# Development of an RFID System for Fixed Asset Monitoring in a University: A Case Study

**Salamat Begmanov and Pisal Yenradee**

Logistics and Supply Chain Systems Engineering Program, Sirindhorn International Institute of Technology, Thammasat University, Pathum Thani, Thailand
Industrial Engineering Program, Sirindhorn International Institute of Technology, Thammasat University, Pathum Thani, Thailand
E-mail: sbegmanov@gmail.com, pisal@siit.tu.ac.th

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*Abstract*—**This paper aims to develop a radio frequency identification (RFID) system for fixed asset monitoring and control in a University. It includes selection of hardware, design and development of software, identification of suitable position and how to attach RFID tags to the fixed assets to obtain 100% readability, conducting experiments to determine the accuracy and time required to read the RFID tags, and performing economic analysis of the RFID system. A case study with real implementation in three selected rooms of Sirindhorn International Institute of Technology, Thammasat University, was performed. Experimental results show that the developed RFID system can achieve 100% accuracy, significantly reduce total time for fixed asset check when compared with the manual system, and economically justified when the number of fixed asset items is relatively high.**

*Index Terms*—**RFID system, fixed asset monitoring, sequential algorithms, intranet of things, economic analysis**

## I. Introduction

A manual system of fixed asset monitoring and checking in Thai Universities is time consuming, tedious, inaccurate, and stressful. Fixed asset data are generally stored in an accounting system database. All fixed asset items must be checked regularly at least once a year or once a semester. Some fixed asset items have an information of its location such as a room number. During fixed asset checking period, staffs of each department will receive a hard copy of check sheet listing all items to be checked within their control. Each fixed asset item has 15 digits number ID, description, number of units (one or more than one), and its location (room number which is optional).

The manual system is time consuming since the staffs must read the description of the asset with 15 digits number ID and try to manually find the asset item in the room. It is inaccurate because the asset items in the room are mixed between the items that need to be checked and other items. It is often found that some items are actually in the room but the staffs cannot find it at the first time of checking. If someone moved the asset out of the rooms that the staffs are not responsible, those items may not be found and may be considered as "Lost" items. It is stressful since responsible persons may need to pay for the "Lost" items, therefore, the check must be done carefully with high concentration. The process is much more time consuming when the "Lost" items are expensive and they need to be checked for the second or third times.

An RFID (radio frequency identification) system is expected to be suitable for monitoring and checking fixed assets in Universities because when the staff brings the RFID reader not too far away from the RFID tags, the tag IDs will be automatically read although the staffs may not see the tags. This characteristic of RFID reduces a chance that the fixed asset item exists but the staff cannot find it.

### A. Objectives

The paper has specific objectives as follows.

1. To develop the RFID system for fixed assets checking, which is fast and accurate, to be used at Sirindhorn International Institute of Technology (SIIT), Thammasat University (TU).
2. To evaluate the time and accuracy of fixed asset checking process.
3. To evaluate whether the RFID system is economically justified to be used in practice at SIIT, TU.

*B. Scopes*

This paper has limited scopes as follows.

1. The RFID reader used in this research is a model of handheld reader that is currently available at SIIT.
2. RFID tags are passive type, which is inexpensive. They have various models with various sizes, which are currently available at SIIT.
3. The application software to be developed is only a prototype that has limited functionalities.
4. Implementation of the RFID system will be performed in only three rooms with different environments, which are a department office, a meeting room, and a graduate research room.

## II. Literature Review

This section provides a review of RFID system and its application in various aspects including advantages, system design, database, RFID tags, fixed assets control, intranet of things, RFID standardization, and benefits and costs analysis. The purpose of this review is to explain the characteristics of developed RFID system when compared with those in literature.

*A. RFID systems advantages*

Advantages of RFID technology is automatic data recording (retrieving, updating), high data accuracy, high durability, reusability and uniqueness of RFID tags [1]. If the RFID system (handheld reader, database storage, IoT) is integrated with an external system (e.g. SAP ERP, etc.), the system would require additional communication protocols, special antenna, internet of things, modified architectural design, tag encoding scheme, etc. This paper focuses on the RFID system without any external system integration but the conclusion section recommends some possible ways of integration.

*B. RFID system development*

Some RFID systems are all-in-one complete system, which may not require further development before use. However, most systems available in the market are non-complete system, which require further development before it is functional. This paper uses the non-complete RFID system where further developments are needed to make it possible to check fixed assets in Universities. Some literatures on RFID applications state perfect reading performance of RFID devices, however, in practice, this assumption does not hold true [2]. Various experiments are needed to reach 100% of tag readability according to a selected environment.

*C. Database storage*

Increasing demand for RFID systems is giving initiative to develop the “RFID smart shelf” applications using full capacity of RFID tags [3]. But the study targets on using only TID memory RFID tag capacity (see section D. Types of tags and readability) as unique unalterable code and using SQL server database to store additional information on fixed assets.

The Application Level Event (ALE) standard of EPCglobal organization [4] allows writing own business logic for RFID tag data manipulation. The ALE does not require a special structured language. For instance, ALE and data stream system for RFID data processing are demonstrated using SQL-based stream query language structure for event-detection organization [5-6]. This paper also utilizes the modern SQL functions for event-detection (data duplicate prevention, registration, retrieve, update, input) within developed software and creates own database schema.

*D. Types of RFID tags and readability*

RFID tags are classified into five classes and the purpose of classification is to reach cheapest versions of various tags [4]. The EPCglobal [7] classifies tags as follows: Class 0/1: passive, 0-factory programmed (TID), 1-user data input, Class 2: passive, read-write memory, Class 3: non-active with battery, longer range and broadband, Class 4: active with additional sensing, Class 5: activator, classified as reader.

Reference [8] explains a 4-month observation on readability and retention rate between passive tags (low frequency (LF) 30-500 kHz, high frequency (HF) 13.56 MHz) showing no difference between LF and HF passive tags at distance 7-10 cm and 10-15cm, respectively.

The study uses UHF (Ultra High frequency, 850-950 MHz) passive tags of Classes 1 and 2 which last long, approximately 10 years [6] and are readable from the default command called “Read” [2]. The typical passive tags consist of four memories called EPC (electronic product code), user, password, and TID (tag identifier). This paper utilizes the TID memory capability which is unalterable, pre-programmed by the manufacturer.

Reference [7] suggests experimenting every selected tag position to avoid the interference of electromagnetic environments on tag readability. Reference [9] conducted experiments with active RFID tags in metallic environments to increase human effort which are comparatively costly. An experiment with active RFID tag and antenna for hidden tag positions yielded 96% of readability [10]. Another deep experiment with passive tags and RFID antenna reached 99% of tag readability but the paper comments if the environment becomes sensitive, the readability decreases accordingly [11]. This paper will conduct experiments with stationary objects (fixed assets) arranged in less electromagnetic environments and expects to reach 100% of tag readability with passive tags and increase the visibility with single and continuous functions of handheld reader.

### *E. Fixed assets*

Fixed assets, known as 'tangible asset", is a term used in accounting for assets and property that cannot easily be converted into cash and are meant for use for many years. Fixed asset depreciates in value year-over-year. Growth rate of fixed assets can be increased by employing more investment [12]. The fixed assets of SIIT are made of both metallic and non-metallic materials of several types, for example, chairs, arm-chair, tables, shelves, air conditioners, wall partitions, personal computers, and electrical appliances.

### *F. Intranet of things*

Internet of Things (IoT) is a global a network infrastructure, linking any RFID systems together through network connectivity [7] or material objects connected to the wide network [13]. This paper does not assume global connectivity but utilizes the local network, hence, the network connectivity is called "intranet of things."

### *G. RFID system standardization*

Developing countries and global companies face challenges in adoption of the RFID technologies as there is less global standards harmonizing EPC Gen 2 into ISO standards [4] and obstacles in sharing "valuable RFID data" [14].

This paper utilizes ultra-high frequency (UHF) passive tags of Classes 1 and 2, EPC Gen2 compliant which follows the RFID air interface protocol for communication between 840 and 960 MHz bandwidth. The EPC Gen2 compliant, by ISO/IEC 1800-6C protocol, enables operations across frequencies in Asia, including Thailand. The handheld reader follows working mode–China Standard 920-925 MHz, output power–between 5 and 30 dBm.

### *H. Cost-benefit analysis*

Reference [1] explains a citation of reference for identification of three inventory discrepancies: inventory shrinkage from thefts, process errors, and misplacement of assets. Identification of such discrepancies, especially asset theft, has great impact to the project investment. Every identification system holding above mentioned costs may be beneficial in terms of company size, but the loss may be huge with traditional monitoring systems.

Typical approach to economic design is to reduce device and labor costs and increase social or environmental positive impacts. But the detailed project investment analysis would involve technical (project planning, design, construction, maintenance) aspects, financial (project budget and other expenses) aspects, and economic (balance between the technical and financial aspects) aspects [15-17]. In this paper, the financial aspect includes the acquirement of RFID hardware and software, development of prototype software, etc., the technical aspects include the environment learning, RFID system design, etc., the economic aspect includes the labor cost saving and investments.

## III. Methodology

The research methodology follows the block diagram (presented in Fig. 1) which explains the main four development steps for the RFID based fixed asset monitoring system. The gathering data step collects specific information for the project by studying the current manual system and the fixed assets, their environments, and the current RFID systems available in the market. The software deployment activities involve the development of the RFID system and the infrastructure. The implementation activities consist of installation of the RFID system and conducting experiments with the passive tags for suitable positions, data accuracy, data visibility and readability rate. The final system performance step involves the economic evaluation of the RFID system.

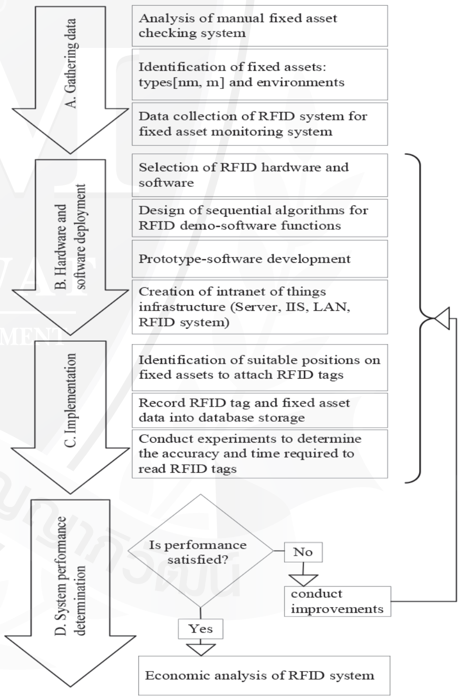



Fig. 1. Block diagram of methodological steps.

### *A. Gathering data*

In this step, the current manual fixed asset checking system, characteristics of the fixed assets and their environments are thoroughly studied. Then components of the RFID system are identified for further developments.

#### *1) Analysis of manual fixed asset checking system*

The manual fixed asset checking system has 6 steps as follows.

1. Two staffs (a staff of responsible department and a witness from other department) go together **into a room** to check each item on the check sheet, which should be in that room. If the item is "**Found**", a **check mark** will be made on the check sheet, otherwise noted as "**Not found**". Please note that some fixed asset items not listed on the check sheet may be available in that room.
2. The two staffs go into the **next room** to check remaining items on the check sheet, which should be in that room and also to find the "Not found" items from previous rooms. The "Not found" items may be changed to a check mark if it is found in this room.
3. Step 2 is repeated until all rooms under their responsibility are completely checked.
4. All fixed asset items without the check mark will be reported as "Not found" items.
5. All "Not found" items will be considered by a management team to be classified as "**Lost**" items **or not**.
6. For the "Lost items", responsible persons may need to **pay for them** based on the remaining book value.

*2) Identification of fixed assets and environments*

This research selects three rooms of SIIT with different functions and different types of materials of fixed assets to test the performances of the RFID system. Rooms 1-310, 1-415, and 1-416 are meeting, office, and graduate student rooms, respectively. They have 74, 51, and 19 items of fixed assets, respectively. Layouts of fixed assets in each room are presented in Figs. 2 to 4. Note that the legends: m, and nm in the layouts mean metallic, and non-metallic materials of the fixed assets.

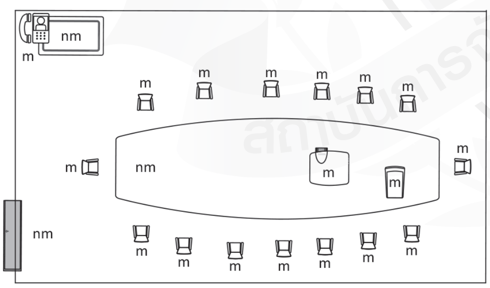


Fig. 2. Layout of Room 1-416.

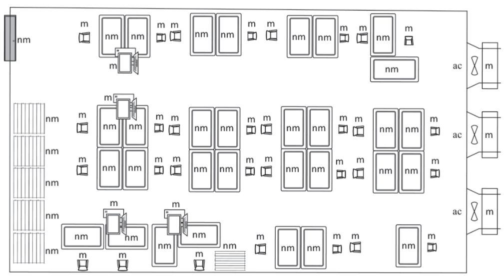


Fig. 3. Layout of Room 1-310.

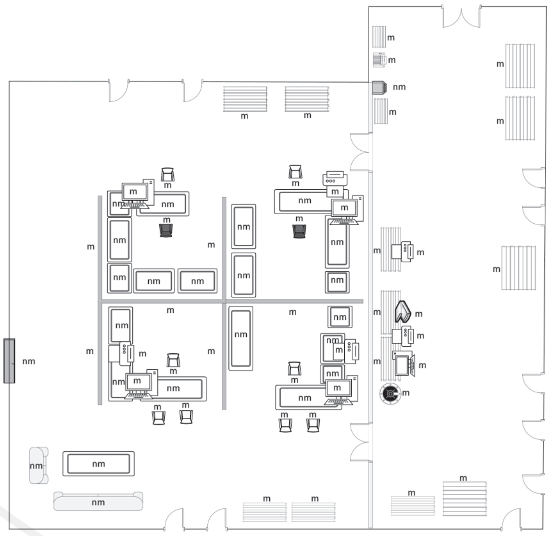


Fig. 4. Layout of Room 1-415.

*3) Main hardware components of RFID system for fixed asset checking system*

The RFID hardware components are RFID tags (serial data transponder), RFID reader (serial data receiver), and data storage as shown in Fig. 5. The handheld RFID reader ensures that the serial (TID) and text data are safely recorded, updated and scanned. The RFID reader is synchronized with the server database storage through the wireless LAN.

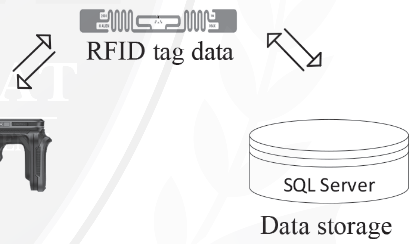



Fig. 5. Components of RFID system.

*B. Hardware and software deployment*

*1) Selection of RFID system and software*

As stated in the scope of this research that the RFID reader and RFID tags must be the current models available at SIIT. Additional hardware and software include Wi-Fi router, MS SQL Server and SQL express for database creation, and Intranet of Things infrastructure.

*2) Design of sequential algorithms*

Sequential algorithms are flexible and are created according to the project design requirements. For example, a sequential algorithm verifies RFID tags by group with the RFID antenna in an offline environment [18]. Another algorithm is created for coordination of the Received Signal Strength Indicator (RSSI) to detect RFID tags stored in digital floor plan and Building Information Modeling (BIM) database [19]. In this research, the algorithms are basically created for single and continuous scan functions of the RFID Prototype-software and for synchronization with the SQL Server database at real time.

The single scan function means that an RFID tag will be read only one time when the user presses the trigger of the RFID reader. The continuous scan function is operated when the user presses a start button on the reader and the reader automatically reads all tags located within operational range until the user press stop button. The user can walk to different locations in a room and also change directions of the reader to allow it to read continuously all RFID tags available in the same room. The single scan function is suitable for registering new data of an RFID tag for a new fixed asset item or for finding a fixed asset item (when it is already registered). The continuous scan function is suitable for checking all fixed asset items available in the room.

*Single scan function*

There are two single scan functions for room and fixed asset related data. Room related algorithm is designed to register information of a new room into the database, or to retrieve information of all fixed asset items belong to that room (see Fig. 6). Fixed asset related algorithm (see Fig. 7) is to a) register information of a new fixed asset item into the database, b) retrieve, or update information of the fixed asset item (if the RFID tag attached to the fixed asset item is already registered).

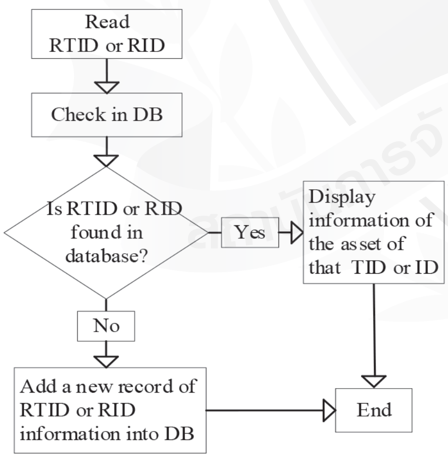



Fig. 6. Room related algorithm.

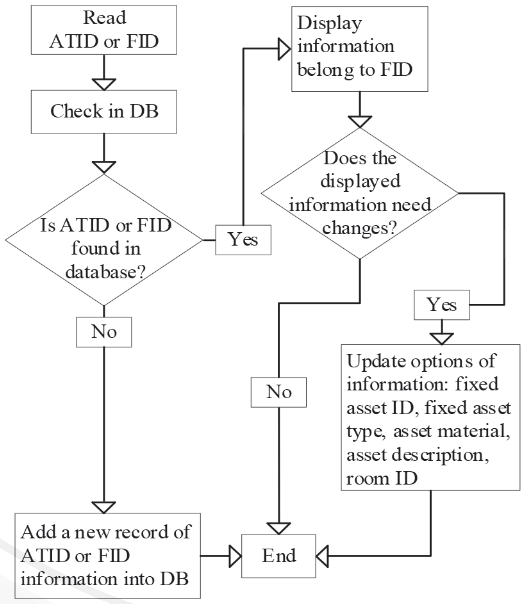



Fig. 7. Fixed asset related algorithm (Single scan).

*Continuous scan function*

The continuous scan function has only one algorithm to continuously read all RFID tags attached to fixed asset items in the room (see Fig. 8). After the user brings the RFID reader to scan all tags, some tags may be detected more than one time. If the tag is detected for at least one time, we consider that the fixed asset item is found. During continuous scan process, we may detect some unknown RFID tags that come with some equipment, which were not registered in the database for fixed asset checking purpose. These unknown RFID tags will be automatically reported. The user has an option to let the database remember them and not report them again. Note that when the RFID reader power is set at a high level, it may detect some RFID tags attached with the fixed assets located in an adjacent room. If these tags were registered in the database, they are not the unknown tags and no action should be taken.

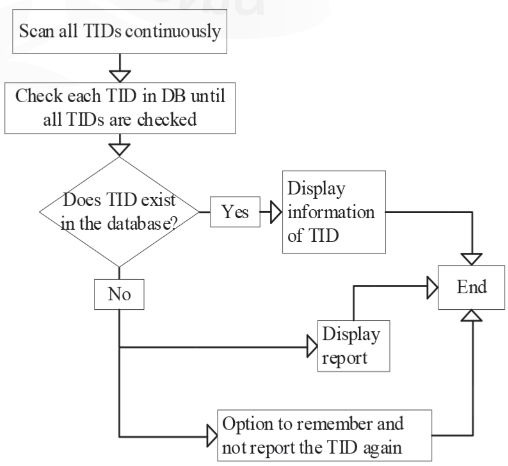



Fig. 8. Fixed asset related algorithm (continuous scan).

*3) Prototype-software development*

The Prototype-software is developed using c-sharp language based on the sequential algorithms for single and continuous scan functions presented in Figs. 6 to 8.

*4) Creation of Intranet of Things (IoT)*

The IoT infrastructure consists of SQL Server, Internet information services manager (IIS), Wireless LAN, and RFID reader as shown in Fig. 9.

The SQL Server is the database storage management system where the database is developed using SQL language to response to the data stream requests from the handheld reader. The tag IDs and additional meaningful data are recorded into the database. The database tables consist of:

1. Room table has two columns of RID (room number) and RTID (tag ID of RFID tag attached to room door).
2. Fixed asset table has 5 columns of ATID (tag ID of RFID tag attached to fixed asset), FID (fixed asset code), asset type, asset material, and asset description.

The IIS, an extensible web server supporting the HTTP protocol, supports the network requests between the handheld reader and SQL Server.

Wireless LAN consists of a Wi-Fi router and a local network that supports the connection between the server and handheld reader using the IIS HTTP protocol.

RFID reader is the data transponder and receiver into/from the server.

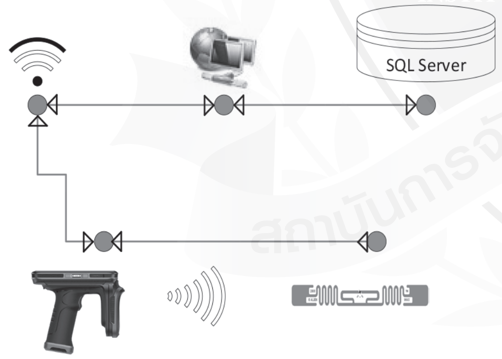



Fig. 9. Intranet of Things structure.

*C. Implementation*

After the RFID hardware components are selected and prototype software is completely developed, the RFID system is ready to be implemented in a real situation of three selected rooms at SIIT, TU. There are three important implementation activities, namely, identification of suitable positions to attach RFID tags on fixed asset items, registration of RFID tags and information of fixed asset items into the database, and conducting experiments to determine the accuracy and time required to read RFID tags.

*1) Identification of a suitable position to attach an RFID tag to each fixed asset item*

Six models of passive RFID tags will be attached to all fixed asset items in three selected rooms. There are some guidelines to identify the suitable position as follows:

1. The suitable position should be at the front side of the fixed asset so that everyone can clearly see the tag whether it is attached or lost.
2. The tags should be attached in the way that the plane of the tag is approximately perpendicular to the direction of wave transmitted from the handheld reader. Based on the layout of the room, it is known that the staff carrying the handheld reader will walk along which route to scan all tags, and what will be the natural direction of wave transmitted from the reader.
3. If it is possible, the tags should be attached at the level between hip and shoulder of a staff to reduce muscle stress of the staff to scan the tag.
4. When the tag is attached to the fixed asset item, trial readings by the reader will be performed to ensure that the tag can be detected by the reader. If the materials of the asset are metallic or mixed between metallic and non-metallic materials, it may interfere the wave transmitted from the reader, hence the tag cannot be effectively read. In this case, a high density (durable) foam material with a thickness of not less than 10 mm is recommended to support the tags to be away from the surface of the fixed asset. Note that a two-sided adhesive tape will be used to fix the foam material directly to the fixed asset, and the tags will be attached to the foam material using its self-adhesive.

*2) Record RFID tags and fixed asset data into database*

The single scan function is used to register RFID tags of rooms and fixed asset items together with descriptions of the fixed asset items into the database. We conduct an experiment to measure the required time to register the rooms and all fixed asset items in the rooms into the database. The results will be reported in the next section.

*3) Conduct experiments to determine the accuracy and time required to read RFID tags*

One of the objectives of this paper is to analyze the accuracy and time required to check all fixed asset items in three selected rooms using the developed RFID system. Note that experiments conducted by references [11] and [21] reported 79-96% readability rate for moving objects but this research conducts experiments with stationary objects, which requires the accuracy target of 100%.

The experiments in terms of data accuracy and time basically consist of continuously identifying the suitable positions until the tag readability rate is satisfied. Other experiments include the changing of power levels of handheld reader to find out a readable distance of RFID tag, and application of the foam material to avoid the electromagnetic interference at the selected positions. The above-mentioned experiments are repeatedly conducted until the system readability rate of 100% is obtained.

*D. System performance determination*

The most important system performance of this research is the accuracy level of fixed asset checking by RFID system. The target of accuracy level is 100%. When the accuracy level from experiments is lower than 100%, causes of error will be identified and solved until 100% is achieved. When the system performance is satisfied, experiments will be conducted to measure the time required using continuous scan function to continuously check all fixed asset items. Finally, an economic analysis of the RFID system and the manual system when it is used for a large-scale checking of all fixed asset items available in SIIT will be performed.

## IV. Results and Discussions

In this section, the results of performance analysis of manual fixed asset checking system, the conducted experiments on suitable tag position, tag readability rate, fixed asset visibility, data accuracy based on analysis of time and RFID system output power are discussed. The economic justification of the developed RFID system will be performed using net present value (NPV) technique.

*A. Performance analysis of manual fixed asset checking system*

An experiment is mainly conducted by the author and partly by fourth year industrial engineering students. They manually check all fixed asset items in three selected rooms where the RFID system is installed. The experiment is repeated by 9 times in each room.

The feeling of stress, discomfort is often experienced, especially when missed assets are occurred and then rechecked. The missed items are more frequently occurred in Rooms 1- 415 and Room 1-310 where the layouts are more complicated and crowded by many fixed asset items than Room 1-416.

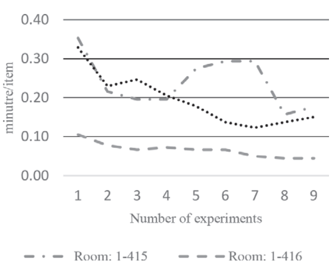



Fig. 10. Average time per item of manual checking in each room based on chronological order.

Fig. 10 shows the average time per item of manual checking in each room based on chorological order of checking. The graphs of Rooms 1-415 and 1-310 show a decreasing trend which indicates that when the same person gains experience in manual checking the average time per item time can be reduced due to learning effect. Note that the replication numbers 5 to 7 of Room 1-415 were performed for the first time by fourth year students. Thus, the average time per item is relatively high when compared with the author that has experiences. The graph of Room 1-416 does not show clear learning effect since the layout of fixed assets in the room is simple and the manual check is an easy task.

TABLE I

Average Time Per Item of All Replications for Manual Checking

| Room: | Complexity of layout | Average time per item |
|---|---|---|
| 1-415 | Complex | 0.24 |
| 1-416 | Simple | 0.067 |
| 1-310 | Complex | 0.194 |

Table I shows the average manual checking time per item of all replications in each room. It is found that the average checking time per item is highly influenced by the easiness of checking which is dependent on the complexity of fixed asset layout or arrangement.

A one-way analysis of variance (ANOVA) technique is used to determine whether the room has significant effect on the average time per item of manual fixed asset checking at the confidence level of 95%. It is found that the effect of the room is significant. When the Fisher's multiple mean comparison technique is used, it is found that the average time per item of Rooms 1-415 and 1-310 are not significantly different. However, the average time per item of Room 1-416 is significantly lower than that of Rooms 1-415 and 1-310.

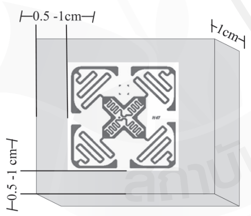
*B. How to attach RFID tags to the fixed asset items to achieve 100% readability*

Based on the developed RFID system and real experiments in three selected rooms, it is found that the suitable positions to attach RFID tags should be carefully determined to achieve 100% readability. There are recommendations to achieve 100% readability as follows.

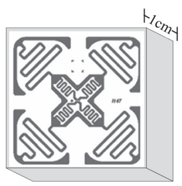
1. If the materials of the fixed asset at the position to attach the RFID tag are non-metallic, (e.g., wood, plastic, foam, fabric, and leather,) the RFID tag can be attached directly on the surface of the fixed assets. The output power of the handheld RFID reader should be set at 5 dBm, and the distance

between the reader and the RFID tag should be about 25 cm.

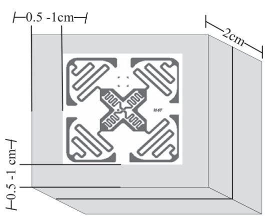
2. If the materials of the fixed asset at the position to attach the RFID tag are metallic or semi-metallic, (e.g., steel, aluminum, plastic or rubber body on steel structure,) they may interfere the RFID tag and the RFID tag should be supported by a hard foam material with a thickness of at least 1 cm. Note that the size of the foam should be bigger than the size of RFID tag (as shown in Fig. 11 (a)) to prevent the interference around the edges of the RFID tag. Fig. 11 (a) shows that when the tag is attached on the foam material, it has top, bottom, left, and right margins of 5 to 10 mm. Fig. 11 (b) shows that there is no margin left at each side of the RFID tag. In this case the readability is not good since it cannot avoid interference around the edges of the RFID tag. Fig. 11 (c) is similar to Fig. 11 (a) but the thickness of the foam is 20 mm instead of 10 mm. This case is recommended when the fixed asset materials are metallic and semi-metallic materials and it has additional interferences from electrical or electronics components, e.g., the air conditioners, printers, and motors. The output power of the handheld RFID reader should be set at 5 dBm, and the distance between the reader and the RFID tag should be about 25 cm.
3. Not all metallic and semi-metallic fixed asset items will interfere the RFIG tag, and need the foam material to support the RFID tag. Therefore, we may try to attach RFID tag directly without the foam material, if the tag cannot be read, the foam materials with thickness of 10 and 20 mm. will be used to support the tag, respectively.




(a) Good




(b) Bad




(c) Excellent

Fig. 11. Tag interference prevention using foam support.

*C. Analysis of time to identify suitable position and attach RFID tag to the fixed asset*

The time to identify suitable position and attach an RFID tag to the non-metallic fixed asset is 1-2 minutes. However, when the fixed asset material is metallic or semi-metallic, the time is 5-7 minutes, which is longer since the tag may need to be supported by a foam material. Additionally, a trial reading by the reader should be done.

Based on the three selected rooms, the suitable position for RFID tag is near the position of the fixed asset code written on the fixed asset for 97% of all asset items. There are 3% of all fixed asset items that the current position of the fixed asset code cannot be easily seen when the staff is walking along the aisles. Therefore, the fixed asset code is rewritten at the suitable position near to the suitable position of the RFID tag.

*D. Analysis of time of RFID system*

To register new data and update data of the fixed asset, the single scan function is used. The function with output power between 5-14 dBm at the distance about 25 cm. is applied. The time to register RFID tag and enter new fixed asset data is 2.3 minutes on average. The time to update data of the fixed asset is 1.3 minutes on average.

An experiment is conducted by using continuous scan function to check all fixed asset items in each room. The output power of the reader is set at 5-14 dBm at the distance about 25 cm. The number of items in each room and the average time per item to check all asset items are recorded. Note that three industrial engineering students performed replication numbers 9 to 20 of Room 1-415 while other experiments were done by the author.

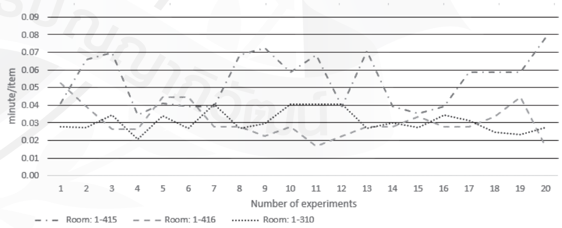



Fig. 12. Average time per item of continuous scan by RFID in each room based on chronological order.

Fig. 12 shows graphs of average time per item of continuous scan function using RFID system in three rooms. Each graph has random fluctuations but the trend is not clearly seen which means that the use of RFID system is very simple and does not require experience of users or the learning effect is not clearly seen. Note that the manual fixed asset checking required experiences to reduce the checking time (see Fig. 10).

The average time per item of all replications of continuous scan function using RFID system is presented in Table II. The one-way ANOVA technique is used to determine whether the room has significant effect on the average time per item of continuous scan function using RFID at the confidence level of 95%. It is found that the effect of the room is significant. When the Fisher's multiple mean comparison technique is used, it is found that the average time per item of Room 1-415 is significantly different from that of Rooms 1-416 and 1-310.

To facilitate comparison between the manual and RFID systems, bar graphs of average time per item in each room of manual and RFID systems are presented in Fig. 13. It can be clearly seen that the RFID system can reduce the average fixed asset checking time per item greatly. When the two samples t-test is used, it is found that the average time per item of the RFID system is significantly lower than that of the manual check system of all rooms at confident level of 95%.

TABLE II
Average Time Per Item for Continuous Scan by Rfid

| Room: | Complexity of layout | Average time per item |
|---|---|---|
| 1-415 | Complex | 0.055 |
| 1-416 | Simple | 0.031 |
| 1-310 | Complex | 0.031 |

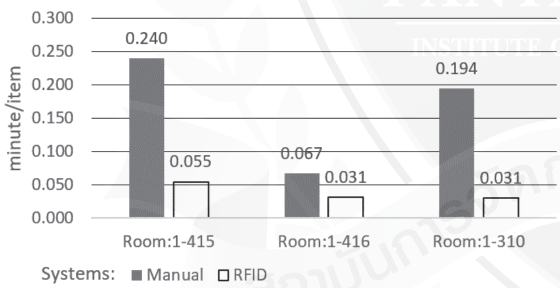



Fig. 13. Comparison of average time per item of manual and RFID systems.

*E. Economic analysis*

This paper focuses on net present value (NPV) technique for economic justification of the RFID system. The NPV technique requires an estimation of investment, operation and maintenance (O&M) cost, labor cost savings, useful life, and minimum attractive rate of return (MARR). The investment includes RFID handheld reader cost of 35,000 Baht, software development cost of 100,000 Baht, and RFID tag cost of 5 Baht per unit. The annual O&M cost is estimated by 5% of RFID and software development cost, plus 1% of RFID tag cost, which is assumed to occur at the end of years 2 to 10. The labor cost saving is assumed to be occurred at the end of years 1 to 10. The useful life of the RFID system is 10 years and the MARR is 5% based on the accounting system of SIIT, TU. The selected three rooms are good representatives of all rooms in SIIT. The average time saving per item is estimated from ((0.240-0.055) + (0.067-0.031) + (0.194-0.031))/3, which is 0.128 minutes. The labor cost of staffs that check the fixed asset is estimated at 200 Baht per hour (35,000 Baht per month). We need two staffs to check the fixed asset (checker and witness). The fixed asset is checked 2 times a year (once a semester).

Let $I$, $O_t$, $S_t$, $i$ represent the investment, O&M cost at the end of year $t$, labor cost saving at the end of year $t$, and MARR, respectively. Equation (1) is used to calculate the NPV.

$$NPV = -I + \sum_{t=1}^{10}(S_t - O_t)(1 + \frac{i}{100})^{-t} \qquad (1)$$

where
$I = 35{,}000 + 100{,}000 + 5X$
$O_t = 0.05(35{,}000+100{,}000) + 0.01(5)\,X$, $t = 2, 3, \ldots, 10$
$S_t$ (0.128/60) (200) (2)(2) $X$, $t = 1, 2, \ldots, 10$

Note that the NPV is dependent on the variable $X$, which is the total number of fixed asset items that need to be checked. Table III shows the NPV at different values of $X$. It is found that the RFID system is economically justified when the total number of fixed asset items is at least 23,048 items and the fixed assets are checked twice a year.

TABLE III
Npv Affected by Total Number of Fixed Asset Items

| Number of items | NPV (Baht) |
|---|---|
| 10,000 | -102,294 |
| 15,000 | -63,094 |
| 20,000 | -23,894 |
| 23,048 | 0 |
| 25,000 | 15,306 |
| 30,000 | 54,506 |

*F. Recommendation on designing and implementing the RFID system*

The RFID tags are attached to the fixed asset item using self-adhesive tape supplied with the tags. It is possible that the RFID tag is accidentally removed or detached from the fixed asset item. If the RFID tag is lost, but the fixed asset item is available in the room. The scanning result will indicate that the fixed asset item is not found in the room, which is wrong. On contrary, when the RFID tag is detached form the fixed asset item but the tag is still in the room while the fixed asset item is already lost. The scanning result may indicate that the fixed asset item is found in the room, which is also wrong. Therefore, a discipline should be set to ensure that each fixed asset item to be checked must have an attached RFID tag, and there is no RFID tag which is free or dropped on the floor.

The developed RFID system for fixed asset checking is economically justified when the total number of fixed asset items is about 23,000 units based on assumptions that all fixed asset items will be checked only twice a year, the benefit is only direct benefit of labor cost saving without considering indirect benefit of more accurate inventory record, the labor cost will not be increased in the next 10 years, and cost of RFID tags will not be reduced in the next 10 years. However, when the indirect benefit, labor cost increasing, and RFID tag cost reduction are considered, the number of fixed asset items to economically justify RFID system investment will be significantly reduced from 23,000 units.

## V. Conclusions

### A. Conclusions

This research was conducted to satisfy 4 objectives. First, the prototype of RFID system for fixed asset checking is successfully developed. Second, the time and accuracy of fixed asset checking are evaluated and it is found that the RFID system is significantly faster and more accurate than the manual system. Third, an economic analysis using the NPV method is performed and found that the RFID system is economically justified if the number of fixed asset items of SIIT is at least 23,000 units. At the moment, it is not economically justified considering only the direct benefit of labor cost saving. Finally, the last objective is to recommend further research and development of the RFID system for fixed asset monitoring and control in Universities. This objective will be satisfied in the next section.

### B. Limitations and recommendations for further development

The developed RFID system has some limitations as follows. First it is only a prototype system with limited functions. Second, it is currently a standalone system, which is not integrated with the accounting system. Real benefits will be obtained when it is integrated with the current accounting system.

There are some recommendations for further development as follows.

1. The developed system is flexible and can be improved with additional modifications. Because of the research time limitation, the author could not finish, for instance, the continuous scan function for scanned TIDs match-checking directly from database storage then save into csv file which would reduce data analysis time. Another example, the database storage can be synchronized by Microsoft Azure Cloud Services where the asset status, reports, etc. can be created directly from web service.
2. The RFID system and technology can be further developed to include full capability of passive tag memories (EPC, write-read, password, user memories) and the algorithms can be modified on continuous scan function to get a more meaningful information.
3. The prototype software and database storage can be improved for saving meaningful image, video, or voice information of expensive fixed assets.
4. The RFID system can be extended for other applications which has more benefits than the fixed asset monitoring and control purpose. It can be integrated with an ERP system. The allocation of codes "from one system to another" [21] should be performed. Standardization of fixed asset IDs would prevent incorrect inputs. Regularity of student attendance check [22-23] with modification of algorithms and a compact handheld reader can be developed. Storage of huge asset data at several university departments integrated with IoT for data security may be done to improve economic justification of the RFID system. IoT with RFID system would collect the asset data from university buildings: an increased complex data visibility for central financial department. Complicated exam scheduling at universities [24] can be developed using RFID. RFID system with IoT can improve "university power consumption" management [25].

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**Salamat Begmanov** received B.A. in Business Management from the National University of Uzbekistan in 2009. Then, he worked in local and international companies in Uzbekistan in different positions until 2016. Currently, he is pursuing his master of engineering in logistics and supply chain system engineering at SIIT, Thammasat University, Thailand and is expected to get degree in July, 2019. His research interests include RFID system development, fixed asset monitoring, sequential algorithms, intranet of things, and economic analysis.

**Pisal Yenradee** is an Associate Professor in Industrial Engineering Program at Sirindhorn International Institute of Technology (SIIT), Thammasat University. He holds a B.Eng. in Production Engineering from King Mongkut's Institute of Technology, North Bangkok and M.Eng. and D.Eng. in Industrial Engineering and Management from Asian Institute of Technology. His research interests focus on production planning and inventory control systems, JIT, ERP, TOC, finite capacity scheduling systems, aggregate production planning, master production scheduling, supply chain, and applied operations research. He has published papers in and served as a reviewer for many international journals.