Optimizing Supply Chain Distribution using Cloud based Autonomous Information

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***Abstract*— The volume of the data and information traffic generated in warehouse management operations is extremely high. They are driven by such frequent events as attempts to locate inventory status files, associated inventory location and integration of specific customer order status tables (such as order payment, and order fulfillment status). The information technology infrastructure required to handle large data volume is expensive with additional cost for complex operations, limiting the operations of small businesses. In addition, any compromise with the infrastructure design may have further implications on the data storage and retrieval affecting productivity. In this research, we seek to investigate the feasibility of a Cloud-based warehouse management system (WMS) that continuously and autonomously captures "RFID" tagged inventory and distributes data handling processes. The purpose of this research paper is to investigate a RFID based WMS (R-WMS) application for mobile devices, including smart phones (such as iPhone, Android, Microsoft Mobile Phone, HTC smart phone, Blackberry, etc) and other handhold smart devices (such as iPad and some light/portable TabletPC) exchanging real-time information through the cloud which is being used to make near optimal decisions and send information back in an acceptable time period. In order to research these possibilities, there is a need to investigate the capacity and dynamic adjustment of workloads for reducing costs and saving energy. Further development of a mobile application of such data intensive operations necessitates exclusive multiple regression data manipulating techniques to provide the most critical information for decision makers. The broader impact of this research paper is the enhancement of mobile user capabilities driving improved productivity. This research will also add to the development of novel warehouse management techniques impacting world-wide business operations helping to realize the world is flatter than anticipated. Further, this multi-disciplinary research will enhance the Computer Science, Industrial and Systems Engineering curriculums by providing greater exposure to emerging areas in supply chain management, mobile computing, operations research, and cloud architecture and computing. The intellectual merit from this research will include ramifications on cloud-based mobile computing, which is the future of modern business operations. This research will train undergraduate and graduate students from both computer science and industrial engineering in the field of supply chain, logistics, mobile computing, and cloud computing.**

***Keywords*—** *RFID WMS, Mobile applications; Cloud Computing;*

1. Introduction

Warehouse Management System (WMS) is software that has been designed to provide instructions to the end-user on the many warehouse activities needed for fulfilling customer's orders. The volume of the data and information traffic generated in warehouse management operations can be extremely high. They are driven by such frequent events as attempts to locate inventory status files, the associated inventory location and the integration of specific customer order status tables (such as order payment and order fulfillment status). The information technology infrastructure required to handle the large data volume can be expensive and the cost of the software to manage complex warehouse operations may be very high and can limit the adoption of these systems by small businesses. In addition, any change to the infrastructure design or software may have further implications on the data storage and retrieval productivity of the system and ultimately limit the system functionality for the end user. In this research, we suggest using web based cloud computing infrastructure for meeting the computing needs of warehouse management systems (WMS) designed for mobile applications. We seek to investigate limiting and optimizing the WMS subroutines required for the mobile application through identifying the required activities for small business operations and capitalizing on Radio Frequency Identification (RFID) technologies. We theorize that as user demand increases, the cloud service provider could instantly scale up the huge required resources. This lowers organizational overhead of investing on new infrastructure, training new personnel,

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and getting licenses for new software. The users would use Web services for running the application or storing the data in the cloud only when necessary and then will pay for only what they use. The users do not have to worry about the maintenance of the networks and servers due to the fact they do not own the platform, infrastructure and/or software in the cloud. They access multiple servers and storage media stored somewhere around the globe and do not know where they are and which ones they are using. The resources are allocated and de-allocated on demand.

The goal of this research paper is to develop an interactive framework of mobile application that supports and develop computing of a data-driven warehouse management system through cloud architecture. This research goal will be addressed through the following specific objectives. Firstly, we have been trying to investigate the feasibility of radio frequency identification (RFID) technologies for inventory location and work optimization for warehouses as well as attempting to identify the key functionalities of warehouse processes both from development and end user perspectives to develop a mobile application for operational efficiency. Moreover, the proposed methodology can help identify the limitations of the minimal functionality provided to the RFID WMS Mobile application with an enhanced Cloud Computing Infrastructure. In this research, we have performed a comparative analysis among three different picking methods such as Voice picking, Pick to light and Mobile RFID Warehouse management System based on Cloud Computing by using multiple linear regression analysis procedure. Multiple linear regression is used as tool in analyzing the significance of two predictor variables i.e. Number of Picks (X1) and Quantity of SKUs picked (X2) in determining the total labor cost. 40 days of data on above two factor variable and one response variable has been taken from ABC Inc. Corp. has been taken as a reference. This analysis has been used to Benchmark Cloud Computing Performance Categories Relative to Warehouse Management.

By addressing these specific objectives, we seek to investigate a RFID based WMS (R-WMS) application for mobile devices, including smart phones (such as iPhone, Android, Microsoft Mobile Phone, HTC smart phone, Blackberry, etc) and other handheld smart devices (such as iPad and some light/portable Tablet PC) exchanging real-time information through the cloud which is helpful to make near optimal decisions and send information back in an acceptable time period.

2. Background

2.1 Warehouse Management System

Warehouse Management Systems (WMS) are decision support systems that utilize complex algorithms to direct personnel to perform warehouse tasks such as receiving, stocking, picking, packing and shipping of inventory. Similar to Enterprise Resource Systems (ERP), WMS are comprised of different software applications and / or subroutines that access multiple databases to perform different functions. For example, there may be a software application that identifies the location of a person who is stocking inventory in a rack so that it can determine the next task he must complete based on his proximity to other inventory, while another routine is identifying the amount of inventory that has been placed in the rack so that it can determine the amount of inventory that can be chosen or picked out of that location by another employee, and another routine that may determine what order inventory should be acquired so that all of the inventory picked that day will have time to be loaded at the shipping dock. WMS systems oftentimes transmit granular data to ERP inventory modules so that the back office tasks such as accounting can be performed. They differ with ERPs in that they use many complex subroutines to tell the warehouse personnel exactly what to do and where to go through the use of scanners and or handheld devices. They are considered execution systems. WMS systems have been driving large complex operations for large business for over thirty years. The typical savings for WMS systems in operations with over 20 personnel is typically greater than 20% through labor reduction and reduction of excess inventory. Smaller companies oftentimes need the benefits of these types of systems in their warehouse and distribution operations but the cost and the complexity of these systems limit their adoption of these systems.

Often the complexity of some of these systems contributes to small businesses not being able to use these systems. For example, these systems have the ability to control complex conveyor systems, Automated and Storage Retrieval Systems (AS/RS), and robotic picking systems. We theorize that the cost and the complexities of these systems can be reduced for the small business through using modern technology. Then later as the organization needs the complexity it can leverage the power of the cloud computing and network computing to scale up to the more complex systems.

2.2 RFID and RTLS Localization

RFID is defined as the process of identifying an object by means of radio frequency transmission. Items can be tracked, identified, sorted, and detected in a wide variety of applications only limited by a person's imagination. Although, the applications of RFID include an endless amount of possibilities, there are three distinct application groups of RFID: item tagging and tracking, transfer of further data, and localization.

RFID works via electromagnetic communication between a reader (interrogator) and a tag (transponder). A tag is attached to an object with some internal memory storage which contains information about the object, such as a serial number, manufacture date, or other information that might be important to the object. A reader emits an electromagnetic field and when a tag enters the field, it transmits back the information stored on the tag. In general, when the reader emits a radio frequency signal, any corresponding tag within range of the reader will detect the signal. Once a tag has verified the signal, it replies back to the reader indicating its presence. A second major application of RFID technology involves not only retrieving an identity from a tag, but also reading and writing data. Some products may provide instructions for operation or handling; for instance, food tags could instruct an oven the optimal cooking time or temperature. The third application, localization, is a mechanism for discovering spatial relationships between objects. Localization is accomplished by ranging, which is the process of determining the distance between objects.

Localization for RFID is the focus of this paper. Radio enabled localization has been used for medical supply tracking, finding lost golf balls, and determining the location of hospital patients. Triangulation methods are generally implemented where distances from static reference readers are measured. The continuous monitoring of movable items using the localization techniques is referred to as a Real Time Location System (RTLS). RTLS systems are typically active systems (using battery operated tags) to detect presence and location within a 2D coordinate system (XY position only, not height).

Most current RTLS systems rely on the signal strength as an indicator for distance approximation. The system works by using received signal strength indications between multiple access points throughout the tracking area. This provides accuracy indoors of 3 to 9 feet (0.91m to 2.74m). The system does not cause any interference to the existing network traffic because the tag communicates only about 60 bytes of data per location update. The tags generally require a 4-6V power source. The tags have built in accelerometers and can be configured to identify and report tag location every time it is moved. Active RFID RTLS and infrared (IR) systems generally have a read range of up to 10 meters. Some passive RFID RTLS systems have reported accuracies within 0.6 m of the actual location using advanced statistical models from data collected from multi-reader configurations.

2.3 RFID and WMS

For efficient warehouse operation, it is critical to identify the optimum order waves (order grouping) and wave order release schedules that will minimize order picking labor as it influences how customer orders are organized and presented in software that is used for distribution operations. Grouping orders into logical sets is commonly called wave batching. These grouping algorithms allow for picking and labor to be coordinated with other operations, such as shipping, to optimize functions in distribution centers. For example, orders may be picked in reverse delivery order so shipping trailers are loaded optimally. The first order picked goes into the back of the trailer to be delivered last. The importance of order wave batching is critical in high speed operations, but inventory inaccuracies can reduce the quality of these batching of orders and reduce their effectiveness. Specifically, we seek to influence order bid process within the network schema defined as the framework in which order agents compete against one another for resources to meet their specific goals, described as the bid process in the negotiation schema. The real-time ability of RFID to provide inventory accuracy and identify secondary location of the inventory immediately can improve the accuracy of the wave batches.

Generally, complex WMS systems use barcode scanners that emulate the screen of different modules of the software. Barcode systems are currently being upgraded to RFID based scanning due to the current adoption of RFID tags in Logistic operations. Currently many readers are being upgraded to read both the Barcode and RFID tags. Using RFID instead of the barcode allows operations to capitalize on the labor savings of not having to see the barcode to capture the location and confirmation of the inventory. For example, in a typical “Bucket Brigade” pick to belt operation utilizing a WMS system, the workers are assigned zones in which they pick inventory. After the inventory for an order in one zone has been captured by one worker, they move the order container (case or pallet) to the next worker to select the inventory in their zone. When inventory is inaccurate, the worker often takes excessive trips within a zone and often moves the container to the next without the correct inventory. RFID technologies can reduce labor in two ways. First, RTLS can provide a triangulated location of the order selector and optimize his/her travel path based on the selector's current real-time position, not assumed work area. Next, real-time inventory status updates (such as damaged, missing, or spoiled inventory) can be incorporated into the order picking schedule to allow workers to bypass inventory locations with bad inventory. The promise of these two RFID functions can save operations labor and provide extreme flexibility in directing distribution labor. Thus, the contribution of RFID systems to the overall logistics model is expected to produce significant contributions in the three areas mentioned above: 1) inventory reduction with respect to safety stock reduction, 2) optimization of order grouping and releases, and 3) and labor reduction with respect to picking and stocking labor. The contribution to this body of knowledge is significant in that it will allow the intelligent based aspects of RFID to be introduced to research models. The broader impacts to companies are that it will introduce and quantify the real-world effects of reducing the inventory bull-whip effects in supply chains, further optimizing orders in the supply chain, meeting customer services, and reducing operational labor costs.

The incorporation of RFID system in warehouse operation has implied a significant change in warehouse procedures. Rawal (2010) established that the changes for the use of RFID technology begin with the fact of processing the information in real time and automation of the activities. The benefit could be summarized as the capacity to process a big amount of data, decrease the labor cost, and increase accuracy in collecting and processing the information. Furthermore, RFID represents the opportunity to improve the production planning control in the warehouse with advances in the control of demand and supply planning. These are in direct relation with activities as pick, pack and ship control.

Bukchin addressed the design of an assembly system facility consisting of multiple assembly lines of different shapes [32]. To achieve this, a facility layout problem was solved using an MIP formulation that models each line as a set of rectangular sub-lines. The efficiency frontier approach was applied to analyze the trade-off between facility area and the transportation distance and an algorithm with the ability to generate a set of efficient solutions was presented. The resulting approach was recommended to provide solutions to small-to-moderate-sized problems using a reasonable amount of computational effort in order to enable designers to see the whole picture and consider complex trade-offs between facility area costs and material handling costs. Larger problems were left to heuristic approaches that needed further research at the time. Later a number of techniques were used to solve the Facility Layout Problem (FLP) such as the SLP. The companies looked systems more productive and efficient. Generally, these systems have a direct connection with the generation of new layout designs. Hammad expresses that “The evaluation of the production system efficiency in the factory is essential for meeting the growing demand of customers with respect to design and size of the housing product. It is imperative to explore alternative layout designs that would be more efficient and productive.

We believe using RFID in our paper is important not only, because it is currently being adopted and reduces costs for small business. It also provides an opportunity to locate the user of the reader. This localization capability or Real time location system ability will allow the researcher to re-optimize the worker location and minimize the computing needs for the WMS software application. There are several research challenges to this problem specific to the RFID technologies including the type of tags that can be utilized to perform these RTLS functions.

2.4 Cloud Computing

Cloud computing is a sophisticated three-layer infrastructure as shown in Figure 1 that provides on-demand computing for anyone within a network connection using a third party service.

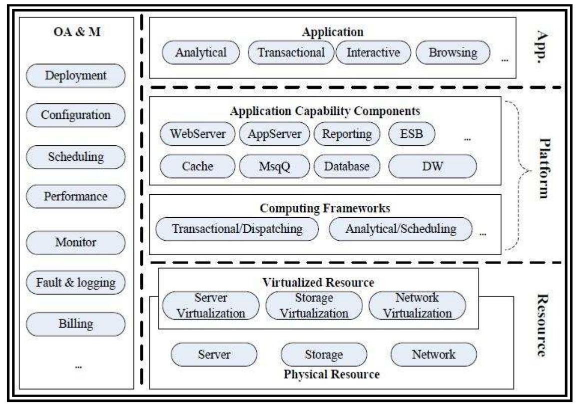

Figure 1. Cloud Computing Reference Architecture [34]

The advantage of using a cloud is the accessibility of the data and application from anywhere, at any time, and with any web-allowed device. This feature of the cloud eliminates the costs and complexity associated with acquiring and managing any information infrastructure. Cloud computing also provides scalable and elastic computing resources that are served from the shared resource pool, the resources being physical or virtualized resources. However, these resources should be available to consumers with integrated dynamic resource scheduling strategies for proper allocation of resources across the network.

Cloud computing allows organizations to run custom applications through platform as a service (PaaS) that offers storage, computing power, and network infrastructure as a service along with runtime environment for compiled application code. The advantage of PaaS over other service types is that only the application code needs to be uploaded, configured, and run, which eliminates the need to upload virtual machines. Microsoft provides PaaS service as Microsoft Azure Platform with Windows Azure as the runtime environment. Windows Azure provides a Windows-based environment to compute and store services for cloud applications. This feature allows programmers to develop applications using ordinary Windows-compatible languages (Visual Basic, C++, C#, Java, Python, or others that can generate Windows binaries) or Web applications (ASP.NET, PHP, Windows Communication Foundation (WCF)). The database management system is a Microsoft SQL Server, which is the most common one used in RFID applications. The Windows Azure Platform not only provides a strong cloud offering for Windows/.NET applications but also for some dynamic language applications. The services are provided at a competitive market price with a flexible Pay As You Go plan. Only the custom code needs to be built and uploaded to the Cloud rather than building and loading virtual host machines. As the application starts, third party software packages do not need to be supported, those being managed by Windows Azure services; only the application itself needs to be supported.

Cloud Computing has attracted much attention from industry and academia in recent years. It has been developed to be a successful business model to share the cost and resources among different companies and communities. How to effectively share the resources for a variety of applications with different characteristics is still an open research problem. In this research, we propose to explore new scheduling strategies for workload-dynamic, real-time, data-intensive tasks on a Cloud Computing environment. Some key research questions are worth further studying, including how scalable Cloud Computing can offer to such data-intensive real-time applications, and what configuration we need to change on the Cloud server to meet the application's requirements? We plan to investigate the challenges of deploying such applications on Cloud Computing environment and provide our insights to these questions.

2.5 Applications for Mobile Device Using Cloud Infrastructure

There have been a number of projects and papers addressing the opportunity of outsourcing mobile applications to improve performance or energy savings. The case for mobile outsourcing to the cloud to save energy has been made [14] and the trade-offs of computation offloading in terms of energy usage have been investigated by Miettinen and Nurminen [12]. Since the cloud is so new, most of the prior work relevant to us concerns outsourcing of mobile applications to external server resources. The Spectra and Chroma projects have focused on compute-intensive interactive applications [5]–[7]. Spectra supports coarse-grained full-application migration and the programmer identifies the objects eligible for remote execution. Chroma extends Spectra to allow pre-specified user tactics for adaptation and placement and the use of multiple servers. However, the application must provide methods for decomposition. In contrast, we treat the application as a black-box and consider the interaction between multiple applications.

Other projects are based on virtualization. Chun and Maniatis present the idea of full VM cloning of a mobile's image to a remote server at a very coarse-grain level, but no implementations have been evaluated [6]. Cloudlets allow a dynamic outsourcing of a VM to a local "cloud" (server at a network access point) to promote network locality vs. a commercial cloud [10]. However, the VM transfer/load times may compromise the low response objective. Protium addresses the issue of session mobility and universal data access from any client [15]. Slingshot evaluated the use of a surrogate running at a hotspot coupled with a remote server [11].

The idea is to use the hotspot for outsourcing when Internet connections between it and the server are poor but to use the remote server when the user is moving and connection to the hotspot is lost. Our approach is more general and considers a wider-range of resource availability beyond networking. Compiler-assisted approaches have also been proposed [16]–[9] – [13]. These works are limited either to static mapping decisions or single application optimization only. Wang considered dynamic placement but only the metric of energy is used and is limited to single applications [9]. Diet uses a Java-based program analyzer which can partition Java programs at the method-level [13].

2.6 Voice Picking

A pick to light or light directed system is suitable for a warehouse in which pickers need to move fast and accurate between multiple picking locations. This system can improve employee capabilities. In this system lights will be placed directly above the racks from where operators pick items. Barcodes are placed on the picking containers which represents the customer order. Depending on the order, operators will pick an item from the bin. The quantity of the order will be displayed by lights above the bins. The operator will press light indictor above the bin after picking an item. This will confirm the pick. Picking of the order is complete when there are no lights illuminated [31]. In this system, quantity of the order will be displayed constantly. The implementation of voice picking method costs about $ 188,000 and annual savings approximate $ 33,683.9 per year. The payback period takes up to six months and twenty one days.

2.7 Pick to Light

This process utilizes speech recognition software and voice direction which allows workers to communicate within warehouses. In this system, operators use a headset which is connected to small portable computer. This computer will guide the operator within the warehouse by verbal commands. Once tasks are done, operators will confirm their tasks by speaking and reading confirmation codes which are printed on products or location. The operators need to confirm their tasks by reading codes instead of scanning bar codes and entering key information [31]. Pick to light implementation costs up to $300,000 and this option saves up to $342,210 per year. The payback period is within ten months and six days.

2.8 Mobile RFID Warehouse management System based on Cloud Computing

Currently there have been WMS suppliers who are looking to move to an open source architecture that allows the users to capitalize on cloud computing. But they do not adequately address the complexity problem nor do they discount the cost of the WMS. In fact when they move to a transaction based model it costs the small companies more than the large company as a percent to sales volume. We propose leveraging the cloud as needed and finding that point when it makes sense. We also do not propose a more complex system when it does utilize cloud computing. We seek to design a mobile application that initially will provide only the need functionality necessary for the small business that has the capability of updating architecture first with the less complex WMS and maybe later if necessary to the more robust WMS system.

3. Methodology

For a particular distribution center (DC) setting (layout/ order picking system), we are interested in determining if the cloud infrastructure based warehouse picking system is significant in reducing the total cost and item pick time in a day. A particular picker may pick in different ways. If pickers pick many items per picking tour then total labor hours for that day may be less resulting in less labor cost. However, the picking methods of each picker may diverge. Hence, by observing a 40 day data for a particular DC on three different picking methods; Voice Picking, Pick to light and Mobile RFID WMS System based on Cloud Computing and conventional picking methods, we came up with the following hypothesis.

Hypothesis No. 1

Ho: Mobile RFID Warehouse management System based on Cloud Computing doesn't reduce item pick time.
H1: Mobile RFID Warehouse management System based on Cloud Computing reduces item pick time.

Hypothesis No. 2

Ho: Mobile RFID Warehouse management System based on Cloud Computing doesn't result in cost savings.
H1: Mobile RFID Warehouse management System based on Cloud Computing results in cost savings.

Figure 2 presents the architecture of the mobile RFID Warehouse management System based on Cloud Computing. The system consists of mobile client software to deal with RFID data from warehouse operations, and a Cloud based data center to handle intensive database transactions. The pervasive mobile computing application for WMS and explore how to best schedule real-time WMS transactions on the dynamic configurable, heterogeneous Cloud Computing environment. The WMS cloud scheduler will dynamically reconfigure the resources and schedule tasks based on the current requests demand, client budget, and system loads.

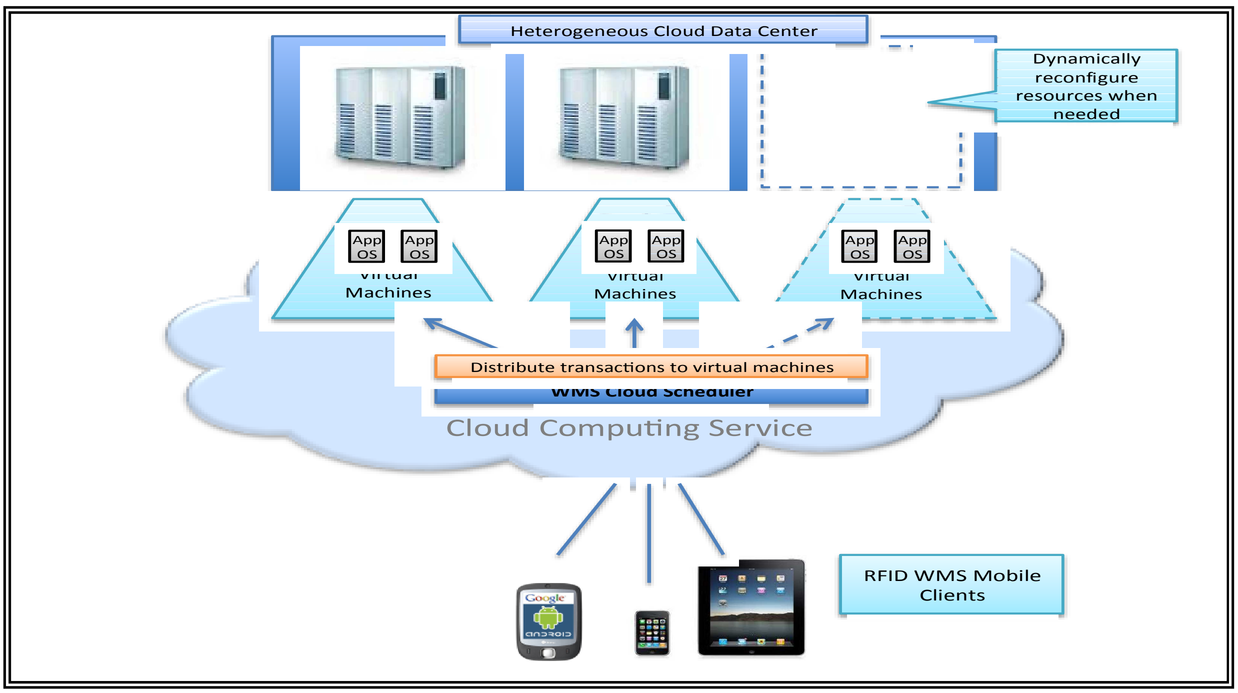

Figure 2. The Proposed Mobile RFID Warehouse Management System on Top of Cloud Computing

The diagram shows the interconnection between automatic devices such as RFID with Cloud based system. Traditionally, RFID technologies have been used in warehouse operations for automated inventory information. However, the volume of data generated with RFID technology is humongous, mandating an investigation of the database size and optimization of data transfer between the database and the smart phone. The memory capacity of the smart phones is limited, and it is necessary to develop an efficient decision-making protocol to provide the most critical information for the end user. We envision that the outcome of this research will be a series of decision options for supervisors to effectively schedule work based on real-time information from the RFID system on activity, inventory and operator location.

To identify the key functionalities of warehouse processes both from development and end user perspectives and also to develop a mobile application for operational efficiency, an advisory board consisting of warehouse management experts and users will provide input on work scheduling, manpower planning, and RFID based inventory management. We are using value stream mapping to identify the key functionalities for the RFID based warehouse management system within our proposed Design for Six Sigma – Research (DFSS-R) methodology. Moreover, the standard application development tools including the Xcode 4 (for Apple smart devices), Android SDK and Eclipse (for Google Android smart phones), and Visual Studio 2010 and Windows Mobile SDK (for Microsoft Mobile) will be used. The development of the application involves extensive coding to provide customization features for specific businesses.

A set of the prototype smart device apps are expected to be delivered as a software platform for testing mobile (smart) devices in the warehouse management system. Our preliminary analysis conducted with our collaborating company tests of an open source system is that the system will be limited to approximately, 10 workers, 500 inventory items, and less than 2,000 transactions per day. This system would support a small business and then would have to be scaled with server capacity. We would then have to adapt or enhance the application schema to work more like an open source system.

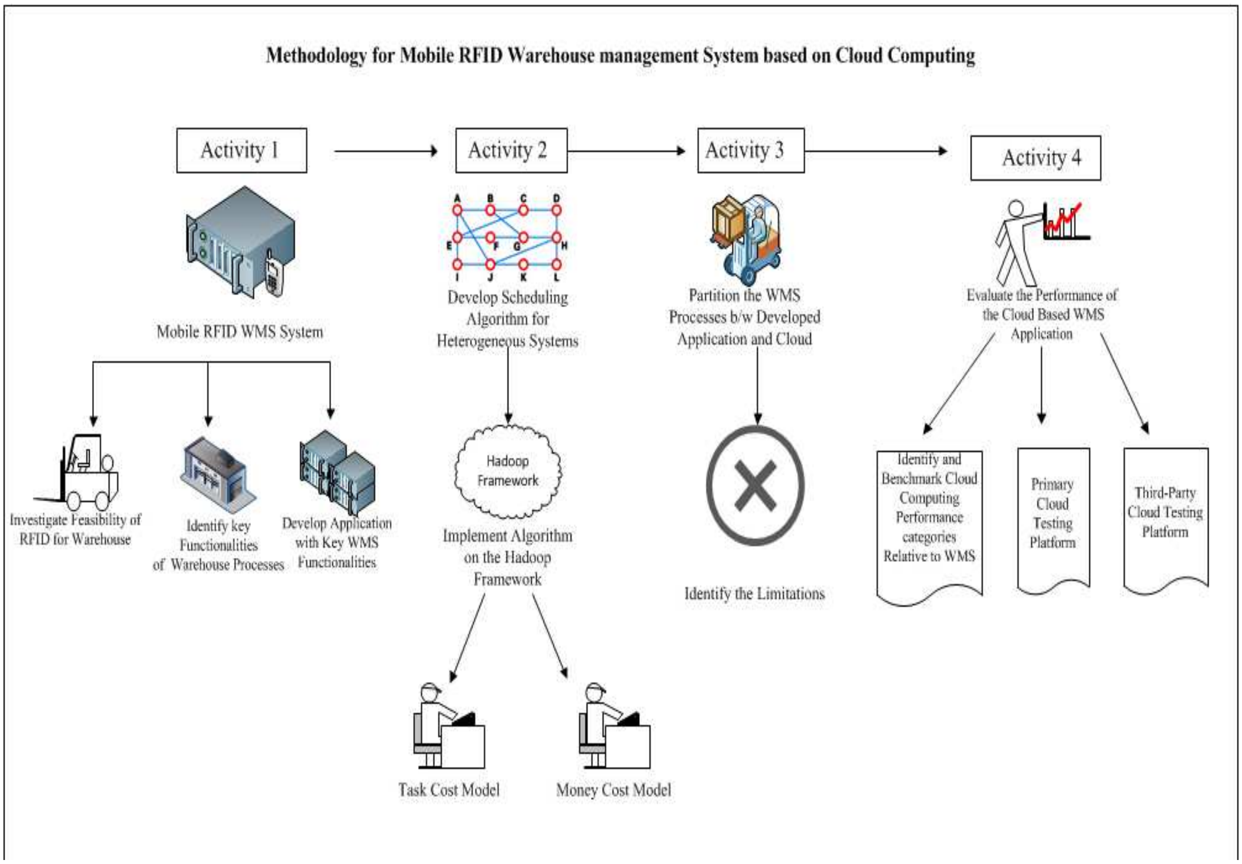

Figure 3. Methodology for Mobile RFID Warehouse Management System based on Cloud Computing

3.1 Activity 1

Task cost model: We propose to use compiler analysis information to estimate the execution cost of a task and create its related properties. The assumption of similar workloads of different tasks is not realistic for real applications. We need to create a methodology to estimate the execution cost of different kinds of tasks in an application. A compiler can analyze a task (a region of code) statically to estimate its execution cost with symbolic representation and summarize its properties, such as computation intensive, memory intensive, I/O, and cache behaviors. The information is evaluated at runtime when a task is submitted to the Cloud scheduler. It is critical to obtain accurate information in order to schedule a task efficiently. We will also use historical information to correct task estimation.

3.2 Activity 2

Money cost model: We will model the money cost using two scenarios: fixed budget and minimized cost with required performance. Since the Cloud is "pay for use," the money cost is a key factor to attract users. We will also use it to select the two different scenarios and schedule tasks accordingly. It is an additional parameter for the scheduler to take into consideration.

3.3 Activity 3

System Model: The scheduler needs to have a global view of the entire Cloud system and the ability to schedule tasks to best utilize the variety of computing resources of a heterogeneous Cloud. Moreover, it should be able to reconfigure resources according to the real-time application demands. The system model will have the entire system configuration, as well as the current allocations of virtual machines/services. It provides the characteristics of different computing nodes on the heterogeneous system to let the scheduler to allocate tasks that are able to best utilize the computing resources on a virtual machines/services. It needs to promptly respond the dynamic real-time performance requirements by expanding or shrinking the resource allocation. It will invoke task/data/service migration. To Integrate with RFID WMS mobile app to test the scheduling efficiency on the PVAMU heterogeneous Cloud system. The scheduler will evaluate a pool of current tasks based on these models to schedule them according to different policies. In this research paper, we will be able to get feedback from the user community to evaluate the algorithm efficiency, which is very valuable to scheduling algorithm improvement.We will seek to use the Cloud as a flexible component for the mobile phone application. We seek to understand the limitations of the application working as standalone system with a minimal need for downloading information to the I-phone. Once that limitation has been exceeded, we seek to enhance the need and capabilities of the mobile application by using a schema that allows the application to scale using server capacity and server software logic. Given the opportunity for unlimited capacity that Cloud Computing may allow, we seek to test the limitations and opportunities of this technology. The traditional schema provided by an Apple application, we seek to identify the limitations of the system with respect to number of workers, the number of tasks, and the amount of inventory.

3.4 Activity 4

For Benchmarking the Cloud Computing Performance Categories Relative to Warehouse Management, an initial set of measures that are generic to cloud computing will be reviewed and used to guide the evaluation analysis. To date, a few of the measures that have been used to benchmark the performance of a cloud computing application are: (1) end-to-end response time and caching; (2) CPU performance; (3) storage I/O; (4) memory I/O; (5) network throughput and congestion; (6) computational performance (CPU-intensive tasks); and (7) cost. To further refine benchmarking the warehouse management system application performance criteria, input from a Technical Working Advisory Group (TWAG) will be obtained. The TWAG will be 8-10 individuals consisting of cloud computing software subject matter experts (SMEs), engineering and computer science graduate/undergraduate students, and warehouse management stakeholders. Their role here is to formulate input on the integration of warehouse processes and cloud computing. This form of partnering will facilitate clarifying performance of the application as well as assist with developing specific and realistic warehouse scenarios to use in testing and measuring performance. Also, the TAWG will have a role to play in our research evaluation plan as well.

A comprehensive analysis will be performed to compare results of three different types of picking processes. When testing the performance of cloud computing platforms, it is important to test multiple instances simultaneously, during different times of the day, and over multiple weeks to get a real measure of system performance. The reason is that the capacity of each cloud platform could vary dramatically given different times of day and load on the platforms. Ultimately, good resource-distribution algorithms, system architecture, and capacity planning will shine through in the performance results between platforms. It should be noted that the amount and timing of samples is important to get a measure of overall system performance for cloud platforms.

The results for all test runs will be averaged, graphed, and compared. A cost analysis of the performance criteria will be performed as well. This information will be shared with the TWAG for review and to seek input for incorporating changes.

4. Results

Multiple linear regression is used as tool in analyzing the significance of two predictor variables i.e. Number of Picks (X1) and Quantity of SKUs picked (X2) in determining the total labor cost. 40 days of data on above two factor variable and one response variable has been taken as a sample reference. It has been assumed and we take 0.01 as the statistical significance level. To check the applicability of MLR model preliminary correlation analysis of both the predictor variables were done for each of the picking systems. X1 vs X2 plots for each picking system and the confirmation is done by the calculation following the plots.

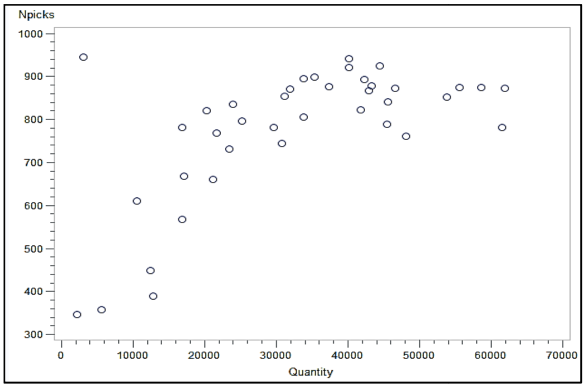

Figure 4. Voice pick

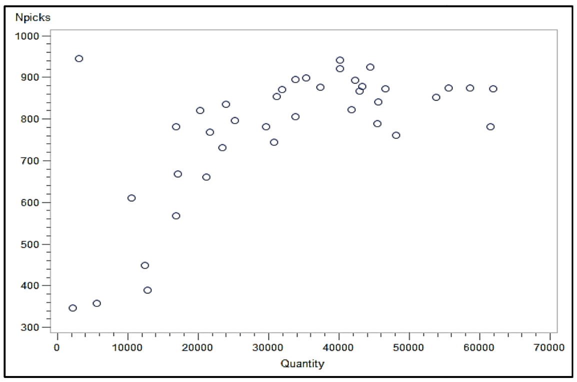

Figure 5. Pick to light

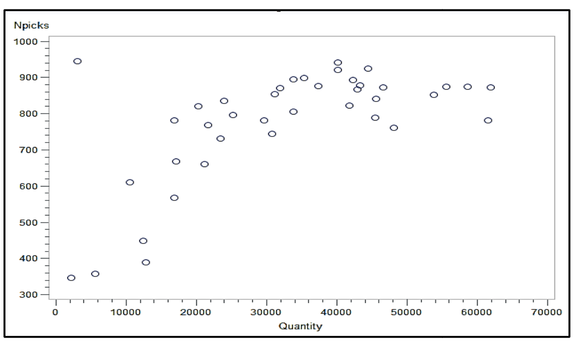

Figure 6. Mobile RFID WMS System based on Cloud Computing

Below table summarizes the Pearson Correlation Coefficient value between the two variables each case.

Table 1. Pearson Correlation Coefficient value

Picking method	Rho (X1, X2)
Voice picking	0.6400
Pick to light	0.6415
Mobile RFID WMS System based on Cloud Computing	0.6400

Since none of the correlation coefficient values are greater than 0.7 hence no serious problems of multi-collinearity are to be feared of (figure 6) and the Multiple Regression model can be continued.

Below are the results of multiple linear regression one of the picking system setting.

1. Voice picking system

Let,

L= Labor cost/ day

X1 = Number of picks

X2= Quantity of SKUs picked

Regress L vs X1, X2 to get the P- Values for independent variables X1 and X2. Below is the ANOVA table after the regressing L with X1 and X2.

Table 2.ANOVA Analysis

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	10224858	5112429.000	1973.05	<.0001
Error	36	93281	2591.13052		
Corrected Total	38	10318138			
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
N picks	1	1.01258	0.06773000	14.95	<.0001
Quantity	1	0.02471	0.00066414	37.21	<.0001

P- Value of F-Test (0.001), which is less than the level of significance assumed for the model, signifies that at least one of the factor variables is important. Also, P-Values from individual t- tests of both the variables signifies that both of the variables are important and cannot be dropped from the model as both the values are less than lever of significance assumed. Hence Ho is rejected at 99% confidence level.

Similarly, Labor cost (L) is again regressed with other two factor variables X1 and X2 for Pick to light and Stock to picker systems. The ANOVA results are as summarized below:

Table 3. ANOVA Results

Picking System	P- Value for F test	P- Value	P- Value for T-Test for

	for model	for T-Test for parameter(X1)	parameter(X1)
Pick to Light	0.0001	0.0001	0.0001
Mobile RFID WMS System based on Cloud Computing	0.0001	0.0032	0.0063

From the P- values for F-Test above for both the picking systems we can conclude that at least one of the parameter is significant and further examining the P-values or T- Test for each parameter, we see that both values are less than the alpha value assumed for the model i.e 0.01. Hence we are 99% confident that both Number of picks (X1) and Quantities of SKU picked are significant in the proposed model and cannot be dropped.

The null hypothesis were rejected in each of the picking system, we conclude that Quantities of SKU picked and No. of picking tours done are both significant in determining the total labor cost for a particular warehouse setting. Hence, we have arrived that none of the cases can be dropped from the model.

As we need to make a choice for the particular order picking type based on solid financial reasons and as per DC management requirements our selection criteria is attractive payback period based on current requirements. We have conducted return on investment analysis and have got the following results.

4.1 Mobile RFID Warehouse Management System based on Cloud Computing

The Mobile RFID WMS System based on Cloud Computing implementation is expensive and demands an investment of $2,200,000. The Stock to pickers system provides annual cost savings of $643,141.93. The payback period is three years, five months and two days.

Table 4. Economical Analysis

	Voice Picking	**Pick to Light**	**Mobile RFID WMS System based on Cloud Computing**
Total Labor hours	5255.5	5239.74	2017.740
Total Direct Labor Cost $	88986.8	88303.6	49702.80
Software $	0.00000	0.00000	200000.00
Machine Cost $	188000	300000	2000000.00
Total Cost $	276986.8	388303.6	2249702.2
Savings for 40 days $	43212.4	43895.6	82496.400
Savings per year $	336883.9	342210.1	643141.93

4 Conclusion

Cloud computing is a large number of highly virtualized managed resources such as applications, data available to users over the web. This system is highly reusable, sustainable, scalable, and customizable. In our previous study, we found out that the efficiency of scheduling heavily depends on system workloads, data location and computation affinity [17], as well as tasks allocations [18]. In this research the developed methodology has helped understanding the activities of mobile RFID warehouse management system based on cloud computing to take decision and necessary action to improve the order picking and warehouse activities. Also, we have performed regression analysis to measure and compare the model validity of three different types of picking methods; voice picking, pick to light and the proposed method. Moreover, economic analysis has been used to estimate the annual savings respect to three different methods. On Cloud, more factors need to be considered, such as budget, dynamic system configurations, and task and data migration. Moreover, we are working on research of programming and scheduling tasks on heterogeneous cluster equipped with combined multicore CPUs and GPGPUs [19]. This area needs to be further investigated in order to efficiently utilize the Cloud resources.

The proposed system is being helpful for virtualization and simulation projects, experiments, clustering. The authorized users those are accessing remotely over the Internet; being provided the convenience of the usage and availability of advanced technology without physically being at the warehouse. With the help of RFID mobile warehouse management system, the warehouse process can be accessible from anywhere and anytime as long as the network connection exists. Cloud computing is a large number of highly virtualized managed resources such as applications, data available to users over the web. This system is highly reusable, sustainable, scalable, and customizable.The analysis showed how the impact of location would affect the future layout of the warehouse. This research was built upon Cloud Computing based Mobile RFID Warehouse management System that were used for determining the ability of RFID of assisting in the automation of facility layout planning by using RFID Portal to optimize Systematic Layout Planning. We utilized a combination of a multiple linear regression approach by which a warehouse performance was evaluated and the baseline for comparison was created and applied multiple linear regression approach for which we sought two basic objectives: one aims at minimizing the item pick time, while the other aims at maximizing cost saving.

We theorize that we can build off of the results of the previous studies including our study with RFID based optimization of travel paths. We can extend the analysis from a RFID enabled system to a person holding a RFID enabled mobile device. By using the information in a different way, we would capitalize on the layout of the facility to determine the optimal path for the person to travel and attain prioritized work tasks.

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