Application of plastic containers with RFID in the marketing of fruit and vegetables in Taiwan

Chih-Cheng Hung, Chung-Teh Sheng

(*Department of Bio-industrial Mechatronics Engineering, National Chung Hsing University, Taichung, Taiwan, China*)

Abstract: This study aims to present a set of operation and management systems for containers used in the transport of fresh agricultural produces. The proposed system utilizes Radio Frequency Identification (RFID) and technologies related to information engineering. An operation and information management system for the marketing of fruit and vegetables using RFID-embedded plastic containers is well planned and developed. In order to promote the use of plastic containers, the study designs an energy-saving and environmentally-friendly container that allows for standardized operation. A related standardized operation flow is tested to fully satisfy the wholesale market demands. The entire flow and operation is also tested by all related sectors of the system. With the application of the RFID tag, real time information generated at the production center can be sent to the wholesale market through a wireless network, thus reducing the labor needed for data input while also reducing human error at the market. This may improve tallying efficiency and reduce costs.

Keywords: RFID, plastic container, informatization, fruit and vegetables, Taiwan

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1 Introduction

The studied strategies to reduce waste in the fruit and vegetable wholesale market have concluded that plastic containers are able not only to reduce fruit and vegetable waste, but also to reduce non-fruit-and-vegetable waste. This work explores the utilization and especially the recycling of plastic containers in the fruit and vegetable wholesale market, and discusses the rights and responsibilities of the entities concerned, such as agricultural administration organizations, wholesale markets, farmer groups, farmers and plastic container manufacturers. The number of plastic bags, packing tapes (ropes), bamboo baskets and cardboard boxes can be reduced by promoting the use of plastic containers. Farmers have long been concerned with the increasing costs of packaging, transport and sales and have proposed the use of recyclable plastic containers to replace costly cartons used in the marketing of fresh fruit and vegetable.

The innovation of the bar code was initially used to improve the efficiency of check-out counters in the retail industry. This technology facilitates fast, accurate and simple data input in the context of commodities sales and transport. As a result, it has been widely used in production, wholesale, retail, warehouse inventory systems and general logistics management. In the international market, the bar code is an indispensable ID number for commodities. The radio frequency identification (RFID) technology uses micro-chips or intelligent tags on products to transmit information to computer networks and track retail inventory. Each intelligent tag will send out a unique ID code and then provide extensive product information such as: sale location, owner, address, expiry date and purchase date.

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Biography: Chih-Cheng Hung, Email: jarsoncchon@yahoo.com.tw.

Corresponding author: Dr. Chung-Teh Sheng, Professor, Department of Bio-industrial Mechatronics Engineering, National Chung Hsing University, Taichung Taiwan. Tel: 04-2286-2846; 04-2285-7579; Fax: 04-2285-7570; Email: ctsheng@dragon.nchu.edu.tw.

Radio frequency identification (RFID) refers to a microchip "intelligent tag" on a product, where each intelligent tag transmits a unique ID code that provides the full information of a product, such as the place of origin, owner, location, expiration date, and purchasing date. The intelligent RFID tag contains intelligent memory and a wireless transmitter. The RFID reader gathers the information, and identifies the product by the memory data stored in the tag. Comparing with the existing bar code system, which reader system can only read the special bar code on the product, the RFID reader can gather the product's information within a specific effective range. The effective range depends on the frequency of the transmitter. The RFID tags can be divided into passive, semi-passive (or semi-active), and active types. The passive tag has no internal power supply. Its internal integrated circuit is driven by the received electromagnetic waves transmitted from the RFID reader. When the tag receives a signal intensive enough, it can send data to the reader. These data contain the ID number (unique global ID) and the data already stored up in the tag. The passive tag is characterized by low price, small size, and power free. Most RFID tags in the market are passive. The passive tag's antenna has two tasks:

1) Receive the electromagnetic waves transmitted from the reader to drive the tag IC.

2) When the tag feeds back signals, the switching is carried out by the impedance of the antenna to make the switching between 0 and 1.

In order to obtain the best feedback efficiency, antenna impedance must be designed in "open circuit and short circuit", thus, the signal will be completely reflected and will not be received by the tag IC. The semi-active tag, which is similar to the passive type, solves this problem with a compact battery that drives the tag IC. The benefit is that the antenna does not need to receive electromagnetic waves, and only needs to feed back the signals. The semi-active type has a higher response speed and efficiency as compared with the passive type.

The active tag has an internal power supply that supplies the internal IC with power to generate external signals. The active tag has a longer reading distance and larger internal storage capacity to store the additional information transmitted from the reader.

RFID has the following functions that create substantial benefits to industrial informatization:

1) Multiple RFID tags can be simultaneously read.

2) Updates can be read without light.

3) Repeatable R/W.

4) It can transfer data for product tracking and security.

5) It can read data in severe and dirty environments.

6) High speed movement reading.

7) The maximum reading speed for each data is 0.1 s.

Since entering the World Trade Organization (WTO), agriculture and husbandry in Taiwan has been facing challenges in the international market. The governmental agricultural administration organizations have started to improve the competitiveness of domestic produce through various actions, such as advocating electronic agriculture, establishing the Technical Service Team for Electronic Agriculture, and promoting research on online domestic produce quality inspection technology and bar code implementation. They also collaborated with GS1 Taiwan, adopting internationally standardized EAN/UCC systems to promote and gradually integrate product bar codes and electronic transactions domestically, and standardize operations in order to enhance the competitiveness of domestic produce in the international market.

With the ever prospering international produce trade and e-commerce, the domestic produce industry also introduced RFID to facilitate production and sales management and to improve market competitiveness. Notably, Taiwan's entering the WTO has changed the overall commercial environment. To ensure the safety of domestic produce and its competitiveness in the overseas market, RFID has the potential to become an important means by which to improve management efficiency. By using internationally compatible encoding methods, RFID can integrate information through the standardization of commodity flow, logistics and information flow. As a result, it can help our producers to successfully enter the international market.

Information computerization is an important goal for farmers who wish to improve their income in the future; it can not only improve logistics flow and marketing efficiency, but also enhance the accuracy and analyzability of data.

2 Research methods and stages

2.1 Design, technology R&D, and testing of RFID-embedded plastic containers

1) Material selection for plastic containers: containers in this study are used in the marketing of domestic fruit and vegetables. Therefore, the materials of which the containers are made are selected by taking into account the utilization costs, expected lifetime of the containers and allowable stress while holding produce.

2) Container specification design: according to volume requirements for current marketing systems of domestic fruit and vegetables, several types of plastic containers of different sizes and specifications are available and from which farmers are able to choose.

3) Model plastic container design: the design is based on the general container specifications used in the wholesale market.

4) Product logo and RFID embedding design: due to the characteristics of the RFID tag, its readability declines due to the effect of water from the fruit and vegetables themselves and from the environment. Therefore, the tag number on each container and the embedding method needs to be designed accordingly. The positioning of the tag on the container needs to be determined such that it is clearly visible when the container is either stacked or displayed in the market.

2.2 Design of the marketing information management and operation system for plastic containers with RFID

1) System flow planning: plan operation flow for the use of plastic containers with RFID from the farmer (the supplier) to the wholesale market (the agent).

2) The agricultural produce with plastic container management and operation system includes the following subsystems:

a) Basic Data Subsystem at the Produce Supplier: users (i.e., farmers, farmer groups and carriers) may input basic produce data, including container production and sales data, into a handheld reader to replace the traditional manually written format, and verify it using the tag ID embedded in the container. The verified result is transferred through a wireless network to the host database of the fruit and vegetable market management system located in the container management center.

b) Agricultural Product Management Subsystem: when the produce is sent to the fruit and vegetable market from the distribution center, counting staff at the market will count the containers with a handheld RFID reader, and transmit the information through a wired network to the host database. A verification action will then be performed to ensure a normal produce transaction.

c) Container management subsystem: the container management center will track the use of the containers, manage the data from container rentals, collect fees from container users and monitor the customers' cash flows.

d) The system development adopts .NET technology to process relevant functions of the handheld reader, including: the Basic Data Subsystem at the produce supply end, the Produce Counting Management Subsystem, and the Container Management Subsystem. By placing both the ASP.NET webpage technology and database system in the host of the management system of the fruit and vegetable market, the system combines software and hardware to realize query and management functions, as well as the E-information goal, thereby improving the utilization of container resources.

3) Information transfer system structural planning: where the goals are to design the information transfer system of suppliers (farmers associations, cooperative communes, and farms) and plan methods to coordinate transferring the supply data to the wholesale market.

3 Results

3.1 Design, technology R&D, and testing of RFID-embedded plastic container

1) Plastic container material: PP (polypropylene)

2) Specification

Three specifications based on different loads of pallets are as follows:

a) L 550 × W 350 × H 280 mm, for 15 kg load

b) L 550 × W 350 × H 330 mm, for 20 kg load

c) L 550 × W 350 × H 380 mm, for 25 kg load

As there are various types of fruit and vegetables with different volumes and specific gravities, the above loads are for reference only.

3) Design of the plastic container model: the container model suitable for RFID tag embedding is designed according to general container specifications used in the current wholesale market (Refer to Figure 1).

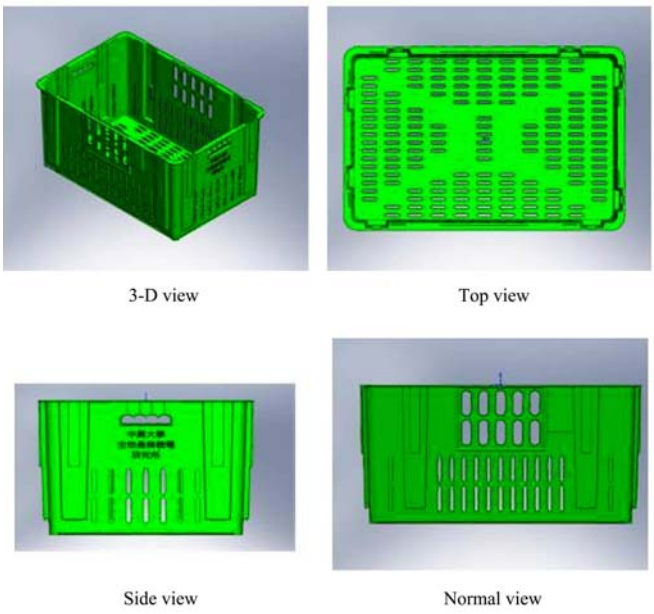

Figure 1 Orthographic view of plastic container model

In order to make the plastic container more user-friendly, to avoid jamming and bruising of the produce when loading them onto the pallet, and to conserve stacking space during recycling and storing, we designed two-direction containers at the initial stage (Refer to Figures 2 and 3).

Figure 2 Forward stacking to avoid compressing the product

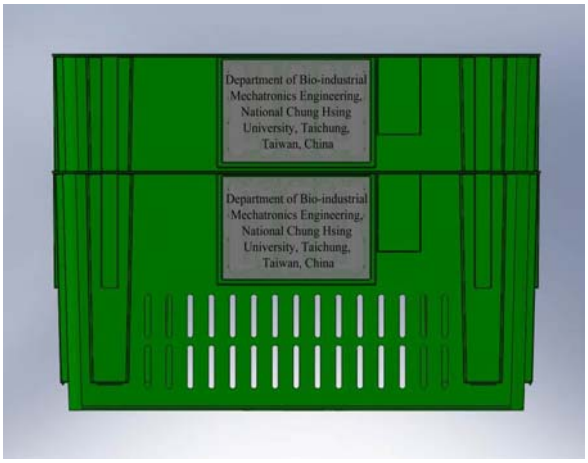

Figure 3 Reverse stacking to save storage space

4) Design of the product information and RFID embedding method: as for the external marking of the container, despite the RFID tag's ability to store adequate product information, when the produce is sent to the wholesale market for transaction, the buyer still needs to ascertain the real-time information, i.e., the supplier, product name, weight and class type. Therefore, we designed a product information field with space for the supplier to mark such information.

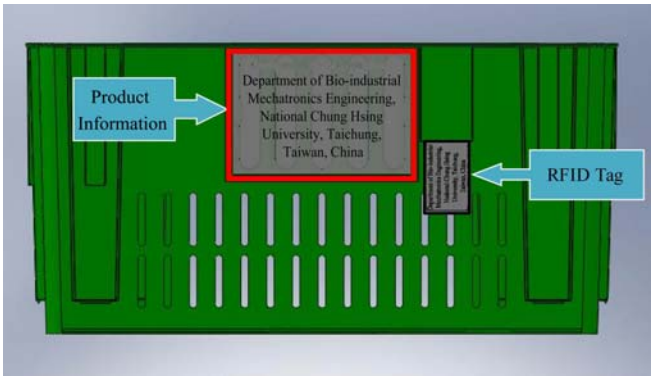

Figure 4 Position and design of product information and RFID tag

5) The design for the RFID embedding: after many tests with currently available materials and technologies, this study suggests designing a groove to hold the tag onto the side of the container, where it could be slotted in safely and thus avoid being damaged. Embedding the tag during the injection process is not practical because an RFID tag is unable to bear temperatures of over 200℃ generated during the injection of the container mould. Furthermore, the pressure of the liquid plastic during the injection may distort the tag, which may in turn damage

its internal structures and circuits. Another option is to embed the tag after being sealed, which will reduce defects but dramatically increase the cost. Furthermore, if the tag is embedded right after the ejection of the container, the container cannot be used if the tag is damaged.

3.2 Design of the marketing information management and operation system for plastic containers with RFID

This system is used to effectively manage the marketing of fruit and vegetables as well as the use of containers. The flow starts with renting the RFID containers, which are distributed by the container management center through the supplying entities who supply farmers. After a harvest by the farmers, the supplying entities will transport the product in the container to the wholesale market for auction. Finally, the buyer winning the auction will get the product and containers, and return the latter to the wholesale market or the container management center.

The flow mainly adopts the e-information system. RFID tools are utilized to read data during the product and container counting and work to improve efficiency.

- Main cooperation organization:
- Wholesale market
- Supplying entity
- Container management center
- The main system is divided into three parts
- Container distribution (container renting, return and query)
- Transportation and sales of product (collection, sorting, auction and query)
- Data management (basic data such as container, supplying farmer, product, buyer, etc)

A. System flow planning

Flow direction of the containers is as follows: the container management center provides the plastic containers to the farmers of the supplying entities, and then the farmers transport the produce in the plastic containers to the wholesale market for sale. After that, the agents buy the produce in the plastic containers and return the containers to the place designated by the container management center within a specified time period. Refer to Figure 5.

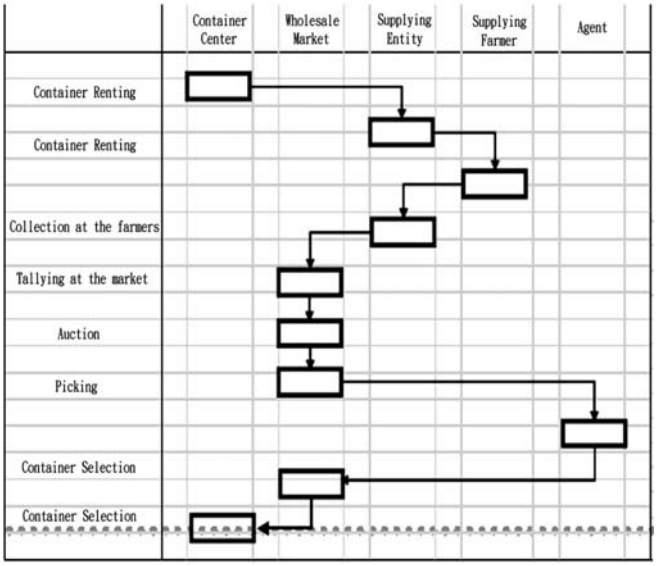

Figure 5 Flow chart

B. Operation system planning

The container management center sends containers in the amount applied for by all supplying entities (farmer associations or cooperatives) to the places designated by the supplying entities for the farmers. Input data, such as the supplying entities' codes and renting dates for the containers are entered into the tags on the containers. The supplying entities then input the code of the farmers and the date. When the farmers pack the products and send them to the distribution center, they will input data such as product name, weight, class and supplying market into the tag. After the collection of all the supply data from the farmers, the information can be sent to all wholesale markets through ADSL. Meanwhile, supply data sheets will be generated. The wholesale market may get the supply details of the supplying entities from the host before the auction, and take it as a basis for tallying after the produce is unloaded. The tally clerk uses the handheld reading devices to verify that the produce and the information on the tag agree, and completes the tallying. After the auction, data (such as the buyers and prices) can be input into the tag. When the buyers return the plastic containers to the designated places, fees for container use can be calculated according to its purchase date, and then the tag data will be erased. The server at the container management center will set up a file for managing the storage places of all of the containers (Figure 6).

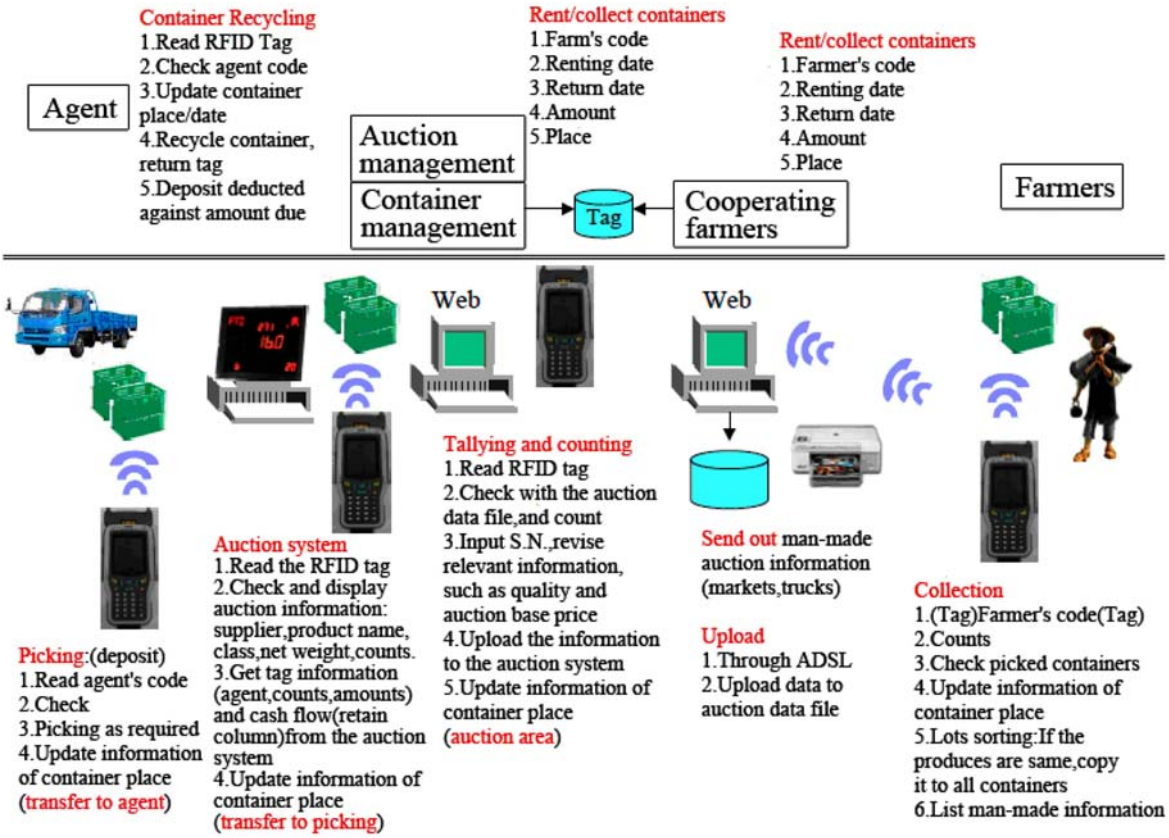

Figure 6 Operation system flow chart

C. Structure of the information transfer system

Wireless bases are set up at the supplying entities (farmer associations or cooperatives) for sending/ receiving the data output to the readers or input to the host. Meanwhile, data are sent to the wholesale market through ADSL. While tallying, the tally clerk at the wholesale market may send the data read from the tag on the container, by using a reading device, to the host at the market to compare with the data sent from the supplying entities. At the same time, it can send the auction data to the host at the container management system (Figure7).

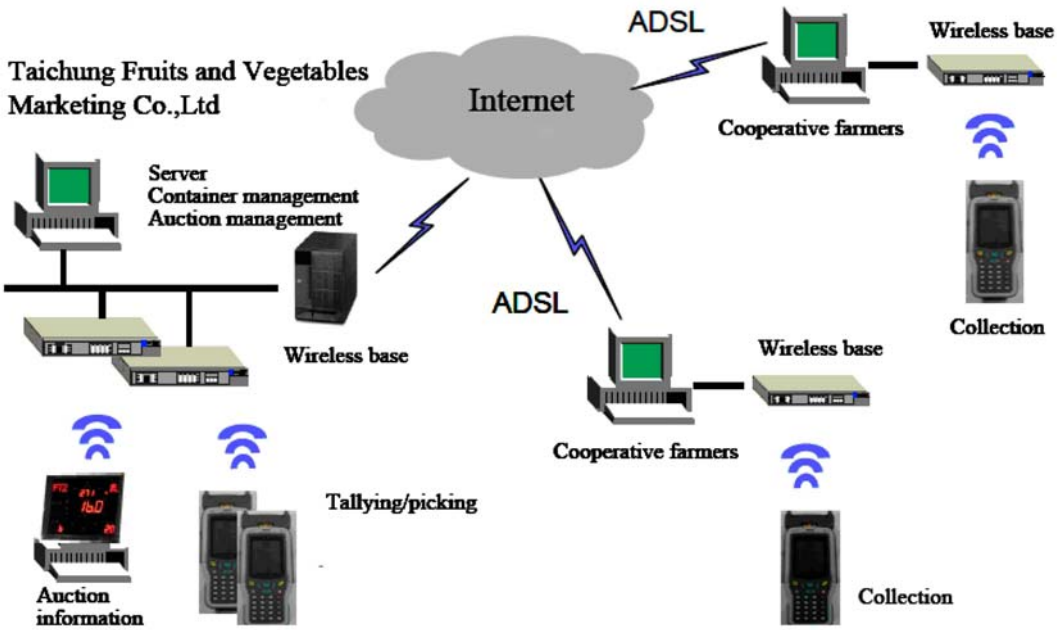

Figure 7 System structure

3.3 Analysis of operating efficiency

A. Analysis of operating efficiency in wholesale market with RFID system

This study tested manual logging of warehousing data by professional and unprofessional tally clerks and RFID logging, for the task of tallying 1 to 80 batches of incoming stock entering into the inventory and stock systems of a wholesale market. The experimental results showed that in the manual logging mode by professional tally clerks, the time required for manual logging increases for every increase of 10 batches of incoming stocks. As the time for tallying becomes longer as the amount of stock increases, tally clerks are tired by the work. Therefore, when the amount of incoming stock is large, the time required for manual logging is longer than that for RFID logging. When the amount of stock for manual logging increases, the human error rate also rises, and the tally clerks need to spend more time correcting the errors, thus making the manual logging time even longer. In sum, using RFID logging (the data processing time for each batch is 1 s) to input the incoming stock data into the computer system of the wholesale market could effectively shorten the processing time, as shown in Figure 8.

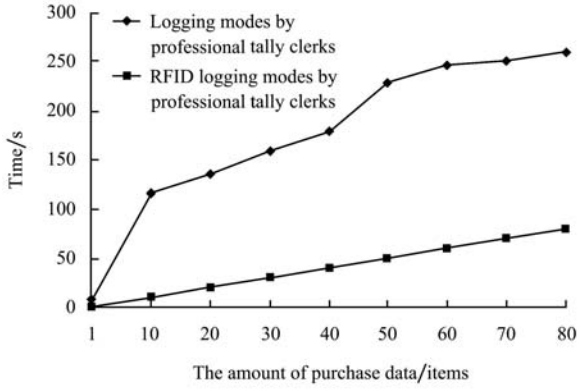

Figure 8 Comparison of processing time of manual and RFID logging modes by professional tally clerks

Regarding unprofessional tally clerks, the experimental results showed that in manual logging mode, the processing time increases for every increase of 10 batches of stock. When the incoming stock reaches 80 batches, the required logging time is significantly longer than the RFID logging time, as shown in Figure 9. RFID logging mode is easy to learn and the unprofessional tally clerks are less likely to be tired. Thus, they can use the RFID logging (the data processing time for each batch is 1 s) to input the incoming stock data when the professional tally clerks are taking leave of absence.

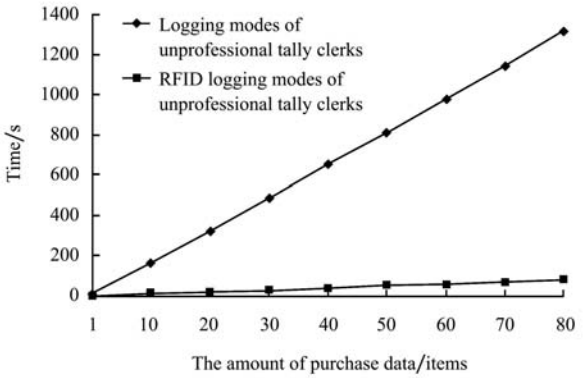

Figure 9 Comparison of processing time manual and RFID logging modes of unprofessional tally clerks

During the tallying operation in the wholesale markets, as it is a labor-intensive work, human initiated errors frequently occur, as the tally clerks may omit, misread, wrongly take, wrongly count, drop, or damage goods. The work may be slowed by cold or hot weather, or fatigue. Moreover, the dullness of the work, fluctuating emotions, and unequal workloads may result in workers' dissatisfaction, thus affecting their operating efficiency. Therefore, this study created an RFID supply and tally system for agricultural products to replace the manual logging and tallying using the inventory and stock system of the wholesale market.

B. Economic benefit analysis of RFID system in wholesale market

According to the cost analysis of this study:

1) Personnel cost: monthly wages for tally clerks of fruit and vegetable wholesale market is estimated at 30 000 NTD.

Yearly salary: monthly wages for tally clerks × 12(months) =30 000(NTD)*12(months) =360 000(NTD).

2) Total quantity of reused containers is 34 000 per year.

3) Unit price of RFID Tag used in this study is 35 (NTD/tag).

The annual cost of RFID tags for a wholesale market can be estimated according to the above data, and

the cost and annual amount of depreciation of this system device can be determined:

1) Amount of annually consumed RFID Tags:

Unit price of tags is 35 (NTD/tag) × total quantity of yearly consumed containers (pcs)

35(NTD/tag)×34 000 (pcs) = 1 190 035(NTD)

2) The cost of RFID supply and tally system device is 399 997NTD, see Table 1.

Total investment cost = 399 997+1 190 035

= 1 590 032NTD

3) Annual amount of depreciation of this system device: (calculated by straight line method of depreciation)

a) Salvage value = cost/(durability +1)

The durability of this system device is five years.

Salvage value = 1 590 032NTD/(5+1)years

= 265 005(NTD)

b) Annual amount of depreciation = assets cost - estimated salvage value/durability

Annual amount of depreciation = (1 590 032(NTD)−265 005(NTD))/5(years)=265 005(NTD)

As seen above, the annual amount of depreciation of this system device is less than the yearly salary of a tally clerk of a wholesale market.

Therefore, one professional tally clerk can be reduced if the wholesale market uses the RFID system for operations; the RFID equipments and tags will prevail as the technology develops in the future, and the price will decrease yearly; thus, its economic benefit will continuously increase.

Table 1 Cost of RFID supply and tally system (excluding RFID tag cost)

Equipment name	Qty	Unit price (NTD)	Total price (NTD)
RFID palmtop data reader	1(set)	67 725	67 725
RFID tag encoder/printer	1(set)	59 500	59 500
AP wireless base station	2(sets)	5 367	10 734
Server	1(set)	40 790	40 790
PC	1(set)	28 465	28 465
UPS	1(set)	7 783	7 783
RFID development kit	1(set)	90 000	90 000
RFID supply and tally software	1(set)	95 000	95 000
Total			399 997

4 Conclusions

This study has the following conclusions:

1) Using RFID technology to manage containers can not only improve container management and recycling, but the real-time transfer and traceability of the RFID also enhances the safety and responsibility of the produce system.

2) With existing materials and technology, we suggest designing a groove to hold the tag at a suitable position on the container, where the tag is protected from the elements and handling damage. This design is both practical and cost-effective.

3) With the application of the RFID tag, real-time information generated at the production center can be sent to the wholesale market through a wireless network, thus reducing the labor needed for data input while also reducing human error at the market. This may improve tallying efficiency and reduce costs.

4) The market may publicize supply information received from all supplying entities, then buyers are able to improve auction efficiency.

5) Computerization of all data may improve the efficiency of all paper work.

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