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DEVELOPMENT AND IMPLEMENTATION OF RADIO-FREQUENCY IDENTIFICATION (RFID) TECHNOLOGY FOR INVENTORY MANAGEMENT SYSTEM: A CASE STUDY

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ABSTRACT

This paper describes a study to develop and implement Radio-Frequency Identification (RFID) technology for inventory management system in a supply store unit. Firstly, data was collected to identify the existing inventory management problems in the supply store management, and then followed by defining requirements of the system which suggested the use of RFID technology to fulfill these requirements. The development process included the utilization of specific hard-ware and self developed software programmed for usage in the supply store management. The system was tested in order to evaluate its efficiency, effectiveness, reliability, security and cost justification. It was found that the newly developed system had successfully managed to capture inventory data, track the borrower ID, keep the record updated and able to display the history of borrowed items, and also the fine imposed due to late return. The system also generated reports for inventory management and audit works in the supply store.

Keywords: *AIDC, RFID, Inventory management, Supply store, Borrow-used-return*

1.0 INTRODUCTION

The field of business operations and management is becoming more competitive in recent years, which makes many companies increasingly interested in developing new management system in order to stay competitive in managing their business operations. Such competitive advantage can help companies to become more successful. In term of the business operations, companies are re-examining their supply chain management system in order to identify opportunities for improvements. Traditionally, inventory systems have been managed manually and independent from other business units, which caused the lack in communication

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between inventory information and controllers. However, in recent years, many companies start to embark into new inventory management systems that utilize latest technology. This trend has been steadily growing in various applications in many industries, such as in the airline industry, cattle industry, construction, logistics, healthcare, and manufacturing. In this study, the authors are proposing the use of a new inventory system that utilizes RFID technology in inventory management. This paper describes the development of an automatic inventory control system using RFID for a typical supply store which was chosen as the case study in this research. In order to explain the detail on how the proposed system works; the development process of the system will be discussed in details. Firstly, we identified problems that were faced on managing the supply store. Then, a new inventory system using RFID technology was developed to overcome these problems and to provide a better inventory control. Finally, we conducted a pilot test to evaluate the system performance in terms of its efficiency, effectiveness, reliability, security and cost justification.

2.0 INVENTORY MANAGEMENT SYSTEM

2.1 Automatic Identification and Data Collection (AIDC) Technology

The usage of information technology in operations management had become a common aspect in present days. Information technology had become one of the key factors in maximizing efficiency and improving competitive advantage of a supply chain management because its ability to improve the speed of information flow since the more information the person has about his or her products, inventory levels and the movement of these products, the less uncertainty he has in managing them, which in turn can result in decrease of inventory holdings, improved productivity and better customer satisfaction [1]. Furthermore, by utilizing information technology in supply chain management, this may improve the speed and accuracy of the information flow in the collection and processing of data, increased product visibility, such as the items identification, location tracking, and real time quantity checks. Consequently, companies may become more lean in their operation by cutting down on wastes from overproduction, avoid lost of revenue due to underproduction or late deliveries and reduce storage costs when they can avoid making or getting products too early or too late to the market. In long run, companies can significantly reduce total inventory costs [2].

The Automatic Identification and Data Collection (AIDC), a type of information technology system, is considered as the heart of the new supply chain management and execution system. This technology collects information and transmits/receives data to/from relevant hardware/software systems for further processing. For example, in an inventory system, a data may include inventory levels, quantity of orders picked in certain time frame or locating products in transit. Figure 1 summarized various types of AIDC technology that are available in the market.

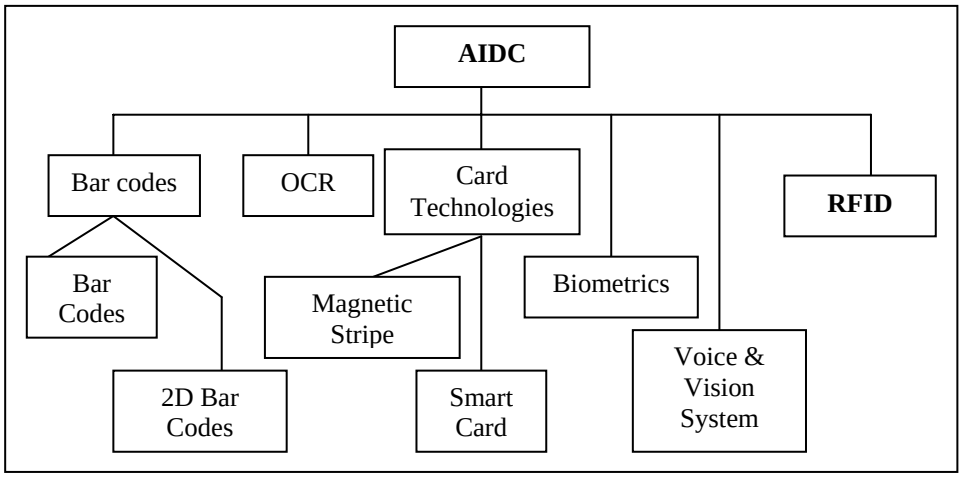


Figure 1: Various types of AIDC technology

2.2 Bar Code

Bar code is one of the best known and most widely used of AIDC technology and was invented in the early 1950s. It consisted of linear bar code which is made up of a pattern of parallel dark lines and spaces between the lines to represent a coding system for the necessary data for various products. A typical barcode stripe normally represents 15 to 50 characters. The Universal Product Code/European Article Number (UPC/EAN), as shown in Figure 2, is the most familiar type of bar code which is widely used in grocery industry. The most common application method of bar code is by printing the bar code on a specific label and then applying it to the product, but sometime it can be directly printed on the body of products [3]. A data is extracted from a bar code by scanning it with an electro-optical system, referred to as a bar code scanner, which operates by illuminating the bar code symbol, measuring the reflected light waveform data, converted it to digital form, and then to be processed by a decoder, and eventually passed it to the computer-based software system.

Figure 2: UPC/EAN linear barcode and EAN coding (adopted from www.aimglobal.org, 2002).

2.3 Radio Frequency Identification

Radio Frequency Identification (RFID) is a type of automatic method used with information technology system in the recent years. RFID is a contact less transmission method for identification of objects. As compared to barcode, RFID has the ability to automatically identify and track objects without line of sight [4]. The basic system consists of three parts; RFID tags, the RIFD readers and a host computer with the IT system. The tags typically consist of a silicon chip and acts as the data carrier, comprised of antennas and an electronic circuits. They are manufactured in many shapes and sizes and possess different performance capabilities based on pre-programmed characteristics, but they are basically representing two types; passive or active. A passive tag uses electromagnetic energy generated by a reader as its power source, which makes it much lighter, smaller and less expensive and has a virtually unlimited useful life, but the disadvantage is that it has a shorter read range, requires more powerful reader, provides less data storage capacity and also more sensitive to electromagnetic noise [3]. However, due to its low cost and long operational lifetime, it is more preferred than active tags in many applications. In contrast, an active tag contains on-board battery source that supply its power which makes it heavier, more expensive, and limited operational lifetime (up to 10 years only). The significant benefit of the active tag is that it can provide longer read range which is more suitable for large-scale operation [5]. Another devise is a RFID reader. It is used to communicate with RFID tags, to send and receive radio frequency waves by generating an electromagnetic or interrogation zone to supply power to passive tags as they enters this zone and collect information by decoding the tags' transmitted signals. It can also send out different signals in order to write additional information onto a re-write tag. The reader then conveys the data back to the host computer to process and update information in the computer data base. Most readers are handheld type; however, fixed-mount type is also being used by RFID system [6]. To complete the system, a computer is needed to host IT system, process the tag's ID number, matches with the database records and transforms data into usable information [7]. Therefore, the success of the data collection and management relies on the ability of the software system to effectively display the desired information accurately and timely. Figure 3, shows the typical RFID system integration.

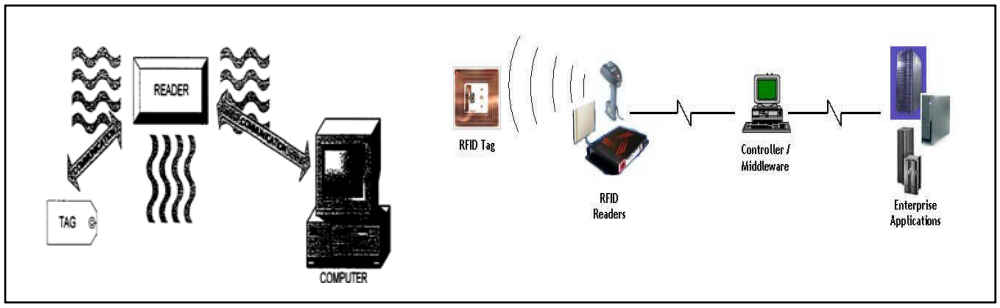


Figure 3: A Typical RFID System [3]

3.0 PROBLEMS FORMULATION AND INITIAL SOLUTIONS

This study was conducted in a store, which supplies items such as books, tools, electrical equipments and many more items used by students and staffs for various activities in a university. However this study only focused on a borrow-use-return items section. Data collected from this section revealed many problems, which have caused negative outcomes to inventory management such as time delay, lack in security and difficulty to trace items' locations (Figure 4). In order to provide initial solutions to overcome these problems, the authors have further studied the root cause of these problems, and through discussions and brainstorming session with staffs involved in managing the store, the authors were able to formulate solution to overcome these problems and defining requirements or specifications of the new system to be developed that can eliminate these problems and be able to improve the overall inventory management system in the borrow-use-return section.

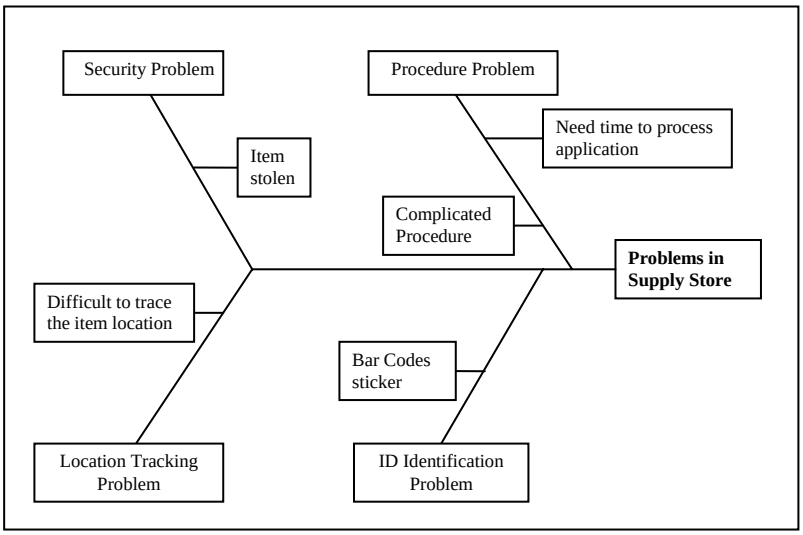


Figure 4: Case and effect diagram for supply store problems

4.0 THE DEVELOPMENT OF RFID INVENTORY MANAGEMENT SYSTEM

Referring to the design feature stated in Table 1, a new inventory system based on RFID technology was proposed to be developed and implemented in the supply store. The following section describes overall system development and implementation issue.

Table 4: Problem formulation and initial solutions

Problems	Negative outcomes	Solutions	Propose Design Feature
Complicated procedure	Delay in processing applications	Develop an integrated information system that automatically updated record simultaneously	Integrated and automatic inventory information system
ID loss or damage	Loss of items information and identification	Use more durable or reliable tags	Heavy duty tags or long usable life years
Lack of security	Items can be accessed easily by non-authorize personnel, may lead to loose or misplace of items. Borrower ID was not recorded accurately	Required an automatic system that be able to scan item as it pass out through entrance of store area	RFID system that has capacity to scan and update data automatically
Difficulty to Track items	Take longer time to track and locate items' positions.	Provide automatic update of items' position and able to display required information accurately	Integrated data base system supported by RFID technology

4.1 The Inventory System

In the supply store environment, there are certain aspects that should be concerned before the development of the inventory system in order to ensure a fully functioned system in the supply store. There are input, processes, output, outcome, feedback, the final outcome and the environment of store management (Figure 5 and Table 2).

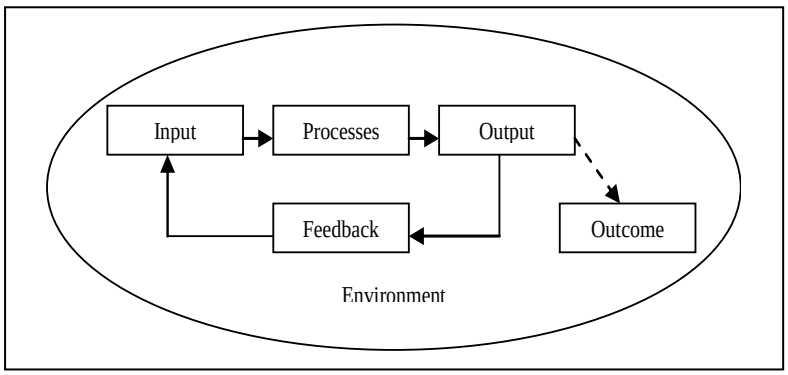


Figure 5: The supply store system interaction

Table 2: Description of inventory system

Items	Descriptions	Data/information
Input	The resources imported from the outside environment	Staffs, equipments and material
Processes	Activities that transform resources into a product	ABC analysis, automatic updates
Output	The products and services created by supply store	Application, approval, products borrow and return system
Outcome	The effect of supply store output on larger environment.	Report generated and graphical charts
Environment	Environment – The larger context outside system, which provides input, receive output and affects on decision making by the system	Staffs and the users inputs
Feedback	Feedback – Information from system and environment that help to make improvements in the future	Measurement and monitoring of performance

4.2 Inventory Classifications

In supply store inventory, there were more than hundred of items in position ready for customers, yet this study only focused on items involved in borrow-used-return section. To effectively manage the inventory, they must be classified and prioritized, for effective monitoring and maintenance. ABC analysis, which is commonly used tool in inventory management, was applied to calculate item's quantity and cumulative values and grouped them into three regions (Figure 6).

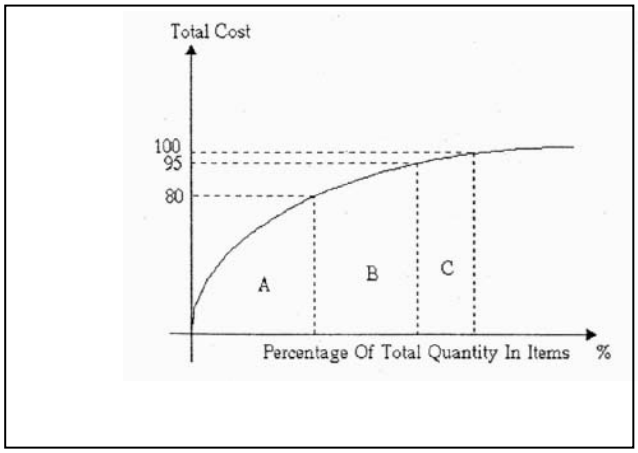


Figure 6: ABC analysis classification

The example calculation of ABC analysis for the item of LCD projectors is explained below and the overall result is summarized in Table 3.

$$\% \text{ item} = \frac{Quantity}{Total\_Quantity} \text{ and } \% \text{ item for LCD Projector} = \frac{8}{194} = 4.1237\%$$

$$\% \text{ RM} = \frac{\text{Price}}{Total\_\text{Price}} \text{ and } \% \text{ RM for LCD Projector} = \frac{81660}{252582.15} = 32.33$$

Table 3: Result of ABC analysis on borrow-used-return items

No.	Parts	Quantity	Price (RM)	% Item	% RM	Cum. %RM	Class
8	LCD Projector	8	81660	4.12371	32.3301	32.33	A
11	Portable P. A. System	10	23720.05	5.15464	9.39102	41.72	A
9	P. A. System	1	19357.7	0.51546	7.66392	49.38	A
1	Video Camera	8	16728	4.12371	6.6228	56.00	A
24	Display Board	2	15682	1.03093	6.20867	62.21	A
28	Wakie Talkie	19	12495	9.79381	4.94691	67.16	A
7	Slide Projector	2	10990	1.03093	4.35106	71.51	A
18	Rear Screen	2	9980	1.03093	3.95119	75.46	A
21	Data Display	1	9150	0.51546	3.62258	79.08	A
6	Overhead Projector	3	7397.4	1.54639	2.92871	82.01	A
2	Still Camera	8	7280	4.12371	2.88223	84.89	B
3	Television	5	6260	2.57732	2.4784	87.37	B
14	Tripod Video Camera	3	5400	1.54639	2.13792	89.51	B
4	Video Player	3	4580	1.54639	1.81327	91.32	B
17	Tripod Screen	4	4026	2.06186	1.59394	92.91	B
10	Power Amplifier	1	3400	0.51546	1.3461	94.26	B
12	Loud Hailer	7	2430	3.60825	0.96206	95.22	C
13	Waistband Sanha	4	2200	2.06186	0.871	96.09	C
20	Flip Chart	5	2097	2.57732	0.83022	96.92	C
30	Mini Waistband	8	1504	4.12371	0.59545	97.52	C
5	DVD/ VCD Player	2	1100	1.03093	0.4355	97.90	C
19	Microphone	6	1100	3.09278	0.4355	98.40	C
29	Reklektif Baton	12	1050	6.18557	0.41571	98.82	C
32	Vest	28	840	14.433	0.33257	99.16	C
15	Microphone Stand	5	600	2.57732	0.23755	99.40	C
16	Light Stand	3	450	1.54639	0.17816	99.58	C
27	Antenna	1	300	0.51546	0.11877	99.70	C
31	Baine Merie	15	225	7.73196	0.08908	99.79	C
26	Wire Conector	10	210	5.15464	0.08314	99.87	C
22	Sport Light	1	150	0.51546	0.05939	99.93	C
23	Laser Pointer	3	120	1.54639	0.04751	99.98	C
25	Polystrene Cutter	4	100	2.06186	0.03959	100	C
	Total	194	252582.15				

4.3 Record of Borrow-Used-Return Items

The data collected from the supply store contain the item's information, frequency of borrow, date of borrow, date of return and the overall record of borrow and return for year 2007 to be included in the system as in Figure 4.3a and based on

Pareto analysis as shown in Figure 4.3b, the authors have chosen only top ten of the most frequently borrowed items to be used for implementation of the system as a pilot study. They were walkie-talkie, LCD projector, video camera, vest, portable P.A. system, wire connector, still camera, tripod screen, loud hailer and baine-merie. They represented different classes in ABC analysis and can be considered suitable items to be initially used in the new system.

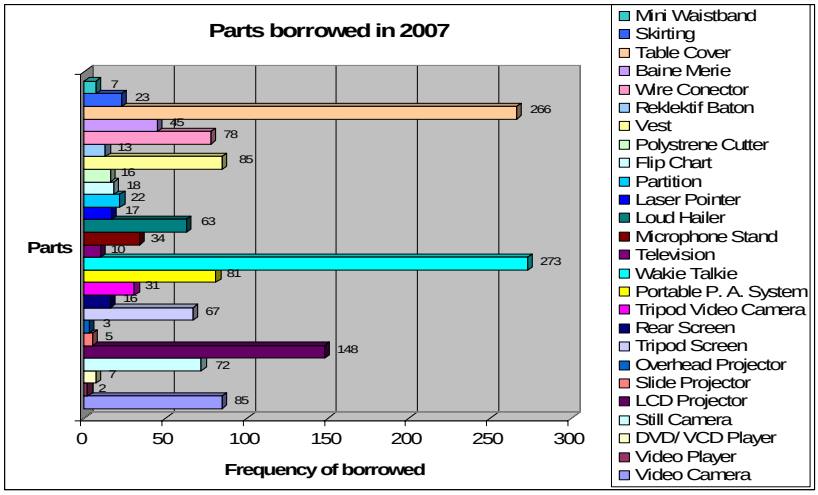
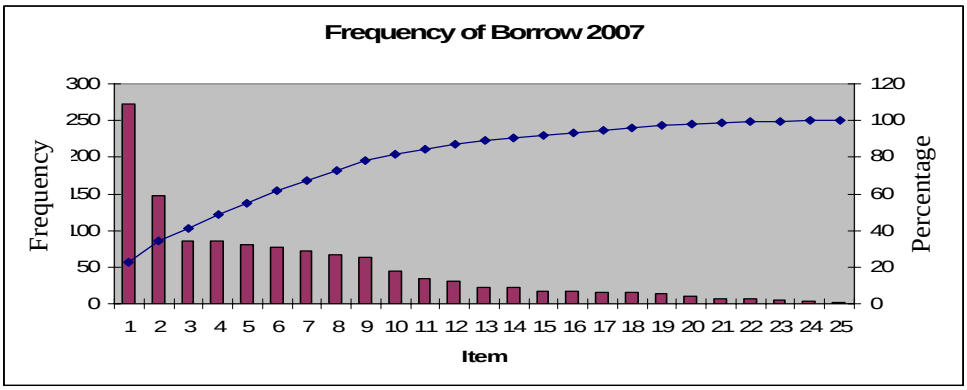


Figure 7: Histogram for frequency of borrow



1	Walkie Talkie	8	Tripod Screen	15	Flip Chart	22	Mini Waistband
2	LCD Projector	9	Loud Hailer	16	Laser Pointer	23	Slide Projector
3	Video Camera	10	Baine Merie	17	Rear Screen	24	Overhead Projector
4	Vest	11	Microphone Stand	18	Polystrene Cutter		
5	PortableP.A. System	12	Tripod Video Camera	19	Reklektif Baton		
6	Wire Connector	13	Skirting	20	Television		
7	Still Camera	14	Partition	21	DVD/VCD Player		

Figure 8: Pareto diagram for frequency of borrow in supply store

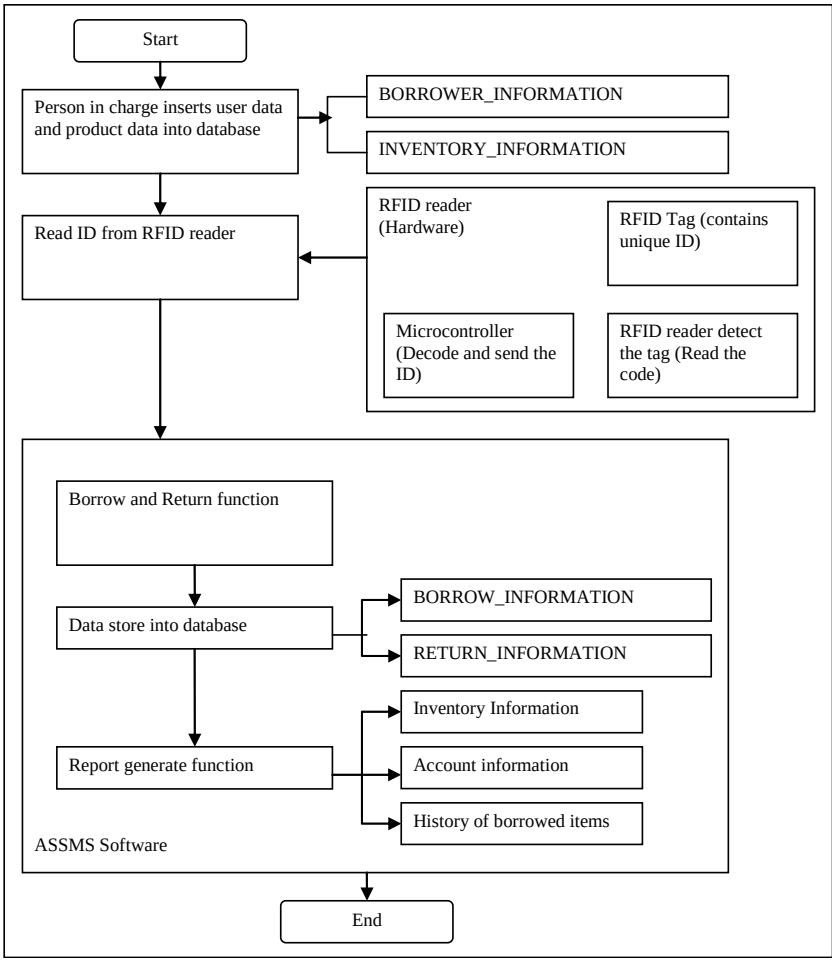


Figure 9: Flow diagram for hardware and software integration

4.4 The Flow of Information

To ensure the system effectiveness, the system must integrate the hardware and the software accurately. In addition, it must be able to store, read and processing data and provide required output. Figure 9 summarizes a developed system called *Automated Supply Store Management System* (ASSMS) to be used in the supply store.

4.5 The System's Hardware

Various hardware used in the system such as RFID readers, RFID tags, USB-Com Port RS232 converters, USB-PS2 converters and a laptop computer. The criteria used for the hardware selection was low cost and availability of items in the market (Figure 10).

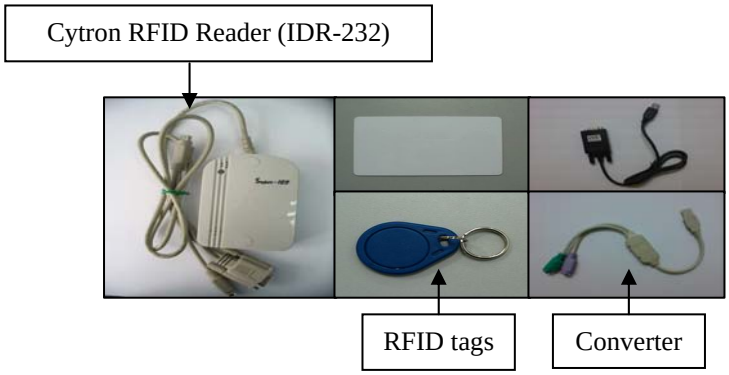


Figure 10: Hardware for ASSMS system

4.6 The System's Software Features

The ASSMS software was developed using Visual Basic® 6.0 and Microsoft Access® data base packages. Table 4 and Figure 11 show descriptions of items in the system.

Table 4: Explanations of ASSMS interface

No.	Explanation
1	Borrow or return mode check box
2	User Information display box
3	Item information
4	Items information display box
5	Transaction menu
6	Fine payment information
7	Administration function

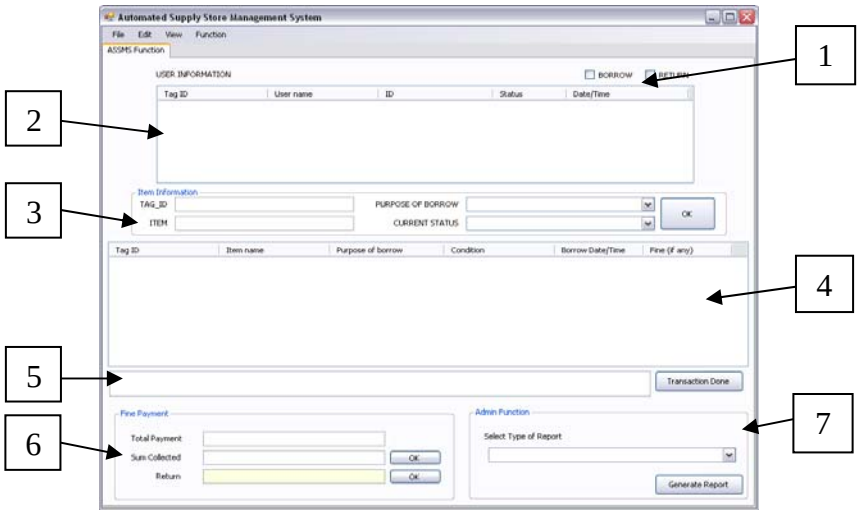


Figure 11: Automated Supply Store Management System (ASSMS) Interface

4.7 Information Flow in ASSMS

The user interface was designed to allow the staff in charge to choose the function (e.g. either borrows or return mode). If the borrow items is chosen, he or she will need to scan the user ID (RFID tag) by passing it through a reader. Then the user ID will be matched with BORROWER_INFORMATION list stored in database. When it matched successfully, the system will scan the item's RFID tag using the same step, or else the program will show error status and need to be repeated again. Consequently, when the staff in charge clicks on the return icon, the system will directly proceed to scan the item's RFID tag and match with the information stored in INVENTORY_INFORMATION in the database, then it would complete the process automatically or it produced an error status if the ID's information didn't match with the database. For the borrow mode, the transaction will update data into the table BORROW_INFORMATION and show the transaction success status.

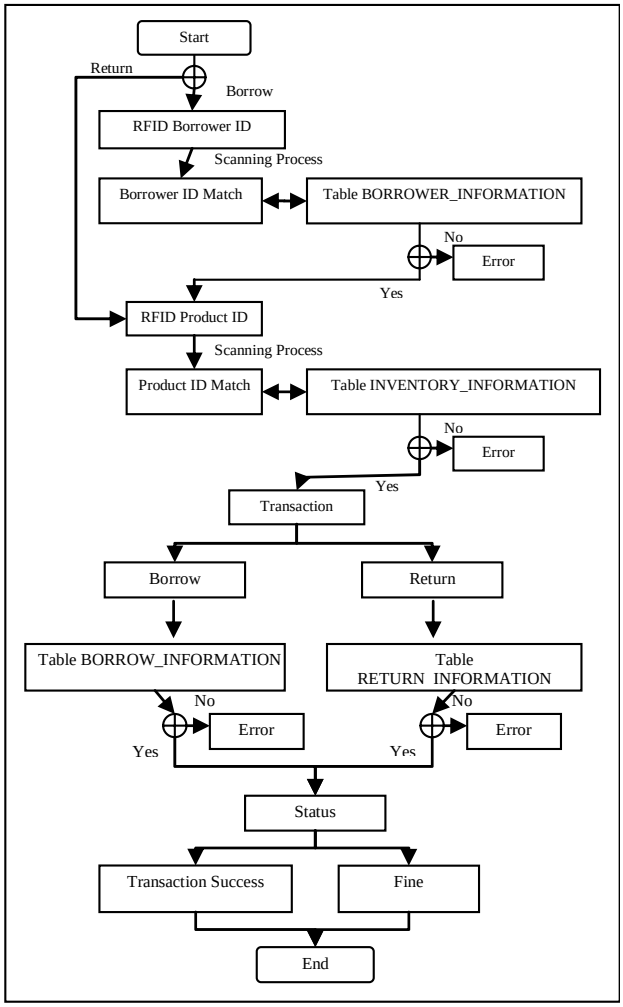


Figure 12: Process flow of ASSMS system

Similarly, for the return mode, the system will check and update information in table RETURN_INFORMATION in the database. The database fields consists of name of borrowers, borrower reference codes, item names, item reference codes and date returns. The program will also calculate the fine imposed in the case of late return exceeding five days, which is depends on the class of the items (e.g. Class A – RM2/day, Class B – RM1/day and Class C – RM0.50/day) (as shown in Figure 12).

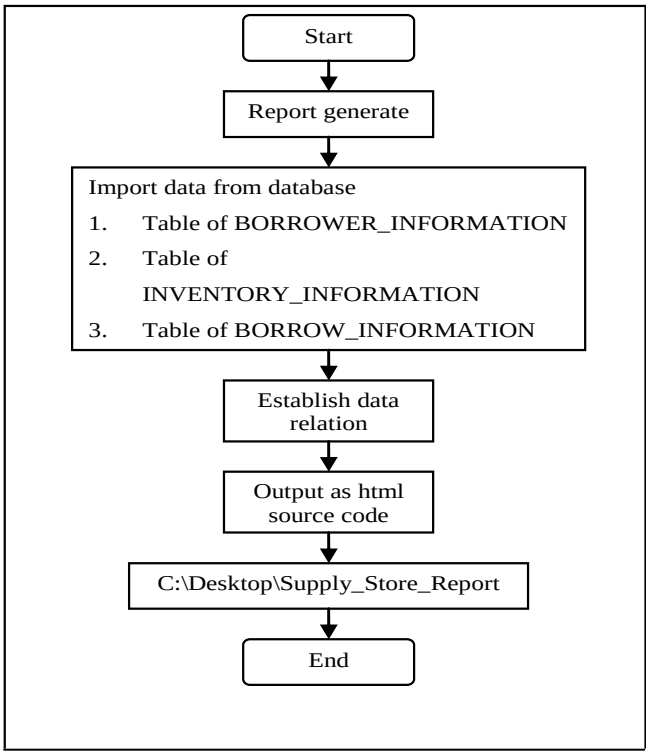


Figure 13: Process flow of report generation

4.8 Process Flow to Generate Report

In the report function, firstly the staff in charge will need to choose the icon on the user interface then; the program will import data from database which contain table of BORROWER_INFORMATION, table of INVENTORY_INFORMATION, table of BORROW_INFORMATION and the table of RETURN_INFORMATION. Then, it will establish the data relation between these tables and produce the output with html format that is ready to be printed (see Figure 13).

4.9 Type of Reports Produced by ASSMS

There were four types of reports the system can generate as described in Table 5. Figure 14a, Figure 14b, Figure 14c and Figure 14d show the details of information displayed by each table to assist the staffs in charge obtaining accurate information for the management and control of the supply store.

Table 13: Category consists in database

Table	**Category**
BORROWER_INFORMATION	Index, borrower's name, reference code, course, contact number and IC number
INVENTORY_INFORMATION	Index, item name, reference code, brand, model, year buy, price, availability and class
BORROW_INFORMATION	Index, borrower name, borrower ref. code, purpose, item name, item ref. code and date of borrow
RETURN_INFORMATION	Index, borrower name, borrower ref. code, item name, item ref. code and date of return

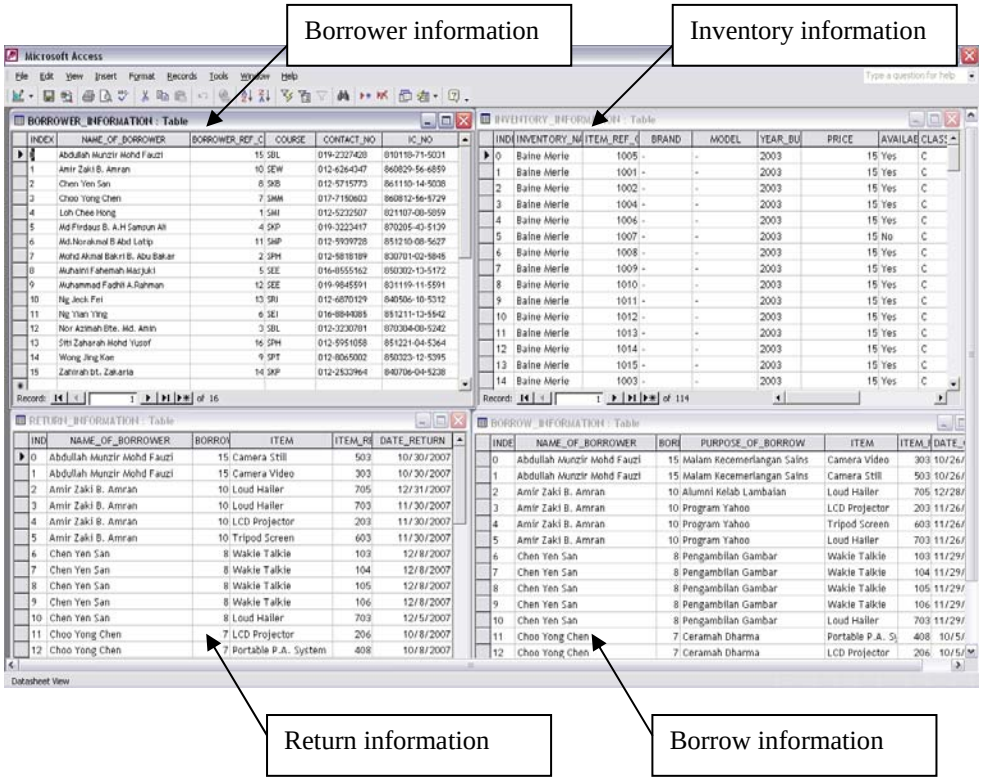
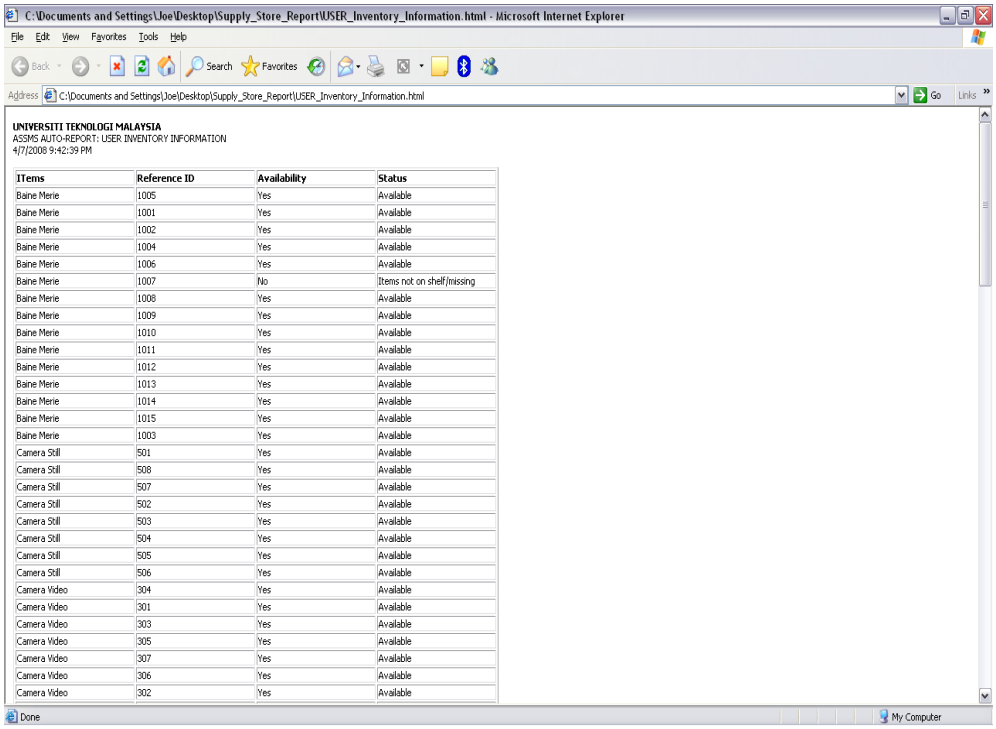
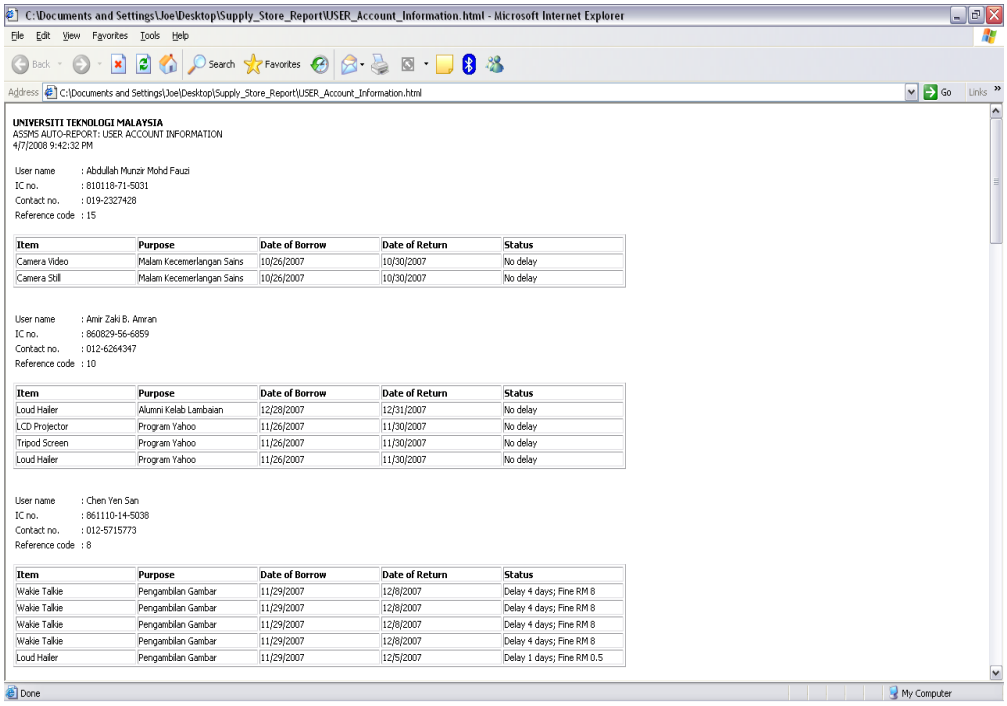


Figure 14a: Tables in the database of supply store



ITems	Reference ID	Availability	Status
Baine Merie	1005	Yes	Available
Baine Merie	1001	Yes	Available
Baine Merie	1002	Yes	Available
Baine Merie	1004	Yes	Available
Baine Merie	1006	Yes	Available
Baine Merie	1007	No	Items not on shelf/missing
Baine Merie	1008	Yes	Available
Baine Merie	1009	Yes	Available
Baine Merie	1010	Yes	Available
Baine Merie	1011	Yes	Available
Baine Merie	1012	Yes	Available
Baine Merie	1013	Yes	Available
Baine Merie	1014	Yes	Available
Baine Merie	1015	Yes	Available
Baine Merie	1003	Yes	Available
Camera Still	501	Yes	Available
Camera Still	508	Yes	Available
Camera Still	507	Yes	Available
Camera Still	502	Yes	Available
Camera Still	503	Yes	Available
Camera Still	504	Yes	Available
Camera Still	505	Yes	Available
Camera Still	506	Yes	Available
Camera Video	304	Yes	Available
Camera Video	301	Yes	Available
Camera Video	303	Yes	Available
Camera Video	305	Yes	Available
Camera Video	307	Yes	Available
Camera Video	306	Yes	Available
Camera Video	302	Yes	Available

Figure 14b: Report of inventory information



User name : Abdullah Munzir Mohd Fauzi
IC no. : 810118-71-5031
Contact no. : 019-2327428
Reference code : 15

Item	Purpose	Date of Borrow	Date of Return	Status
Camera Video	Malam Kecemerlangan Sains	10/26/2007	10/30/2007	No delay
Camera Still	Malam Kecemerlangan Sains	10/26/2007	10/30/2007	No delay

User name : Amir Zaki B. Amran
IC no. : 860829-56-6859
Contact no. : 012-6264347
Reference code : 10

Item	Purpose	Date of Borrow	Date of Return	Status
Loud Hailer	Alumni Kelab Lambaian	12/28/2007	12/31/2007	No delay
LCD Projector	Program Yahoo	11/26/2007	11/30/2007	No delay
Tripod Screen	Program Yahoo	11/26/2007	11/30/2007	No delay
Loud Hailer	Program Yahoo	11/26/2007	11/30/2007	No delay

User name : Chen Yen San
IC no. : 861110-14-5038
Contact no. : 012-5715773
Reference code : 8

Item	Purpose	Date of Borrow	Date of Return	Status
Wakie Talkie	Pengambilan Gambar	11/29/2007	12/8/2007	Delay 4 days; Fine RM 8
Wakie Talkie	Pengambilan Gambar	11/29/2007	12/8/2007	Delay 4 days; Fine RM 8
Wakie Talkie	Pengambilan Gambar	11/29/2007	12/8/2007	Delay 4 days; Fine RM 8
Wakie Talkie	Pengambilan Gambar	11/29/2007	12/8/2007	Delay 4 days; Fine RM 8
Loud Hailer	Pengambilan Gambar	11/29/2007	12/5/2007	Delay 1 days; Fine RM 0.5

Figure 14c: Report of account information

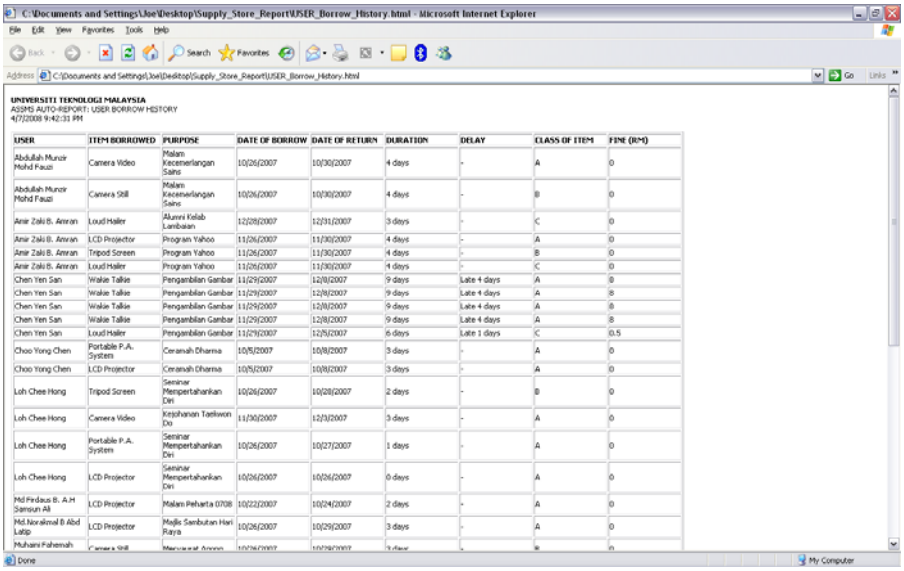


Figure 14d: Report of history of borrowed items

4.10 System Evaluation

In order to validate the performance of this system, the authors has implemented the system as a pilot scale and evaluated the outcomes by comparing it with the existing method used in the supply store. The result has proven that the new system was able to eliminate most problems faced by the supply store. In addition the new system was also considered more superior than the existing method in term of efficiency, effectiveness, reliability, security and cost aspects. The outcomes of the evaluation were summarized in Table 6.

Table 6: System Evaluation

Item	Present (Manual)	RFID System
Efficiency	Need more activity and paper works, time consuming	Fast - automatic record, retrieve and report, time saving
Effectiveness	Difficulties in monitoring item, borrower and inventory status	Accurate and up to date information available on requested
Reliability	Data missing due to item ID defects or lost	Water prove, scratch prove and ware & tare proof tag, lifetime used
Security	Data may be changed or replaces in the supply store by unauthorized persons	ID for item and borrower are unique and cannot be changed, unique ID represent each borrower and each item
Cost Justification	Need more man power in managing inventory, searching lost/misplace item or to update or audit each asset - high cost in long run	System can be expended to provide more information as needed in the future with minima cost

5.0 DISCUSSIONS

The study has addressed many issues related to management of inventory in the supply store environment. The requirements of a better inventory system were formulated and incorporated in the design features of a new system which was based on RFID technology that is currently used in solving problems in inventory management. In trying to evaluate the system, the authors prioritized and selected only critical inventory items to be included in implementing the system as a pilot project. Based on discussions and brainstorming sessions with staffs involved in supply store management section, the authors have able to demonstrated satisfactory results of the new system to solve problems faced by the existing inventory management system. Among the features that would provide benefits for the inventory management staffs and authority were automatic data scanning capability, automatic data retrieval and update, report generating function on of items and borrow history, late return items, amount of fine incurred and the total amount paid for a financial period.

There were few limitations in the newly developed system, which can be considered as aspects in the future works. The system was not able to solve the location problem which was stated in the problem formulation section. However, this problem could be solved if the readers and the tags used have longer read ranges. Another limitation of this study was that part of the security problem still exists because the reader cannot be installed rightly at the entrance of the supply store, which was also due to shorter read ranges of the reader and tags and therefore could be solved using the same approach.

6.0 CONCLUSIONS

The increase in reliability of RFID technology over other systems has brought many benefits in developing the technology for various applications, especially in the inventory management. In this project, RFID technology was developed and implemented on a pilot scale in inventory management system of a supply store section. As a result, this project has demonstrated a successful development and implementation of RFID technology for supply store inventory management system. The system managed to keep the record updated and able to display information accurately and timely. Another feature of the system was the ability to generate the schedule reports on borrower information, items information and borrow history, which would help staffs and management to perform the inventory audit or to take immediate action whenever necessary for improving inventory management efficiency in the supply store.

The future works could be repeated by using RFID hardware with higher reading range to provide a greater efficiency and effectiveness of the system for larger area. To increase the security feature, not only tags that must be embedded well into items to make them hidden, but they must also be able to provide strong signals to readers. The process for embedding tags correctly is worth to be studied. There are many other extended features that can be added to the system in the future study (e.g. automatically generate email to alert borrowers on late return

through short massage system, auto tracking items in different locations and web-based system which can be accessed online by the authorize personnel).

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