An Radio Frequency Identification and Enterprise Resource Planning -Enabled Mobile Asset Management Information System

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***Abstract*—While more and more companies plan to implement asset management solutions to control supply chain costs and public sectors strive for effective and timely management of public facilities, there are significant moves coming to improve both asset management processes and the information technology (IT) that support them. In the arena of IT, Radio Frequency Identification (RFID) is one of the most promising technologies to improve the effectiveness of asset management. In this research we propose an RFID and ERP enabled Mobile Asset Management Information System (MAMIS) that will produce real value in the form of reduced costs, staff productivity, and effective management today. The proposed system was designed for tagging valuable assets or equipment, providing asset location information, auditing and triggering for service, and retrieving maintenance requirements and procedure based on data in ERP.**

***Keywords*—Asset management, Mobile Asset Management Information System (MAMIS), Radio Frequency Identification (RFID), Enterprise Resource Planning (ERP)**

I. Introduction

A. Background

"Asset" by definition includes holdings of obvious market value (cash, real estate), harder-to-measure value (inventory, aging equipment), and other quantities (pre-paid expenses, goodwill) considered an asset by accounting conventions but possibly having no market value at all. The term "asset" used in this research is defined as "a long-term, tangible asset held for business or public sector use but not expected to be converted to cash in the near future such as manufacturing equipment, real estate, and public facilities". "Mobile assets" in this research stand for the assets that are not in close proximity or not in the possession of a company or a public sector. These assets may locate at wide-spread locations or install on customer side. Asset management has been a complex problem traditionally by itself and mobile asset management adds another dimension of complexity to the problem.

Asset management is a systematic approach of maintaining, inspecting, and operating physical assets effectively. Good management of assets has always been crucial to business success and has drawn tremendous attention. While more and more companies plan to implement asset management solutions to control supply chain costs and enhance customer services; public sectors also strive for effective and timely management of public facilities. Traditional management of mobile assets operations have been performed by using a paper-based system. Staffs always spend time walking extra miles and carry paperwork to each individual site where the service and repair is performed. In the case the process of the inspection or maintenance finds the assets which are broken or parts of assets need to be replaced, staff might not take the relevant paper report with them or cannot access the information such as a replacement part's availability, cost of repair, service contracts etc. on site. Staffs frequently need to return to the office for retrieving related information and instructions and then travel back to the site. The result leads to critical delays and inefficiencies in conducting necessary repair. Moreover, after completing a service order, the paper-based reports are clearly subject to human errors such as incorrect identification of defects, which leads to delay in maintenance and unnecessary costs. Moreover, there is no assurance that the maintenance work had been actually carried out with the completion of paper report.

Advances in widespread, robust and inexpensive location-based and wireless communication technologies have resulted in an explosion of activities in the field of mobile services. Timely and relevant information enables informed decision-making and offers improvements for productivity, safety and security. One particular form of mobile service, as known as Mobile Asset Management System (MAMS) has garnered significant interest from corporations desiring more efficient methods in managing their asset fleets. Integrating MAMS with technology such as RFID and ERP to extensively enhance the effectiveness of asset management has further become an emerging trend.
An effective MAMS should be capable of aiding or performing operational decision-making and be capable of collecting and storing information from the field and process the data to and from numerous databases for data retrieval, editing, analysis, presentation and decision-making functions. With this aim in mind, we propose a Mobile Asset Management Information System (MAMIS) with ERP and RFID support to make such an ultimate MAMS possible.

B. Motivation

Many organizations and public sectors have already implemented a computerized maintenance management

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system (CMMS) or asset management system (AMS). However, many still rely primarily on paper-based communications and tracking. The reliance on paperwork and data entry stands in the way of the maintenance staff's primary function. As a result, maintenance staffs spend up to 50 percent of their time with paperwork or data entry and less time performing corrective or preventive/predictive maintenance activities. For customers, delays or shutdowns in an operation due to assets unexpected failures can result in the loss of profits.

For many organizations, traditional MAMS fails to fully overcome critical shortcomings of a paper-based maintenance process. These problems include that Traditional MAMS:

1) is unable to ensure that the asset maintenance tasks are faithfully carried out according to planned schedule by designated staff. It may cause damage, increase work backlogs, and add extra costs;
2) fails to provide mission-critical information for designated staffs to complete their assigned works. For example, staffs may need information regarding replacement parts availability on site to derive a reasonable estimate for the completion schedule of the maintenance task;
3) does not support real-time assessment of cost estimation for the asset maintenance or access important information of the asset owner such as service contract or maintenance agreement; and
4) does not provide maintenance staffs current information at the point of activity. Regardless of the job function, the staffs constantly have to locate and retrieve work orders, documentation, parts, tools and assistance. This "travel time" to locate and retrieve information and equipment takes the staffs away from the actual time for maintenance. Once work is performed, details are recorded at a later time which causes multiple problems and devalues the purpose of MAMS.

To overcome the above-mentioned pitfalls, an effective MAMS needs to be developed to improve maintenance staff productivity and enable them spending more time on preventive tasks, which translates into more uptime for strategic physical assets of organizations and/or public sectors.

The proposed MAMIS in this research addresses issues that are geared toward increasing efficiency of wide-spreaded resource usage and maintenance by integrating mobile/wireless technologies with the support of RFID and ERP. This integrated system is capable of improving mobile asset management effectiveness, enhancing customer service and staff productivity, and producing real values in the form of reduced costs. In the end, companies make assets available when needed and ensure their efficient and safe use.

C. Objective

The core issue is to perform the preventive maintenance/inspection for long-term assets. Effective asset management can result in the reduction on the failure costs of manual processing and the level of capital employ on spare parts and debtors; while ensuring that equipment and engineers are used more efficiently. Developments in technology have now boosted the potential of asset management. This research aims to extend the traditional MAMS for managing mobile assets more efficiently. The ultimate objective of this research is to develop an RFID-Based Mobile Asset Management Information System with ERP Support to manage a variety of mobile assets effectively. Staffs can perform on-schedule preventive maintenance for mobile assets effectively. RFID (radio frequency identification) and ERP, for example, enable physical assets to communicate and rich business information access. Wireless networks create a channel for this communication to the extent that machine-to-machine mobile communication is expected soon to outstrip the number of people talking wirelessly. Improvements in data capture and ERP also mean that more value can be extracted from the information that assets produce. Therefore, major objectives in this research include:

1) The RFID technology helps streamline key processes of mobile asset management via a mobile device. Moreover, companies and public sectors can ensure that the asset tasks are faithfully carried out according to on-schedule maintenance by designated staff.
2) By back-end ERP system support, staffs enable to issue service contracts, retrieve maintenance requirements and procedures, perform on-line checking for stock availability, and analyze costs of maintenance. Therefore, staffs can be responsive to customer demands and allow customers to make decisions related to mobile asset management in timely fashion.
3) The information system will also be used for all real-time required data to remote staffs and support simultaneous access by wireless network. The data not only downloads or retrieves the data (e.g., asset name, etc) but do on-line retrieving all repair-related data.

The proposed system, MAMIS, is focused on improving mobile asset management tasks. The results of this study may be of interest to managers and public sectors attempting to develop the MAMIS and maybe helpful to increase staff's productivity and improve mobile asset management effectiveness.

II. System Architecture

RFID has received a great deal of press in recent years, especially since the first business applications emerged and the world's largest retailers began to put the vision of smart items into practice. Although many companies have explored RFID and ERP technologies' value for tracking materials throughout the supply chain, few have reported on how RFID and ERP support their management and operation of assets and facilities.

The proposed RFID-Based Mobile Asset Management Information Systems with ERP Support (MAMIS) have potential to significantly improve the effectiveness of mobile asset management. The system focuses on tagging valuable assets or equipments, providing asset location information, auditing and triggering for service, and retrieving maintenance requirements and procedure. In the following sections, we describe the MAMIS for realizing the process of managing assets, including the system architecture, the

descriptions of MAMIS server, the RFID application, and ERP functional support.

A. Mobile Asset Management Information System (MAMIS) Architecture

In the research, the ultimate goal is to allow organizations to manage deployed assets effectively. Effective mobile asset management encompasses such activities like locating assets, tracking the usage of the assets and ensuring its maintenance. The integration of mobile, RFID, and ERP technologies has great potential to deliver a system for the management of mobile assets. The proposed system architecture of MAMIS is shown in Fig. 3-1.

The architecture offers a single platform to manage various aspects of the enterprise applications, including integrating a front-end RFID system and a back-end ERP system. The front-end RFID system is applied in two aspects: to track and record the performance of asset management, and to link the necessary data directly with the assets. As a result in most tasks in asset management, like identification of assets, tracking can be done effectively. The back-end ERP system mainly provides the staff with the ability to check the stock, availability, lead time and cost before maintaining assets. The staffs can be more responsive to customers about the required cost and time of maintenance. In addtion to the basic functions mentioned above, the MAMIS supports mobile devices, such as personal digital assistants (PDAs), laptop computers, and smart phones. MAMIS is able to communicate over various networks including the Internet, Wireless LAN, GPRS and 3G, etc, and it incorporates the highest security standards, and provides a user-friendly interface for the end users. MAMIS is composed of three components: 1) the MAMIS server, 2) RFID enabled mobile device, and 3) ERP system. The MAMIS server primarily contains:

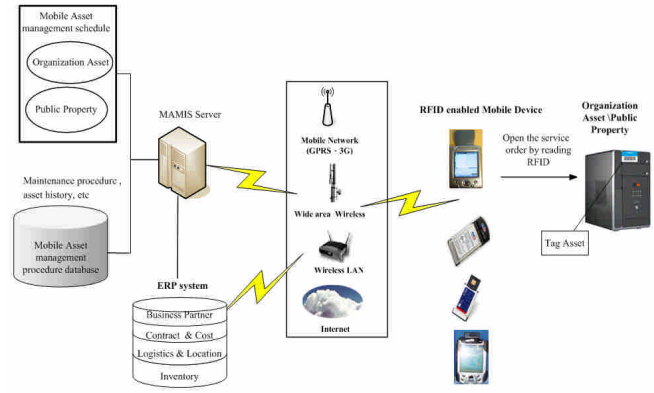

Fig. 3-1 The architecture of the MAMIS

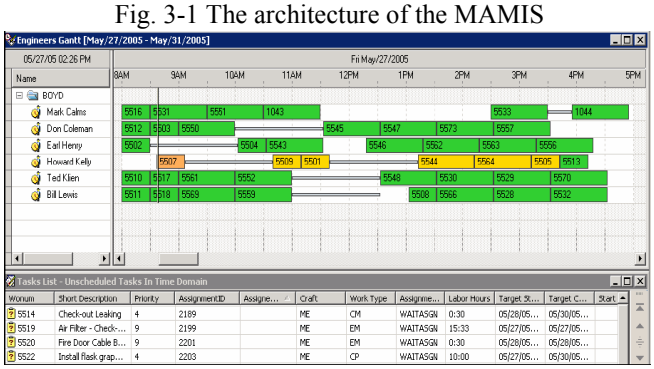

Fig. 3-2 an example of mobile asset management schedule

1) mobile asset management schedule module: the corresponding functionality is to manage and arrange the schedule and prioritize work orders for assets.
2) mobile asset management procedure database: the database encapsulates the asset information details (e.g., asset history, asset structure, maintenance procedures, usage data, etc.).

B. MAMIS Server

Better Scheduling is key to effective mobile asset management programs. Scheduling and assigning work has typically been a troublesome process, often involving planners at a white board struggling to match technician skills with availability of productivity. This commonly results in poor productivity and work load bottlenecks. In order to improve scheduling and maximize technician productivity, a mobile asset management schedule module is built into the MAMIS server for scheduling and prioritizing works. A seamless information flow is also required because asset-related information need to be collected from the field, stored into the database, accessed, manipulated and edited by staffs. The MAMIS server includes mobile asset mamagement procedure database which encapsulates the asset information details. By advanced wireless communication, providing the staffs with real-time and accurate information enables informed decision-making.

Mobile Asset Management Schedule Module: The mobile asset managmenet schedule module mainly functions for arranging and prioritizing on-schedule maintenance works for the management of mobile assets. When customers suddenly ask the company to perform the repair for assets, we don't consider the emergent conditions in this module. The module offers important factors that provide planners to balance resources with operating needs. Examples of these factors include work zones, working hours, availability, holiday schedule, work order duration, travel time between work orders and more. In addition, work assignments, expected duration of each assignment, and expected travel time are charted on an easy-to-read timeline in the module as shown in Fig. 3-2. The factors and easy-to-read time line enable planners to be more efficient and make smarter planning decisions by optimizing the schedule according to these constraints. As staffs complete service orders, updates can be transmitted to the MAMIS server via real-time wireless data flow. The updated data provides planners that have the ability to make optimum assignments easily. Planners can re-optimize and re-direct resources to ensure high-priority work assignments are completed. This is useful for increasing productivity, improving on-time completion of preventive work orders, and an elimination of work load bottlenecks.

Mobile Asset Management Procedure Database: MAMIS must be capable of collecting and storing information from the field and process data from the database for performing data retrieval, manipulation, analysis, presentation and decision-making functions. Therefore, getting the right data, of the right quality, and at the right level of detail was another challenge we encountered. In the MAMIS server, the mobile asset management procedure database encapsulates the information pertaining to the mobile assets. The information pertaining to the mobile assets includes asset history, asset structure, maintenance procedures, usage data, etc. Through wireless network staffs are able to retrieve, view, edit data and

eventually make informed decisions regarding assets. Moreover, staffs transmit the data back to the database after completing assigned tasks for storage and analysis in real time. In order to contribute to the operational decision-making process, managers are must update the data immediately, ensuring that there were no errors in the records. Having the accurate asset-related data is useful in improving the efficient maintenance for mobile assets.

C. RFID Support

With RFID organizations can track the performace of mobile asset management. Moreover, information about mobile assets can be stored, transmitted, and updated, all without direct human intervention. The proposed RFID based system for mobile asset management is described below:

There are RFID tags on the inside of the asset. Each RFID tag has the unique identification number stored in its memory. The asset-related information is stored in the mobile asset management procedure database. When MAMIS server atomatically dispatch the service orders to staffs on time, all service orders are downloaded to mobile devices by staffs. There is an RFID reader installed in the mobile devices. On the spot scanning of the tags before the designated task begins assures that the staff is present. Service orders can also be opened when the RFID tag is read. As soon as the reader has successfully received the tag's identification number, it starts to request the asset information from the datadase. This unique identification number operates as a pointer to the database from which the staff is able to load the asset-related information (e.g., asset name, parts, asset histories and maintenance procedure) to a mobile device. The asset-related information transferred between the mobile device and the asset management server is realized via wireless networks which may be GPRS, WLAN, etc. The asset-related information is then displayed on the mobile device and then the staffs can tick off upon completions and records service work details. After the service work is completed, the staff must scan the tags again. The service order can then be closed and service information will be stored in the database for noting the important problems of the assets. The process of the RFID system is shown in Fig. 3-3.

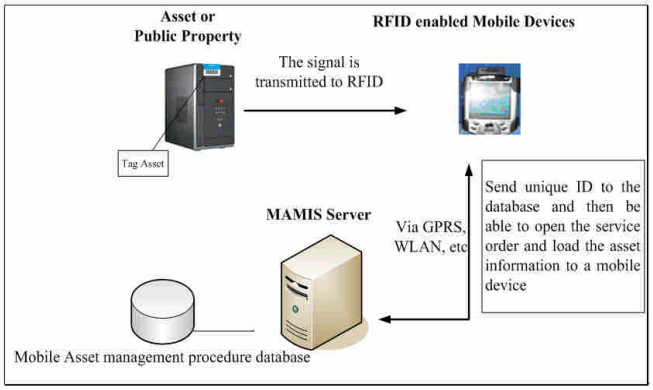

Fig. 3-3 The process of the RFID system

Integrating a front-end RFID can significantly enhance the performance of mobile asset management and achieve the following key points.

1) Each RFID tag can be attached to the inner of the asset. Staffs can directly read the tags by RFID reader without cantacting and aiming at the tags. As a result, it is hard to be broken and copied for RFID tags. In addition, because the technology is difficult to counterfeit, RFID provides a high level of security.
2) RFID reader can read many tags at a time. In the case of one RFID tag malfunctioning, other tags still can be read. The staff can load the asset information to the mobile device and proceed with his designated work. Moreover, when acquiring the tag IDs, we can ensure that the asset belongs to our company. Otherwise, the assets may have been replaced by customers without any announcements.
3) According to the shape of assets, RFID tag can be manufactured all kinds of shapes to adapt all kinds of assets. It is convenient to stick tags in the asset.
4) RFID can work effectively in hostile environments where excessive dirt, dust, moisture, and/or poor visibility would normally hamper rapid identification.

D. ERP Functional Support

Enterprise Resource Planning (ERP) has grown as an integration tool where the aim is to integrate all enterprise applications to a central data repository and provide easy access to all relevant parties [1]. An ERP system can also store, retrieve, and process transactions of all business functions of an organization. Therefore, integrating a back-end ERP system supports the staffs with fast, accurate access to a unified view of operational and financial information.

The back-end ERP system creates a single version of the truth that cannot be questioned because everyone is using the unique database of the system. The staffs may access information such as the maintenance contract, stock availability, cost of part replacement, etc. via ERP before maintaining assets.

In the case that an asset installed on customer side is broken and some parts need to be replaced, the staff can access service contract information through ERP. If the asset is under warranty period, the staff checks the availability of the replacement parts in the warehouse and may perform maintenance work without informing the customer. Simultaneously, in case the required parts run out of stock, the staff needs to notify the purchasing department to generate purchase orders to suppliers immediately. After completing the service order, the staff records and stores maintenance details which include time and date. If the asset's warranty period expired, the staff does the on-line checking to look up the stock of the required parts and then the staff may call the customer or send E-mail or fax a maintenance agreement to inform the customer about required cost and time for the maintenance. If the customer agrees on the agreement, the maintenance work can be initiated after the agreement is signed on the staff's wireless terminal (e.g., PDA). Moreover, the staff is authorized to take a sales order for the customer's demand. While the required parts run out of stock, the staff must notify the purchasing department to generate purchase orders to suppliers instantly. If the customer disapproves the needed maintenance work, the staffs record the disagreement details, have the customer signs on the wireless terminal and subsequently send it to MAMIS.

In summary, by accessing existing maintenance data and

identifying objects using the RFID-enables mobile device, the staff avoids manual data entry, which speeds up inspection. Recording the reported data on the mobile device and synchronizing data daily with the ERP system significantly reduced the time needed for the process. The electronic assignment of service orders to staffs improves the efficiency of the assignment process. MAMIS reduces maintenance times by eliminating the time-consuming distribution of paper, instead electronically recording the data on site and then synchronizing with the ERP system. In conclusion, the major benefit of using MAMIS is the consistent and comprehensive documentation of all maintenance work. This reduces the costs and potential risks that incorrectly performed maintenance poses.

III. System Implementation

According to the proposed architecture of MAMIS, a prototype implementation of MAMIS is developed for feasibility study. It embodies our generalized and proposed functional design concepts for mobile asset management. A simple example of mobile asset management of maintaining the elevator is used for demonstration purpose.

A. Hardware Configuration

As one of the main focuses of our research is that ordinary industries, even small to medium-scale companies are able to afford, we only utilized ordinary PCs for the MAMIS development. For the MAMIS server, we have used a PC with Intel (R) Pentium (R) IV 3.00 GHz CPU as a server running Windows XP version 2002. In addition to MAMIS server, the user equips with tags and the mobile RFID reader. The mobile RFID reader directly links the RFID reader to the mobile device and makes it an independent information collector.

B. Server

The MAMIS Server contains all of the communications, synchronization, security, and error handling, needed to successfully manage and support mobile asset management. In the MAMIS server, the mobile asset management schedule module has been implemented using Visual Basic.Net for managers to arrange on-schedule maintenance. The mobile asset mamagement procedure database allows staffs to retrive maintenance procedures on site. For the prototyping of The mobile asset mamagement procedure databas, Microsoft SQL Server 2000 Database and ADO.NET (ActiveX Data Objects.NET) framework for database connection were used. In addition, the back-end ERP support is responsible for sending the repaired important information.

C. The back-end ERP system

In the research, the back-end ERP system that we exercise is SMEC (smart ERP & CRM). SMEC is the ultimate ERP business solution for the Small-Medium Enterprise (SME) in distribution and service. SMEC provides a comprehensive solution for small-medium enterprises (SME) in the global marketplace covering all areas from customer management, supply chain and accounting. SMEC is easy to install and implement. SMEC fully accounts for the fact that different people have different requirements. This allows for a very personalized access and gives the user what he needs.

D. RFID Maintenance Scenario

This section will focus on how to use this technology to improve asset maintenance. So far RFID middleware has been the main focus of RFID related software development activity taking place globally [2]. It extracts data from the RFID readers, filters data, aggregates the information and routes the data to SMEC. Therefore, we use a reader interface which is provided by a factory owner to communicate with the RFID reader and then retrieve the tag data. In order to make the utilization of the reader as straightforward and effortless as possible, the reader interface must operate as simply as possible. The reader interface was developed by using Visual Basic.Net. There are mainly two sections in the reader interface. One is auto scan ID. When the “Auto Scan” is clicked, RFID reader reads the tags within its proximity. The ID will be displayed in the blank of Unique ID (UID) and in the second session (Information Display). The second session mainly displays read time, and UID. If the Tag IDs are valid, the staff is allowed to acquire the asset-related information.

E. Case Demonstration

We give a simple example of maintaining elevator for feasibility study. From the mobile device, the technician has access to all assigned works within two months. The technician can view the order ID, start/due date, and address. By selecting the Order ID of the work order, the technician can view the asset name, location, and tools.

The technician enters the reader interface of the RFID system. The technician presses Auto Scan. The tags of the asset rely upon the reader to come within a certain distance to activate them and read tag ID. The reader mounted on the PDA reads the data through a non-contact process across the air interface. The technician can see the unique ID and time. In case the reader has successfully received the tag’s ID, it starts to request the asset information from the datadase. However, we may repeat to read the tags. We can set that the technician must read at least two different tag IDs. The technician can then open the service orders.

The technician is able to load the asset information to a mobile device via the available wireless networks. The technician can mainly view procedure, inventory, contract, records. When the elevator needs to be repaired, with the back-end ERP support the technician can check the maintenance contract, cost, lead time, and more. The technician can notify the customer of the repair and then derive a reasonable estimate for the completion schedule of the maintenance task.

While finding the assets which are repaired, the technician can view the maintenance contract with the back-end ERP support. The technician can enable informed decision making. The technician can also notify customers by e-mail or telephoning immediately.

If the parts have to be replaced, the technician can choose the parts which need to be replaced in the Product Name and then the technician can view the important information with the back-end ERP system. The technician can calculate a reasonable expense to inform the customer. Meanwhile, if the required parts are lower safety stock, the technician must

notify the purchasing department to generate purchase orders to suppliers instantly.

As soon as the customer approves to perform the repair and replaces the parts, the technician can take a sales order for the customer's demand. The technician only inputs the order quantity. The total will be displayed automatically.

After completing the service order, the technician must put down all records about assets. Then the system will take down date and time automatically. When the technician enters the RFID system and starts to perform the assigned works, the Inspection Date will be taken down. The technician must record the problems (reasons) of the assets and touch the button of Complete, otherwise the technician unable to close the order and complete their work.

After the maintenance work is completed, the technician must also scan the tag a second time. Simultaneously, the service order can then be closed and service information will be stored in the database.

MAMIS enables staffs to automate the collection of asset information, eliminating reliance on paperwork and wasted foot traffic. Data is uploaded into the MAMIS server from the field. Companies ensure that the asset management tasks are faithfully carried out by designated staffs.

IV. Conclusion and Future Work

A. Conclusion

This research focuses on the development of MAMIS which is targeted to improve the effectiveness of mobile asset management for organizations and public facilities. MAMIS possesses a set of comprehensive functionality with capturing timely and accurate data, confirming the performance of mobile asset management and checking required cost, parts availability, and service contract.

MAMIS possesses a set of comprehensive functionality by integrating mobile/wireless technologies, RFID, and ERP. RFID can be a viable technology to use in making sure the performance of mobile assets management and automatically access the asset data. It is flexible enough to be applied in many application domains for automation. For the application of asset management, it saves time, money, and the hassles of maintaining assets. The ability to automate the process may also increase the operational efficiency of the organization. In addition, the ERP system creates a single version of the truth that cannot be questioned because everyone is using the unique database of the system. Staffs can be on-line to check the current stock quantity in the warehouse, service contract, and the cost of parts. Meanwhile, for the staff it will be convenient to enter a new sales order according to current customer's demands or to notice the purchase department to create a purchase order to the supplier. The ERP system as the back-end support strengthens the mobile asset management.

The result of this study may lead to the development of effective methods for organizations to better plan, control, and document the work of mobile asset management.

B. Future Works

There is a great potential for applying MAMIS on mobile asset management. Although it is our conclusion that the idea of MAMIS is feasible, there are many issues to resolve before any fully-fledged deployment. Some of the issues are

1) Improved security- because RFID tags can be read and written to remotely, the technology is sometimes perceived as being insecure. Security is the key issue in RFID. An organization that implements RFID does not want competitors to track its asset-relate information. It is significant security vulnerabilities in RFID. In order to enhance the security level of MAMIS, we should confer on the best way to security in RFID.
2) Enhanced tracking capability- Each asset has to be at the right place, at the right time and in working condition to prevent any downtime in operations. As assets move and perform tasks, companies must effectively track and monitor how they are being used, how often they are idling. Moreover, monitoring the assets' condition real time enables managers to do decision-making for emergency. It is a critical issue.

As future work, these issues will be investigated.

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