

A Case Study on Impacts of RFID Adoption in Tree Inventory Management

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Abstract—Radio Frequency Identification (RFID) is widely used in various fields. Its application in private organizations is common. Typically, in private organizations, the impacts of RFID are quantified using measures like the Return on Investments. However, gaps on RFID's impacts on public organizations still exist. The research attempts to fill this gap. We used a single case study approach at the Forest Research Institute Malaysia (FRIM) with the view that RFID is contemporary [15] to provide insights into its application and integration. In this paper, we discuss our findings on its impacts of the adoption and provide recommendations on integration architecture for further consideration.

Keywords— RFID; real time; tags; reader; tree inventory.

I. INTRODUCTION

RFID is an abbreviation for Radio Frequency Identification. It refers to “a generic term for technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a serial number that identifies a person or object, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers that can make use of it.” [1]

There are many applications of RFID. Examples include proximity cards, automated toll-payment transponders, payment tokens, ignition keys of many millions of automobiles as a theft-deterrent, checking-in and out for parking space management and books tracking in libraries. In the health care, RFID tags are used in supporting the automatic identification of a patient's identity, understanding effects of drugs he or she takes and then synchronizing identity with the registration in the Electronic Healthcare Record (EHR) [6]. RFID has been acknowledged as a solution to privacy, authentication and anti-counterfeit issues [7]. In the business environment, RFID is used typically to enhance internal efficiencies i.e. in production line and management of pistachio harvests and throughput of containers [8].

The supply chain was one of the early adopters of RFID. Prior researchers in supply chain had identified the use of

RFID for solving data collections, data organizations and data security [3]. Other related research has also demonstrated that RFID when integrated with temperature sensors provides the capability for monitoring of products in a warehousing system [4]. See Figure 1 for the architecture of such system.

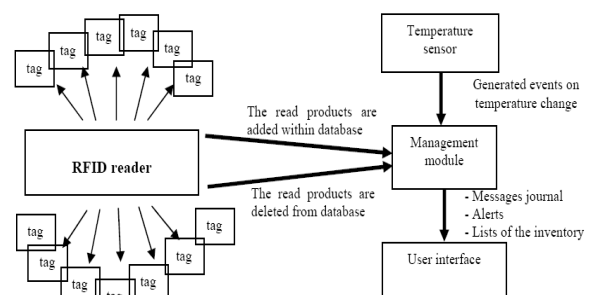


Figure 1. Warehouse monitoring system architecture [4]

One reader is used for multiple tags. Further, an Anti-Collision Algorithm is used to ensure multiple tags reading to achieve the fullest advantage of RFID technology [4].

Another intriguing application of RFID is in forestry. Forestry involves the steps to turn trees into customer products. The cutting of trees is followed by an identification of wood and tree process. This was done by stamping the wood with a number. This stamped number provided information that identifies wood and was necessary for further processes. It was usually done by using some materials (e.g. stamps and paint) that were cheap. However, this was not efficient because such materials could not withstand the rough handling environment and would be easily damaged by the machinery that handled the logs. The tags or labels had to resist hard weather conditions e.g. the influences of temperature, aridness, humidity and dirt. Their conditions had to be preserved when left outdoors. RFID offered the capability as a substitute of stamping the wood for better process efficiency.

An extension of forestry is tree inventory. Tree inventory is essential in that if an inventory reveals “many dead and diseased trees or areas that are bare of trees, this suggests that a program incorporating tree planting is badly needed.” [9].

Based on the literature, we note that the number of papers on RFID has been increasing steadily since 2005. As evident, research concerns have been on the application of RFID typically on business organizations. As suggested by Curtin, Kauffman and Riggins [2], future research direction in RFID should address:

- a series of research questions about how RFID technology is developed, adopted and implemented by organizations
- how it is supported within organizations and alliances
- what its impacts on individuals and business processes, organizations, and markets.

Many past researches were concerned with the impacts of RFID on private organizations and addressing security issues. In private organizations, the impacts of RFID projects revolve around Return on Investments (ROI). Impacts are quantified and measured against investments incurred for the project. Gaps still exist in public organizations where ROI as an impact on the organizations is meaningless. Further, little is known about the adoption of RFID and its integration with other application systems in public organizations. The aim of this paper is to fill this research gap. This is consistent with Curtin, Kauffman and Riggins. We chose a public organization in Malaysia that involves itself in forestry management. In particular, our research question is: *What are the impacts of RFID adoption in managing tree inventory?*

In this section, we have provided an overview of the research. In section two, we present the methodology. Section three discusses the background of the case study. We provide the findings in section four. The last section deals with the recommendation and conclusion of this project.

II. METHODOLOGY

Since the use of RFID in managing tree inventory is still new, there is a need to adopt an exploratory approach. We used a single case study approach at the Forest Research Institute Malaysia (FRIM) with the view that RFID is contemporary in nature [15]. We obtained an approval to conduct an open-ended group interview with the Head of Urban Forestry Department, a senior system analyst from the Information Technology Department and a landscape architect. This selection is consistent with Rush [10]. The interview was conducted in English, taped and subsequently transcribed for our analysis.

III. BACKGROUND OF CASE STUDY

FRIM is one of the leading institutions in tropical forestry research in the world. It is government funded. It was initially founded as Forest Research Institute by a British colonial forest scientist in 1929. The first chief research officer was Dr. F. W. Foxworthy. It then became a statutory body governed by the Malaysia Forestry Research and Development Board under the Ministry of Primary Industries in 1985. In 2004, FRIM became a statutory body governed under Ministry of Natural Resources and Environment.

Currently, there are 600 workers conducting forestry research and more than 150 of them are scientists.

FRIM undertakes research and development activities on forestry and forest-based industry sectors. FRIM is concerned with improvements in the production, extraction, processing, storage, transportation and utilization of forest produce. One of its priority areas is urban, landscape and recreational forestry. FRIM studies the structure and functions of tropical forest ecosystems so as to maintain a wealth of species diversity. Managing tree inventory is one aspect of this study. Tree inventory refers to gathering accurate information on the health and diversity of the community forest.

The initiation phase of RFID began in 2001. Back then, there was a Penang Urban Tree Information System (PETIS) that stored data about tree inventory. FRIM also developed other systems e.g. SIP3 system for tree preservation and Tree Appraisal System to support the operation of analysis and assignment of the status for assessed trees.

Prior to the implementation of RFID in FRIM, FRIM used paints and subsequently aluminium plates on trees to label a particular tree. The label data was then recorded in a manual form and later stored with other tree profile data such as tree location, size, species, age, growth dimension, growing environment, health status, maintenance needs etc. in an application system now known as the Arbor-tracker system. Data resided in MS SQLServer. Issues cited with such process include:

- Paint wore off with time and climate changed
- Both paint and aluminium plates were not pleasant to the eyes and prone to vandalism
- The label data on the manual form were vulnerable to errors during data capture into the Arbor-tracker system

The scope of RFID implementation at FRIM covered its integration with the Arbor-tracker system and Geographic Information System (GIS). Figure 2 shows the current integration architecture.

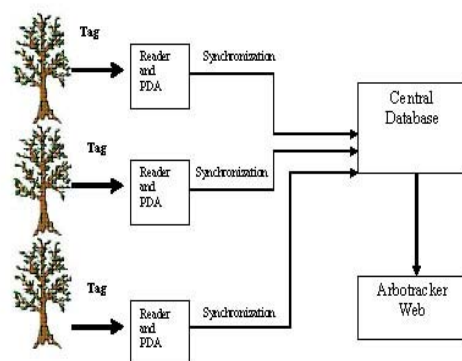


Figure 2. Current integration for RFID, Arbor-tracker and GIS

We illustrate the processes in managing tree inventory by its phases and steps. There are two phases in the processes. Phase I is the tagging and mapping of a tree. There are three

steps in phase I. The first step is tagging of a tree that involves the use of a transponder and drilling into the tree (see Figure 3).

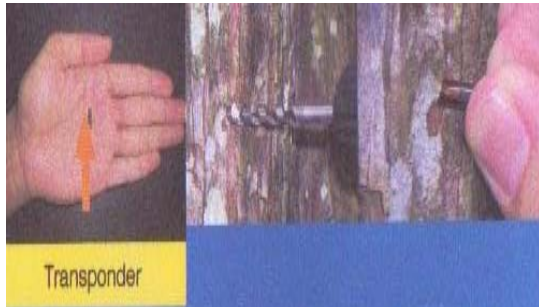


Figure 3. Transponder and drilling

The second step in the first phase is mapping that makes use of a DGPS device to capture location (see Figure 4).



to capture location

The third step in Phase I is data capture (see Figure 5). In this step, information is captured with the use of an Evo M2 (reader) and Personal Digital Assistant (PDA).



Figure 5. The use of Evo M2 and PDA

The second phase covers two steps i.e. synchronization and reporting. In synchronization, the information taken from the

tags and stored in PDA is then synchronized to be stored in the central database (see Figure 6).

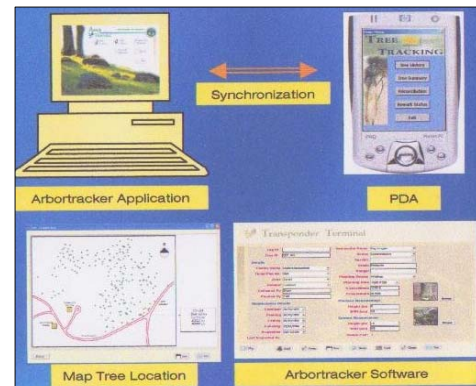


Figure 6. Synchronization

The last step is reporting that is made available with the Web Arbor-tracker system.

There is a future plan in FRIM to use smart sensors along the trees to detect any noticeable changes in the tags and send the respondent to the system in a real time manner.

IV. FINDINGS

The adoption of RFID and its integration with the Arbor-tracker system and Geographic Information System in FRIM follows a stage approach i.e. initiation, adoption and implementation. This is consistent with many previous research findings on innovation adoption. As a government-funded Institute, the impacts of RFID were not measured with the classical Return on Investment (ROI) method commonly used in the private sector. *“We are a research institute under the Ministry and we used grants to implement RFID in this project.”*

We discuss the impacts below as lessons learnt from the outcomes of the group interview.

Lesson 1: Eliminate unsightly appearance of paints and aluminium plates on tree trunks.

“We drilled a little hole into the tree trunks to place the transponder. It [the hole] doesn’t affect the tree. We don’t need paint or aluminium plates anymore. Now, the trees don’t look as ugly as when they were with the paint or aluminium.”

Lesson 2: Eliminate loss of information about the tree characteristics.

“Vandalism still occurs but the label [tag] of a particular tree is still there. Also, we don’t have the issue about the paint that wears off because of the weather. Plus, the [tree] characteristics are in the database.”

Lesson 3: Reduce errors during data capture of tree characteristics.

“We have RFID, Arbor-tracker, PDA and GIS. We’ve come a long way. They all help us reduce data capture and numerous potential human errors.”

Lesson 4: Enhance information technology staffs' skills in systems integration.

"We initially outsourced this part [integrating RFID with the Arbor-tracker systems and GIS]. But the guy who worked on this resigned. We had problems with the outsourcer. In the end, we decided to do this on our own. But we've learned a lot. The experiences were good for us."

Lesson 5: Simplify job tasks.

"RFID makes our jobs easier."

V. RECOMMENDATION AND CONCLUSION

As evident, FRIM has experienced positive impacts from RFID adoption. We note that there are future areas for enhancements in that the processes for tree inventory management in FRIM could be fully automated and the integration in real time.

In this section, we further discuss the challenges for a real-time system if it were to be considered for adoption at FRIM. We also present our recommendations to overcome these challenges. The first point is about using fixed readers located along the tags. The space between the tag on the tree and the reader is usually limited. One reader can be used for several tags located in the same place. The reader should be able to read from the tags and send the information to the system. Secondly, the accuracy of the collected data is dependent on many factors: the reader frequency and the collision that occurs when one reader reads multiple tags at the same time.

There were many past studies conducted to solve such problem. There are mainly two approaches. *Deterministic Collision Resolution* works by muting subsets of tags that are located in the same area and cause the collision [11, 12]. By successively muting larger subsets, only one tag can send a message at a time. Once a tag has successfully sent its message, it will go into silent period, and the other tags are woken up one after another. The other approach is *Stochastic Resolution of Collisions*. Since tags use a shared communication medium, it is natural to fall back upon an Aloha-like protocol that provides slots for the tags to send their data. Whenever a collision occurs, another frame of slots is provided [13].

The Anti-Collision Algorithm as discussed earlier in this paper simply enables RFID reader to read several tags in its reading range automatically for a short period of time. If more than one tag try to communicate to the reader at the same time, a collision will take place. An RFID reader will have to solve this collision with a view to correctly identify all the tags in its reading range. An RFID reader has to establish rules on communication so that only one tag can communicate to the reader at a certain moment, during which period all the other tags should remain silent [4]. FRIM may consider this approach. The tags of the trees are located nearby each other to fully automate the system and to maximize the advantages of RFID. Each reader would collect the data from a specific number of tags with the use

of an Anti-Collision Algorithm in ensuring the accuracy of information collected (see Figure 7).

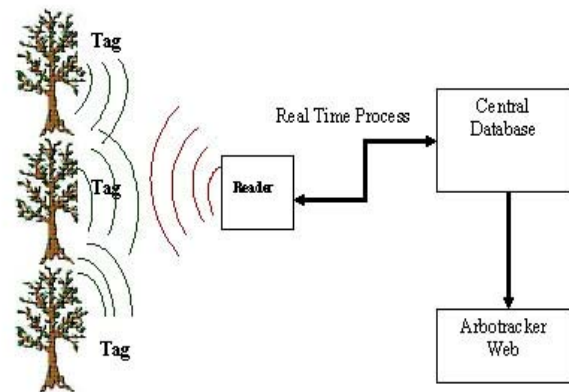


Figure 7. Proposed integration

The third point is about integration challenges. In case the two previous problems are solved, it remains that the most important challenge is the real time integration with the central database. This would entail the use of an RFID middleware. The term middleware, as employed in RFID has a somewhat different definition from its use in other embedded systems. In RFID's term, a middleware is the software translation layer between the front-end RFID reader and the back-end enterprise system. The middleware filters the data from the reader and ensures that it is free of multiple reads or bad data. In early RFID systems, the middleware ran on the server but the filtering of RFID data is now often performed on the reader before sending it through the enterprise's network. This degree of increased functionality is another advantage embedded processors bring to this application space [14].

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