EVALUATING THE IMPACT OF AUTO ID TECHNOLOGIES ON OIL AND GAS ERP SYSTEM DATA ACCURACY AND RELIABILITY

by

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Abstract

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Most of Enterprise Resource Planning (ERP) systems currently use manual entry or mass upload methods to enter data collected from warehouse operations. These methods are highly unreliable and prone to manual error affecting the data accuracy. Data accuracy and accurate real-time data are required by businesses for many critical decisions. Unreliable data becomes invalid and have a negative performance impact on ERP systems that can lead to economic loss to the organization. Automatic Identification (Auto-ID) technologies are used to track and collect data in real time or near real time. They can be integrated into ERP systems automatically to provide live updates without human intervention thereby reducing the data's inconsistency and increasing timeliness. In this research we hypothesize that by integrating Auto ID technologies, namely RFID and barcodes, into an ERP system that the data accuracy and reliability would be increased significantly by utilizing live data updates. The research begins with identifying the variables affecting the ERP data accuracy by interviewing the business ERP and warehouse users. Then a survey was conducted among, ERP specialists and users, and warehouse specialists and users from an oil company, to collect their perceived impact of these variables on the ERP data accuracy. A Multiple Linear Regression (MLR) model was developed to explain the effect of these variables on the ERP data accuracy. The

model was improved by developing a model with better predictor variables. The economic impact of the implementing Auto ID with the ERP system on the data accuracy was then simulated for a variety of accuracy levels for a single product line. Our results were that a known group of experts, including data entry clerks and programmers, determined that Auto ID technologies improve ERP systems data accuracy and that the Return on Investment determined by Net Present Value (NPV) analysis indicates savings would be significant.

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Chapter 1

Introduction

Organizations continuously seek effective ways to conduct their business and operations by employing various techniques and tools. Enterprise resources planning (ERP) is an important tool that has been in practice by the organization for more than a couple of decades. By 2013, the ERP world market size has reached $24.5 billion (Forbes, 2013). ERP is a suite of integrated applications or software for business management that store the data from every stage of business operations (inventory, production planning, cost and development, etc.) in a centralized database. The data stored in ERP are used in various business decisions like purchasing raw materials, delivery date determination, lead time for delivery date etc. Inaccurate data will lead to bad decision making eventually hurting the company in terms of money, customer satisfaction, etc. Data accuracy is affected the most by manual errors and data update intervals. Some examples of these decisions are purchasing the raw materials, production schedule, customer credit decision etc. It is necessary to maintain accurate data to avoid these types of situations. Inventory level tracking is one of the areas most affected by the inaccurate data and in adequate tracking system.

The investment in software and hardware for ERP systems is well over $15 billion per year and additional $10 billion in professional services (Davenport, 2000). Various critical business decisions are made based on the data available in the ERP system. Some examples of these decisions are purchasing the raw materials, production schedule, customer credit decision etc. The data stored in the ERP system should have high accuracy; inaccurate data will lead to bad decision making eventually hurting the company in terms of money, customer satisfaction, etc. Therefore, it is necessary to maintain accurate data to avoid these types of situations. Inventory level tracking is one of the areas most affected by the inaccurate data and in adequate tracking system.

Traditionally, the inventory levels were counted manually for each product line at the end of the manufacturing shift or end of the day. The data are then entered into the ERP system manually or through mass upload of data sheets. There is a high possibility of error in the data collected and entered into the ERP system. Recent advances in Auto ID capture technologies like radio frequency identification (RFID) and barcode are greatly increasing the accuracy of the data collected. These technologies are also integrated with ERP directly to decrease the human error in manual data entry (Chiu, Mark, Kafeza, and Wong, 2011).

The objective of this research was to evaluate the impact of Auto ID technology on the ERP data accuracy. This was performed by developing a questionnaire that measures the perceived impact of Auto ID technologies on ERP data accuracy. The questionnaire was answered by the ERP and warehouse specialists and end users. Regression analysis was performed on the data collected to develop a mathematical model to identify the variables effects on the ERP data accuracy.

Chapter 2

Background

Overview

This chapter describes the previous research related to the current research. It also describes the ERP history, their overview, main modules, how an ERP system is selected for an enterprise, how it is implemented, how to attain a successful implementation and the factors affecting this success. Next RFID history, system and components overview are explored and how integrating the RFID with ERP improves the ERP data accuracy are explained. Previous researches explored this approach is also mentioned.

Relevant research

This research is timely in that other funded research has explored this for warehouse management integration with Enterprise resource planning (NSF - 071E and Muriel, 2013), using RFID to track inventory management (NSF – 078E and Ryan, 2013, NSF – 1504 and GAO, 2013). Given all this research, we seek to evaluate the performance and economic impact of Auto ID on ERP systems. This research is necessary because the traditional ERP systems are insufficient to integrate different stakeholders such as customers, suppliers, and other business parties, especially when they are out of the company premises (Chiu, Mark, Kafeza and Wong, 2011).

There are various research efforts to improve the ERP performance but there is not enough research on using Auto ID with ERP. In this research impact of economic and performance impact of using Auto ID with ERP is evaluated, which is inadequately studied before. The remainder of this paper is organized as follows. First background and related work are provided. Then the research question, hypothesis and objective are discussed. Next, data collection techniques and statistical methodologies employed to analyze the data are explained. The results are discussed next. Finally, current limitations and future research are discussed.

Literature search and definitions

ERP History

In a manufacturing environment, the quantity of each finished product to be manufactured in each planning period is specified by the master production schedule (MPS). The required quantity of the finished product can be achieved only when the number of parts and raw materials required for each finished product is available. To achieve this goal many production planning and control techniques were used in MPS. Material resource planning (MRP) is one such tool which was adopted during 1970 due to the distinction between independent and dependent demand items (Chen, 2003). The MRP is used to plan and create purchase orders for the raw materials and components for the final product based on the required quantity of the final product in a planning period.

MRP evolved continuously in subsequent years to include various business functions. In early 1980 MRP developed into a company-wide system virtually planning and controlling all the organization resources from a material planning and control system. Since this concept is different from the basic concept of MRP, Wight (1984) gave a new term MRP II referring to manufacturing resources planning. In addition to integrating manufacturing functions like production, marketing and financing MRP II also integrated other functions like personnel, engineering and purchasing into the planning system. Since the MRP II is a company-wide system enabled it to have a simulator built in to simulate various business and production scenarios to the organization. These simulation helped organization to save huge cost and time by providing information about various scenarios in advance even before the real production began. The overview of the MRP II system is shown the Figure 2-1.

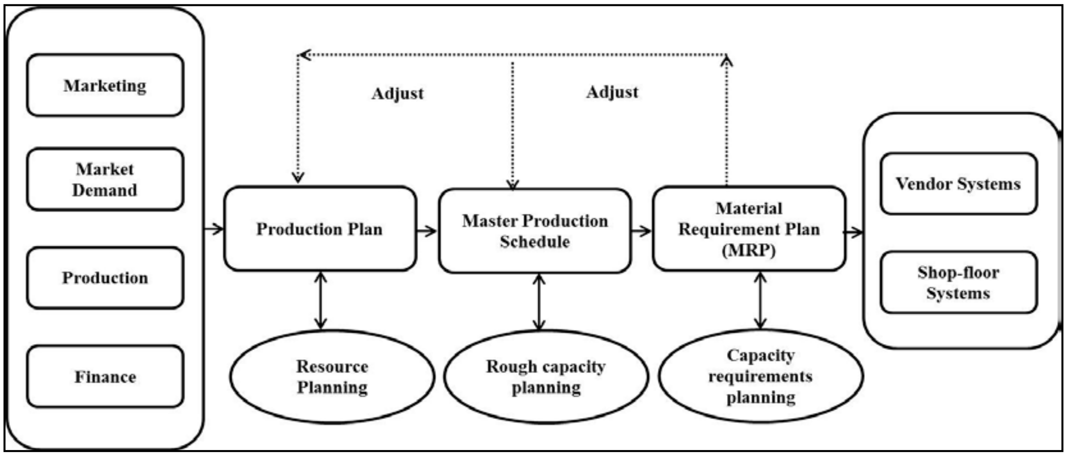

Figure 2-1 A general MRP II system flow

In the beginning of 1988 the ERP systems evolved from MRP II systems as Dow Chemical Company purchased the ERP module from Systems, applications, and products in data processing (SAP) AG of Germany (Schaaf, 1999). Gartner Group of Stamford, Connecticut, USA used the term “enterprise resource planning” to describe the system designed to plan and schedules all resources of an enterprise. Thus the main difference is that MRP II focuses on internal resources planning while the ERP system additionally also focus on planning and scheduling supplier resources as well. However the terms MRP II and ERP were used interchangeably during 1988 to 1994. The evolution of ERP systems is shown the Figure 2-2. The recognition of ERP systems as a stand-alone system was pioneered when the SAP AG in 1994 released the R/3. The R/3 release also shifted the technology platform to UNIX- based client-server architecture from mainframe. Many companies began to invest heavily in the SAP in the succeeding years.

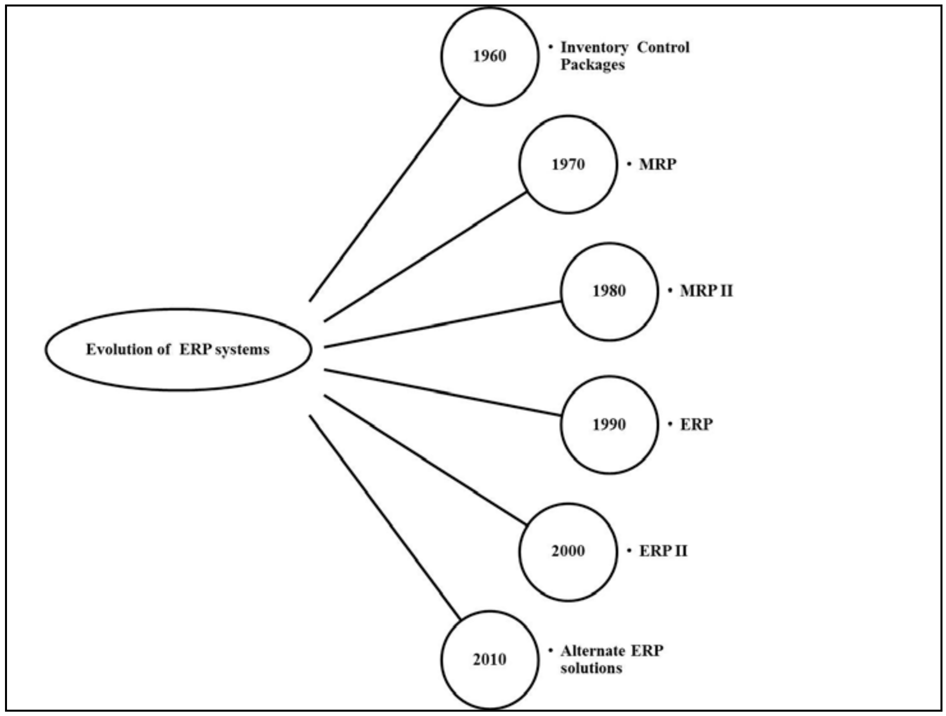

Figure 2-2 Evolution of ERP systems

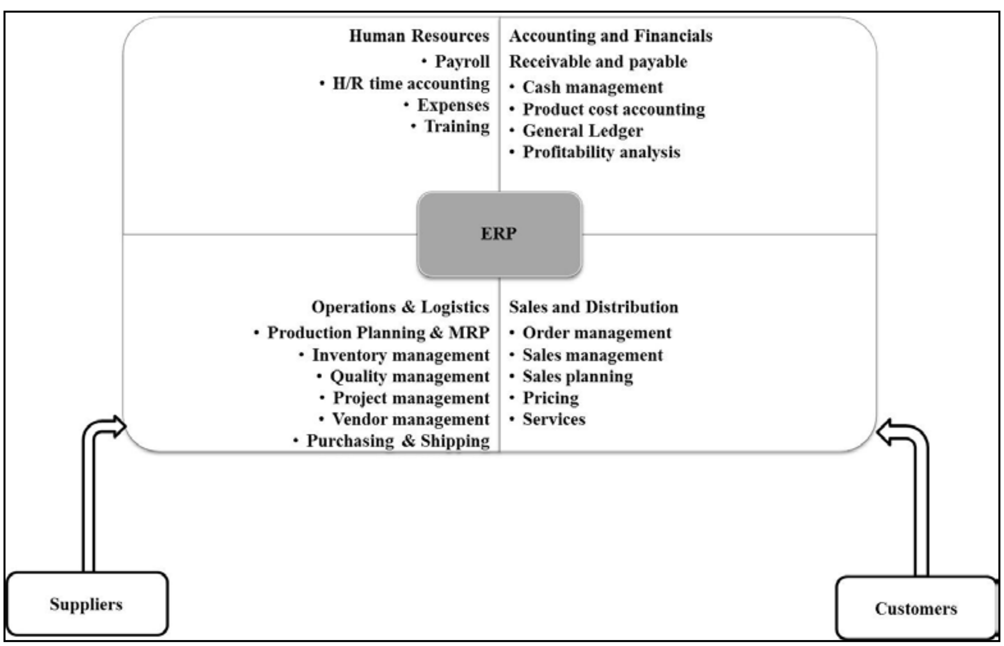

Figure 2-3 Overview of an ERP system

A suite of software modules comprise the ERP system. Each module is responsible for a separate business function or a group of separate business functions. An overview of an ERP system is given in the Figure 2-3.There are four main functional areas of operations in most of the companies namely marketing and sales (M/S), supply chain management (SCM), accounting and finance (A/F), and human resources (HR) (Ellen and Bret, 2006). The main functions of these areas are shown in Table 2-1. In addition to these functional areas there are also other modules like customer relation service, warehouse module, project management etc. These modules are adopted by the organizations depending on the requirements, affordability and various other criteria's.

Table 2-1 Main functions of functional areas

Marketing and Sales (M/S)	Supply Chain Management (SCM)
Develop products: Interact with the customer, market and gather the requirements for the features need to be added in the next iteration of the existing product or fix issues and develop a complete new product.	**Manufacturing:** Manufacture the product that is required.
Determine pricing: Determine the cost for the products based on the market and features in the products.	**Purchasing:** Purchase the raw materials and raw components required to manufacture the final products.
Promote products to customers: Create promotional materials, contact customers and organizations, conduct seminars to educate the potential customers about the products.	
Interact with customers: Customer survey,	

Table 2.1—*Continued*

keep track of returning customers. **Sales:** Keep track of the sales**,** credit for each repeat customers etc.	
Sales Forecasts: Analysis the historical sales data and provide forecast about the required sales in different markets in different seasons	
Accounting and Finance (A/F)	**Human Resources (HR)**
Sales: Track the sales of the any product or services sold by the organization. Analysis the information to provide profitability of the products. **Raw material purchase:** Track the purchase of raw materials, components or services needed to manufacture the final product. **Payroll:** Pay and track the employees compensation **Receipt:** Issues receipt of cash to the customers	Recruit, train, evaluate and compensate the employee.

Various business functions are comprised in these functional areas of operation. Examples of common business functions are shown the figure 4. Recently, organizations began to think in terms of business process rather than business functions (Ellen and Bret, 2006). Business process is collection of input activities to create an output desired by the customer. Examples of business processes are shown in the Table 2-2.

Table 2-2 Example of Business process (Source Book: Concepts in enterprise resource planning 2006)

Input	Functional area responsible for input	Process	Output
Request to purchase product	Marketing and sales	Sales Order	Order is generated
Financial help for purchase	Accounting and Finance	Arranging financing in-house	Customer finances through the company
Technical Support	Marketing and sales	24-hour help line available	Customer's technical query is resolved
Fulfillment of order	Supply chain Management	Shipping and Delivery	Customer receives the product

Customer's perspective can be understood by the organization by thinking in terms of business process. Customer interacts with different functional areas of business from placing an order and receiving the product. Organization must integrate these functional areas efficiently to provide quality service and satisfaction to the customer. The information about the product specification, inventories, prices, promotional information must also be shared accurately and efficiently between the integrated functional areas. The process view of business is illustrated in the Figure 2-4.

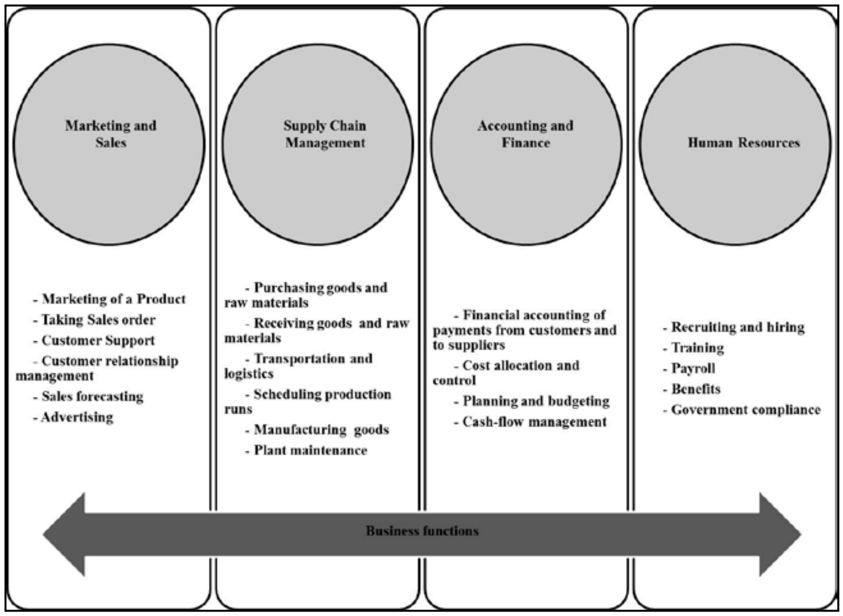

Figure 2-4 Examples of functional areas of operation and their business functions

(Source Book: Concepts in enterprise resource planning 2006)

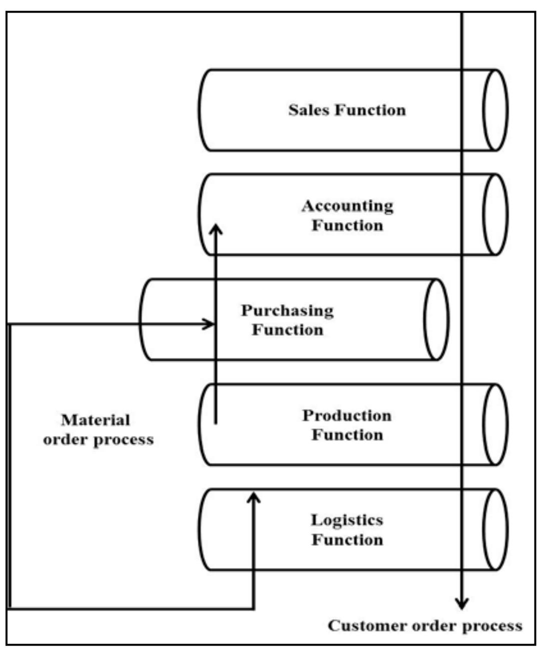

Figure 2-5 A process view of business (Source Book: Concepts in enterprise resource planning 2006)

ERP information system

ERP system software modules in addition to integrating the functional areas they also share and transfer the information efficiently (Hicks and Stecke, 1995). All the information is stored in a centralized database providing the same information across all modules and also avoids multiple entries.

Information System in Marketing and sales (M/S): The information in Marketing and sales starts from when a customer is placing an order. These orders are received by M/S via telephone, email, fax, web, etc. The information is shared with SCM for production planning purposes, with accounting for billing purposes and with HR for hiring sales force, legal requirements and other purposes. Analyzing the sales order data can provide valuable information about sales trends helping in business decision making. An example is that sales trend of a product can be used in evaluating marketing efforts and determine sales force strategies. One another example is that the information can be used in determining product price. A typical information exchange between Marketing and sales and other functional areas is illustrated in the Figure 2-6.

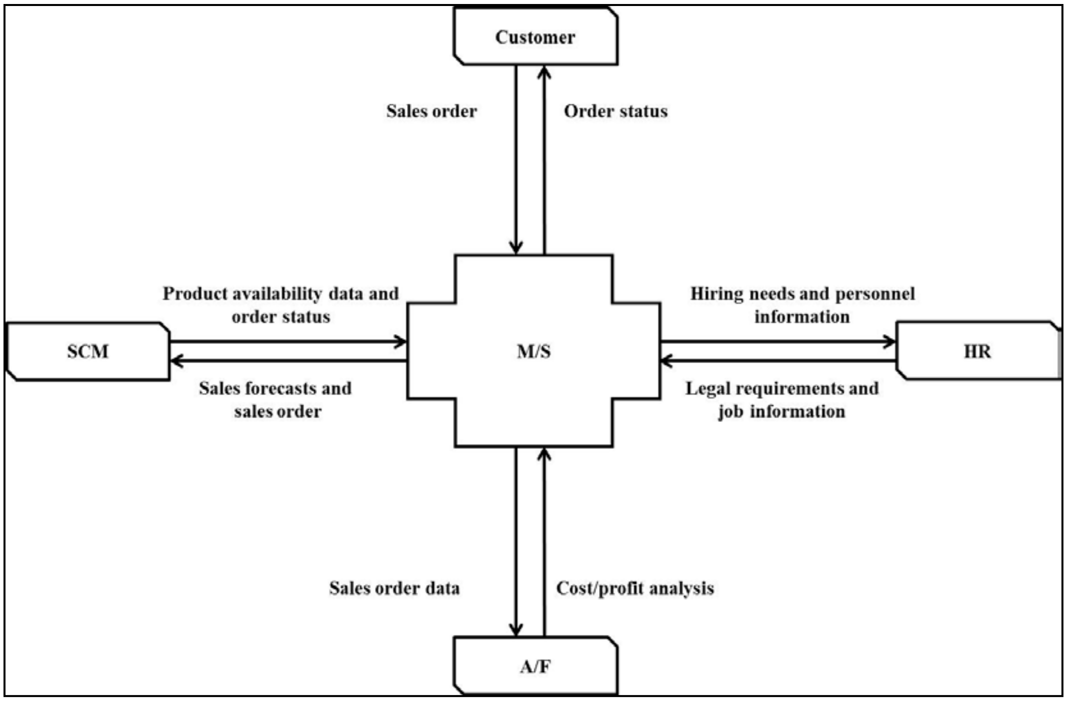

Figure 2-6 Information sharing between marketing, sales and other ERP modules

(Source: Monk, 2006)

Information System in Supply chain management (SCM): Supply chain management (SCM) shares and receives information between the other functional areas as shown in the figure 6. The organization develop production plan to meet the final product requirement which is obtained by the sales data from the marketing and sales (both projected and actual). The planning for internal resources like includes the plan for manufacturing capacities, allocating overtime, additional work force, etc. The plan for the external resources includes raw materials, service and any other additional components required. The inaccurate forecast may result in two scenarios; the first scenario is excess finished good products or raw materials. This results in loss of money associated with the storage of the excess inventory, in some cases the product might pass the expiry date, depreciation value, out of style, etc. The second scenario is less finished good product or raw materials called as stock out. In this scenario the company may lose potential business because customer decided to find different source, damage the relationship between the company and the customer, less customer satisfaction, etc.

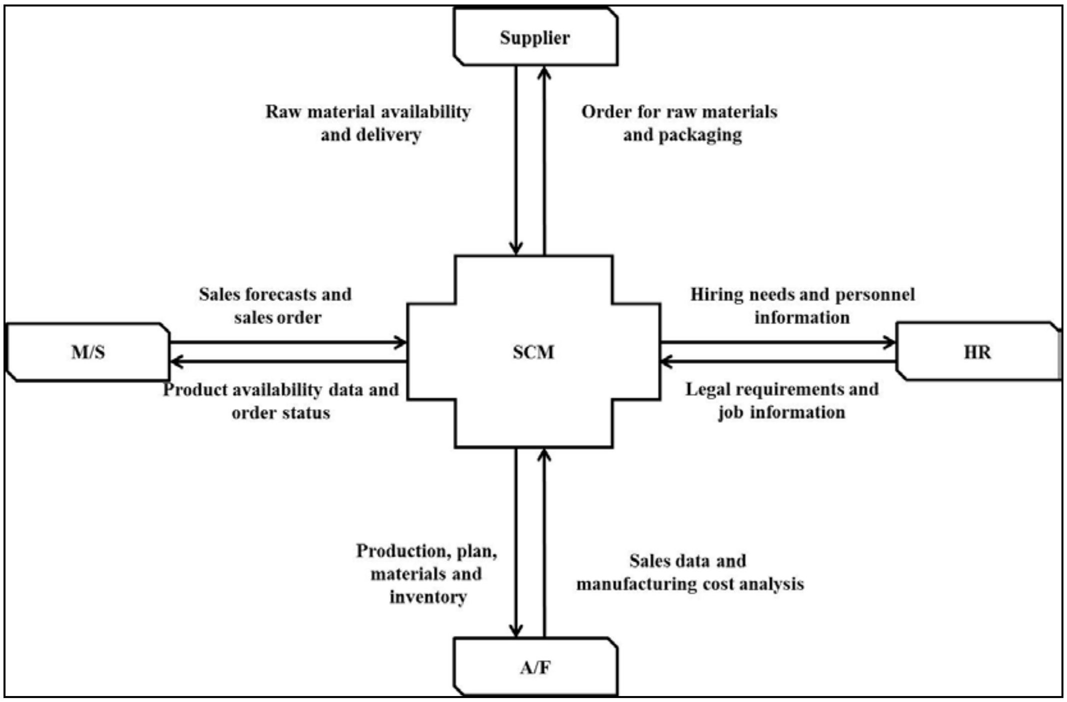

Figure 2-7 Information sharing between supply chain management and other ERP modules (Source: Monk, 2006)

Information System in Accounting and Finance (A/F): Accounting and finance shares and receives information between the other functional areas as shown in the figure 7. A/F keep track of the accounts receivable for each sales order and cash receipts issued to the customers at the time of payment, accounts payable for the each purchase order for the raw materials, components, and services. Based on all this data they prepare various reports about the profitability and organizations financial situation. A/F receives sales data from M/S, production and inventory data from SCM and payroll and benefit from HR. M/S access customer credit determined by A/F for credit approval when an order is placed. Invalid accounts would lead to the approval of credit for the high risk customers which in turn lead to the loss of money. In some other cases M/S personnel can deny the credit for a high value customer therefore damaging the relationship between customer and the company.

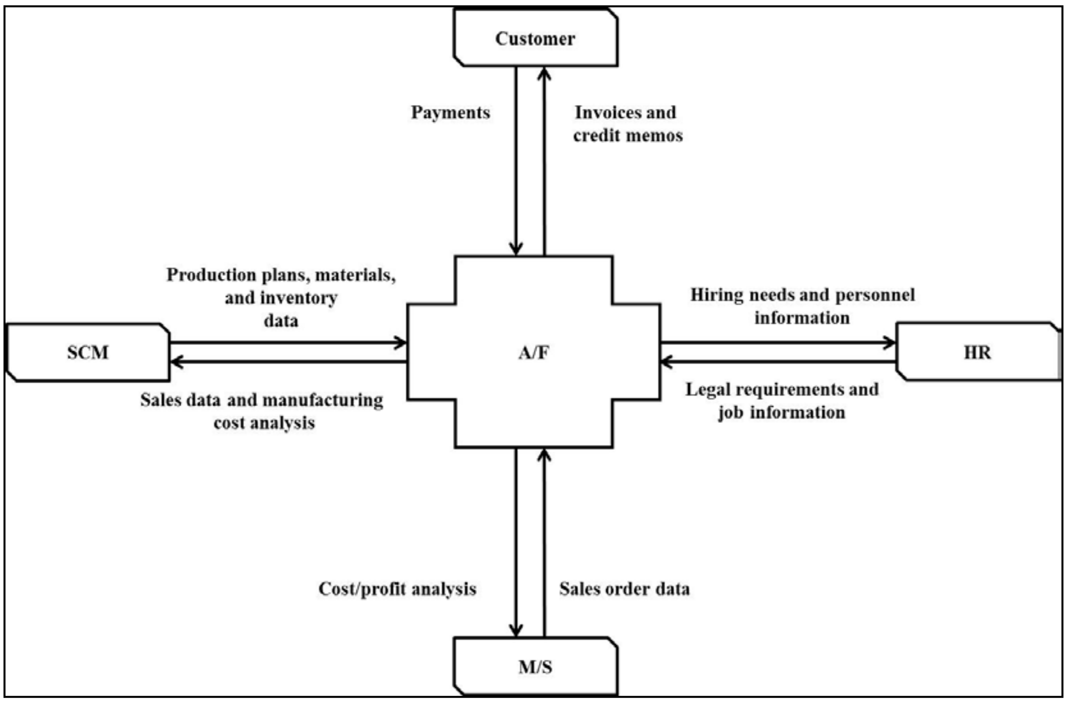

Figure 2-8 Information sharing between Accounting and Finance and other ERP modules (Source: Monk, 2006)

Information System in Human resources (HR): Human resources shares and receives information between the other functional areas as shown the figure 8. HR determines the work force requirements like the number of employee (to meet the production plan from SCM, and other functional areas), type of skills required, compensation, training, benefits etc. To determine all these requirements HR need accurate information from all the functional areas. The input and output of all the functional modules are shown in the Figure 2-9.

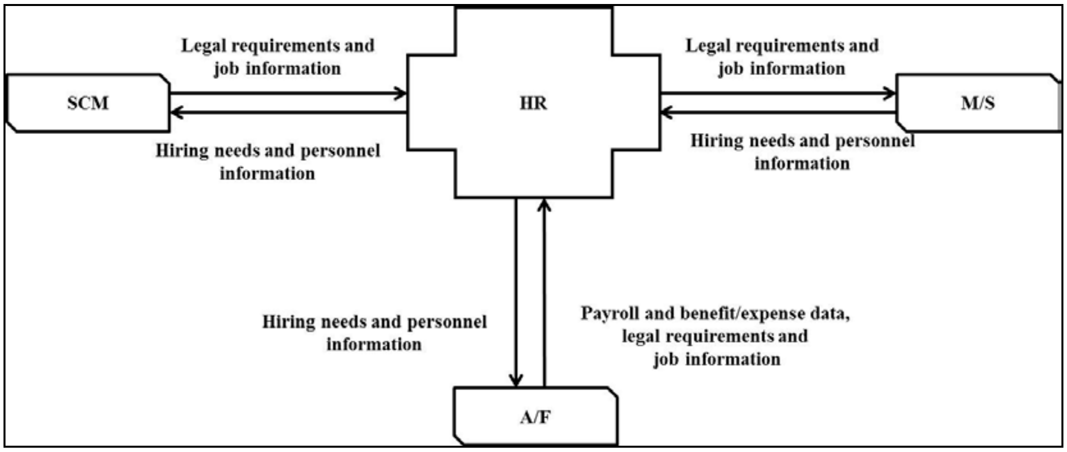

Figure 2-9 Information sharing between human resources and other ERP modules

(Source: Monk, 2006)

ERP implementation

The investment in software and hardware for ERP systems is well over $15 billion per year world over and additional $10 billion in professional services (Davenport, 2000). Because of the huge cost not all firms adopt all the modules of the ERP. The firms that can afford adopt entire ERP modules (Chalmers, 1999). Smaller firms adopt few components of each module (Ferman, 1999). Customers and suppliers can access the authorized information over a secured network through an external communication interface.

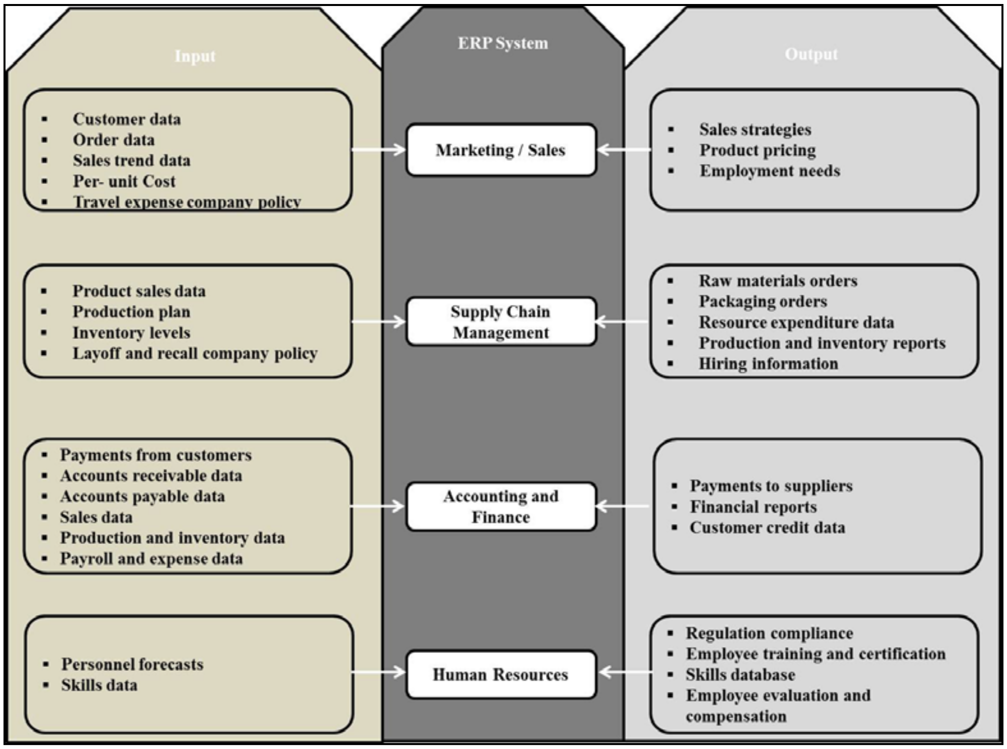

Figure 2-10 Input information and output from the ERP modules

ERP system selection

Davenport (1998) estimated that 50-75% of the US firms suffer failure to certain degree in implementing advanced manufacturing technology. An ERP system is a very complicated system imposing its own logic on organization strategy and culture. The majority of the implementation failure occurs when the ERP specifications and organizations requirements are mismatched. Therefore it is very important to perform a careful ERP system selection process. Most of the ERP systems are similar only with minor differences. Research indicates that 80-90% of the ERP systems are the same across various organizations only 10-20% varies due to the customization for the organization need (Langdoc, 1998, Ptak, 1999 and Langenwalter, 2000. Therefore the organization should identify the critical business needs and desired features to select the suitable ERP system. There are two methods available for the selection of the ERP system (Umble et al. 2003). One method is to focus on the information technology infrastructure to implement the overall business strategy. This method is usually employed by the companies of large size to have a centralized data and control. Companies of small and medium sizes employ method in which the ERP system is customized to match the specific functions and business process to increase operation efficiency, reduce costs and mange business easily (Krupp, 1998 and Ptak, 2000).

Based on the previous research (Langenwalter, 2000, Minahan, 1998 and Oden, Langenwalter and Lucier, 1993) the following are the recommended steps in selection process

1. **Create the vision:** Define the organization objectives, strategy and mission. Identify the critical and executive level users to examine, identify and redesign the business process. This ensures the required buy-in from all levels of the organization. In the case of multiple plants and sites, the team should include participants from all the plants and sites. Clearly define the reasons for ERP system implementation. Once the approval from the top management is obtained for the vision, broadcast it throughout the organization.

2. **Create a feature and function list:** A team of with experience in the both the ERP systems and company process should identify required the feature and functions of the software to support the company vision and functional areas. The business managers should map the existing business processes and map the processes to best suit the ERP application model.

3. **Create a software candidate list:** The ERP systems choices can be narrowed down by industry type and size. The systems that can closely meet the

organization requirements need to be selected. Communicating with the users of the ERP can also help to narrow down the list.

4. Narrow the field to four to six candidates: This is accomplished by analyzing each ERP system's strength and weakness and performing goodness of fit test.

5. Create the request for proposal (RFP): RFP contains the function and feature list describing the company needs in each functional areas or department and the ''outer wrapper,'' consisting of the terms and conditions, instructions to the supplier, supplier response forms, and so forth.

6. Review the proposal: The strength and weakness of the system is considered in the review. Request additional information when the provide information are unclear or not sufficient.

7. Select two or three finalists: It is a good practice to select more than one finalist at this stage.

8. Request for a demonstration from the finalist: In order understand and select the best ERP system all the critical business from all level of management should be present for the demonstrations.

9. Select the final ERP system: General tendencies of the companies are to select the ERP system based on prize. But it is recommended to consider other factors like closeness of fit to the company's business, supplier support, flexibility, ease of implementation and total value to the company versus the total implementation cost.

10. Justify the investment: The selected ERP system's tangible and intangible benefits must be compared with the costs. Some of the tangible benefits are reduced costs, improved material control, better visibility of future requirements, increased on-time deliveries, increased productivity, elimination of redundant and contradictory data bases and improved customer services. Some examples of intangible benefits are substantially reduced chaos and confusion, higher morale and improved communications.

11. Negotiate the contract: Negotiate the price, service and various legal issues with the ERP systems vendor.

12. Run a pre-implementation pilot: The pilot can be helpful in identifying the unexpected good and bad scenarios or issues. This can be used to adjust the final implementation.

13. Validate the justification: Final go or no go decision is made based on all the available and collected information. In some cases a different ERP system can be selected, renegotiate the existing contract or change the vendors.

ERP implementation steps

ERP implementation can be either simple or complex depending on the organization and level of customization. Implementation can be made smoother and easier by using a disciplined, structured approach. Various researchers (Langenwalter, 2000, Oden, Langenwalter, and Lucier, 1993, Ptak, 1999, and Ptak and Schragenheim, 2000) have compiled the steps as shown in the Table 2-3.

Table 2-3 ERP implementation steps

Steps	Description
Review the pre-implementation process to date	First step is to verify that all the critical implantation success factors are in place. Also verify that the system selection process is completed satisfactorily.
Install and test any new hardware	Before the real implementation, perform a test on the hardware to verify that it is capable of supporting the software, provides smoother operations and meet the required performance
Install the software and perform the computer room pilot	After installing the software a technical person should test the software to make sure the software is installed correctly.
Attend system training	The in house developers and users must attend the training to learn operation of the systems, features, transactions, etc.
Train on the conference room pilot	A mock up business environment from the order input to shipping the product to customer is created to perform pilot and understanding the system.
Establish security and necessary permission	All the user authorizations and permissions for the required data must be implemented during the room pilot.
Ensure that all data bridges are sufficiently robust and the data are sufficiently accurate	The data obtained from the legacy system should have high level accuracy in order to convince the users to trust the new system.
Document policies and	Create document policies like format, authorization for

Table 2.3—*Continued*

procedure	creating, editing, and deleting the document should be clearly established.
Bring the ERP system online for entire organization in a single or phased approach	In a single approach the whole company is brought into the new system. This may results in shutdown for one or two week. In the phased approach ERP system are brought on line one module, plant and product sequentially. The first implementation can be used to adjust or modify the next implementation.
Celebrate	This is an important step in the implementation process because it recognizes the milestone achievement and also demonstrates the project importance.
Improve continually	The initial implementation may not address all the scenarios, some scenarios may arise after the implementation. Therefore the system must be improved continuously.

ERP implementation success

Table 2-4 Five non-financial criteria's some researchers used them

Criteria	Researchers
Project management success like "time, budget and predetermined goals"	Kamhawi, 2007
DeLone and McLean's (1992, 2003) success models	Chien and Tsaur, 2007, Fan and Fang, 2006
Technology Acceptance Model (TAM) developed by Davis (1986)	Dezdar, and Ainin, 2011
User satisfaction	Wu and Wang, 2007
Combination of the above	Bradley, 2008, Chien et al., 2007, Nah et al., 2007, Ramayah et al., 2007, Sawah et al., 2008, Wang and Chen, 2006, Zhang et al., 2005

A successful implementation of the ERP system depends on the view points of the people evaluating the implementation. ERP implantation team identifies the implementation as success when the project is completed within budget and within the project timeline. The ERP system end users identify the success based on the smooth operations of the system. The management identifies the success when the predetermined goals are achieved and the business is improved (Somers and Nelson, 2004 and Zhang et al, 2005). The success of the ERP can be measured through two approaches using objective financial measures like profits figures and company cost (Dezdar, and Ainin, 2011) or self-reported subjective measures (Nah et al., 2007; Bradley, 2008;Muscatello and Chen, 2008; Sawah et al., 2008). The most popular approach is using financial measures but it is difficult to quantify the benefits and impacts (Wu and Wang, 2007) and isolate the ERP effect and other variables affecting the performance of organization (Chien and Tsaur, 2007).

Researches indicate that there are five main non-financial criteria’s that are used to measure the ERP success. The Table 2-4 shows the five non-financial criteria’s some researchers used them in their research.

Factors affecting the successful ERP implementation

There are many factors affect the success of ERP system implementation. Many researchers have identified various factors that are responsible for the failure or success of the ERP implementation (Zhang et al., 2005). For example, Somers and Nelson (2004) have identified 22 critical factors; Al-Mashari et al. (2003) identified 12 critical factors; Umble et al. (2003) categorized these factors into 10 categories; Dezdar and Sulaiman (2009) categorized the factor into 17 categories. The following are most important and prominent factors for a successful ERP implementation are clear understanding of strategic goals, commitment by top management, excellent project management, organization change management, a great implementation team, data accuracy, extensive education and training, focused performance measures, and multi-site issues

1. Clear understanding of strategic goals: Key people throughout the company who can provide a clear and strategic vision of the company should be identified. With the help of them, strategic goals are established to improve customer satisfaction, provide more responsibilities to employees and facilitate the long term suppliers. The goals must be defined clearly along with the expectations and deliverables. The organization must provide a clear reason the ERP system implementation and critical business needs (Krupp, 1998, Latamore, 1999, Schragenheim, 2000, Travis, 1999).

2. Commitment by top management: ERP implementation can be successful only when there is a strong leadership, top management commitment and participation (Davis and Wilder 1998, Laughlin, 1999, Oden, Langenwalter, and Lucier 1993, and Sherrard (1998). It is important to have an executive management planning committee with clear knowledge of ERP, supports the demands, payback and costs of the implementation (E. Umble, Haft, and M. Umble, 2003). In addition to the committee the project should be led by a champion who is highly respected and in an executive level position (Maxwell, 1999).

3. Excellent project management: An excellent project management includes a clear objective definition, good work and resource plan and accurate tracking of project (Davis and Wilder 1998, Laughlin, 1999, Oden, Langenwalter, and Lucier 1993, and Sherrard, 1998). An unclear objective definition may lead to “scope creep which increase the budget, impeding the project progress and creating complication in implementation (Davis and Wilder 1998, Laughlin, 1999, Minahan, 1998).The project plan schedules should be more aggressive but achievable (Laughlin, 1999).

4. Organization change management: The legacy structure and processes of an organization may not be compatible with the ERP systems structure, tools and types of information. Thus reengineering or developing of existing business process or new business process respectively may require to support the organization goals while implementing ERP systems (Minahan,1998). Organization control may need to be realigned to support the redesign of the business process. The realignment affects the most of the organizations functional areas and social systems. This in turn can result in significant modification in organizational structures, policies, process and employees (E. Umble, Haft, and M. Umble, 2003).

Many of the executives view the ERP implementation as a software implementation to address a technological challenge. But executives fail to understand that ERP can fundamentally change the business process of an organization. This is a major issue faced by the ERP implementation. The ERP implementation must be driven by the business and their requirements not to address a technological challenge (Chew, Barton and Bohn, 1991, Minahan, 1998). Inadequate preparation of employees in the organization for these changes may lead to denial, resistance and chaos. All these can be avoided by preparing the employees to embrace the change.

5. A great implementation team: The implementation team should be comprised of personnel's who are skilled, with great reputation, flexibility and past accomplishments. The team should be able to make critical decisions without interruption and in constant communication with the management team (Davis and Wilder 1998, Laughlin, 1999, Minahan, 1998, and Sherrard, 1998). The team is also responsible for creating project plan, determining the project schedule, assigning responsibilities, determining due dates and maintaining availability of the required resources

6. Data accuracy: Data accuracy is one of the important requirements since the data is shared throughout the integrated functional areas of ERP. When inaccurate information is entered in one functional area it also affects all other areas. Therefore the data entry personnel should be well educated about the importance of the data accuracy and also be trained to enter the accurate data (Stedman, 1999 and Stein 1999). Additional training to adopt the new system not to work around the system must be provided. Employees convinced by educational seminars to commit to the new system.

Further to support the commitment old systems must be removed. Employees tend to use the old system if they exist with the new system (Hutchins, 1998)

7. Extensive education and training: The most recognized critical factor for the success of ERP implementation is the education and training of the user. The training enables the users to the system more efficiently and in a standard operating procedure, without training user may invent separate procedure to operate the system (Schragenheim, 2000). In order for the training to succeed the users should be trained early in the implementation process most likely before the implementation started. The reports indicate that assigning 10-15% of the entire project budget for the training results in 80% success rate of the implementation (McCaskey, Okrent, 1999 and Volwer, 1999).

The users are expected to use the system efficiently after the training and education, but much of the learning comes from the hands on experience. Hence there should be a permanent contact for the users to help with the issues they face and to monitor the user. Regular interactions with the users are required to identify the issues with the system and encourage the users to share the knowledge learned by hand on experience and increase the system familiarity Travis, 1999.

8. Focused performance measures: Performance measures must be constructed accurately and efficiently to indicate system performance. It also should be designed to encourage the employee's behaviors by all individuals and functions. These measures include on-time deliveries, customer order-to-ship time, inventory turns, gross profit margin, vendor performance, inventory turns, etc. (E. Umble, Haft, and M. Umble, 2003). For the success of system implementation, the compensation should be tied with the system implementation. When compensation and implementation are not tied together the bonuses and raises will be paid even if the system is not implemented leading the failure of the implementation. The goals must be clearly defined and the realistic expectations from the vendor, implementation team, and management should be set. When the goals are not achieved the concerned team or individual should be provided with the assistance or replaced. The individual or team should be rewarded in a visible way when they meet the goals within the allocated time. The system should be measured and monitored continuously for the successful operations (Hutchins, 1998).

9. Multi-site issues: There are many concerns regarding the multi-site implementations and addressing these concerns can increase the success rate of the ERP implementation. The level of autonomy for each site mainly depends on the two factors namely: the degree of remote sites process, the products consistency and degree of need for a control and access the information, system setup and usage through a centralized system. Another factor affecting is that the degree of capabilities for the remote site to tune the system for their unique situations. The issue in this situation is that the difference between organization culture and the individual sites local culture. Both the organization culture and local optimization of the system have their own advantages. Optimizing the system for the organizational culture provides the ability to move products and people around the sites more effectively and consolidating the data across all the sites easily. Local optimizations results in effective and efficient operations and reduction in costs.

Another issue is whether to implement in all sites simultaneously or one site at time. Many companies prefer to implement the ERP system in all sites in order to recover from the investments as soon as possible. The recommended approach is to select a site do a pilot implementation. The results from the pilot implementation helps to make a decision to further proceed with entire project due to the success or cancel the project due to the failure. Furthermore the lessons learned from the pilot implementation can make further implementation more smooth and efficiently (E. Umble, Haft, and M. Umble, 2003).

ERP implementation success rate

ERP provide many benefits to different business depending on the ERP module adopted by the firm. One of the common and main benefits is ability to integrate business process (Brakely, 1999; Davenport, 1998, 2000). The customer satisfaction can also be greatly improved by adopting ERP. For example, NEC Technologies increased order processing and invoicing speed and quick customer-service response times by adopting the ERP systems (Michel, 1997). ERP is also effective in reducing inventory costs, improving efficiency and increasing profitability (Appleton, 1997 and Brakely, 1999). Manufacturing lead times can also be reduced by adopting ERP (Goodpasture, 1995). Other potential benefits of ERP includes reduction in inventory, decrease in working capital, information about customer requirements and needs are readily available and integrated system enabling view and manage the vendors and customers as an integrated whole.

Despite all the benefits of ERP systems not all the firms adopted has a successful implementation. The failure rates of ERP systems remain in 67%-90% range (Calogero, 2000 and Shore, 2005). 65% of the ERP implementation results in overrun in cost and scheduling with an average of 178% and 230% respectively and the rest of 35 % being cancelled (Amid, Moloagh, and Ravasan, 2012). According a survey the percentage of ERP implementation failure to provide the anticipated benefits is in 70% (Wang, et al., 2007). Many surveys indicate that even in best situations ERP systems integral fails produce the desired results (X. Liao, Y. Li, B. Lu, 2007). Many reports are available showing that ERP have failed in well-known organizations like Hershey, FoxMeyer, Nike, etc. Failure of ERP implementation will results in loss of investments leading to bankruptcy (Cotteleer, 2002). FoxMeyer Drug ($5 billion pharmaceutical company) claimed that the reason for their bankruptcy was that their ERP system was creating shipments with excess products for incorrect orders (Bicknell, 1998; Boudette, 1999).

Despite all these case studies there are no unique definition exists for ERP system implementation failures or success (Chen 2001). Various researchers have classified the reasons behind failure or success based on their own viewpoint, but in general it can be classified into two categories (Al-Turki, 2011). The failures in first category are defined as failure to achieve the implementation goals like integrating organizational information, better decision making, improving inter-organizational communications and decreasing operational bottlenecks (HSU, Chen, 2004, Spathis, and Ananiadis, 2005, Olhager and Selldin, 2003). Achieving these goals is defined success.

In the second category different levels of failures or successes are considered and definitions are provided for the each level. Heeks (2002) classified the success or failure into three categories as shown the Figure 2-11. Gargeya and Brady (2005) later classified the level of failure and success into completed two levels namely complete failure and partial failure. The cancellation project or omission from project before full implementation is considered to be complete failure. Increase in implementation costs from the initial estimation, extended project period, non-compliance of implemented processes with agreed ones, not achieving goals and not meeting the required return on investment (ROI) or user satisfaction are considered to be partial failure.

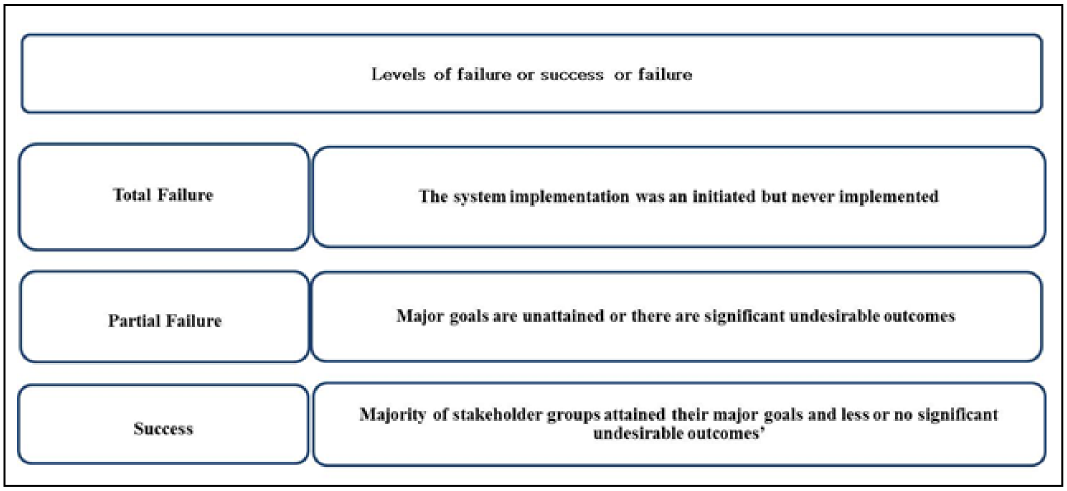

Figure 2-11 Level of failure or success by Heeks (2002)

RFID history

The existence of RFID technologies have been traced back to pre-World War II era (Jones and Chung, 2007). Radar discovered by Sir Robert Alexander Watson-Watt (1935), is used to track the aircraft by the allies and axis during the war. The major drawback was that the planes cannot be distinguished between friend and foe. Further research by Watson-Watt led to the development of IFF system to identify the friend or foe. This was considered as the first active RFID system (Jones and Chung, 2007). The aircraft is identified as friendly when the on board transmitter receives the signals from the radar station and signal back as the friendly.

In 1950s and 1960s the development in radar and RF communication systems provided a new application as a way to identify the objects remotely. Many stores began use this application of the RF system as an anti-theft system. This anti-theft system uses a single bit tag, either on or off. The bit is deactivated when the product price is paid and allowed to leave the store. The reader will read the products with tags that are not deactivated and alert the authorities therefore preventing from any unpaid products to leave the store.

Los Alamos National Laboratory in 1970s developed a system to track nuclear materials at the request of the United States Department of Energy (Jones and Chung, 2007). The concept the system is to have a transponder in each truck and readers at the gates of the facilities. This system was later commercialized by the former Los Alamos scientists in mid-1980s to develop automated toll payment systems. Today these systems are more commonly used all over the world.

Figure 2-12 Cattle tagging (Jones and Chung, 2007)

In 1970s Los Alamos investigated animal tracking efforts using microwave systems. The main focus was to track the medical history for the cows. This ensures that all the cows receive the correct dosage. In later 1980’s a passive RFID system with 125-kHz radio waves along with transponder in a glass enclosure injected under the cow ears was developed by Los Alamos. This type cattle tagging is illustrated in the Figure 2-12. Similar researches are also conducted in Europe using inductive technology (Jones and Chung, 2007).

Figure 2-13 Toll Road Authority tag (Jones and Chung, 2007)

Table 2-5 History of the RFID system (Source Schuster, Scharfeld and Kar, 2004)

1940s	1960s	1980s	1990s	Today
WWII Friend or Foes	EAS	Railcar Tagging	Security Access & Control	Low cost tags
		Animal Tracking	Highway Toll Passes	IT infrastructure
			Vehicle immobilization systems	

In 1980s in United State the application of RFID are focused on transportation, personnel, and animals. The focus in Europe was on animals, industrial and business applications. During 1980s various other countries namely Italy, Spain, Portugal, and Norway also started to employ RFID in their toll roads (Jones and Chung, 2007). In US Container Handling Cooperative Program and Association of American Railroads were supporting the used of RFID in the tolls. The first commercial application of the RFID in tolls began in Norway in 1987. The US followed next in using RFID in toll in Dallas North

Turnpike in 1989. New York and New Jersey port authority began the practice of using RFID for the buses travelling through the Lincoln Tunnel.

By 1990's electronic toll using RFID were widely in use throughout US. In Oklahoma 1991 an open highway electronic tolling system was opened which eliminated the need of cameras and barriers and the vehicles to travel through the toll at highway speed. In 1992 Harris County Toll Road Authority installed the combined system of traffic management and toll collection. A sample of toll road authority tag is shown in the Figure 2-13. The tag was used in Harris county toll. The brief history of the RFID system is illustrated in the Table 2-5.

RFID components overview

In a high level RFID system requires the following components, tags (one tag is embedded in each object that needs to be tracked), one or more antennas (installed in the locations where the tags need to be read when they pass through the location), and a reader (all the antennas are attached to the reader). The Figure 2-14 illustrates this basic setup of RFID system.

Figure 2-14 Basic RFID components (Jones and Chung, 2007)

Tag

Tags are embedded into each individual object, box, pallet or container of final product that needs to be tracked. The tags come in various shapes and sizes; the organization has to choose the tag that fits their need. A common tag is shown in the Figure 2-15. The tag's primary function is to transmit the information stored in the tag to the rest of RFID system. The tags can be classified with the respect to: Power sources, Frequencies, Writing capabilities, Tag components, Tag costs and Tag generations (Jones and Chung, 2007).

Figure 2-15 Common RFID tag (Jones and Chung, 2007).

Power sources:

All tags require power to operate and communicate with antenna. The tags are classified into three types based on its power source. They are active tags, passive tags and semi - passive tags. The type of tag chosen for the RFID system drives the selection of the other RFID components.

Passive Tags:

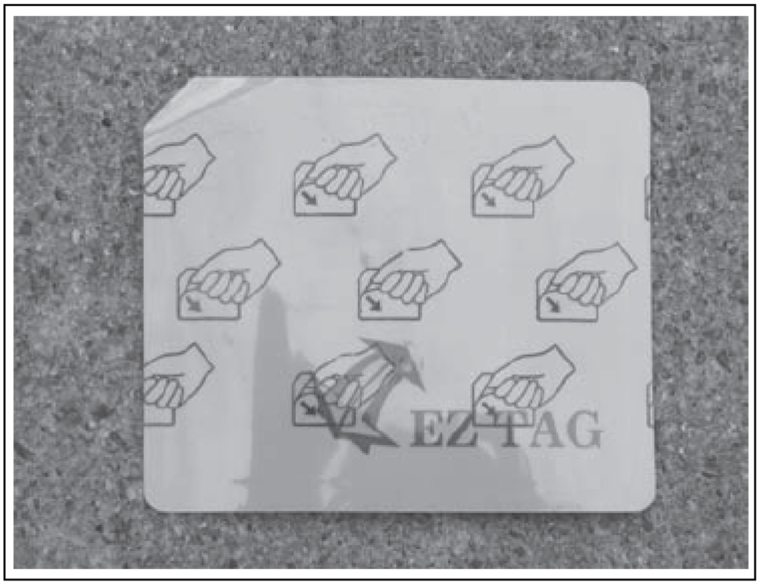

Figure 2-16 Example of passive tag (Jones and Chung, 2007)

In passive tags there is no individual power source. The tag is powered by the electromagnetic power obtained from the antenna. The elimination of the power source made the passive tags less expensive, with simple design and long shelf life. It also has a drawback in the form of limited range. Tag has to be in the close proximity of the antenna in order to obtain the required power for transmitting the signal. An example of passive tag is provided in the Figure 2-16.

Active tags:

Active tags have on board power source, a small battery with additional circuitry to provide a long read range. Integrating the battery with the tag requires a plastic enclosure for both safety and design purposes. These additional requirements of the active tags increase their cost considerably when compared to passive tags. One other disadvantage is that the huge sizes of the tag prevent them from adhering to the product using an adhesive layer. They usually preferred to track pallets or containers. Active tags will be in a sleep mode until it enters the RFID system interrogation zone. This will reduce the battery usage and prolong the battery life. Advanced active tags can be integrated with other systems like satellite communication system or global positioning system (GPS) for various purposes.

Figure 2-17 Example of Active tag (Jones and Chung, 2007)

Semi-active tag:

Semi-active tags are designed to have features of both passive and active tags. The on board power sources is used to power the tags circuitry but for communication purposes it uses electromagnetic field power from the antenna. Therefore these type tags will have long read range compared to passive tag but smaller size and less cost compared to active tags. Additionally the power source is also used to power sensors to monitor environmental conditions like humidity and temperature.

Sound Acoustic Wave (SAW):

Active and passive tags use semiconductor physics concept to generate the power required for the operation. In SAW tags receives the wave from the reader and converts them on the surface of the chip into nanoscale surface acoustic waves. These waves are then encoded into a unique pulse train, converted back into waves and transmitted back to the reader. Since the SAW tags do not require DC power to operate they provide long read range. They also measure the temperature by calculating the distance between the reader and the tag. The general operating temperature range is -100°C to 200°C.

SAW RFID Tags:

Surface acoustic wave (SAW) tags are passive in nature but operate on a different theory compared to typical RFID tags. The common tags generate power for its operation based on semiconductor physics. In SAW tags the incoming waves are converted on the chip surface into acoustic waves. The acoustic waves are then encoded into unique pulse train and transmitted back to the reader antenna. This also allows the measuring of temperature by calculating the difference between tag and the reader distances. The operating temperature range of the SAW tags is between -100°C and 200°C.

Tag Frequencies:

Different frequency ranges on which the tags normally operate are provided in the Table 2-6. For specialization operations active tags may use microwave frequencies. The selection of the operating frequencies depends on the materials that is used in the product or the packaging materials tracked by the tags. This is because the strength of the RF frequencies can be reduced either by reflecting or absorbing depending on the metals or liquid respectively present in the system. This result decreases in operating range and power required to activate the tag.

Table 2-6 Tag operating frequency ranges

Frequency	High Frequency (HF)	Ultra High Frequency (UHF)
Range	13.56 MHz	902 – 928 MHz Or 2400 – 2500 MHz

Writing capabilities:

The tag stores the information in any one of the following format: ASCII, hex characters or decimal characters. The tags are classified into three types based on the writing capabilities of these data.

Read Only: The data stored in these types of tags can be only be read but cannot be altered. The data is stored in the tag by the manufacture and the data is either provided by the purchaser or by the manufacturer. An example is E-Z pass tags, in which the tag data is usually a number and these numbers are associated to a vehicle.

Write once, Read Many (WORM): The purchasers are provided with opportunity to enter the data into the tag in this type of tag. But once the data is entered they cannot be altered or erased which means if incorrect information is entered the tag becomes invalid.

Read/Write: The tag data can be programmed and reprogrammed as many times as purchaser requires in this type of tag. This allows the purchaser correct the tag data if incorrect information is entered.

Tag Components

The minimum components of any type of tags are integrated circuitry chip, an antenna, and a substrate or tag housing. The figure illustrates these basic components.

Additional components like battery and specialized integrated components are added to monitor temperature, humidity, vibration or various other environment conditions.

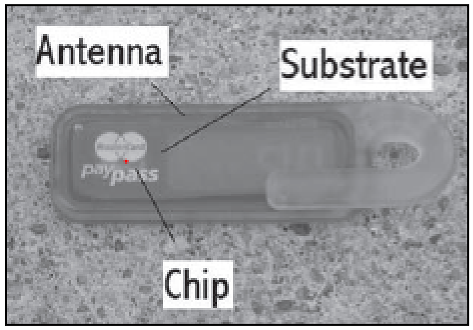

Figure 2-18 Tag components (Jones and Chung, 2007)

Tag Integrated Circuitry: It contains the data, logic to decode the reader RF signal and code the data to transmit back to the reader. Passive tags are capable of transmitting 96 bits of data where-as the active tags are limited by the integrated components capability.

Tag Antennas: Tag antenna receives the RF signals from the reader antenna and passes it to the integrated circuitry. The integrated circuitry response is then transmitted back to the reader antenna by the tag antenna. The tag frequency determines the configuration of the antenna. Linear shaped antennas area used in UHF tags and coils shape for HF tags. The greater read range of tag is directly proportional to the tag sizes. The antenna size determines the capability of absorbing and transmitting the RF signals. Some common antenna designs are illustrated in the Figure 2-19.

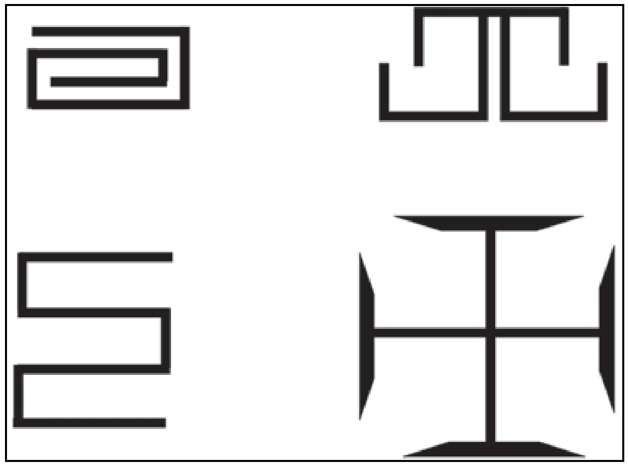

Figure 2-19 Common Tag antenna designs (Jones and Chung, 2007)

Tag Substrate or Tag Housing: Tag housing serves a dual purpose: front surface provides the housing to the tag components and the back surface provides adhesive surface to attach the tag to the item. Thin plastics are one of the common materials used for the tag housing.

Antenna

Figure 2-20 A common antenna (Jones and Chung, 2007)

An antenna in the RFID system is used for receiving and transmitting the RF signals from and to the tag by the reader. A single antenna can be used when the angle of the tag and reader is always constant like manufacturing applications. In situations where the angle varies all the time multiple antenna are required. The tag read accuracy increases with the increased number of antennas. Generally Antenna is enclosed by a rectangular shaped plastic housing to provide protection against the damage, environmental hazards, etc. The housing also serves as a means to attach the antenna to the position. A common antenna is illustrated in the Figure 2-20.

Reader and scanners

Reader: The reader receives the data stored in the tag through antenna and transmits back to the middleware software installed in a host computer. General location of the readers in manufacturing environment is on top of the conveyor or as a portal in the loading docks. An example of the reader is illustrated in the Figure 2-21.

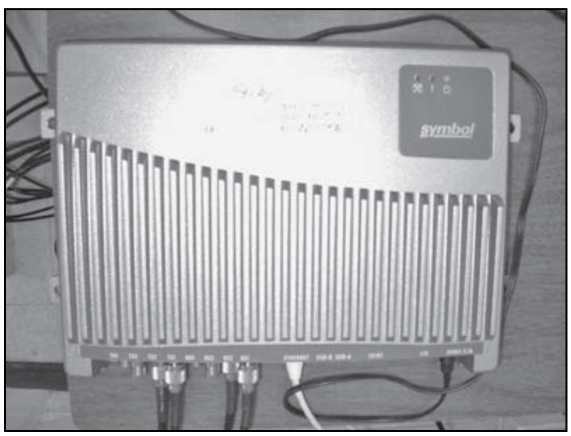

Figure 2-21 Common RFID reader (Jones and Chung, 2007)

Figure 2-22 commonly used scanner (Jones and Chung, 2007)

Scanner: In situation where the material has to be scanned away from the mounted reader like scanning the individual item during picking and packing a scanner can be used. The user can carry the scanner to anywhere in the warehouse to verify the RFID data of the interested items. In some cases they are also mounted on the mobile equipment such as a forklift. The scanner verifies the RFID data wirelessly communicating with the middleware installed in a host computer. A commonly used scanner is illustrated in the Figure 2-22.

How RFID can improve accuracy for ERP systems

My hypothesis is that the RFID can improve the ERP data accuracy and related research is provided below.

Previous Auto ID Implementation on ERP systems

The invention of the barcode in 1954 marked the beginning of the Auto ID (Schuster, Scharfeld and Kar, 2004). It received it recognition in 1974 and the industries start to adopt the technology and develop the st.andards (Haberman, 2001). Many firms benefited by barcode in automatic data capture for raw materials, work in process (WIP) and finished goods. It also improved data accuracy by decreasing the human error and reduced amount of labor required for many business transactions. Later advance in Auto-ID enabled to track the inventories wirelessly providing the infrastructure capable of new levels of interconnectivity (Dinning and Schuster 2003). Schuster, Scharfeld and Kar (2004) indicated that this Auto-ID technologies will have an important impact on ERP system. American Production and Inventory Control Society (APICS) conducted a survey in 2004 for determining the main reason for implementing the Auto-ID technologies. The results are given in the Table 2-7.

Table 2-7 APICS survey (Source Schuster, Scharfeld and Kar, 2004)

What is your main goal in implementing an Auto-ID solution	
Improve inventory accuracy	55%
Trading partner requirement	13%
Increase inventory turns	10%
Reduce out-of-stock situation	9%
Enhance supplier relationship	9%
Improve fill rate	4%
Sample Size	658 respondents
Survey conducted online	April 2004

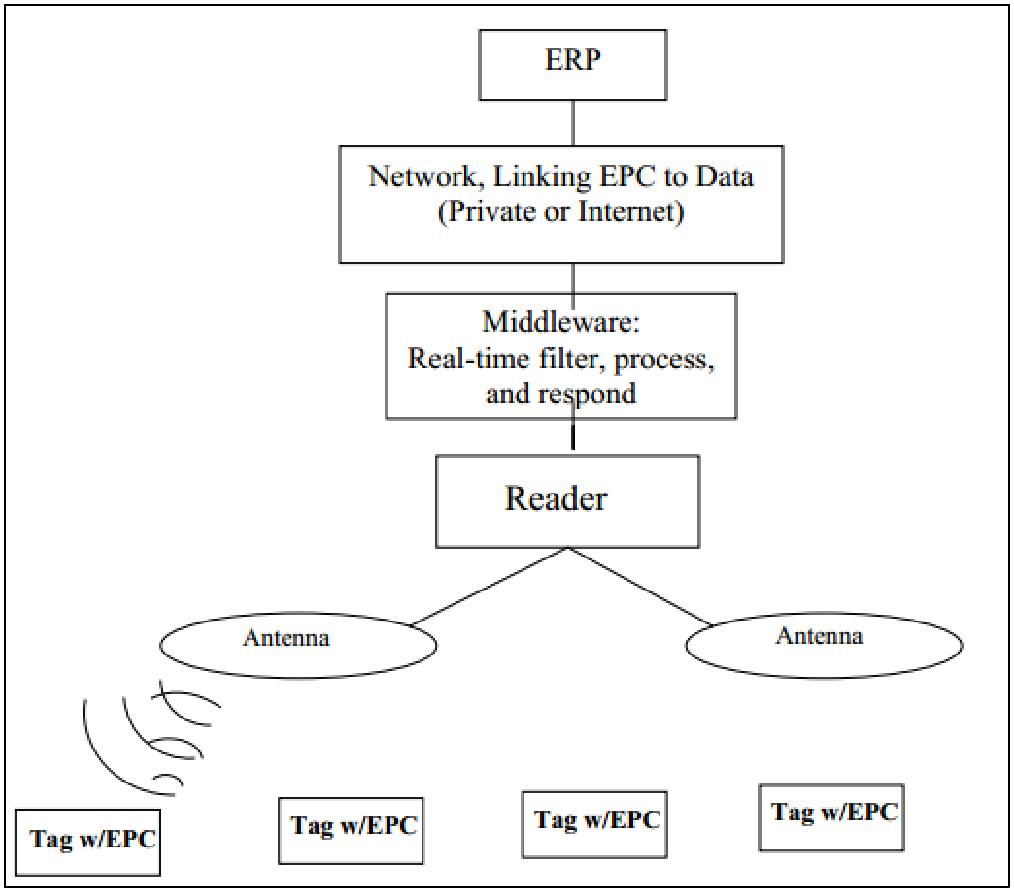

Figure 2-23 Simplified Auto-ID system (Source Schuster, Scharfeld and Kar, 2004)

Data is collected by the proximity optical scanning in barcode method and update the data in ERP in batch mode. This has an drawback of configuring fully automatic data collection points and true high-speed which in turn affects the timeliness of inputs into the ERP system. Auto-ID not only does not have these drawbacks but also enables real-time streaming data, processing , filtering, and response (Schuster and Koh, 2004). A simple Auto ID system is illustrated in the figure 10. The data capture techniques used in material requirements planning (MRP), manufacturing resource planning (MRPII), the current ERP systems, and ERP with Auto-ID systems and their advantages and disadvantages are shown in the Figure 2-23.

In a supply chain environment billions of items are need to be tracked and maintained. This requires a comprehensive information technology infract structure to handle the huge volume of data generated by these items. Auto-ID provides the required infrastructure by utilizing radio frequency identification (RFID).

Table 2-8 Comparison of Data capture technologies (Source Schuster, Scharfeld and Kar, 2004)

	MRP (1960s)	MRPII (1980s)	ERP (1990s)	ERP + Auto-ID(2004)
Data Capture	Manual	Barcode + Manual	Barcode + Manual	RFID
Data Type	SKU code	SKU code	SKU code or item serial number	Mass serialization – a serial number for each item or component
Pro/Con	Improved planning capabilities – limited data available, accuracy problems	Speed collection of data and improved accuracy, Batch mode – delays in updates	Standardized collection of data, some lost control - limited serial number control, lack of middleware, mature technology	Granular data at serial number level, middleware to manage serial numbers, common standards, real time – initial stages of development, technology to read tags must be refined

This research seeks to evaluate the impact of the RFID on the ERP system data accuracy. This was done by answering the research questions in the chapter3.

Chapter 3

Research Questions

Overview

There are two research questions in this section namely: 1. what is the observed perspective of impact of auto id on ERP system? 2. Does the Auto ID technology have an economic impact on the ERP system data accuracy? To answer the first research question one three specific aims were set: 1. Questionnaire development, 2. Perceived impact of the RFID on the ERP data accuracy and 3. Identify better predictor model. The second research question was answered by attaining the following the specific aim: Evaluation of the economic impacts of Auto ID on ERP data accuracy

Research questions

This research evaluates the impact of the Auto ID technologies on the ERP system data accuracy and reliability by two different approaches. In the first approach the impact on accuracy and reliability is evaluated by comparing the traditional manual data entry methods and Auto ID technologies accuracy and reliability. In the second approach, mathematical model representing the perceived impact of data from different warehouse areas on the ERP systems data accuracy is built by developing a survey and collecting the answers from various SAP business champions. Regression analysis will be used to analyze the data collected

Research question 1: What is the observed perspective of impact of auto id on ERP system?

A survey was developed to measure the impact of RFID on the warehouse data and how they affect the overall ERP data accuracy. This survey was answered by ERP users from various levels within the organizations. A regression model was developed to identify the effect of these warehouse data with RFID implemented on the ERP data accuracy. A better model was also developed that can predict the ERP data accuracy behavior.

To answer this research questions three specific aims was attained

Specific aim 1: Questionnaire development

A survey was developed to measure the impact of Auto ID on overall ERP and its functional areas. This survey was be answered by Auto ID and ERP users from various levels within the organizations.

Specific aim 2: Evaluate Perceived impact of the RFID on the ERP data accuracy

The data collected from the questionnaire in the specific aim 1, was analyzed using regression to provide an impact model. Regression analysis on the data to develop a mathematical model to represent the effects of warehouse areas (finished good product inventory, raw materials inventory, package materials inventory, storage location, and delivery planning) on ERP data accuracy. The model obtained is further analyzed to identify a model with better predictor variable.

Research question 2: Does the Auto ID technology have an economic impact on the ERP system data accuracy?

Net Present Value (NPV) analysis was calculated for the different levels of ERP data accuracy levels. NPV identified the economic benefits depending on the required data accuracy levels.

To answer this research questions one specific aims was attained

Specific aim 3: Evaluation of the economic impacts of Auto ID on ERP data accuracy

NPV is calculated for the different levels of ERP data accuracy.

Chapter 4

Research Hypothesis

Overview

In this section six hypothesis are explained that helps to answer the research questions. The hypothesis one to five relates to the specific aim 1 and the hypothesis six relates to the specific aim 2.

Specific aim 1: Questionnaire development

Hypothesis 1:

Null Hypothesis

H_0: The independent variable x_1 has no impact of the dependent variable

$$X_1 = 0$$

Alternate Hypothesis

H_a: The independent variable x_1 has impact of the dependent variable

$$X_1 \neq 0$$

Two sided test statistics: $t < 0.05$ reject null hypothesis at α level 0.05

The null hypothesis is that the independent variable logistic handling has no effect on the dependent variables (ERP data accuracy) The alternate hypothesis is that the independent variable logistic handling affects the dependent variable ERP data accuracy. Rejecting the null hypothesis means that the independent variables logistic handling contributes to the model indicating that the ERP data accuracy is indeed affected the logistic handling.

Hypothesis 2:

Null Hypothesis

H_0: The independent variable x_2 has no impact of the dependent variable

$$X_2 = 0$$

Alternate Hypothesis

H_a: The independent variable x_2 has impact of the dependent variable

$$X_2 \neq 0$$

Two sided test statistics: t < 0.05 reject null hypothesis at α level 0.05

The null hypothesis is that the independent variable storage location has no effect on the dependent variables (ERP data accuracy). The alternate hypothesis is that the independent variable storage location affects the dependent variable ERP data accuracy. The null hypothesis is rejected at α level 0.05. Rejecting the null hypothesis means that the independent variables storage location contributes to the model indicating that the ERP data accuracy is indeed affected the storage location.

Hypothesis 3:

Null Hypothesis

H_0: The independent variable x_3 has no impact of the dependent variable

$$X_3 = 0$$

Alternate Hypothesis

H_a: The independent variable x_3 has impact of the dependent variable

$$X_3 \neq 0$$

Two sided test statistics: t < 0.05 reject null hypothesis at α level 0.05

The null hypothesis is that the independent variable raw material inventory has no effect on the dependent variables (ERP data accuracy). The alternate hypothesis is that the independent variable raw material inventory affects the dependent variable ERP data accuracy. The null hypothesis is rejected at α level 0.05. Rejecting the null hypothesis means that the independent variables raw material inventory contributes to the model indicating that the ERP data accuracy is indeed affected the raw material inventory.

Hypothesis 4:

Null Hypothesis

H_0: The independent variable x_4 has no impact of the dependent variable

$$X_4 = 0$$

Alternate Hypothesis

H_a: The independent variable x_4 has impact of the dependent variable

$$X_4 \neq 0$$

Two sided test statistics: $t < 0.05$ reject null hypothesis at α level 0.05

The null hypothesis is that the independent variable finished goods inventory has no effect on the dependent variables (ERP data accuracy). The alternate hypothesis is that the independent variable finished goods inventory affects the dependent variable ERP data accuracy. The null hypothesis is rejected at α level 0.05. Rejecting the null hypothesis means that the independent variables raw material inventory contributes to the model indicating that the ERP data accuracy is indeed affected the finished goods inventory.

Hypothesis 5:

Null Hypothesis

H_0: The independent variable x_5 has no impact of the dependent variable

$$X_5 = 0$$

Alternate Hypothesis

H_a: The independent variable x_5 has impact of the dependent variable

$$X_5 \neq 0$$

Two sided test statistics: $t < 0.05$ reject null hypothesis at α level 0.05

The null hypothesis is that the independent variable packaging material inventory has no effect on the dependent variables (ERP data accuracy). The alternate hypothesis is that the independent variable packaging material inventory affects the dependent variable ERP data accuracy. The null hypothesis is rejected at α level 0.05. Rejecting the null hypothesis means that the independent variables raw material inventory contributes to the model indicating that the ERP data accuracy is indeed affected the packaging material inventory.

Specific aim 2: Evaluate Perceived impact of the RFID on the ERP data accuracy

Hypothesis 6:

Null Hypothesis

H_0: All the dependent variables ($x_{1,}$ x_2, x_3, x_4, x_5) has the same effect on the independent variable

$$X_1 = X_2 = X3 = X4 = X_5$$

Alternate Hypothesis

H_a: All the dependent variables ($x_{1,}$ x_2, x_3, x_4, x_5) does not have the same effect on the independent variable

$$X_1 \neq X_2 \neq X_3 \neq X_4 \neq X_5$$

Two sided test statistics: t < 0.05 reject null hypothesis at α level 0.05

The null hypothesis is that all the independent variable has same effect on the dependent variables (ERP data accuracy). The alternate hypothesis is that each independent variable has different effect on the dependent variable ERP data accuracy. The null hypothesis is rejected at α level 0.05. Rejecting the null hypothesis means that the independent variables contributes in a different capacity to the model indicating that the ERP data accuracy is indeed affected differently by the independent variable.

Chapter 5

Methodology

Overview

This section includes the data collection a technique, software's used and the approach to analyze the data.

Data Collection

The data are collected from volunteer participants who are ERP specialist and users, warehouse specialist and users in an oil company (Carmienke, et al., 2013)

Software used

The data was analyzed by the statistical software SAS. The ERP package SAP was selected as the test bed because of their market share.

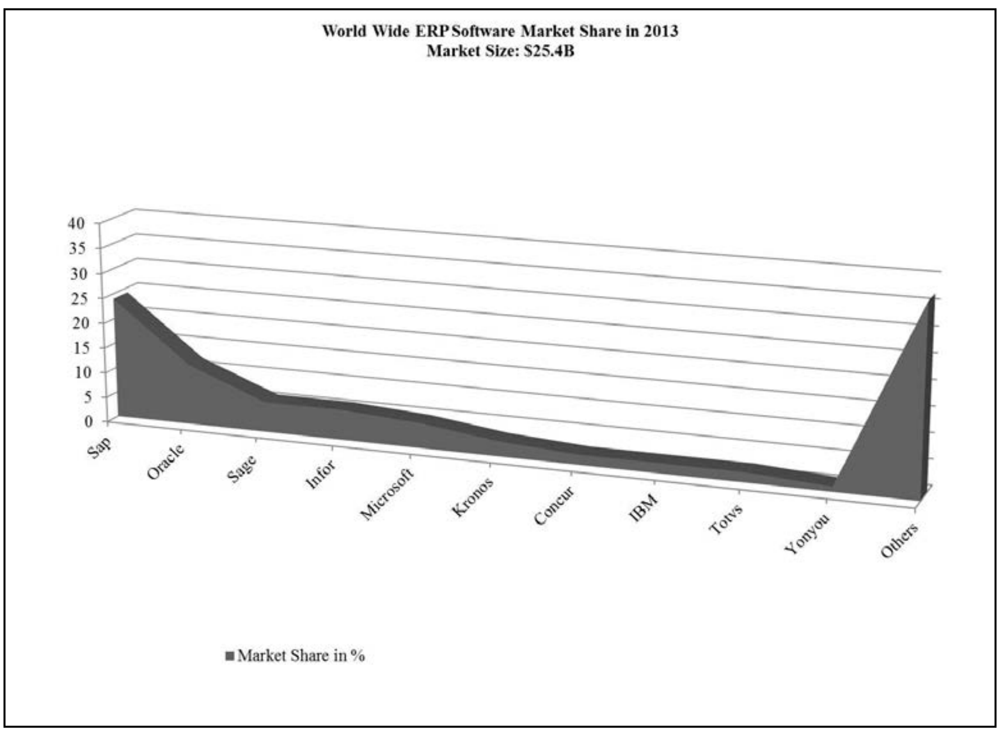

Figure 5-1 2013 SAP market shares (Source: Forbes, 2014)

Approach

Overview

There are three phases in the approach section. Phase one contains three steps. Phase two has two steps. The first step has nine sub steps. The second step has three sub steps.

Phase 1

Overview

Phase one has 3 steps. Step one is the questionnaire development, step two is the administering the questionnaire and the last step is the evaluation of the data obtained from administering the questionnaire.

Specific Aim 1: Questionnaire development

Step 1: Questionnaire development

Based interviews conducted with more than 100 ERP and warehouse users over a time period of 6 months various variables that affects the ERP data accuracy are identified. They are grouped into five main variables as shown in the Table 5-1.

Table 5-1 General definitions of variables

Variables	Variables Description	Variables definition

To measure the dependent and independent variable a questionnaire is developed with four questions for each variable based on Likert scale as shown in the Table 5-2. Likert scale is commonly used in many of the survey questionnaires (Barua, 2013). Analyzing the Likert scale capture can identify a pattern of the independent variables being considered (Carifio, 2007; Jamieson, 2004). These analyses can also help to identify which variable has more impact on the dependent variable (Jamieson, 2004).

Table 5-2 Likert Scale

Scale	Description
1	Strong Disagree
2	Disagree
3	Neither agree nor disagree
4	Agree
5	Strongly agree.

Step 2: Questionnaire dissemination

The survey was answered the volunteers who are ERP specialist and users, warehouse specialist and users in an oil company.

Step 3: Questionnaire evaluation

The incomplete or invalid surveys are evaluated and did not included in the results

Phase 2

Overview

In the phase 2 there are two steps. In the first step a regression model is developed to identify the significance of the independent variables on dependent variables. Then the residual analysis, normality test, modified levene test for constant variance, test for regression significance, test for multicollinearity, test to identify x-outliers and y- outliers and their influences are performed on the model. The model is further analyzed using the following methods, backward deletion, subset and stepwise to identify model with predictor independent variable

Specific Aim 2: Perceived impact of the RFID on the ERP data accuracy

Step 4: Data Evaluation

Sub step 4.1: Multiple linear regression models

Multiple regression analysis (Aiken, West, & Pitts, 2003; Hunter, Nachtsheim, Li, & William, 2013)was performed on the data collected on the variables in the Table 5-3 to determine the significance of the independent variables on dependent variable.

Table 5-3 General description of the variables split the table

S.No	Variables	Variables Description	Dependent Variable	Independent Variables
1				x_1
2				x_2
3				x_3
4				x4
5				x5

Multiple regression analysis is a system for investigating the relationship between collection of independent variables and a single dependent variable (Aiken, West, & Pitts, 2003; Hunter, Nachtsheim, Li, & William, 2013). The variables which can be used to predict the dependent variables are called as the independent variables. The variables which can be predicted using the independent variables are called as the dependent variables.

A matrix scatter plot is plotted between the dependent variable and independent variables and among the independent variables to identify the correlation effects. Correlation indicates that there is a linear relation between two independent variables. If the correlation values are less than 0.7 then there is no correlation problem (Hunter, Nachtsheim, Li, & William, 2013). The scatter plot also helps to identify the potential complications like x and y outliers, multicollinearity. Multicollinearity means there is a relation between the multiple independent variables (Alin, 2010). If the multicollinearity exists it is necessary to add the interaction terms to the module.

An initial model is then developed for the dependent and independent variable. The initial model will provide the pattern of the independent variable effect on the dependent variable. An example of the initial model is provided in the Equation 6-1

$$\overline{\mathrm{y}} = \beta_0 + \beta_0 \mathrm{x}_1 - \beta_2 \mathrm{x}_2 + \beta_3 \mathrm{x}_3 - \beta_4 \mathrm{x}_4 + \beta_5 \mathrm{x}_5$$

Equation 5-1 Example of the fitted model

Where as

$\overline{y}$ is the depend variable

$\mathrm{x}_1, \mathrm{x}_2, \mathrm{x}_3, \mathrm{x}_4$, and x_5 are the independent variable

β_0 is the y intercept

Sub step 4.2: Residual analysis

Residual analysis is performed on the initial analysis to verify the following model assumptions

- linear model is reasonable
- the residuals have constant variance
- the residuals are normally distributed
- the residuals are uncorrelated
- no outliers

Some example of perfect residual analysis vs the interaction graphs are provided in the Figure 5-2 and Figure 5-3.

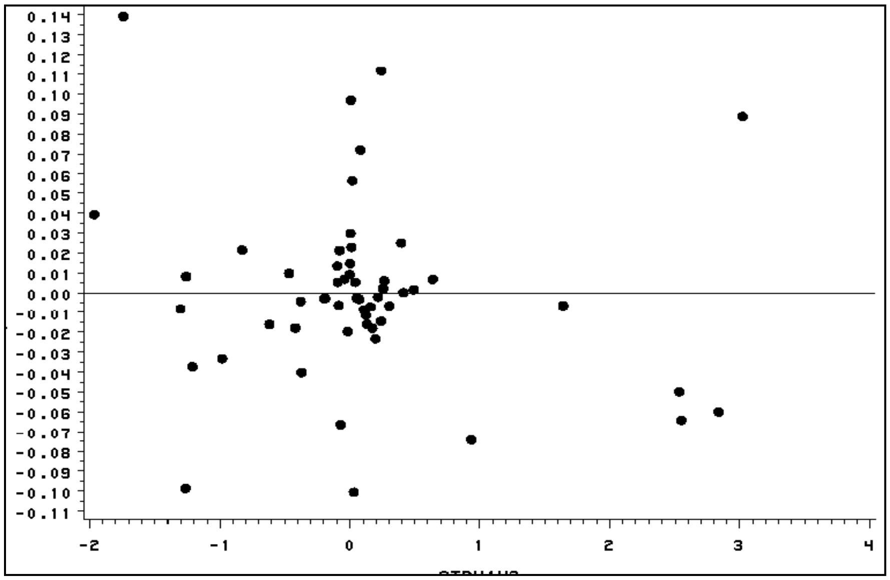

Figure 5-2 Sample Residual vs Interaction term

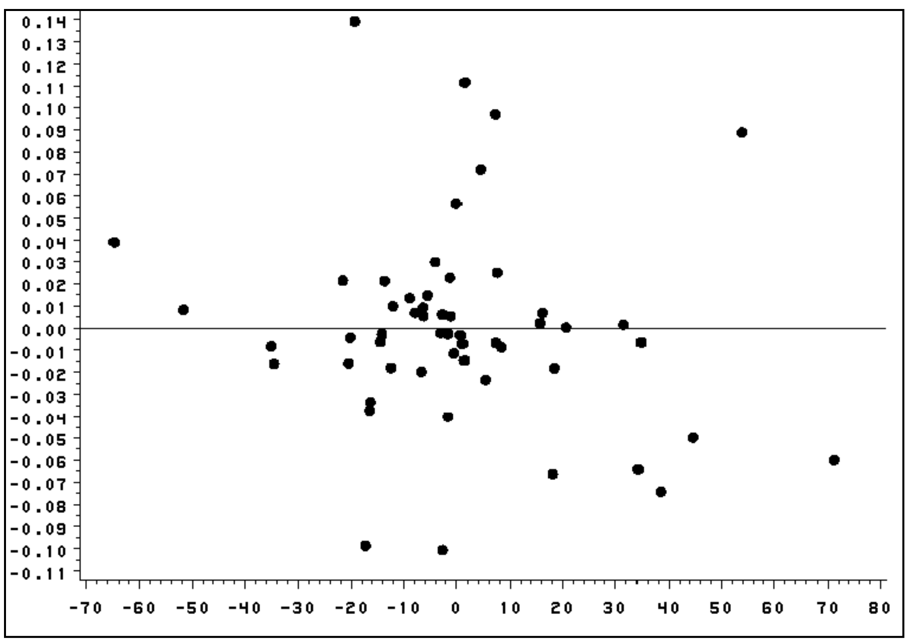

Figure 5-3 Sample Residuals Plots Vs independent variable

Sub step 4.3: Normality Test:

The model is tested for the normality using the following test statistics

Null hypothesis

H_0: Normality is OK.

Alternate Hypothesis

H_1: Normality is violated.

If $\rho > c(\alpha , n)$ Reject null hypothesis ($\alpha = 0.10$) (Hunter, Nachtsheim, Li, & William, 2013).

Sub step 4.4: Modified-Levene Test for non-constant variance

The data is divided into two set, if variance is different for the two sets, then error variance is non constant. The absolute deviations of the residuals around the group medians d_i1 and d_i2 are calculated and a two sample t-test is conducted on these two groups of observations.

Null Hypothesis

H_0: Means of *di*1 and *di*2 populations are equal.

Alternate Hypothesis

H_1: Means are not equal.

If $P < p(\alpha , n)$ Reject null hypothesis ($\alpha = 0.10$) (Hunter, Nachtsheim, Li, & William, 2013).

Sub step 4.5: Significance of Regression

To test the significance of regression an F-test is conducted

Null Hypothesis

H_0: Regression is not significant.

Alternate Hypothesis

H_1: Regression is significant.

If F > f(α , n) Reject null hypothesis ($\alpha = 0.10$) (Hunter, Nachtsheim, Li, & William, 2013).

Sub step 4.6: Variance Inflation –Test for Multicollinearity

Multicollinearity means there is a relation between the multiple independent variables (Alin, 2010). If the multicollinearity exists it is necessary to add the interaction terms to the module. Multicollinearity is not a problem if max $(VIF)_k < 5$ and average (VIF) equal to 1 (Hunter, Nachtsheim, Li, & William, 2013).

Sub step 4.7: Y-Outliers

To identify the y-outliers the following test statistics is used

$$t\left(\left(1-\frac{\alpha}{2n}\right), n-p-1\right)$$

If the $|t_i|$ value is greater than the value calculated by the above formula then it is a y-outlier (Hunter, Nachtsheim, Li, & William, 2013). If there are y-outliers then model transformation is required.

Sub step 4.8: X- Outliers

To identify the x-outliers the following test statistics is used

$$\frac{2p}{n}$$

If the h_{ii} value is greater than the value calculated by the above formula then it is an x-outlier (Hunter, Nachtsheim, Li, & William, 2013). If there are x-outliers then model transformation is required.

Sub step 4.9: Inflation of the x-outliers

The inflation of an x-outlier is identified by calculating the following test statistics 2/(sqrt n) and comparing to the DFBETAS values. If the DFBETAS are lesser than the test statistics then the x-outliers are not influential.

Step 5: Model search

The initial model developed involves all the independent variables and it shows how exactly all the independent variable affects the dependent variable. But if the behavior of the dependent variable is need to be predicted more accurately a model with the independent variable which affects the dependent variable behavior significantly is need to be identified. There are many methods are available for this purpose, but in this research the following methods (Derksen & Keselman, 1992; Mundry & Nunn, 2009) are chosen

- Backward deletion method
- Stepwise
- Best subset model method.

Sub Step 5.1: Backward deletion method

The independent variable in the initial model with the highest p value is identified. With that variable removed another model is created. In the second model again independent variable with the highest p value is identified and removed and new model is developed. The process is repeated until the final model with the p value less than α = .10 is identified.

Sub Step 5.2: Stepwise method

SAS software is programmed to provide the subset models. In those models, the model where the adjusted R^2 and R^2 levels off and also c (p) is close to p is identified. It also should contain the minimum value for AIC and SBC.

Sub Step 5.3: Subset Method

SAS software is programed to provide the best models.

The final model is then again tested for the normality, multicollinearity, outliers, inflation of the outliers and variance. The various models independent variables estimates will be filled in the sample Table 5-4.

Table 5-4 Model Examples with various dependent variables removed.

Dependent Variable	Constant	Independent Variable					Error Value	R^2
EAC		LH	SL	FI	RI	PI		
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2
$\bar{y}$							e	R^2

Phase 3

Overview

In this phase NPV are calculated for various accuracy level.

Specific Aim 3: Evaluation of the economic impacts of Auto ID on ERP data accuracy

Step 6: Economic evaluation

The cash inflow and outflow for five years are calculated for the three different scenarios with accuracy: 0 to 50%, 50 to75 % and 75 to 100%. Using the cash flow the net present value (NPV) is calculated to determine whether the project is economically viable. NPV is method that is used to analyze the profitability of an investment project in capital budgeting. NPV is calculated using the formula

$$\mathrm{NPV} = \frac{\mathrm{R_t}}{(1+\mathrm{i})^{\mathrm{t}}}$$

Equation 5-2 Net Present Value

Where as

t – the time of the cash flow

i – the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)

Rt – the net cash flow i.e. cash inflow – cash outflow, at time *t*.

The initial investments includes initial audit for the RFID implementation, RFID equipment's and software, actual implementation and the human resources. The project is considered economically viable if the NPV value is positive. The best scenario is selected by selecting the one with the higher NPV value.

Table 5-5 NPV values for different economic scenarios

Scenario (Accuracy range)	NPV Value ($)	Investment $	Savings
0 – 50 %			
50 – 75 %			
75 – 100 %			

Chapter 6

Results

Overview

This section provides the results of all the phases and steps described in the methodology section.

Phase 1: specific aim 1

Overview

In this section results for Phase one is presented. I identified the variables and developed the questionnaire and administered the questionnaire and evaluated the data obtained from administering the questionnaire.

Step 1: Questionnaire development

Based interviews conducted with more than 100 ERP and warehouse users over a time period of 6 months various variables that affects the ERP data accuracy are identified. The five main variables and the ERP module in which the data are generated are shown in the Table 6-1.

Step 2: Questionnaire dissemination

The survey was answer by 500 ERP and warehouse specialist and users. The no of participants responded back are given in the

Table 6-2. The participants are between age group 25 – 40. The participant from different skill level is given in the Table 6-4. Eliminating incomplete surveys the total number of participants and their demographic information is given in the Table 6-5.

Table 6-1 Independent Variables with ERP modules

Variables	Variables Description	Variables definition	ERP Module
LH	Logistic hand	Logistics handling includes tracking, locating, managing the movements and storage of the inventory	Sales and distribution, Warehouse management, and Logistics control
SL	Storage location	Storing the inventory in invalid locations	Sales and distribution and Warehouse management
FI	Finished good products inventory	The invalid quantity various Finished good products	Sales and distribution, financial and Warehouse management
RI	Raw materials inventory	The invalid quantity various Raw materials	Sales and distribution, financial and Warehouse management
PI	Package materials inventory	The invalid quantity various Package materials	Sales and distribution, financial and Warehouse management

Table 6-2 Participants response

Total no of participants	No of participant responded	No of participant with no responded
500	468	32
Percentage	0.94	0.06

Table 6-3 Participants age group

Min Age	Max Age
25	40

Table 6-4 Participants skill level

ERP system		Warehouse	
Analyst	Users	Analyst	Users
157	134	102	75

Table 6-5 Demographic Information of the participants

Total no Participants	Male	Female
468	263	205

Step 3: Questionnaire evaluation

The mean and standard deviation for the dependent variables and independent variables are given the Table 6-6 and Table 6-7.

Table 6-6 Dependent Variable mean and standard deviation

Variables	Variables description	Mean	Standard Deviation
EAC	Respondent perceived ERP data accuracy	84.3	3.28

Table 6-7 Independent variables mean and standard deviation

Variables	Variables description	Mean	Standard Deviation
LH	Logistic hand	4.02	0.81
SL	Storage location	3.55	0.50
FI	Finished good products inventory	2.33	0.48
RI	Raw materials inventory	1.90	0.84
PI	Package materials inventory	1.61	0.50

Phase 1 Outcome

The outcome of the phase 1 is that the variables are identified in Table 6-1. The questionnaire (Appendix A) was developed. The questionnaire was administered to the participants and the results are shown in the Table 6-2 to Table 6-7.

Phase 2: Specific aim 2

Overview

I developed regression model to identify the significance of the independent variables on dependent variables. Then the residual analysis, normality test, modified levene test for constant variance, test for regression significance, test for multicollinearity, test to identify x-outliers and y- outliers and their influences are performed on the model.

The model is further analyzed using the following methods, backward deletion, subset and stepwise to identify model with predictor independent variable

Step 4: Evaluation

Regression Analysis: Matrix Scatter Plot

The matrix scatter plot is shown in Figure 6-1 provides scatter plots in relation to the EAC all 5 of the X Variables listed in the above variables section. In addition the 5 variables are also provided scatter plots amongst each other, thus by looking at the rows and columns one can determine which combination they are looking at. The top row correlates EAC score vs. LH, SL, FI, and PI. These plots demonstrate that LH, SL, FI, and PI seem to have a correlation with the accuracy.

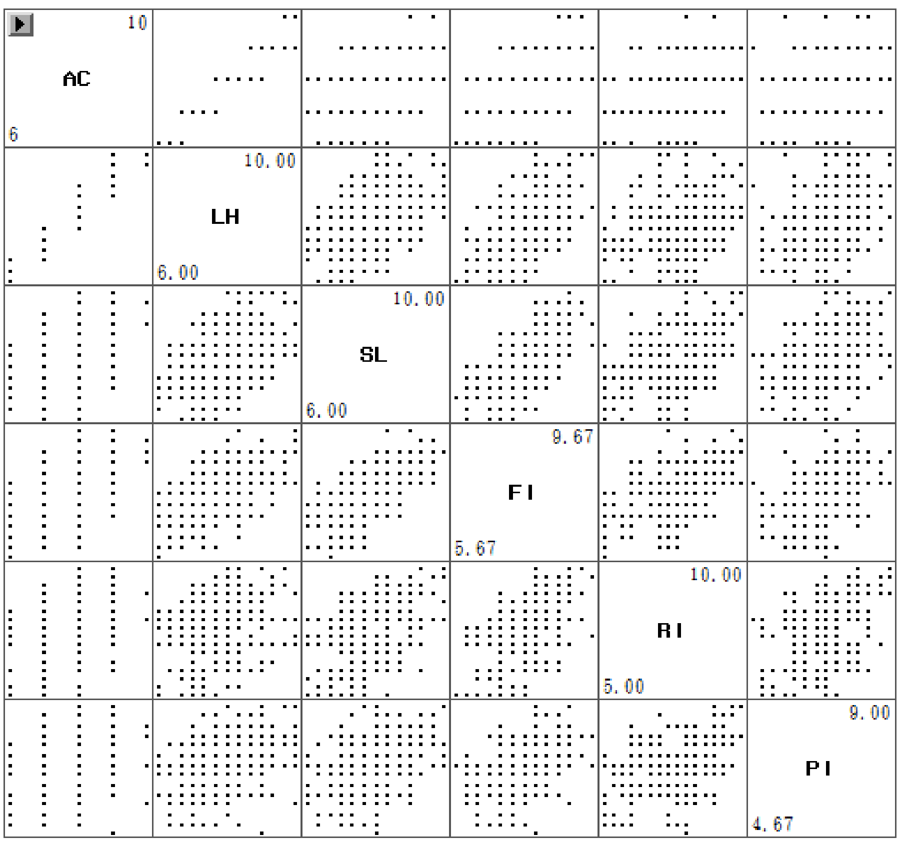

Figure 6-1 Scatter plot between predictor variable and response variable

Response-predictor pairwise correlations:

The plot between the predictor variable LH and response variable accuracy has an upward trend indicating there is strong correlation between them. The plot between the other predictor variables (SL, FI, RI, and PI) and response variable AC has slight upward trend indicating weaker correlation between them.

Predictor-predictor pairwise correlation:

All the plots have empty space, but in a perfect situation this plot will be filled.

LH rating vs. SL: The plot indicates a slight upward trend indicating that these variables may be correlated.

LH vs. FI: The plot indicates a slight upward trend indicating that these variables may be correlated.

LH vs. RI: The plot indicates a slight upward trend indicating that these variables may be correlated.

LH vs. PI: The plot indicates a slight upward trend indicating that these variables may be correlated.

SL vs. FI: The plot indicates a slight upward trend indicating that these variables may be correlated.

SL vs. RI: The plot indicates a slight upward trend indicating that these variables may be correlated.

SL vs. PI: The plot indicates a slight upward trend indicating that these variables may be correlated.

FI vs. RI: The plot indicates a slight upward trend indicating that these variables may be correlated.

FI vs. PI: The plot indicates a slight upward trend indicating that these variables may be correlated.

RI vs. PI: The plot indicates a slight upward trend indicating that these variables may be correlated.

The above values indicate predictor variable, logistic handling is highly correlated with the response variable EAC. And the predictor variable SL, FI, RI and PI have low correlation with the response variable EAC. These results agree with the scatter plot. The values between the dependent variables are less than 0.7 (Aiken, West, & Pitts, 2003; Hunter, Nachtsheim, Li, & William, 2013). This indicates that there may be some multicollinearlity between these variables. This also matches with the scatter plot.

Table 6-8 Pearson correlation

Pearson Correlation Coefficients, N = 468						
	EAC	LH	SL	FI	RI	PI
EAC	1.00000	0.93232	0.47476	0.54312	0.31627	0.40891
LH	0.93232	1.00000	0.46507	0.54418	0.29723	0.40883
SL	0.47476	0.46507	1.00000	0.63349	0.44032	0.41019
FI	0.54312	0.54418	0.63349	1.00000	0.48690	0.45971
RI	0.31627	0.29723	0.44032	0.48690	1.00000	0.49848
PI	0.40891	0.40883	0.41019	0.45971	0.49848	1.00000

Initial Multiple Linear Regression Model Analysis:

Initial model is

$$\hat{y} = 0.13862 + 0.89616\, x_1 + 0.03095\, x_2 + 0.02330\, x_3 + 0.01559\, x_4 + 0.009932\, x_5$$

Equation 6-1 Initial model

The intercept *0.13862* indicates the value of the EAC when the value of LH, SL, FI, RI and PI is 0.

Table 6-9 Description of the relevant variables

S.No	Variables	Variables Description	Independent Variables	P Value	Effect on dependent variable (Ranking)
1	LH	Logistic hand	*0.89616*	<.0001	First – The highest significant variable
2	SL	Storage location	*0.03095*	0.1574	Second – The second highest significant value
3	FI	Finished good products inventory	*0.02330*	0.3910	Fourth – The second lowest significant
4	RI	Raw materials inventory	*0.01559*	0.2052	Third – Medium significant
5	PI	Package materials inventory	*0.00993*	0.6445	Fifth – The lowest significant

Analysis of Variance:

The analysis of variance is shown in the Table 6-10. The coefficient of Multiple Determination R^2 is a measure of goodness-of-fit of linear regression. It has a value of .8724 (Table 6-9) which implies 87.24% of variation in the EAC is explained by the predictor variables LH, *SL, FI, RI, and PI*. This is a good value as high values of R^2 are desired.

P value in the parameter estimates are shown in Table 6-11**.** identifies the high significant dependent variable to the least significant. Lower the P value higher the significance and higher the P value lower the significance. It is summarized in the Table 6-9.

Table 6-10 ANOVA table for the initial model

Model 1 Dependent Variable : EAC Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Values	Pr > F
Model		296.77947	57.35589	631.49	< .0001
Error	462	41.96198	0.09083		
Corrected Total	467	328.74145			
Root MSE		0.30137	R-Square	0.8724	
Dependent Mean		7.75427	Adj R-Sq	0.8710	
Coeff Var		3.88656			

The slope *0.*89616 indicates the increase in the mean of the score of EAC when there is unit increase in the LH.

The slope *0.*03095 indicates the increase in the mean of the score of EAC when there is unit increase in the SL.

The slope *0.*02330 indicates the increase in the mean of the score of EAC when there is unit increase in the FI.

The slope *0.*01559 indicates the increase in the mean of the score of EAC when there is unit increase in the RI.

The slope *0.*009932 indicates the increase in the mean of the score of EAC when there is unit increase in the PI.

Table 6-11 Parameter estimates for the initial model

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|	Variance Inflation
Intercept	1	0.13862	0.16	0.84	0.4021	0
LH	1	0.89616	0.02	43.59	<.0001	1.52967
SL	1	0.03095	0.02	1.42	0.1574	1.80594
FI	1	0.02330	0.02	0.86	0.3910	2.11503
RI	1	0.01559	0.01	1.03	0.2052	1.53611
PI	1	0.00932	0.02	0.46	0.6445	1.52679

Correlation:

Table 6-12 Predictor variables and r values for initial model

Predictors Variable	Predictors Variable	r value	Correlation
LI	SL	$r_{12} = 0.46$	Somewhat positively correlated.
LI	FI	$r_{13} = 0.54$	Somewhat positively correlated.
LI	RI	$r_{14} = 0.29$	May be positively correlated.
LI	PI	$r_{15} = 0.40$	Somewhat positively correlated.
SL	FI	$r_{23} = 0.63$	Somewhat positively correlated.
SL	RI	$r_{24} = 0.44$	Somewhat positively correlated.
SL	PI	$r_{25} = 0.41$	Somewhat positively correlated.
FI	RI	$r_{34} = 0.48$	Somewhat positively correlated.
FI	PI	$r_{35} = 0.46$	Somewhat positively correlated.
RI	PI	$r_{45} = 0.49$	Somewhat positively correlated.

Table 6-13 SAS output for the correlation

The CORR Procedure Variable : EAC LH SL FI RI FI Simple Statistics						
Variable	N	Mean	STD Dev	Sum	Minimum	Maximum
EAC	468	7.75	0.83	3629	6.00	10.00
LH	468	7.82	0.83	3661	6.00	10.00
SL	468	7.86	0.85	3680	6.00	10.00
FI	468	7.67	0.74	3590	5.67	9.67
RI	468	7.64	1.13	3579	5.00	10.00
PI	468	6.96	0.85	3259	4.67	9.00
Pearson Correlation Coefficients, N = 468						
	EAC	LH	SL	FI	RI	PI
EAC	1.00	0.93	0.47	0.54	0.31	0.40891
LH	0.93	1.00	0.46	0.54	0.29	0.40883
SL	0.47	0.46	1.00	0.63	0.44	0.41019
FI	0.54	0.54	0.63	1.00	0.48	0.45971
RI	0.31	0.29	0.44	0.48	1.00	0.49848
PI	0.40	0.40	0.41	0.45	0.49	1.00000

Model Assumption

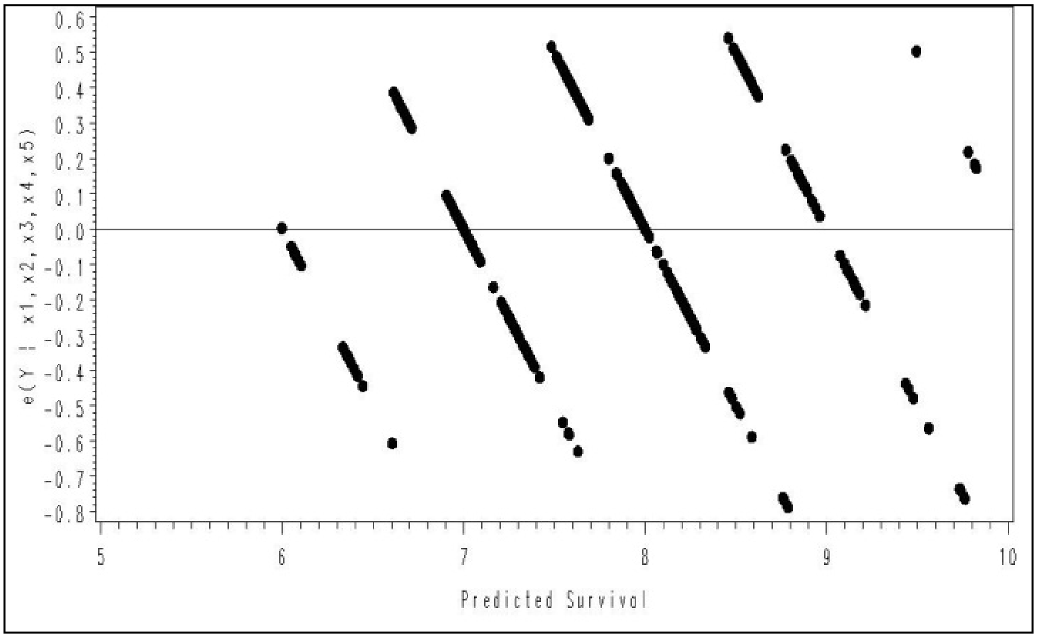

Figure 6-2 Residuals (e) vs ŷ

The plot inidicates that the data points are not randomly distributed therefore the linear model assumption may not be resaonable There is a funnel shape indicating the variance is not constant.

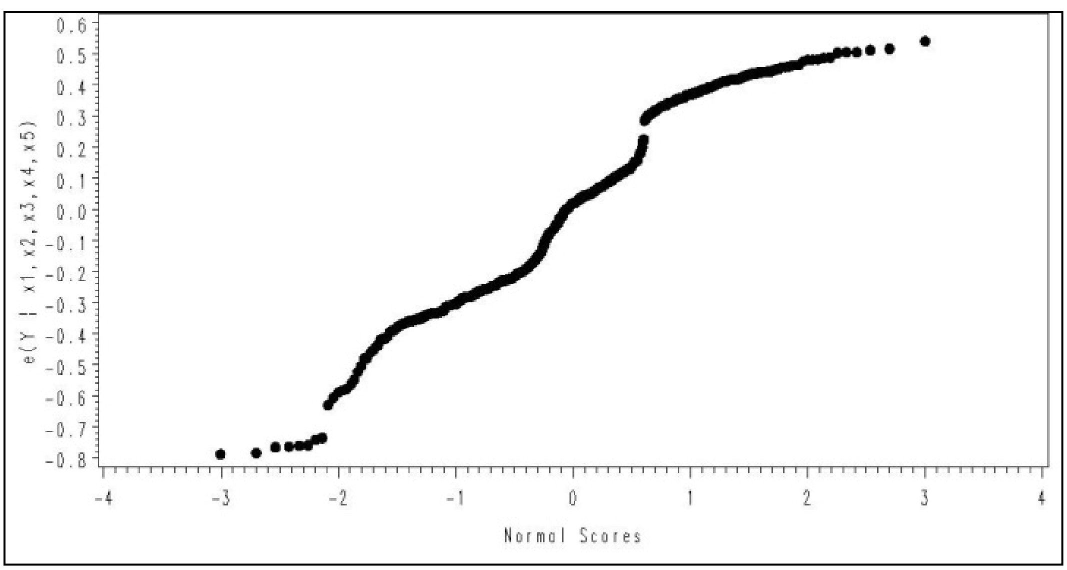

Figure 6-3 Normal Probability Plot

The distribution of the residuals has shorter tails (on both sides) than the normal distribution. Normality is violated.

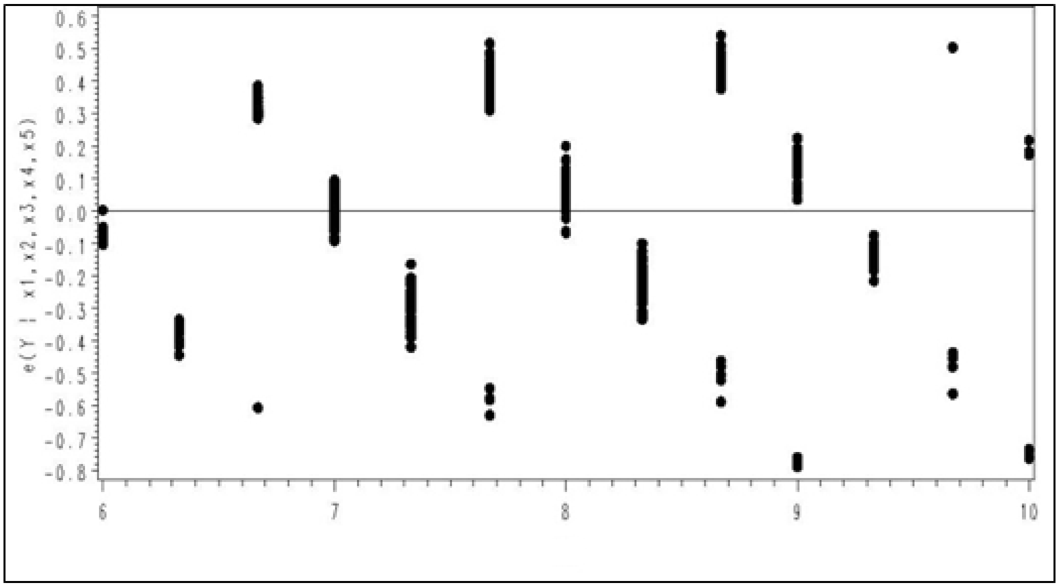

Figure 6-4 Residuals (e) vs. LH (x1)

There is no curvature indicating current MLR form may be reasonable. There are no y outliers there may be some x outliers when x = 6 and 10.

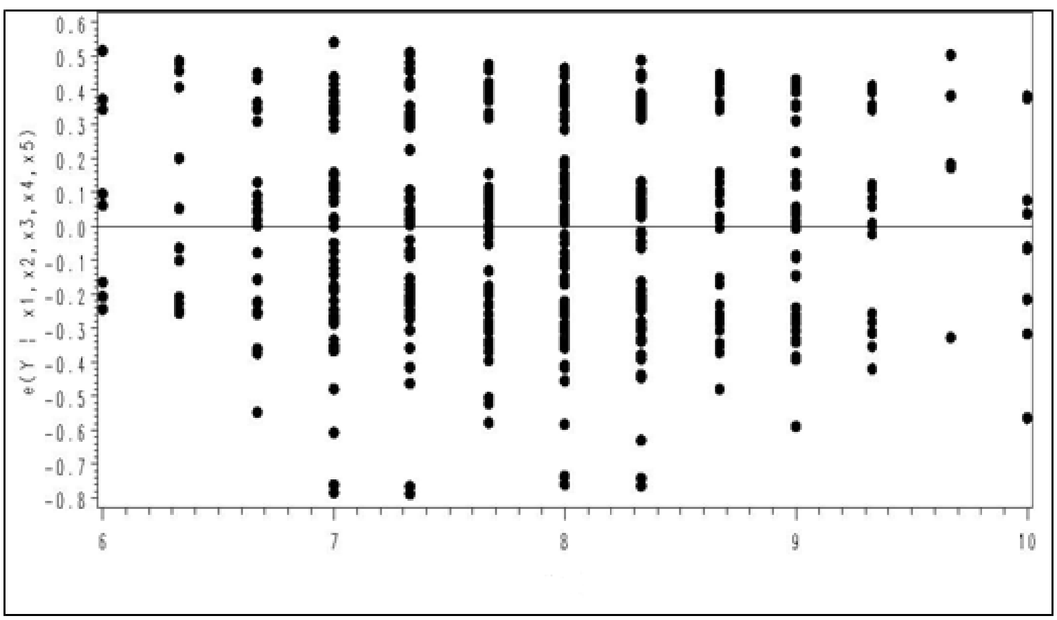

Figure 6-5 Residuals (e) vs. SL (x2)

There is no curvature indicating current MLR form may be reasonable. There are no y and x outliers.

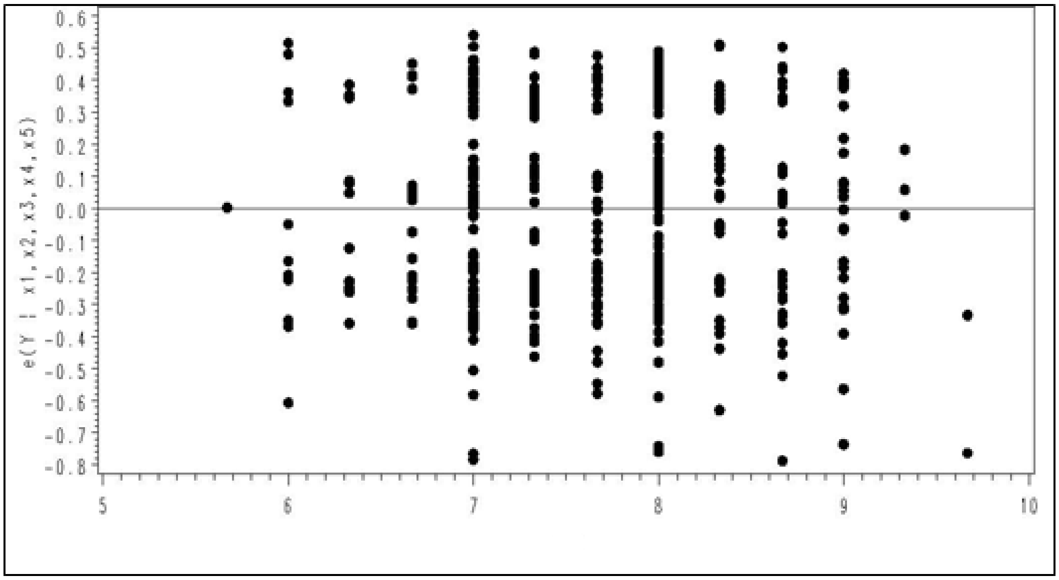

Figure 6-6 Residuals (e) vs. FI (x3)

There is no curvature indicating current MLR form may be reasonable. There are no y outliers there may be some x outliers when x is <6 and >9.

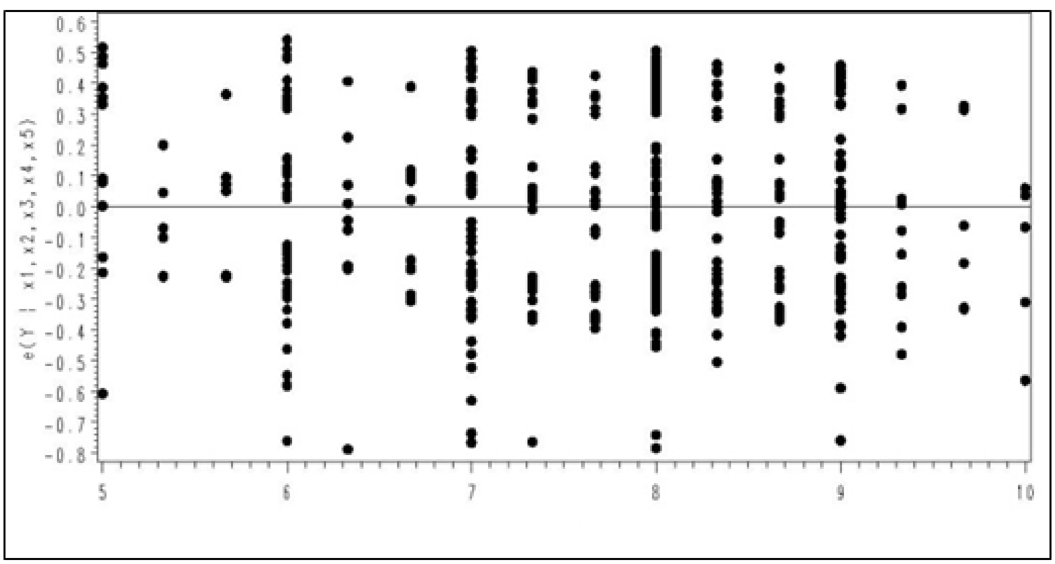

Figure 6-7 Residuals (e) vs. SI (x5)

There is no curvature indicating current MLR form may be reasonable. There are no y outliers there may be some x outliers when x <5.

Y – Outliers (Bonferroni Outlier Test):

Cut off values for the y outlier $t\left(\left(1-\frac{\alpha}{2n}\right), n-p-1\right)$ = t (.9998931624, 462) = 3.73195. The $|t_i|$ values greater than 3.73195 (Table 6-14) are considered as the y outlier. None of the $|t_i|$ values are greater than the cutoff value 3.73195 indicating they are no y outliers.

Table 6-14 Bonferroni Cut-off values

OBS	EAC	LH	SL	FI	RI	PI	Yhat	e	tres	cookdi	hii
1	8.33	7.67	8.00	6.33	7.00	8	8.19	-0.19	-0.63	.0006	.009
2	7.33	8.67	7.00	6.67	6.67	7	7.30	-0.30	-1.01	.0024	.014
3	7.67	9.33	8.33	6.00	7.33	8	7.65	0.34	1.15	.0058	.025
4	8.00	8.67	7.00	6.67	6.67	8	7.90	0.09	0.31	.0002	.014
5	7.33	8.33	7.33	6.00	7.00	7	7.29	-0.29	-0.98	.0021	.013

X – Outliers:

The leverage value (the highest h_{ii} value) is 0.042413.

To check the x-outliers the h_{ii} values should be less than $\frac{2p}{n}$ = ((2*6)/468) = 0.025641.

Values h_{ii} at observations 3, 50, 56, 58, 88, 91, 94, 112, 206, 237, 259, 263, 272, 279, 307, 309, 312, 334, and 459 are greater than 0.025641. This clearly indicates the values at these observations are x outliers.

Influence:

Table 6-15 DEBETAS & Cut-off values

Ob	X - Out	DFBETAS - Cutoff Value - .0042735					
		Intercept	RE	RES	ASS	EMP	TAN
3	Y	-0.0355	-0.0654	0.11	0.0396	-0.1417	0.0459
50	Y	0.0048	-0.0254	0.0166	-0.0167	0.0118	0.0169
56	Y	0.1896	-0.2582	0.1533	-0.1839	0.1519	0.0203
58	Y	-0.0066	0.062	-0.0383	0.0303	-0.0365	-0.0275
88	Y	-0.0388	-0.0622	0.0511	0.0031	-0.1015	0.1389
91	Y	-0.1035	-0.0128	0.0517	0.0598	-0.0595	0.0398
94	Y	0.2013	-0.2998	0.1237	0.1363	-0.0597	-0.2094
112	Y	-0.0531	0.0895	0.0038	0.0251	0.0505	-0.1201
206	Y	0.0207	0.016	-0.0169	-0.0021	-0.0053	-0.0155
237	Y	0.0171	-0.0516	-0.0125	0.0179	-0.0412	0.0593
259	Y	0.0773	-0.0657	0.0057	0.1033	-0.1061	-0.0825
263	Y	0.0654	-0.0631	0.1119	-0.0115	-0.114	-0.0251
272	Y	-0.0181	-0.0277	0.0259	-0.0156	0.016	0.0296
279	Y	0.0549	-0.1808	0.1998	-0.278	0.1462	0.1765
307	Y	0.002716	0.009154	0.0329	1.0476	0.0017	0.0009
309	Y	0.5161	1.7449	0.0326	1.0066	0.3202	0.00176
312	Y	-0.0695	-0.234	0.0318	1.0456	-0.0424	-0.0164
334	Y	0.0009	0.0671	-0.004	0.0092	0.0441	-0.12
459	Y	-0.0228	-0.0495	-0.0079	0.0325	-0.0475	0.0815

Grey Background – above the cutoff values, No Background – below the cutoff values

The cutoff values for the DFBETAS is 2/(sqrt n) = 2/(sqrt (468)) =0.092450033. Since DFBETAS for all the outliers are less than the cutoff values Table 6-15. The values at both the x and y outliers are not influential.

DFFITS:

The cutoff values for the DFFITS is 2(sqrt (p/n)) = 2(sqrt (2/468)) = 0.13074409. DFFITS for all the variables at the outliers are lesser than the cutoff values at these observations. This indicates that the observations at the x outliers are not influential.

Cooks Distance

If the d_{ii} > F (.50, 1,461) it indicates that the outliers are influential. But from the SAS output it is clear that is not the case indicating that the outliers are not influential.

Inflation:

Since max $(VIF)_k$ = 2.11503 is < 5 and average (VIF) = 1.702708 is not much bigger than 1, conclude that serious multicollinearity is not a problem.

Modified -Levene Test:

Modified Levene test is performed by dividing the data into 2 groups based on the median of yhat.

Table 6-16 Modified-Levene Test

The TTEST Procedure Statistics									
V	group	N	Lower CL Mean	Mean	Upper CL Mean	Lower CL STD Dev	STD Dec	Upper CL STD Dev	STD err
d	1	219	0.24	0.265	0.28	0.13	0.15	0.16	0.01
d	2	249	0.21	0.236	0.25	0.16	0.17	0.19	0.01
d	Diff (1-2)		-0.002	0.029	0.05	0.15	0.16	0.17	0.01

T-Tests					
Variable	Method	Variances	DF	t value	Pr > |t|
d	Pooled	Equal	466	1.87	0.0628
d	Satterthwaite	Unequal	465	1.88	0.0601

Equality of Variances					
Variable	Method	Num DF	Den DF	F Value	Pr > F
d	Folded F	248	218	1.39	0.0135

T- Test for Variance constant check:

H_0 : Variance is constant

H_a : Variance is not constant.

Decision rule: P-Value (t-Test) < .05

p=.0135< p=.05 (Table 6-16). Therefore reject the $H_{0.}$

This indicates that the variance is not constant for the initial model. This agrees with the plot.

Normality Test

Table 6-17 Normality Test

	e	Enrm
e(y | x1, x2, x3, x4, x5)	1.00000	0.98175

C(α=.01, n =468) = .982 (Since the value at n=100 is almost 1, we take n= 100)

ρ = 0.982< 0.985.

Assumption of Normality is violated at alpha level of 0.01.

Furthering this assumption of non-normal data can be argued that the violation occurring at the third decimal place can be treated as a normal data which may be an artifact of the experiment of data collection process. For this reason the data can be assumed as a normal data for further computations and does not warrant transformations. This conclusion has been made by looking at the residual plots of the independent variables which indicate a random pattern. Therefore the initial model is same as the Equation 6-1.

The regression coefficients can be interpreted as the unit change in the predictor variable increases the unit changes in the dependent variable. For example per unit change in LH increases the EAC by 0.13862, when all other predictor variables are held constant. Similarly per unit change in that SL, FI, RI, and PI increase the EAC by 0.89616, 0.02330, 0.01559 and 0.009932 respectively while other predictor variables are held constant.

Significance of Regression:

F-test on the significance of regression

At α=.05 and for n = 468

F(.95,4,125) = 2.233274717

F* = 57.35589/.09083 =631.4641638>2.44417. Therefore the regression is significant.

Exploration of Interaction Term

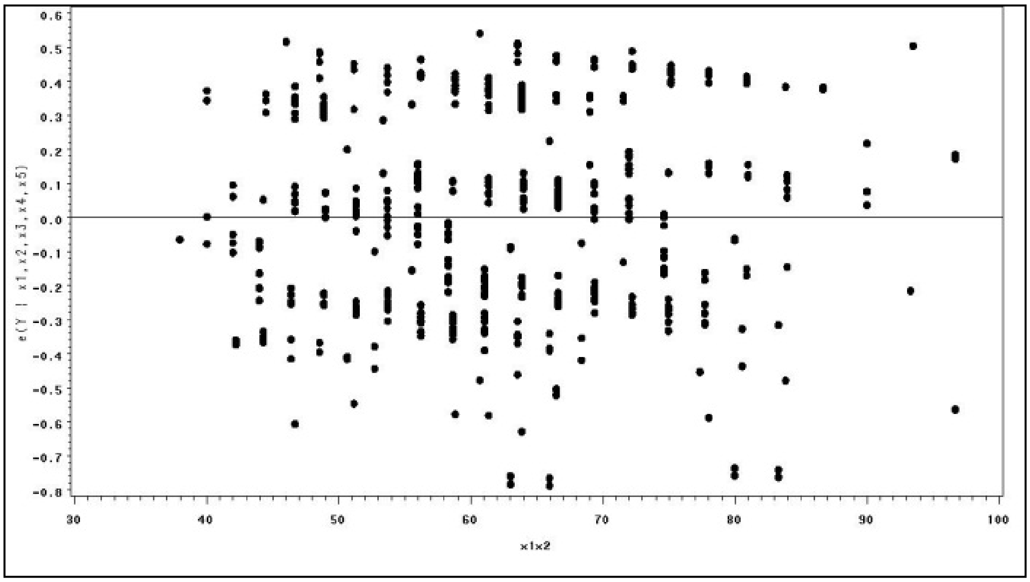

Figure 6-8 e Vs x1x2

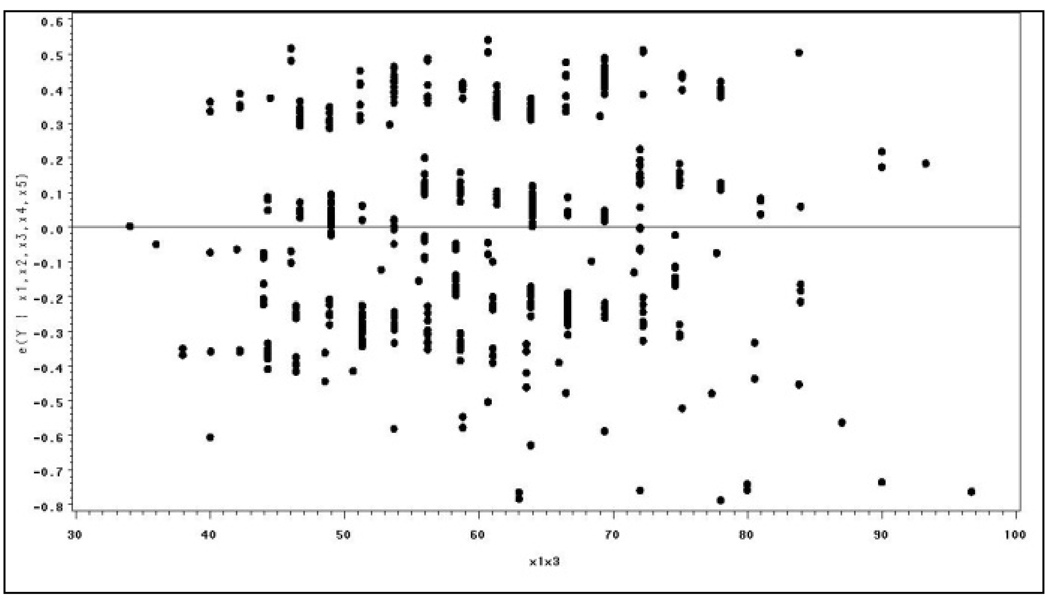

Figure 6-9 e Vs x1x3

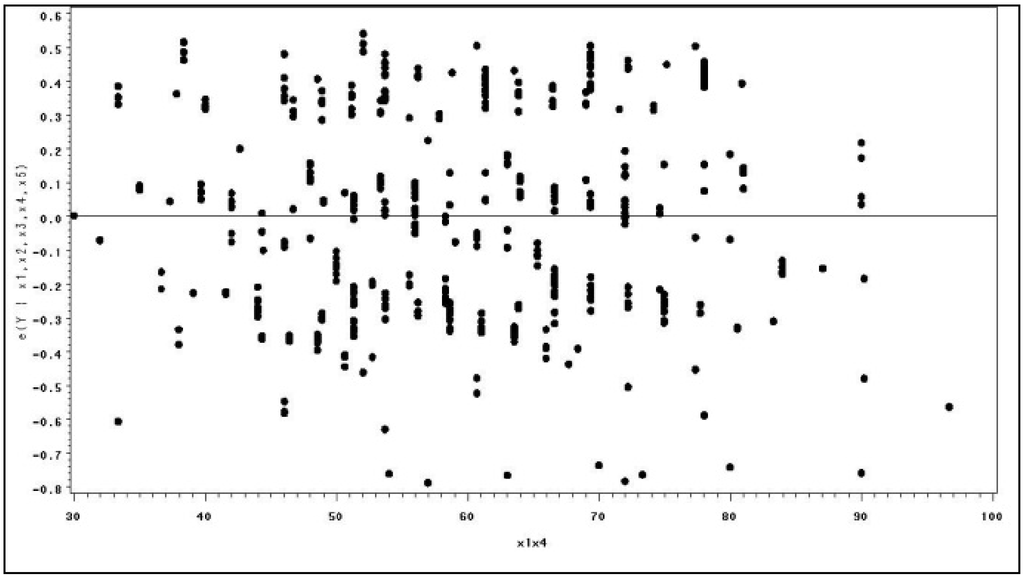

Figure 6-10 e Vs x1x4

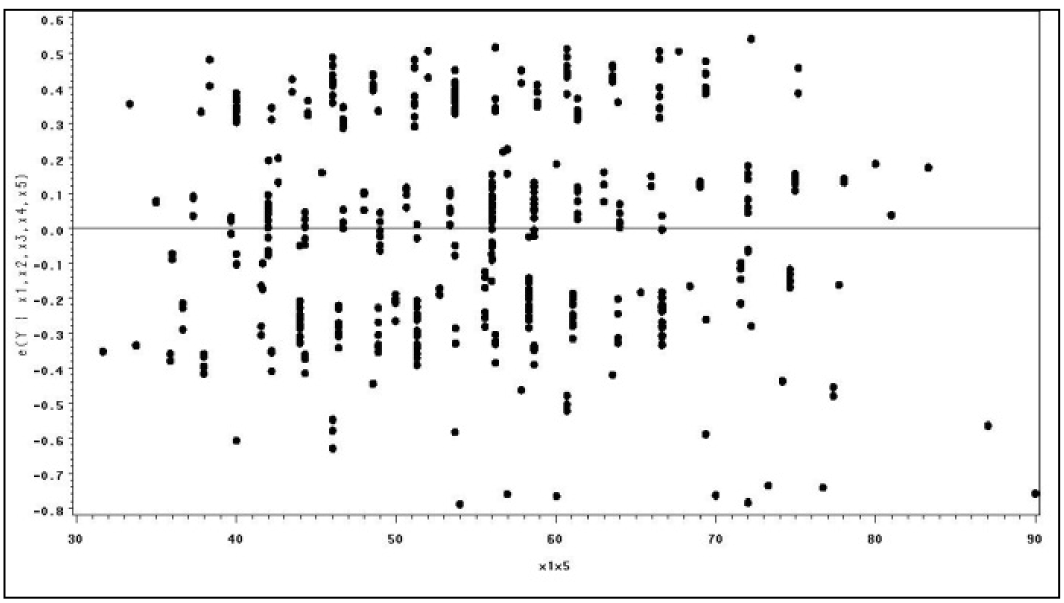

Figure 6-11 e Vs x1x5

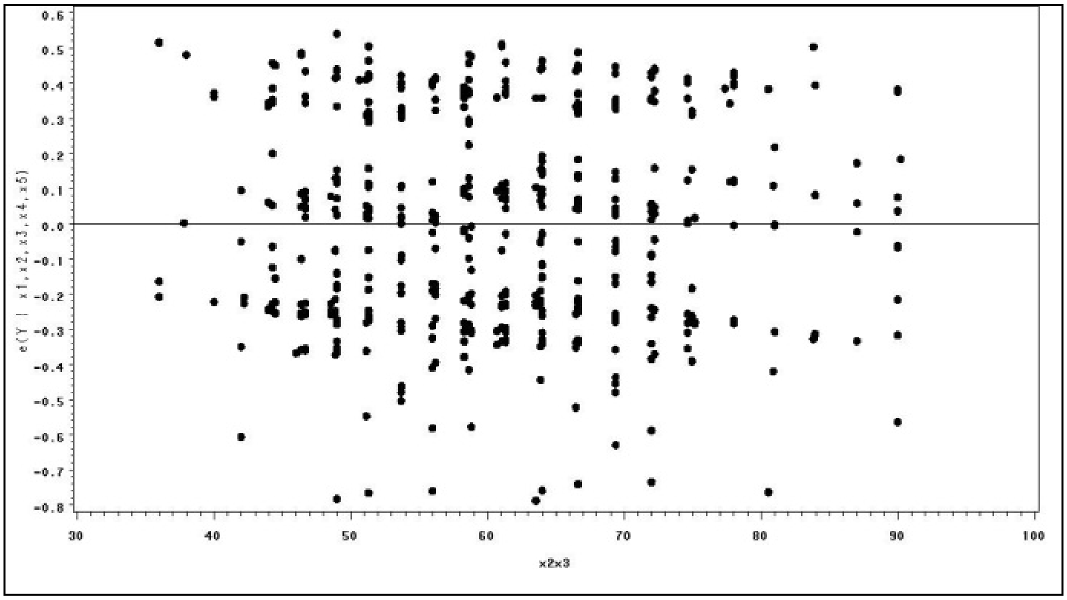

Figure 6-12 e Vs x2x3

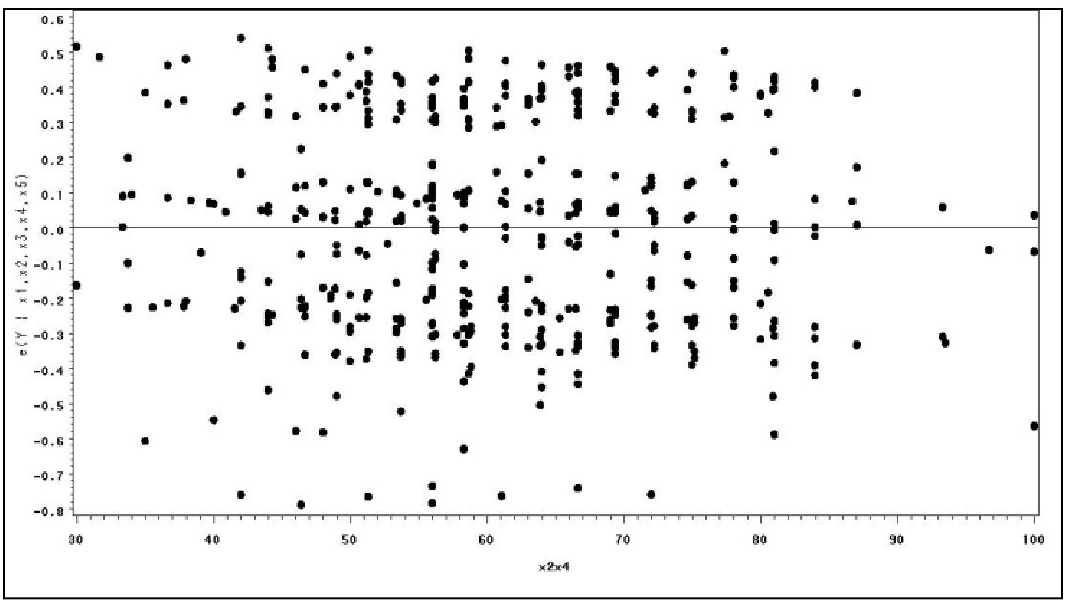

Figure 6-13 e Vs x2x4

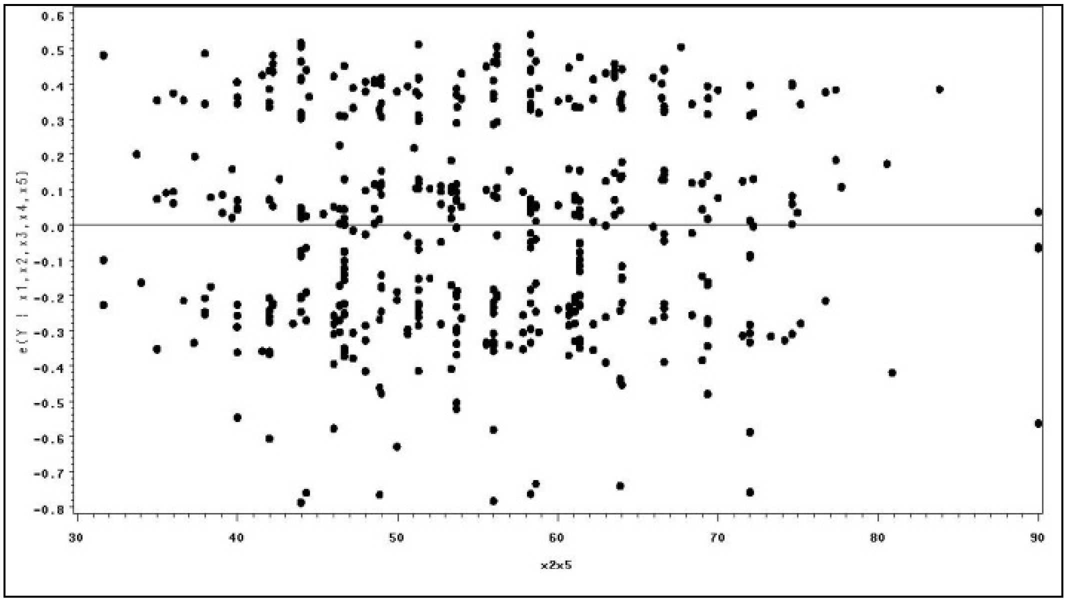

Figure 6-14 e Vs x2x5

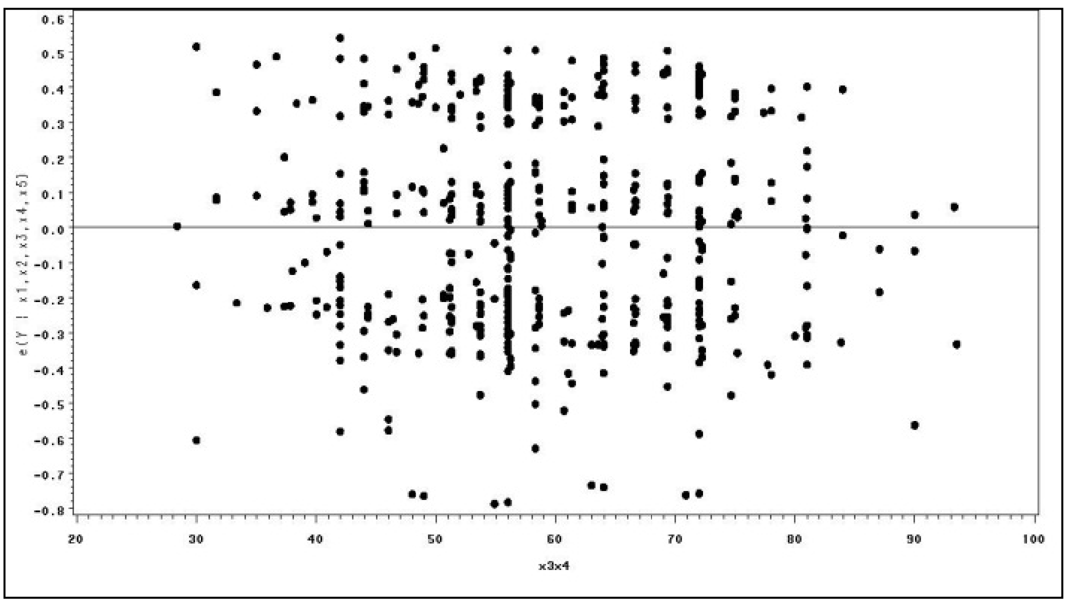

Figure 6-15 e Vs x3x4

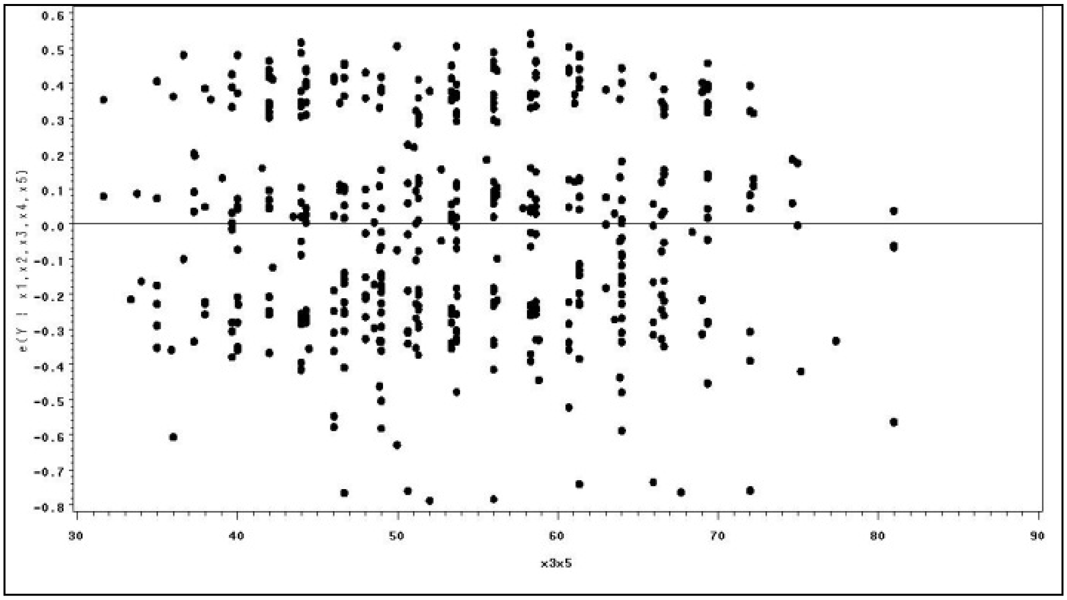

Figure 6-16 e Vs x3x5

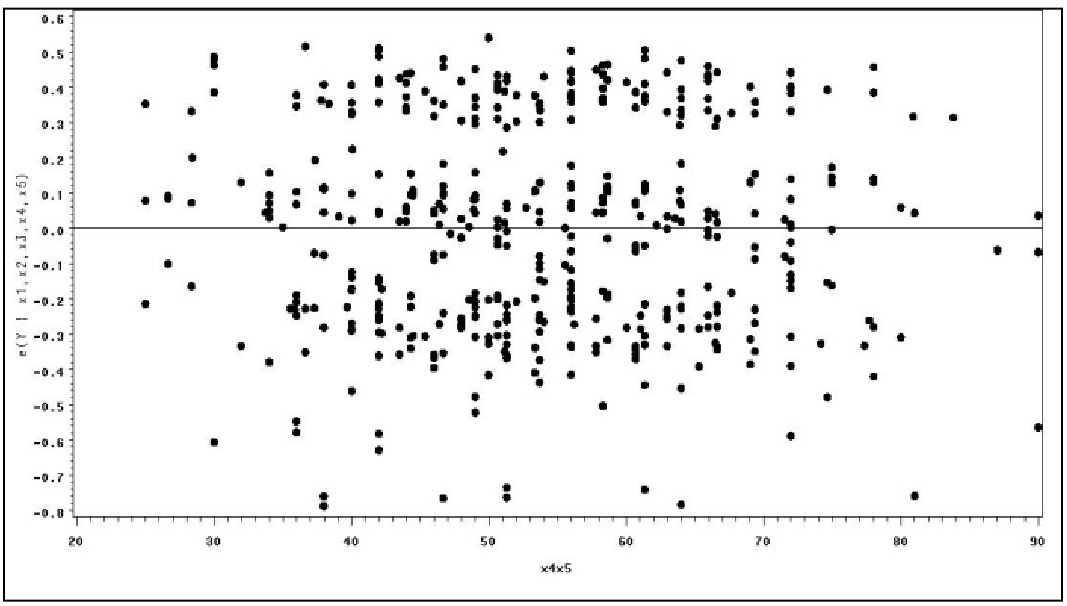

Figure 6-17 e Vs x4x5

The possibility of adding interaction terms to the regression model can be verified by the partial regression plots. The plots indicate that there are no trends in any of the interactions. Therefore we can conclude that there is no need consider any of the interaction terms in the model.

Step 5: Model Search

Sub Set 5.1: Backward Deletion Method:

The α=.10 is chosen.

Step 0: The initial full model is shown in the Table 6-18. This model has all the dependent variable and their significance is provided in the Table 6-9

Table 6-18 Initial Model

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	286.77	57.35	631.49	< .0001
Error	462	41.96	0.090		
Corrected Total	467	328.74			
Root MSE		0.3013	R-Square	0.8724	
Dependent Mean		7.754	Adj R-Sq	0.8710	
Coeff Var		3.88656			

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|	Variance Inflation
Intercept	1	0.13	0.16	0.84	0.40	0
LH	1	0.89	0.02	43.59	<.0001	1.52
SL	1	0.03	0.02	1.42	0.15	1.80
FI	1	0.02	0.02	0.86	0.39	2.11
RI	1	0.01	0.01	1.03	0.20	1.53
PI	1	0.00	0.02	0.46	0.64	1.52

The model is

$$\hat{y} = 0.13862 + 0.89616\ x_1 + 0.03095\ x_2 + 0.02330\ x_3 + 0.01559\ x_4 + 0.009932\ x_5$$

Equation 6-2 Initial Model (Model 1)

The variable PI has the highest p value.

Step 1: Model with the variable PI removed

In this model the dependent variable PI is removed since it has the highest P value.

Table 6-19 Model without PI

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	286.76	71.69	790.65	< .0001
Error	463	41.98	0.09		
Corrected Total	467	328.74			
Root MSE		0.30	R-Square	0.87	
Dependent Mean		7.75	Adj R-Sq	0.87	
Coeff Var		3.88			

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|
Intercept	1	0.153	0.16	0.95	0.34
LH	1	0.898	0.020	44.58	<.0001
SL	1	0.031	0.021	1.46	0.14
FI	1	0.024	0.026	0.92	0.35
RI	1	0.017	0.014	1.26	0.20

The model is

$$\hat{y} = 0.15374 + 0.89801x_1 + 0.03174x_2 + 0.02474x_3 + 0.01794x_4$$

Equation 6-3 Model 2

The variable FI has the highest p value.

Step 2: Model with the variable FI removed

In this model the dependent variable FI is removed since it has the highest P value.

Table 6-20 Model without FI

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	286.68	95.56	1054.27	< .0001
Error	464	42.05	0.09		
Corrected Total	467	328.74			
Root MSE		0.30	R-Square	0.8721	
Dependent Mean		7.75	Adj R-Sq	0.8712	
Coeff Var		3.88			

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|
Intercept	1	0.19	0.15	1.28	0.20
LH	1	0.90	0.01	47.89	<.0001
SL	1	0.04	0.01	2.05	0.04
RI	1	0.02	0.01	1.57	0.11

The model is

$$\hat{y} = 0.19764 + 0.90445x_1 + 0.04035x_2 + 0.02159x_4$$

Equation 6-4 Model 3

The variable RI has the highest p value.

Step 3: Model with the variable RI removed

In this model the dependent variable RI is removed since it has the highest P value.

Table 6-21 Model without RI

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	286.45	143.22	1575.18	< .0001
Error	465	42.28	0.092		
Corrected Total	467	328.74			
Root MSE		0.30	R-Square	0.86	
Dependent Mean		7.75	Adj R-Sq	0.86	
Coeff Var		3.88876			

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|
Intercept	1	0.24	0.15	1.64	0.10
LH	1	0.90	0.018	48.33	<.0001
SL	1	0.05	0.018	2.80	0.0054

All the p values are less than α=.10, i.e., the model is significant at α=.10. This is the potentially good model provided by the backward deletion method. The maximum variance inflation factor for each variable are not greater than 5 and average (VIF) = 1.27598 is not bigger than 1. Therefore mulitcollinearity is not a problem.

The potentially good model is

$$\hat{y} = 0.24887 + 0.90790\, x_1 + 0.05139 x_2$$

Equation 6-5 Potential good model from backward deletion method (Model 4)

Sub Set 5.2: Stepwise:

The best model by the stepwise method is

$$\hat{y} = 0.46185 + 0.93233\, x_1$$

Equation 6-6 Potential good model by stepwise method (Model 5)

All the p values are less than α=.10, i.e., the model is significant at α=.10. The maximum variance inflation factor for each variable are not greater than 5 and average (VIF) = 1 is not bigger than 1. Therefore mulitcollinearity is not a problem.

Table 6-22 Step Wise Best Model

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	285.74	285.74	3097.23	< .0001
Error	466	42.99	0.09		
Corrected Total	467	328.74			

Parameter Estimates				
Variable	Parameter Estimate	Standard Error	F value	Pr > F
Intercept	0.46	0.13	12.28	0.1009
LH	0.93	0.016	3097.23	<.0001

Table 6-23 Best Subsets Analysis

Number in Model	Adjusted R-Square	R-Square	C(P)	AIC	SBC	Variables in Model
1	0.8689	0.8692	9.35	-1113.31	-1105.02	LH
1	0.2935	0.2950	2087.770	-324.87	-316.58	FI
Number in Model	Adjusted R-Square	R-Square	C(P)	AIC	SBC	Variables in Model
2	0.8708	0.8714	3.52	-1119.12	-1106.67	LH SL
2	0.8705	0.8710	4.77	-1117.86	-1105.42	LH FI
Since the above adjusted R^2 and R^2 levels off and also c(p) is close to p=3, the model with LH and SL is a potential good model						
Number in Model	Adjusted R-Square	R-Square	C(P)	AIC	SBC	Variables in Model
3	0.8712	0.8721	3.0554	-1119.69	-1103.01	LH SL RI
3	0.8710	0.8719	3.7869	-1118.87	-1102.27	LH SL FI
Since the above adjusted R^2 and R^2 levels off and also c (p) is close to p=3, the model with LH, SL and RI is a potential good model. It also contains the minimum value for AIC and SBC						
Number in Model	Adjusted R-Square	R-Square	C(P)	AIC	SBC	Variables in Model
4	0.8712	0.8723	4.2131	-1118.46	-1097.71	LH SL FI RI
4	0.8710	0.8722	4.7372	-1117.93	-1097.18	LH SL RI PI
Number in Model	Adjusted R-Square	R-Square	C(P)	AIC	SBC	Variables in Model
5	0.8710	0.8724	6.0000	-1116.67	-1091.78	LH SL FI RI PI

Sub Set 5.3: Potential Good models by Best Subsets:

The first potential good model is

$\hat{y} = 0.24887 + 0.90790\ x_1 + 0.05139x_{2.}$

Equation 6-7 First potential good model by subset method

The maximum variance inflation factor for each variable are not greater than 5 and average (VIF) = 1.27598 is not bigger than 1. Therefore mulitcollinearity is not a problem.

Table 6-24 First potential model by Subset method

Parameter Estimates							
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|	Tolerance	Variance Inflation
Intercept	1	0.24	0.15	1.64	0.1009		0
LH	1	0.50	0.01	48.33	<.0001	0.78	1.27
SL	1	0.05	0.01	2.80	0.0054	0.78	1.27

The second potential good model is

$\hat{y} = 0.19764 + 0.90445\ x_1 + 0.04035x_2 + 0.02159\ x_{4.}$

Equation 6-8 Second potential good model by subset method (Model 4)

The maximum variance inflation factor for each variable are not greater than 5 and average (VIF) = 1.33794 is not bigger than 1. Therefore mulitcollinearity is not a problem. But this model has an insignificant predictor, so it cannot be a candidate.

Table 6-25 Second potential model by Subset method

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|
Intercept	1	0.19	0.15	1.28	0.2018
LH	1	0.90	0.01	47.89	<.0001
SL	1	0.04	0.01	2.05	0.0405
RI	1	0.02	0.01	1.57	0.1164

Best Models:

Model 1: $\hat{y} = 0.46185 + 0.93233\ x_1$ (from stepwise Equation 6-8 and backward deletion method Equation 6-5)

Model 2: $\hat{y} = 0.24887 + 0.90790\ x_1 + 0.05139 x_2$ (from best subsets method Equation 6-7)

Model Selection:

Model 1: Model with logistic handling (Equation 6-5 and Equation 6-8)

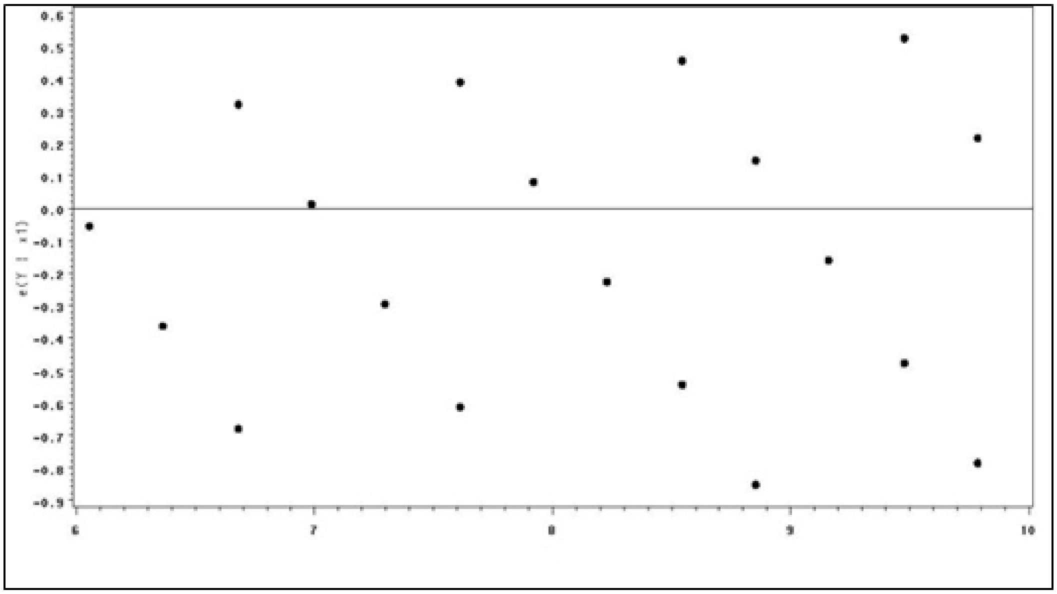

Figure 6-18 Model 1 residual Plot

There is no funnel shape indicating the variance is constant

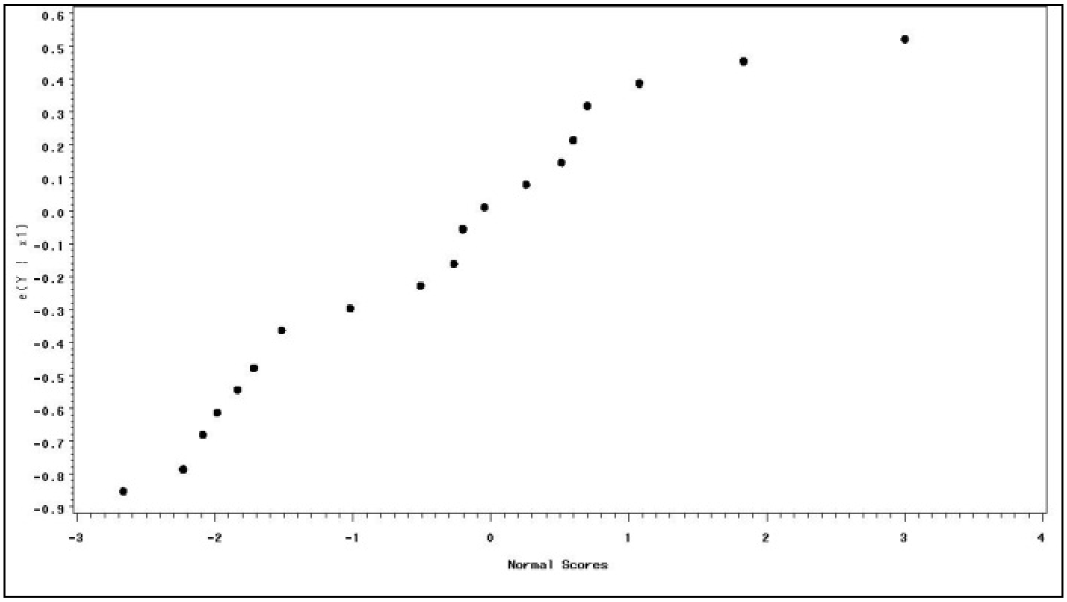

Figure 6-19 Model 1 normality plot

Normal plot has right tail. Normality might be reasonable.

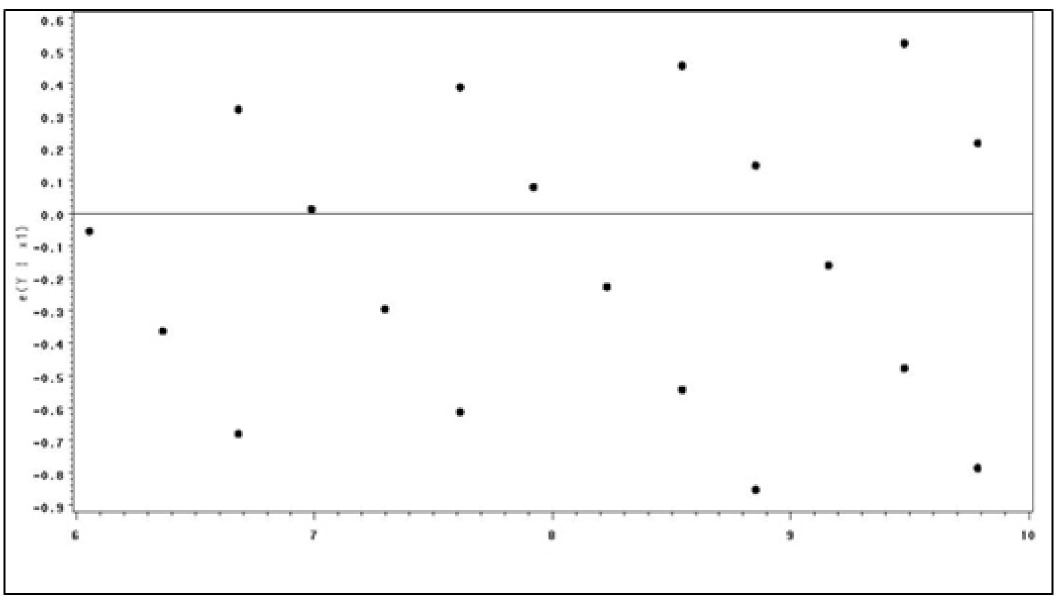

Figure 6-20 Model 1 residuals plot 1

There is no curvature indicating current MLR form may be reasonable. There are no x or y outliers

Table 6-26 Model 1

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	285.74	285.74	3097.23	< .0001
Error	466	42.99	0.09		
Corrected Total	467	328.74			
Root MSE		0.30	R-Square	0.87	
Dependent Mean		7.75	Adj R-Sq	0.87	
Coeff Var		3.91			

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|	Variance Inflation
Intercept	1	0.46	0.13	3.50	0.0005	0
LH	1	0.93	0.0.16	55.65	<.0001	1.0000

Y – Outlier:

Cut off values for the y outlier $t\left(\left(1-\frac{\alpha}{2n}\right), n-p-1\right)$ = t (.9998931624, 466) = 3.73169. The $|t_i|$ values greater than 3.73169 are considered as the y outlier. None of the $|t_i|$ values are greater than the cutoff value 3.73195 indicating they are no y outliers.

The leverage value (the highest h_{ii} value) is 0.042413.

X – Outlier:

To check the x-outliers the h_{ii} values should be less than $\frac{2p}{n}$ = ((2*1)/468) = 0.0042735.

Values h_{ii} at observations 87, 94, 99, 101, 107, 109, 110, 111, 118, 190, 220, 261, and 425 are greater than 0.042413. This clearly indicates the values at these observations are x outliers.

Inflation

The cutoff values for the DFBETAS is 2/(sqrt n) = 2/(sqrt (468)) =0.092450033. DFBETAS for all the variables at the outliers are lesser than the cutoff values at these observations. This shows that the observations at the x outliers are not influential.

DFFITS

The cutoff values for the DFFITS is 2(sqrt (p/n)) = 2(sqrt (2/468)) = 0.13074409. DFFITS for all the variables at the outliers are lesser than the cutoff values at these observations. This indicates that the observations at the x outliers are not influential.

Cooks Distance

If the d_{ii} > F (.50, 1,466) it indicates that the outliers are influential. But from the SAS output it is clear that is not the case indicating that the outliers are not influential.

Variance Inflation

Since max $(VIF)_k$ 1< 5 and average (VIF) = 1 is equal to 1, conclude that serious multicollinearity is not a problem.

Model 2: Model with LH and SL (Equation 6-7)

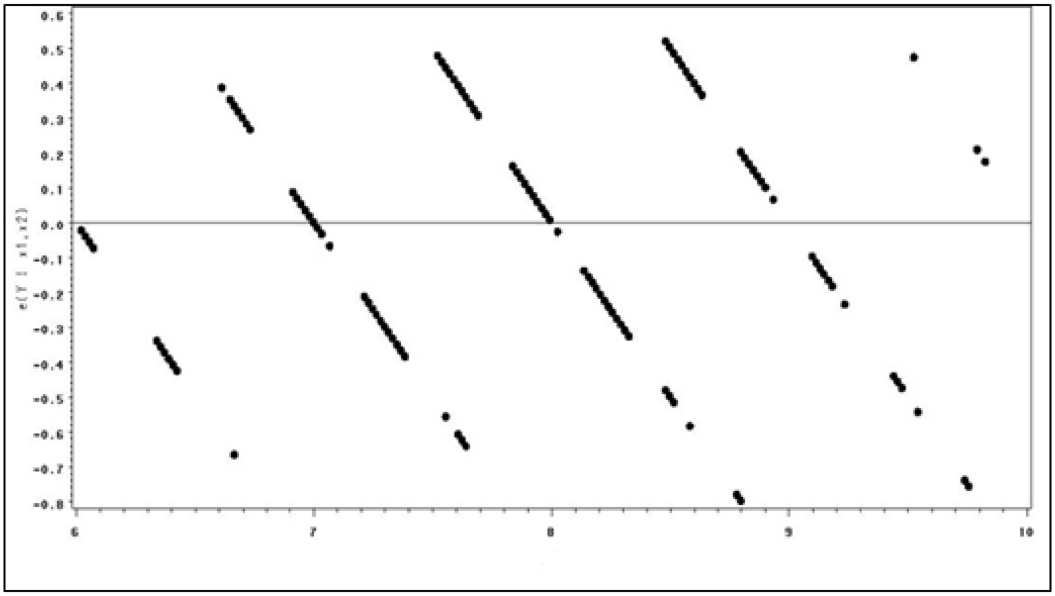

Figure 6-21 Model 2 residual Plot

There is no funnel shape indicating the variance is constant

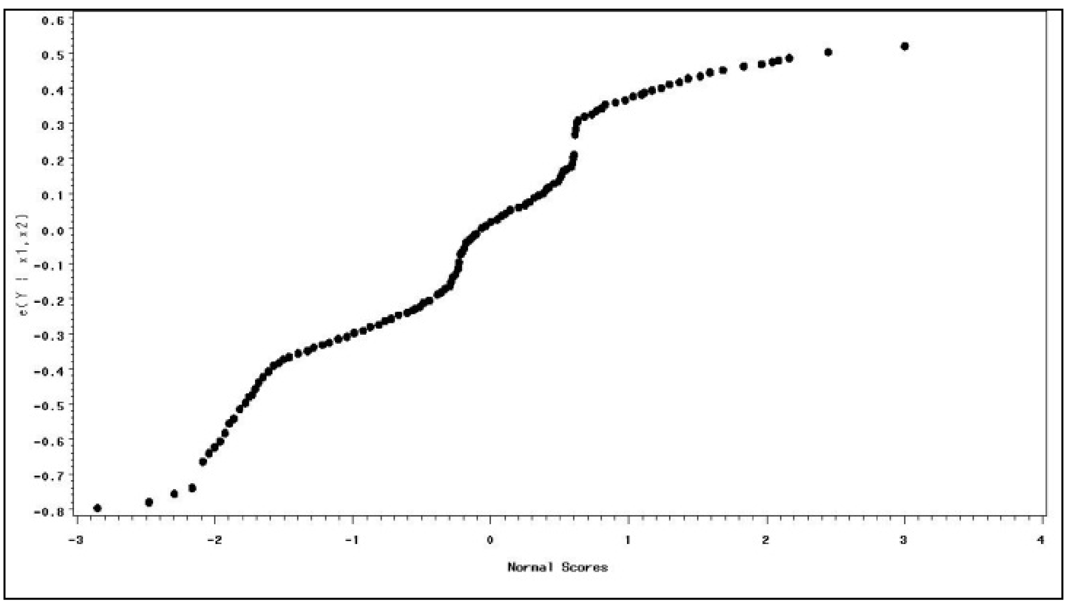

Figure 6-22 Model 2 normality plot

Normal plot has right tail. Normality is violated

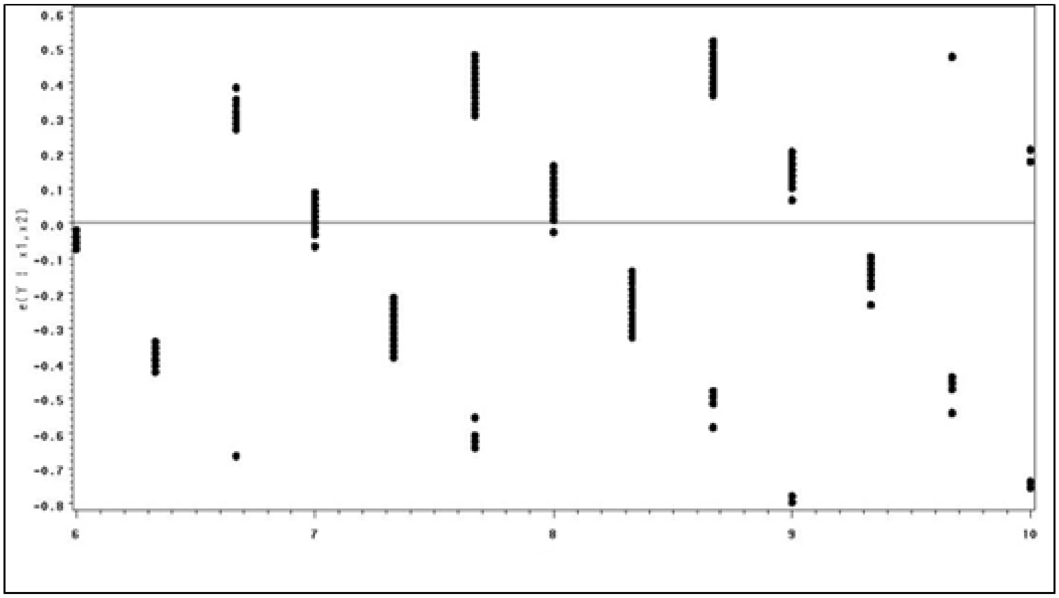

Figure 6-23 Model 2 residual plot 1

There is no curvature indicating current MLR form may be reasonable. There are no x or y outliers

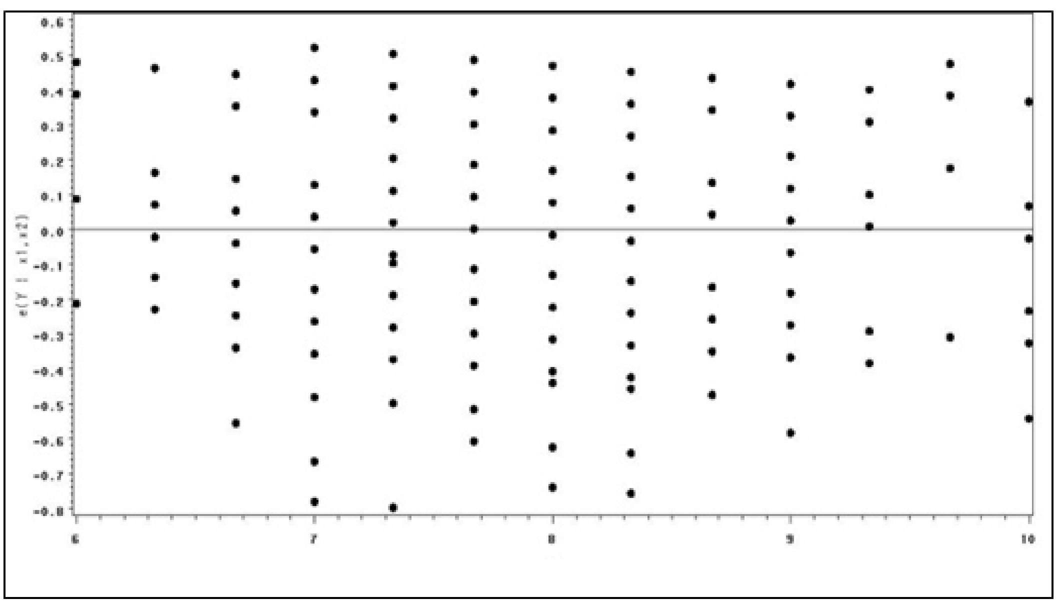

Figure 6-24 Model 2 residual plot 2

There is no curvature indicating current MLR form may be reasonable. There are no x or y outliers

Table 6-27 Model 2

Analysis of Variance						
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	
Model	2	286.45	143.22	1575.18	< .0001	
Error	465	42.99	0.09			
Corrected Total	467	328.74				
Root MSE		0.30	R-Square	0.87		
Dependent Mean		7.754	Adj R-Sq	0.87		
Coeff Var		3.88				
Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|	Variance Inflation
Intercept	1	0.24	0.15	1.64	0.1009	
LH	1	0.90	0.01	48.33	<.0001	0.78
SL	1	0.05	0.01	2.80	0.0054	0.78

Y – Outlier:

Cut off values for the y outlier $t\left(\left(1-\frac{\alpha}{2n}\right), n-p-1\right)$ = t (.9998931624, 465) = 3.73176. The $|t_i|$ values greater than 3.73169 are considered as the y outlier. None of the $|t_i|$ values are greater than the cutoff value 3.73195 indicating they are no y outliers.

X - Outlier:

The leverage value (the highest h_{ii} value) is 0.042413.

To check the x-outliers the h_{ii} values should be less than $\frac{2p}{n}$ = ((2*2)/468) = 0.008547.

Values h_{ii} at observations 7, 38, 51, 56, 83, 122, 149, 168, 198, 218, 239, 241, 342, 357, 382, and 418 are greater than 0.042413. This clearly indicates the values at these observations are x outliers.

Inflation

The cutoff values for the DFBETAS is 2/(sqrt n) = 2/(sqrt (468)) =0.092450033. DFBETAS for all the variables at the outliers are lesser than the cutoff values at these observations. This shows that the observations at the x outliers are not influential.

DFFITS

The cutoff values for the DFFITS is 2(sqrt (p/n)) = 2(sqrt (2/468)) = 0.13074409. DFFITS for all the variables at the outliers are lesser than the cutoff values at these observations. This indicates that the observations at the x outliers are not influential.

Variance Inflation

Since max $(VIF)_k$ 1.27598< 5 and average (VIF) = 1.27598 is less than 1, conclude that serious multicollinearity is not a problem.

Model comparison:

Table 6-28 various models

Model No	C	Independent Variable					Error Value	R^2
		LH	SL	FI	RI	PI		
1 (Equation 6-2)	0.13	0.89	0.03	0.02	0.01	0.009	0.0908	0.8724
2(Equation 6-3)	0.15	0.89	0.03	0.02	0.01		0.0906	0.8723
3(Equation 6-4)	0.19	0.90	0.04		0.02		0.0906	0.0906
4(Equation 6-5)	0.24	0.90	0.05				0.0922	0.8692
5(Equation 6-6)	**0.46**	**0.93**	**[Chosen Model]**				**0.0909**	**0.8714**

The variations between the two potential models are minimal. The chosen model is one with the variable LH. This model is has less number of x outliers. The r square is also higher which is desired. Also the slope for the predictor variable (LH) of the chosen model is higher than the slope of the other models predictor variables (LH and SL). This indicates that the predictor variable LH in the chosen model has more impact than the predictor variables LH and SL together on the EAC. Therefore the chosen model is

$$\hat{y} = 0.46185 + 0.93233\ x_1$$

Equation 6-9 Final Model

Phase 2 Outcomes

The model representing the significance effect is identified and shown in the Equation 6-1. The ranks in which the independent variables affect the dependent variable are shown in the Table 6-9. The model with the better predictor variable is shown in the Table 6-28.

Phase 3: Specific aim 3

Step 6

Scenario 1: 0 – 50 % accuracy

This is a current accuracy, so there is no requirements for any implementation indicating there is no investment and hence no NPV value.

Scenario 2: 50 – 75 % accuracy

Table 6-29 Scenario 2 initial investment

Equipment’s	Cost ($)
RFID readers and antennas	310,000
Tags	80,000
Implementation	200,000
Labor cost	300,000
Total Cost	890,000

Table 6-30 Scenario 2 Five years cash flow

Year	All Cash Out ($)	All Cash In ($)	Net Cash Flows ($)
Year 0	890,000		
Year 1	0.00	250,000	250,000
Year 2	0.00	250,000	250,000
Year 3	0.00	250,000	250,000
Year 4	0.00	250,000	250,000
Year 5	0.00	250,000	250,000

The initial investment in this scenario is 890,000 $. The detail split is provided in the Table 6-29. The cash flow for 5 years is provided in the Table 6-30. The required annual rate of return is 12%. The NPV is calculated as $11,194.05 using the NPV formula. The NPV value profile is provided in the Table 6-31.

Table 6-31 Scenario 2 NPV Analysis

NPV Profile		
Annual Rate of Return (Discount)	+ NPV: Accept	-NPV: Reject
5%	192,369	
6%	163,091	
7%	135,049	
8%	108,178	
9%	82,413	
10%	57,697	
11%	33,974	
12%	11,194	
13%	-10,692	-10,692
14%	-31,730	-31,730
15%	-51,961	-51,961
16%	-71,427	-71,427
17%	-90,163	-90,163
18%	-108,207	-108,207
19%	-125,591	-125,591
20%	-142,347	-142,347
21%	-158,504	-158,504
22%	-174,090	-174,090
23%	-189,132	-189,132
24%	-203,654	-203,654
25%	-217,680	-217,680

Scenario 3: 75 – 100 % accuracy

The initial investment in this scenario is 1190000 $. The detail split is provided in the Table 6-32. The cash flow for 5 years is provided in the Table 6-33. The required annual rate of return is 14%. The NPV is calculated as $71,671.67 using the NPV formula. The NPV value profile is provided in Table 6-34.

Table 6-32 Scenario 3 initial investment

Equipment's	Cost($)
RFID readers and antennas	500,000
Tags	100,000
Implementation	250,000
Labor cost	340,000
Total Cost	1,190,000

Table 6-33 Scenario 3 Five years cash flow

Year	All Cash Out ($)	All Cash In ($)	Net Cash Flows ($)
Year 0	-1,190,000		
Year 1	0.00	350,000	350,000
Year 2	0.00	350,000	350,000
Year 3	0.00	350,000	350,000
Year 4	0.00	350,000	350,000
Year 5	0.00	350,000	350,000

Table 6-34 Scenario 3 NPV Analysis

NPV Profile		
Annual Rate of Return (Discount)	+ NPV: Accept	-NPV: Reject
5%	325,317	
6%	284,327	
7%	245,069	
8%	207,449	
9%	171,378	
10%	136,775	
11%	103,564	
12%	71,672	
13%	41,031	
14%	11,578	
15%	-16,746	-16,746
16%	-43,997	-43,997
17%	-70,229	-70,229
18%	-95,490	-95,490
19%	-119,828	-119,828
20%	-143,286	-143,286
21%	-165,905	-165,905
22%	-187,726	-187,726
23%	-208,784	-208,784
24%	-229,115	-229,115
25%	-248,752	-248,752

The NPV analysis for the different accuracy scenarios is given in Table 6-35. The scenarios can be chosen based on the business requirements.

Table 6-35 NPV values for different economic scenarios

Scenario (Accuracy range)	NPV Value ($)	Investment $	Savings
0 – 50 %	N/A	N/A	N/A
50 – 75 %	11,194.05	890,000	145000
75 – 100 %	71,671.67	1,190,000.00	310000

Phase 3 Outcomes

The NPV value for the each scenario along with the savings was identified (Table 6-35)

Final results

Table 6-36 Final Multiple Linear Regression Model

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	285.74	285.74	3097.23	< .0001
Error	466	42.99	0.090		
Corrected Total	467	328.74			
Root MSE		0.30	R-Square	0.8714	
Dependent Mean		7.75	Adj R-Sq	0.8708	
Coeff Var		3.91			

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t value	Pr > |t|	Variance Inflation
Intercept	1	0.46	0.13	3.50	0.0005	0
LH	1	0.93	0.0.167	55.65	<.0001	1.0000

The intercept 0.4618 indicates the value of the EAC when the rating for LH and 0.

The slope 0.93233 indicates the increase in EAC when there is a unit increasing in the LH.

The r square is .8692 which is close to 1 indicating that the model is reasonable.

Joint C.I.'s for parameters β_1

b_1 = .93233 s $\{b_1\}$ = 0.01675

At α = 10

B=t(1- α/2g;n-p) = t(1-.10/2(1);468-2) = t (.95,466) = 1.64813

C.I for β1 = 0.93233 ± (1.64813*.01675) = (0.9599, 0.9047)

With confidence coefficient of 0.90, we can conclude that the slope accuracy lies between the 0.9599 and 0.9047.

Inferences for x_h

We are interested to find out the mean response of EAC at which the LH is at its highest values. We chose the following value because the LH score is highest,

EAC	LH
10	10

Confidence Interval (C.I) at x_h:

CI is (9.2387, 9.8374). 90% confidence interval for the EAC was developed with the lower limit 9.2387 and upper limit 9.8374.

Confidence Band

W= $\sqrt{p * F(1-\alpha, p, n-p)}$ = $\sqrt{2 * 2.314}$ = 4.628

F(.9, 2, 466) = 2.314

Two sided confidence band is (7.6233, 10.4624) 90% prediction interval for the EAC was developed with the lower limit 7.6233 and upper limit 10.4624.

Prediction Interval (P.I)

PI is (8.9317, 9.9374). 90% prediction interval for the EAC was developed with the lower limit 8.9317 and upper limit 9.9374.

Chapter 7

Limitations

The variables are identified in this research may not be applicable for all types of industries. And also further analysis required using cluster method and statistical quality approach. There are also other variables affects the accuracy. The data used here are observed values, but in reality the accuracy may vary from the observed values. The design and implementation issues are not considered in this research. They might affect the results as well

The economic analysis is done only using only one product line. Adding additional product line may alter the results. Furthermore some of the data used are simulated due to the restricted access and may vary when using the real data

Chapter 8

Results

Overview

The conclusion for the each specific aim and what conclusion can be obtained are provided in this section. The results from the Phase 1 are provided in the Table 8-2. The results from the Phase 2 are presented in Table 8-3 and Table 8-4. The results from the phase 3 are shown in the Table 8-4.

Research question 1: What is the observed perspective of impact of auto id on ERP system?

Specific aim 1: Questionnaire development

Hypothesis 1:

From the Table 8-2 it is clear that the parameter estimates for the independent variable LH is 0.88616 and is not equal to zero. Therefore the null hypothesis is rejected. Rejecting the null hypothesis indicates that the dependent variable should be considered in the model for predicting the dependent variable EAC.

Reject the null hypothesis: The independent variable x_1 has no impact of the dependent variable at α level 0.05

Hypothesis 2:

From the Table 8-2 it is clear that the parameter estimates for the independent variable SC is 0.03095 and is not equal to zero. Therefore the null hypothesis is rejected. Rejecting the null hypothesis indicates that the dependent variable should be considered in the model for predicting the dependent variable EAC.

Reject the null hypothesis: The independent variable x_2 has no impact of the dependent variable at α level 0.05

Hypothesis 3:

From the Table 8-2 it is clear that the parameter estimates for the independent variable FI is 0.02330 and is not equal to zero. Therefore the null hypothesis is rejected. Rejecting the null hypothesis indicates that the dependent variable should be considered in the model for predicting the dependent variable EAC.

Reject the null hypothesis: The independent variable x_3 has no impact of the dependent variable at α level 0.05

Hypothesis 4:

From the Table 8-2 it is clear that the parameter estimates for the independent variable RI is 0.01559 and is not equal to zero. Therefore the null hypothesis is rejected. Rejecting the null hypothesis indicates that the dependent variable should be considered in the model for predicting the dependent variable EAC.

Reject the null hypothesis: The independent variable x_4 has no impact of the dependent variable at α level 0.05

Hypothesis 5:

From the Table 8-2 it is clear that the parameter estimates for the independent variable PI is 0.009932 and is not equal to zero. Therefore the null hypothesis is rejected. Rejecting the null hypothesis indicates that the dependent variable should be considered in the model for predicting the dependent variable EAC.

Reject the null hypothesis: The independent variable x_5 has no impact of the dependent variable at α level 0.05

Table 8-1 Independent Variables with ERP modules

Variables	Variables Description	Variables definition	ERP Module
LH	Logistic hand	Logistics handling includes tracking, locating, managing the movements and storage of the inventory	Sales and distribution, Warehouse management, and Logistics control
SL	Storage location	Storing the inventory in invalid locations	Sales and distribution and Warehouse management
FI	Finished good products inventory	The invalid quantity various Finished good products	Sales and distribution, financial and Warehouse management
RI	Raw materials inventory	The invalid quantity various Raw materials	Sales and distribution, financial and Warehouse management
PI	Package materials inventory	The invalid quantity various Package materials	Sales and distribution, financial and Warehouse management

Specific aim 2: Evaluate Perceived impact of the RFID on the ERP data accuracy

Hypothesis 6:

From the Table 8-2 it is clear that each independent variable has different effect on the dependent variable EAC. This indicates that the ERP data accuracy is indeed affected differently by the independent variable.

Reject the null hypothesis: All the dependent variables ($x_{1,}$ x_2, x_3, x_4, x_5) has the same effect on the independent variable at α level 0.05

Table 8-2 Description of the relevant variables

S.No	Variables	Variables Description	Independent Variables	P Value	Effect on dependent variable (Ranking)
1	LH	Logistic hand	*0.89616*	<.0001	First – The highest significant variable
2	SL	Storage location	*0.03095*	0.1574	Second – The second highest significant value
3	FI	Finished good products inventory	*0.02330*	0.3910	Fourth – The second lowest significant
4	RI	Raw materials inventory	*0.01559*	0.2052	Third – Medium significant
5	PI	Package materials inventory	*0.00993*	0.6445	Fifth – The lowest significant

From further analysis a better predictor model for the dependent variable is identified (Equation 6-9). According to this model the dependent LH is the most contributing factor in predicting the dependent variable EAC behavior. This suggests that the method or the system employed in the material handling affects the accuracy of the ERP data. The EAC can be improved by implementing a robust logistics handling systems like RFID system and various other systems. Employing the RFID as logistics handling system also provides additional advantage like live inventory update, storage location identification, can monitor environment conditions required for certain products, etc.

Table 8-3 various models

Model No	C	Independent Variable					Error Value	R^2
		LH	SL	FI	RI	PI		
1 (Equation 6-2)	0.13	0.89	0.03	0.02	0.01	0.009	0.0908	0.8724
2(Equation 6-3)	0.15	0.89	0.03	0.02	0.01		0.0906	0.8723
3(Equation 6-4)	0.19	0.90	0.04		0.02		0.0906	0.0906
4(Equation 6-5)	0.24	0.90	0.05				0.0922	0.8692
5(Equation 6-6)	**0.46**	**0.93**	**[Chosen Model]**				**0.0909**	**0.8714**

Research question 2: Does the Auto ID technology have an economic impact on the ERP system data accuracy?

The economic selection criteria for the different level of accuracy are given in the Table 8-4. The current scenario does not need any investment and also there is no savings either. The scenario 2 and 3 both has positive NPV values. Hence both the scenario can provide savings. The project can be selected based on the accuracy requirements.

Table 8-4 NPV values for different economic scenarios

Scenario (Accuracy range)	NPV Value ($)	Investment $	Savings
0 – 50 %	N/A	N/A	N/A
50 – 75 %	11,194.05	890,000	145000
75 – 100 %	71,671.67	1,190,000.00	310000

Chapter 9

Contributions to the body of knowledge

The primary aim of this researcher in this study is to evaluate the impact of RFID on the ERP data accuracy from new perspective. So far most of the studies involve implementing the RFID with ERP system and evaluating its performance. In this study the researcher focus on the impact on the ERP data rather than the performance of the RFID and ERP interface. The researchers also identify which warehouse data affects the ERP data accuracy. The survey conducted helps to identified that the logistics handling impact the ERP data accuracy in a significant way. This provides a base line to improve the ERP data accuracy by improving the logistics handling.

Chapter 10

Relations to the classes taken

Multiple Linear Regressions (IE 5318 – Advanced Engineering Statistics) – Provided the knowledge to perform the regression analysis and other statistics calculations.

Tracking (IE 5300 - Radio Frequency Identification Automation) - Enabled the understanding of Automatic Data Capture (ADC) technology that supports tracking inventory from a reliability point.

Technology Development (IE 5346 – Technology Development and Deployment) - Enabled the understanding of management issues in developing and implementing new technologies and methodologies into an organization that supports tracking inventory reliably.

Inventory Control (IE 5329 – Production and Inventory control systems) – Provided the knowledge that required to understand the inventory systems and policies.

Economic (IE 5304 – Advanced Engineering Economics) – Provided the knowledge about economics that required to perform the economic analysis.

Chapter 11

Future Research

Future research is to develop the interface between the RFID and ERP system and evaluate it. It is evaluated by comparing the accuracy and reliability of the data entered into the ERP system by the manual entry, barcode and RFID. In manual entry method the data are entered into the ERP system using different personnel for each trial. The personnel chosen will be having various experience levels and different age groups. In the barcode method, the inventories are tracked using the barcode. The ERP system will be integrated with barcode reader and as the product is read by the barcode scanner the data are captured and entered into the ERP system directly. In the RFID methodology, instead of barcode, RFID will be used. The experiment is repeated with different volume of inventories, different product, sizes and types, and different intervals of time.

Appendix

Survey

(1 being the lowest and 5 being the highest)

01. RFID captured data will improve data accuracy for shipping

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

02. RFID captured data will improve data accuracy for receiving

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

03. RFID captured data will improve data reliability for shipping

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

04. RFID captured data will improve data reliability for receiving

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

05. RFID captured data provide accurate inventory storage location

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

06. RFID provide much more efficient way to identify the storage location

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

07. Bin numbers tagged with SKU numbers by using RFID is more reliable

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

08. RFID makes the locating the products more easier

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

09. The raw material inventory captured by the RFID is more accurate

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

10. The raw material inventory captured by the RFID is more reliable

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

11. The raw material can be easily identified using RFID

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

12. The raw material can be easily located using RFID

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

13. The Finished good inventory captured by the RFID is more accurate

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

14. The Finished good inventory captured by the RFID is more reliable

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

15. The Finished good can be easily identified using RFID

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

16. The Finished good can be easily located using RFID

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

17. The Packaging material inventory captured by the RFID is more accurate

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

18. The Packaging material inventory captured by the RFID is more reliable

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

19. The Packaging material can be easily identified using RFID

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

20. The Packaging material can be easily located using RFID

1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree

21. Based on your selections how accurate the ERP data do you think would be? (Between 1 -100 percentage) ___________

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