaining products in the warehouse.

(2) Data of operations in the workstation: the proposed function records the input,

output, and quantity of the materials and finished products, the list of materials and components for assembling the finished products (the BOM), and the demand showing either the required name and number of the materials from the warehouse or the assigned name and number of the finished products. Also, the routing for transferring the materials and products along the operation within the workstations is recorded.

(3) The reorder point and safety stock size: the administrators input the direct value or raw data of the reorder point and safety stock to calculate and create the ordering and assigned signal from the succeeding to preceding workstations.

Lastly, the Kanban statistics are responsible for reporting problems in the production operation such as the bottlenecks, deadlocks, and unequally or unfairly distributed resources in the real-time. This function also collects and analyzes the events of the Kanban-RFID process operation in respect to the benefits and unbalanced scenarios for the administrators.

For clarification, the proposed model for the selected rice mill operation and the creation of the model with the computer simulation are shown in the next section.

Experimental Method

In this section, the rice mill operations' process complying with the National Bureau of Agricultural Commodity and Food Standards' (2010) good manufacturing practices for a rice mill (GMP) is analyzed and selected as a case study for the proposed Kanban-RFID system. Rice products processed by rice mills, which are the middle party within the rice product supply chain, generate substantially high incomes in Thailand. If certain rice mill operations are improved, particularly the related processes, it may make it possible for this business sector to increase profits; thus, the rice mill operation became the case study. There are 3 steps for the experiment. First, there was analyzed and determined the operational process of the rice mill. Secondly, a metric evaluation was assigned. Lastly, the constraints of the input and output variables were determined and the simulation

model of the assigned rice mill operation was developed.

Analyzing the Kanban-RFID for the Rice Mill Operation

The Rice Mill Operation

A rice mill is one of the food manufacturing processes primarily responsible for transforming paddy into rice. The 6 operations of the rice mill conforming to the GMP were analyzed as follows:

(1) The purchasing and ordering operation: this is the first logistical step of the rice mill operation. The paddy is mostly supplied by farmers and rice merchants. According to the GMP, the source of paddy ordered and purchased should be tracked and traced. In addition, the paddy production must comply with good agricultural practice.

(2) Controlling the paddy quality operation: This step emphasizes inspection and quality control of the paddy grain. Some of the paddy is sampled for a quality test in the laboratory in respect of cleanliness, impurities, moisture, color, pests, and contamination by toxic substances. Afterwards, the paddy is weighed and transported to the paddy storage warehouse. If the moisture content of the paddy is higher than 14%, it is subject to a process to decrease the humidity within 24 h before taken to the paddy warehouse to prevent mold. The dehumidification of the paddy could be conducted through 3 means, sun drying, mechanical drying, and fluidized bed drying.

(3) The paddy warehouse operation: In this operation, the paddy grain is transported to the paddy warehouse. Practically, SME rice mills separate the area of the paddy warehouse into 2 sections, the new paddy storehouse and old paddy storehouse, to manage the effective and efficient - first in, first out (FIFO) - transfer to the milling process. It is noted that the temperature and relative humidity inside the warehouse are maintained lower than the conditions where microorganisms and pests in the storehouse can live or develop. Furthermore, both the warehouse and outside the warehouse must be thoroughly cleaned, particularly the floor which must be free from running water, static water, mud, and garbage.

(4) The milling operation: this activity can be divided into 5 procedures:

(4.1) Cleaning procedure: the paddy is transported to the cleaning equipment to eliminate unwanted items such as the rice husks, broken rice, soil, rocks, and contamination.

(4.2) Hulling procedure: The treated paddy is transported to the hulling equipment. Eventually, this procedure yields brown rice.

(4.3) Polishing procedure: the layer of rice bran is polished to obtain the rice grain.

(4.4) Grading procedure: the rice grain obtained from the polishing procedure is separated into the rice (whole grain) and broken rice.

(4.5) Packaging procedure: this procedure is included in the milling operation because the rice should be immediately packed into sacks or plastic bags after being milled completely. The package sizes will vary according to the customers' needs. Moreover, the rice containers must be protected from moisture and contamination.

(5) The rice warehouse operation: the time for storing completely packed rice products should be as short as possible and the number of products should be prepared to respond to customers' demands by means of FIFO.

(6) The transportation operation: the rice mills carefully make every transportation plan to reduce the cost of transport. The vehicles should be sufficient to serve the number of products and orders. Moreover, the vehicles must be protected from outside deteriorating factors such as water, contamination, and pests.

However, the particular focus is on the production and warehouse operations of the rice mill in the installation of the Kanban-RFID system; thus, the rice manufacturing processes are dealt with as follows.

(1) Controlling the paddy quality operation: After the paddy product is ordered and delivered, it is necessary to inspect the quality of the grain, including the moisture content, the shape and size of the grain size, and the grade of paddy to set purchasing prices. If the moisture content exceeds 14%, the rice produce is treated to reduce grain moisture by drying. To systematically evaluate

the procedure, the researcher assigned the received paddy to transfer to the drying process. Afterwards, the paddy grain is put into jumbo sacks and attached with the product identification.

(2) The paddy warehouse operation: In this step, the dried paddy is transferred to the warehouse. The number of paddy sacks are checked, counted and sent to the paddy warehouse. At the warehouse, the basic information of paddy products is recorded, including the number, level, grade types, warehouse position, and other relevant data.

(3) Milling operation: a number of paddy sacks are picked up from the paddy warehouse and moved for the milling operation through FIFO sorting. Afterwards, the paddy goes through the milling procedures, comprising cleaning, hulling, polishing, and grading. Lastly, the rice is packaged with its label code attached.

(4) The rice warehouse operation: In this step, the rice products are transferred to the warehouse after being arranged onto pallets. Again, the number of rice sacks are counted, recorded, and made ready for delivery to customers.

In the next sub-section, a solution for the operation is suggested by integrating the Kanban-RFID model into the rice mill operation.

Integration of Kanban-RFID into the Rice Mill Operation

Figure 2 shows the proposed Kanban-RFID system introduced into the workstation for the paddy and rice products. Each of the workstations is subdivided into the production and warehouse sections. The RFID readers are installed at the exit doors of the sections. The RFID tag is attached to both the paddy and rice products. In the milling production section, the RFID tags are reused as new RFID tags and are returned to the paddy quality control section. By means of the communication process of the Kanban-RFID system, the customer's order is sent to the proposed system via the monitoring device within the rice product warehouse section. Eventually, the relationship of the signal of the Kanban-RFID and the trigger

events start from step 1 (Table 1); thus, the proposed process is complete on step 9.

Metric Evaluation

Two metrics' evaluations of the proposed Kanban-RFID model are selected. First, the average of the amount of waiting time spent on performing the determined operational process compared between the traditional model and the proposed model. Secondly, the break-even point (BEP) and return on investment (ROI) are examined (Sarac *et al.*, 2010) to evaluate the investment in the proposed system.

Experiment Design

The conditions for the proposed operational process of the rice mill and creation of the simulation model using the Arena program were as follows:

(1) The paddy and rice workstations comprising subsections of the production and warehouse were created.

(2) The amount of paddy produce brought by farmers is 1 ton per 5.4 h or Random Expo (5.4) h.

(3) The amount of paddy milling is 1 ton per 5.45 h or Random Expo (5.35) h.

(4) The number of orders from customers is 1 ton per 5.45 h or Random Expo (5.5) h.

(5) The employees and machinery work 10 h per day with 0% error.

(6) The replication length is 365 days and the number of replications is 10 rounds.

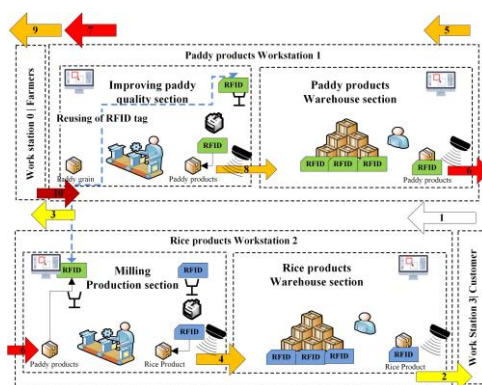


Figure 2. The rice mill operation process integrated with the Kanban-RFID

(7) The average time and process analysis of the rice mill operations are shown in Table 2.

To test the performance, 2 simulation models were developed to compare between the traditional model and the proposed model.

Table 1. The relation of trigger and events occurring in the rice mill

An event triggered when products move via the RFID readers		When receiving the trigger of ordering operation via the monitoring device	
Step	Event	Step	Event
2.	Delivering rice products to customers: the rice products with the RFID tag are delivered from the rice product warehouse section to customers.	3.	Starting the Milling operation: at the milling product section, paddy products are prepared and milled into rice products.
4.	Transferring rice products to warehouse: The finished products are attached to the RFID tag from the milling production section and are transferred to the rice products warehouse.	5.	Starting delivery of paddy to milling operation: at the paddy product warehouse section, paddy products are prepared for delivery to the milling operation.
6.	Transferring paddy products to Milling operation: The paddy products are attached to the RFID tag from the paddy product warehouse section and transferred to the production milling workstation.	7.	Starting control of paddy quality: at the section of paddy quality section, the mechanism for maintaining the quality of paddy is used by reducing and maintaining the moisture of paddy grain to not more than 14%
8.	Transferring paddy products to warehouse: The paddy products are attached to the RFID tag at the rice mill section are transferred to the rice warehouse.	9.	Starting the ordering of paddy grains: the paddy grain are ordered from the farmers.

Table 2. The analysis of logistic operations in the rice mill

Section Operation	The average time	The process analysis
1. Controlling paddy quality section	5.58 h	
1.1 The employees receive and count the number of paddy sacks.	35 min	Delay
1.2 The employees treat and control the paddy moisture level (moisture level < 14%).	300 min	Process
1.3 The employees pack the paddy grains into the sacked or jumbo bags attached to the label code/RFID tag.	25 min	Process
2. Transfer paddy product to warehouse section	40 min	
2.1 The employees transfer the paddy products to the paddy warehouse.	25 min	Delay
2.2 The employees check and count the number of the paddy products and place them in the right place.	15 min	Delay
3. Milling production section	4.9 h	
3.1 The employees count and sort the paddy products using to the FIFO (First In, First Out) method before transferring the paddy grain to the milling machine.	35 min	Delay
3.2 The employees transfer the paddy to the milling machine and the rice grains are then conveyed to the arranged package attached to barcode/RFID tag.	200 min	Process
4. Transfer rice products to warehouse section	60 min	
4.1. The employees sort and move the rice products to the pallets.	15 min	Delay
4.2. The employees move the pallets of rice products to the rice warehouse.	20 min	Delay
4.3. The employees check and put the rice products in right place within the rice warehouse.	25 min	Process

In Figure 3, the traditional model is proposed which is divided into 3 layers. In the first layer, the employees receive the paddy from the farmers and transfer their products to section 1.1 in order to enter the quality control section. The paddy is moved to process 1.1, 1.2, and 1.3, respectively. Then, the products passing the quality control section are transferred to be temporarily kept in the paddy warehouse (section 1.2), having previously been moved through process 2.1 and 2.2. In the second layer, the planning department assigns the employee to mill the paddy. The milling operation initially picks the paddy from process 2.3, called the hold warehouse paddy module, to enter section 2.1, comprising process 3.1 and 3.2, respectively. When the milling operation

is completed, the rice products are transferred to (section 2.2), the hold warehouse rice module, having thoroughly passed process 4.1, 4.2, and 4.3, respectively. In the last layer, when customers order rice products, the rice products from process 4.4 are picked. Then, the rice products are transferred via section 3.1 and 3.2, respectively. In the last step, the rice products are moved to section 3.2 (customer received product).

The Kanban-RFID model (Figure 4) is divided into 6 layers which is explained as follows. In layer 1: After the customer orders the rice products as demonstrated in section 1.1, the signal is abruptly sent to section 2 on ST 4P and the Mach 4P module. In layer 2: Simultaneously, the rice products which have been finished by process 4.1, 4.2, and 4.3,

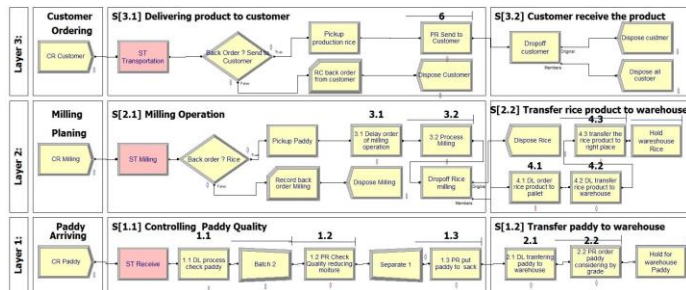


Figure 3. The traditional logistic operation of rice mill simulation

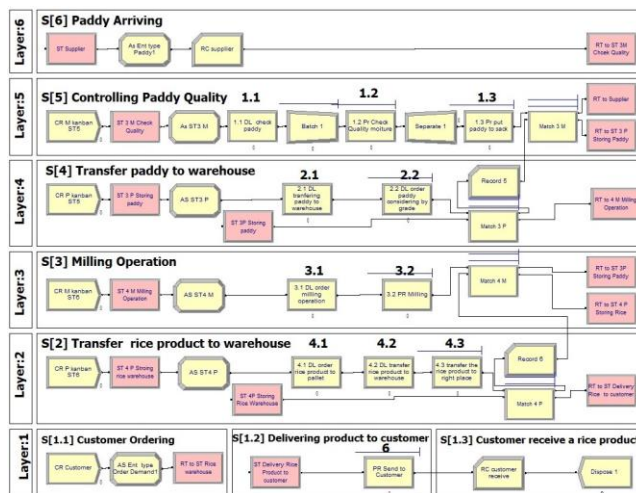


Figure 4. The Kanban-RFID for logistic operation of rice mill simulation

respectively, are moved to the Mach 4P (RFID reader) module and the finished products are delivered to section 1.2 (station delivery rice products); meanwhile, the signal is sent to the device PC of section 3 on the Match 4M module. In layer 3: The rice products which have previously entered process 3.1, and 3.2, respectively, are then moved from the Match 4M (RFID reader) module to layer 2 (station 4P storing rice warehouse); meanwhile, the signal is sent to the device PC of the 4 on the ST 3P and Match 3P module. In layer 4: For a while, the paddy products which have completely entered the process 2.1, and 2.2, respectively, reach the Match 3P (RFID reader) module and move to layer 3 (station 4M), respectively; meanwhile, the signal is sent to the device PC of layer 5 on the Match 3M module. In layer 5: Simultaneously, the finished paddy products which have passed the quality control on moisture and have previously entered the process 1.1, 1.2, and 1.3, respectively, are moved to the Match 3P (RFID reader) module and go to layer 4 (station 3P); meanwhile, the signal is sent to the device PC of layer 6 on the station supplier to order the paddy grain. In layer 6: The products are sent from the station supplier and routed to station 3M.

Results and Discussion

The procedure of this section is carried out as follows. First, the results including the average and individual waiting time of the workstation are shown. Then, the models of the Kanban-RFID and traditional system with the investment

costs are compared. Finally, the BEP and ROI of the Kanban-RFID system to the rice mill are examined

Waiting Time of Workstation

According to running simulation, Table 3 shows the comparison of the average waiting time between the traditional model and Kanban-RFID model focusing on the 6 processes, namely, processes 1.2, 1.3, 2.2, 3.2, 4.3, and 6. The 4 processes 1.3, 2.2, 4.3, and 6 demonstrate the slightly different results of both models. Meanwhile, the waiting time of the traditional model of process 1.2 (42.75 min) and 3.2 (147.07 min) are higher than process 1.2 (0.00 min) and 3.2 (76.37 min) of the proposed model, respectively. In addition, the amount of waiting time of the proposed model is lower than that of the traditional model by 56%. Moreover, the simulation indicates that the number of finished products (rice products) delivered to customers increased from 615 to 651, a difference of 5.73%.

Comparison of Kanban-RFID based on IT and Cloud Computing

In this section, the component services based on the hardware and software of the Kanban-RFID system and primary operational costs applied from the AWS_calculator, (Amazon Web Services LLC, 2010) both on IT and cloud computing within the rice mill manufacturing were assigned by considering 3 years to conduct the BEP and ROI in the next section. The component services of the Kanban-RFID system are \$6200, made up of the following which need to be deployed both on IT and cloud computing infrastructures; the Kanban-

Table 3. The comparison of average time of traditional and RFID-Kanban

Process	The average waiting (Min)			
	Traditional Model		Proposed Model	
	Average	Half width	Average	Half width
(1.2) Check quality reducing the moisture	42.75	6.07	0.0	0.0
(1.3) Put paddy into the sacks	12.49	0.02	12.53	0.03
(2.2) Process order of paddy considered by grade	0.9	0.02	0.3	0.04
(3.2) Process milling	147.07	15.34	76.37	3.06
(4.3) Transfer the rice products to the right place	0.0	0.0	0.0	0.0
(6) Send products to the customer	0.0	0.0	0.0	0.0
Amount of time	203.21	21.45	89.2	3.13

RFID application (\$2300), 4 computer monitors (\$600), a fixed RFID reader and 4 antennas (\$2300), and 2000 RFID tags (\$1000). The investment in the server hardware, network hardware, and hardware maintenance based on IT infrastructure are \$1000, \$320, and \$192, respectively; meanwhile, the costs based on the cloud computing infrastructure are \$400, \$200, and \$128, respectively. Furthermore, The IT infrastructure may require expense on the license of the operating system; Microsoft Windows and the database management software, which costs at least \$300 and the administrator's salary is \$21000. Meanwhile, there are costs for the instance servers which are located in East Asia (Microsoft Azure, 2018). The cost of the virtual machine of A2 standards tier (\$0.18 per hour) for the Azure region, and the data transfer are \$2259 and \$600, respectively.

In Figure 5, the costs incurred in the Kanban- RFID system based on the IT and cloud computing infrastructure for 3 years are \$27069 and \$7743, respectively. In the next section, the costs incurred in Kanban-RFID are analyzed with the BEP and ROI.

The Analysis of BEP and ROI

Given the investment of Kanban- RFID based on cloud computing for 3 years (\$7743), the earned profit is derived from the termination of the employment of an employee at the rice mill enterprise. If implemented, the Kanban-

RFID system may not reduce the waiting time but will increase the number of finished products. Moreover, it assures the improvement of the automation operation to seamless and smooth orders in the production and warehouse operation; therefore, one employee's employment is terminated; thus, the profit is derived from the elimination of the employee's salary, which is \$428.57 per month. Considering 3-year's interest at 10% per annum, the time of the break-even point is at 1 year 7 months and the calculation of the ROI is 15.18%, as shown in Figure 6. Due to the short amount of time before generating profit, it can be argued that SME entrepreneurs can afford to implement the Kanban-RFID system in their manufacturing.

Conclusions

The cloud based Kanban-RFID model with the low cost investment and short waiting time of the operating process in manufacturing is proposed. The essential functions and information communications of the Kanban-RFID components are presented through the enterprise and cloud computing layers.

According to the implementation of the proposed Kanban-RFID system operation, the average waiting time decreases by 56.26% which increases the number of the rice products sold to customers by 5.73%. Furthermore the cost

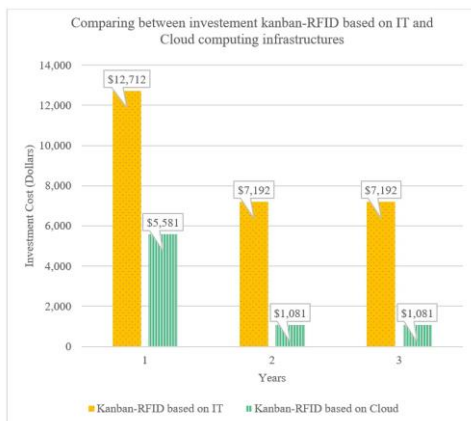


Figure 5. The Kanban-RFID based on IT and cloud computing investment

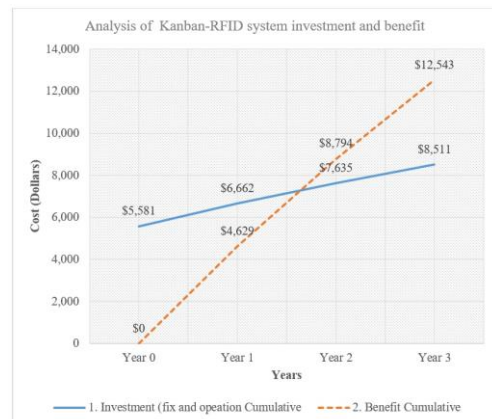


Figure 6. The analysis of investing and profit for BEP and ROI

on investment of the proposed system, which is lower than the traditional system, shows a short break-even point for accounting purposes which is less than 2 years.

According to the results from the proposed Kanban-RFID model, the proposed system could improve the operation of a manufacturing business in respect of the reduced waiting time and the value on investment especially for SME enterprises.

References

- Alfonso, C.D., Caballer, M., Alvarruiz, F., and Moltó, G. (2013). An economic and energy-aware analysis of the viability of outsourcing cluster computing to a cloud. *Future Gener. Comp. Sy.*, 29(3):704-712.
- Altmann, J. and Kashef, M.M. (2014). Cost model based service placement in federated hybrid clouds. *Future Gener. Comp. Sy.*, 41:79-90.
- Amazon Web Services Llc. (2010). AWS_calculator. Available from: https://media.amazonwebservices.com/Amazon_EC2_Cost_Comparison_Calculator.xls. Accessed date: Jan 9, 2018.
- Jarupathirun, S., Ciganek, A.P., Chotiwanakawmanee, T., and Kerdpitak, C. (2009). Supply chain efficiencies through E-kanban: A case study. *International Journal of the Computer, the Internet and Management*, 17(SP1):40-44.
- Mell, P. and Grance, T. (2011). The NIST Definition of Cloud Computing. NIST Special Publication 800-145. National Institute of Standards and Technology, US Department of Commerce, Gaithersburg, MD, USA, 3p.
- Microsoft Azure. (2018). Available from: <https://azure.microsoft.com/en-us/pricing/details/virtual-machines>. Accessed date: Feb 5, 2018.
- National Bureau of Agricultural Commodity and Food Standards. (2010). Good Manufacturing Practices For Rice Mill. Thai Agricultural Standard TAS 4403- 2010. National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives, Bangkok, Thailand, 31p.
- Naufal, A., Jaffar, A., Yusoff, N., and Hayati, N. (2012). Development of Kanban system at local manufacturing company in Malaysia – Case Study. *Procedia Engineering*, 41:1721-1726.
- Ngai, E.W.T., Moon, K.K.L., Riggins, F.J., and Yi, C.Y. (2008). RFID research: An academic literature review (1995–2005) and future research directions. *Int. J. Prod. Econ.*, 112(2):510-520.
- Nomura, J. and Takakuwa, S. (2004). Module-based modeling of flow-type multistage manufacturing systems adopting dual-card kanban system. *Proceedings of the 2004 Winter Simulation Conference*; December 5- 8, 2004; Washington, DC, USA, p. 1065-1072.
- Sarac, A., Absi, N., and Dauzère-Pérès, S. (2010). A literature review on the impact of RFID technologies on supply chain management. *Int. J. Prod. Econ.*, 128(1):77-95.
- Singh, A., Mishra, N., Ali, S.I., Shukla, N., and Shankar, R. (2015). Cloud computing technology: Reducing carbon footprint in beef supply chain. *Int. J. Prod. Econ.*, 164:462-471.
- Su, W., Ma, L., Hu, K., and Zhang, L. (2009). A research on integrated application of RFID- based lean manufacturing. *Chinese Control and Decision Conference 2009*; June 17-19, 2009; Guilin, China, p. 5781-5784.
- Tabanlı, R.M. and Ertay, T. (2013). Value stream mapping and benefit– cost analysis application for value visibility of a pilot project on RFID investment integrated to a manual production control system– a case study. *Int. J. Adv. Manuf. Tech.*, 66:987-1002.
- Tian, W., Xue, R., Dong, X., and Wang, H. (2013). An approach to design and implement RFID middleware system over cloud computing. *Int. J. Distrib. Sens. N.*, 9(10):13.
- Wan, H. and Chen, F.F. (2008). A web-based Kanban system for job dispatching, tracking, and performance monitoring. *Int. J. Adv. Manuf. Tech.*, 10(38):995-1005.
- Wang, S.J., Liu, S.F., and Wang, W.L. (2008). The simulated impact of RFID-enabled supply chain on pull-based inventory replenishment in TFT- LCD industry. *Int. J. Prod. Econ.*, 112(2):570-586.
- Yeh, K.C., Chen, R.S., and Chen, C.C. (2011). Intelligent service- integrated platform based on the RFID technology and software agent system. *Expert Syst. Appl.*, 38(4):3058-3068.
- Zhong, R.Y., Dai, Q.Y., Qu, T., Hu, G.J., and Huang, G.Q. (2013). RFID-enabled real-time manufacturing execution system for mass-customization production. *Robot. Cim-Int. Manuf.*, 29(2):283-292.
- Zhu, X., Mukhopadhyay, S.K., and Kurata, H. (2012). A review of RFID technology and its managerial applications in different industries. *J. Eng. Technol. Manage.*, 29(1):152-167.