The Impact on Inventory with the Implementation of RFID into SCOR based ERP Modules

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***Abstract* – Many ERP systems on the market today follow some of the same guidelines based on the SCOR model. Through the various modules in each ERP system, they implement the different aspects of the model in Plan, Source, Make, Deliver, and Return. Many of the activities in these systems are manual and prone to data entry mistakes forcing the system to be less reliable than it could be. RFID is a technology that has been used to reduce these errors and increase the speed at which the data is obtained and implemented in the system. It is hypothesized that by implementing RFID into specific components used in the modules in the ERP system that the technology will have an impact on the inventory value. The expected results are that a clearer understanding of how RFID affects the SCOR components utilized in ERP systems will be seen through a reduction in inventory values.**

***Keywords* –** *RFID, ERP, SAP, SCOR Model, EOQ Model*

1. Introduction

Radio Frequency Identification (RFID) is seen as a technological solution to solving multiple problems. It is used in real time locating systems (RTLS) as a method of locating an object spatially and in Auto Identification systems (Auto-ID) as a manner in which items are uniquely identified. Though this may sound as a trivial use for the technology, it can be assumed by the interest shown in the technology by industry and government that these two solutions are a result of significant financial hardship. This is more visible when evaluating the amount of time that is exhausted in searching for items, in counting and identifying items, or in dealing with data entry errors from manual manipulation of the system.

ERP systems, since the late 1980's, have been developed around the SCOR model of Plan, Source, Make, Deliver, and Return. Many of the tasks that need to be performed in an ERP system are manual labor intensive. These tasks include accepting and entering an order into the system, procurement and production planning, and kitting and shipping of completed items. The speed at which this information is entered into a system is slow and prone to contain mistakes when manual entry is used. Though the use of other types of technology, such as barcoding, can reduce the number of errors introduced into the system, they still require manual manipulation of product so that items can be identified [12]

The aim of this paper is to evaluate the possible impact of RFID on the inventory when RFID is implemented into a SCOR based ERP system. In order to achieve this, key areas of an ERP will be identified that could integrate with RFID technology. Upon identification of these areas, a trial will be run based on the SAP Sales and Distribution (SD), Production Planning (PP), and Warehouse Management (WM) modules in order to validate the areas that could be impacted by RFID. The paper will also look at the multi-part EOQ model and how the set of data is affected by changes in order frequencies. It is posited that an RFID enabled system will allow for quicker responses to changes in demand and consumption. Based on this premise and the existing literature, it is expected that by changing the order frequencies, the on hand inventory values will change as well. This is commonly referred to as the inventory turns metric and will be utilized as a component of the test metric in this paper.

The remainder of this paper will be organized in the following manner. In the Background Section, previous and related work will be discussed on RFID and its uses as well as how the SCOR model has been integrated into ERP systems. The Methodology Section will discuss the actual process used in the paper to query the hypotheses. The Results Section discusses the expected results of the paper and the limitations of the research while the Conclusion wraps up the paper and identifies the next steps.

2. Background

The reasons to use RFID technology are widely discussed in literature. It can be seen in multiple sources that RFID can speed up the time in which items are

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identified [11]-[16] where items may be located [2]-[3] or how items have been treated in the supply chain [14]. With real-time data provided by Auto-ID, the forecast will be more accurate and demand planners will not have to create extra buffers to ward off uncertainty [1].

There are many reasons why RFID would be implemented into an ERP system. In many systems, the data that is fed into the model is collected and posted at specified times during the shift resulting in less than optimal decisions made during the workday. MRP/ERP systems generally run their planning operations at set intervals, such as at night when the operation is closed, on a reduced shift, or over a weekend. If a large order was processed or a bad quality lot was identified, the data needed to make an appropriate decision may not be available until a later point in time or the decision may have to be made based on activities outside of the system. Depending on the severity of the change in inventory availability, the company may be forced to expend additional resources to try and resolve the issue. The data update's impact on the inventory model is expressed in Jones' article which discusses how the "EOQ can be categorized in two ways: as a periodic review system or as a continuous review inventory system. Which system is used depends on how often you get the information and how often you can order." [6] Even more information may be needed if the inventory is hard allocated to specific projects or contracts. The need for this type of information and the increased speed at which the information has to be ascertained drives the need for a company to know an item's instantaneous status, the processes it has been through, and the history of its transactions and movements. [16]

One tool that has been implemented with success in providing instantaneous information is RFID. RFID allows its users to read data at a faster rate than manual processes with an expected higher accuracy. In work done by Poon, et al, they found that a manual process took 103 seconds to count items that needed action. After setting up the same facility with an RFID system, they were able to obtain the same information in 2 seconds with a higher accuracy. [8] According to Saygin, individual items can be tagged to allow item level tracking, monitoring, and identification. [11] This would allow items and lots to be monitored for use and movement. This also provides the real time awareness that makes more informed decisions possible.

Lee and Ozur showed in their work how the system benefited from RFID with a decrease in inventory adjustments and a lower average inventory. [7] Because of this information and the use of the inventory models such as the Q, r model, order frequencies can be increased while batch quantities are decreased. It is theorized that this should provide a decrease in costs due not necessarily to labor savings, but due to the inventory quantities allowed to decrease. These statements are visually denoted in Figure 1.

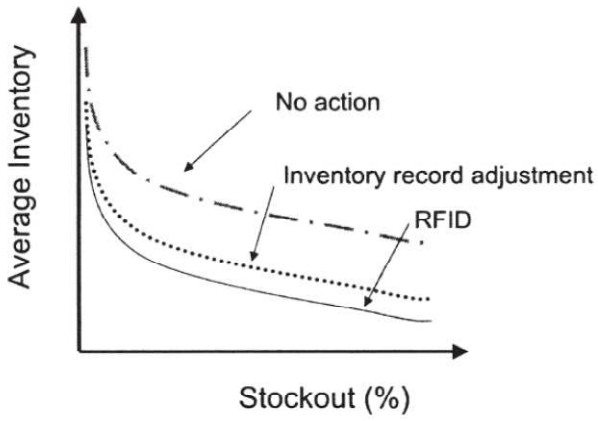

Figure 1 Impact of RFID on Average Inventory and Stockout [6]-[7]

Since the majority of costs to a manufacturer are typically tied up in inventory, the labor savings normally allocated as an increase in indirect labor could be simultaneously decreased due to inventory accuracies. Bose and Pal show this in their research as well when they state that the accuracy of operation, asset utilization, and inventory carrying costs can be improved through the tracking and monitoring functions associated with Auto-ID. [1] They showed where RFID would affect specific supply chain operations as seen in Figure 2.

Performance attribute	Customer-facing			Internal-facing		Direct effect of Auto-ID
	Reliability	Responsiveness	Flexibility	Costs	Assets	
Delivery performance	X					Y
Fill rate	X					Y
Perfect order fulfillment	X					Y
Order fulfillment lead time		X				Y
Supply chain response time			X			Y
Production flexibility			X			N
Supply chain management cost				X		Y
Cost of goods sold				X		Y
Value-added productivity				X		Y
Warranty cost or returns processing cost				X		Y
Cash-to-cash cycle time					X	Y
Inventory days of supply					X	Y
Asset turns					X	Y

Figure 2 How Auto-ID Affects Supply Chain Operations [1]

3. Methodology

3.1 SAP Modules and the SCOR Model

To evaluate the impact of RFID on inventory in an ERP system a sample must be run through an ERP system. For this experiment, SAP's SD, PP, and WM modules have been selected to perform the evaluation. These modules are based on SAP's Global Bike Inc. case study that takes the user through the basic functions in SAP. In this study, one run is performed in order to validate where it is believed that RFID will have an impact. These locations in SAP will be identified through the use of the case study. Times for how long the user spent interfacing with the ERP will be determined based on the SCOR components. The SCOR components, their corresponding SAP module components, and the locations where RFID would benefit the process are shown in Tables 1, 2, and 3.

Table 1 SCOR components for SAP SD module

SCOR	SCOR Component	SAP SD Model	RFID Enabled?
Plan	sEP.1	Create new customer	
Plan	sEP.1	Create contact person	
Plan	sEP.1	Change customer	
Deliver	sD2.1	Create customer inquiry	
Deliver	sD2.1	Create customer quotation	
Deliver	sD2.2	Create sales order referencing a quotation	
Source	sES.4	Check stock status	
Plan	sEP.1	Display sales order	
Deliver	sD2.3	Start delivery process	X
Source	sES.4	Check stock status	X
Deliver	sD2.9	Pick materials on delivery note	X
Deliver	sD2.12	Post goods issue	X
Deliver	sD2.15	Create invoice for customer	X
Deliver	sD2.11	Display billing document and customer invoice	X
Deliver	sD2.15	Post receipt of customer payment	
Deliver		Review document flow	

Table 2 SCOR components for SAP PP module

SCOR	SCOR Component	SAP PP Model	RFID Enabled?
Plan	sP3.4	Display stock/requirements list	X
Plan	sEP.7	Display Bill of Materials	
Plan	sEP.7	Display multi-level Bill of Materials	
Plan	sEP.7	Display routing	
Plan	sEP.7	Display routing/BOM in engineering workbench	
Plan	sEP.7	Display work center	

Table 3 SCOR components for SAP WM module

SCOR	SCOR Component	SAP WM Model	RFID Enabled?
Source	sS2.1	Create a PO	
Source	sES.4	Display material inventory	
Source	sES.4	Display material inventory value	X
Source	sS2.2	Receive goods	X
		Run bin status report	
Source	sS2.4	Create transfer order	
		Confirm transfer order	

3.2 RFID and the Q, r Model

The effects of RFID on the inventory will be validated by using the multiproduct Q, r model as seen in Hopp and Spearman's *Factory Physics*. [4]

The Q, r model that will be used is the multipart stockout model. The stockout model was selected for evaluation though similar results were expected using the backorder model. The source taken from Hopp and Spearman represents four parts with differing demands and costs as is seen in Table 4. [4]

Table 4 Input Data for Multiproduct Q, r Model [4]

Part $_j$	D_j	c_j	h_j	ℓj (days)	θj (units)	σj (units)
1	1,000	100	100	60	164.4	12.8
2	1,000	10	10	30	82.2	9.1
3	100	100	100	100	27.4	5.2
4	100	10	10	15	4.1	2.0

Table 5 Notations and Definitions defines the variables used in this paper. These notations are from Hopp and Spearman's *Factory Physics* and are used for Tables 4, 5, 7, 8, and 9. [4]

Table 5 Notations and Definitions [4]

Notation	Definition
D_j	annual demand for part j
c_i	unit cost for part j
h_j	holding cost for part j
ℓ_j	leadtime for part j
θ_i	expected demand for part j during the leadtime
σ_j	standard deviation of the expected demand for part j during the leadtime
Q_i	economic order quantity for part j
k	penalty cost to make the average fill rate 95%
r_i	replenishment quantity for part j
F_j	order frequency for part j
S_i	fill rate for part j
B_i	backorder level for part j
I_j	inventory level in dollars

The multipart stockout model used in Hopp and Spearman's book showed the results of the model with a frequency of 12 times per year, or inventory turns of 12 turns per year. Since it is believed that the use of RFID will allow for quicker responses to inventory, calculations for the Q, r stockout model will be performed for inventory turns of 15 and 18 turns per year to show what the resulting inventory costs will be on the same four parts given in Table 4. In this evaluation, the k value used is a constant of 7.213 in order to make the fill rate for a frequency of 12 turns per year equal to 95%. [4]

In this study, the null hypothesis is that an implementation of RFID into a SCOR based ERP system will not create an impact on inventory. From this null hypothesis, two alternatives can be created. The first alternative, H_1, is that RFID will have a beneficial impact on the inventory. The second alternative, H_2, is that RFID will have a detrimental impact on inventory. Evaluation of the hypotheses will be through the inventory value on hand and how it is affected by the number of inventory turns.

4. Results

4.1 SD Module

Though much of the SD module in SAP is handling customers and customer orders, there are several components in the module that benefit from RFID. The first component that would benefit from RFID is the check stock status which allows the user to verify stock availability for a customer order. RFID allows for real time data on product position and condition. This up-to-date information allows companies to make quicker decisions on procurement and distribution of items. The next component, the start delivery process, allows the user to update customers when orders become ready. A third component is the current information on order processing status which allows companies to make decisions about which orders to ship or hold. RFID speeds up the pick materials process by allowing materials to be issued to orders automatically. Depending on the complexity of the system, information such as item numbers and serial numbers can be automatically linked to customer orders. This not only aides in the initial issue to an order, but it also provides traceability in the system for repairs and compliance to regulations.

4.2 PP Module

The PP module in SAP is mainly concerned with setting up the processes for planning production of the items in the system. As can be seen in Table 2, there is little direct impact on the ERP system from RFID. The module is often used by an Industrial Engineer, Manufacturing Engineer, or Planner to plan the processing of a product. Through the engineering workbench, orders can be released to the production floor and modified per order or orders released as planned. The RFID is beneficial to this module in that it allows for real time analysis of where items are and their availability. This helps the planner to make better decisions about jobs that need to be released and what stages other jobs are in. It also allows for real time status for the production lines by showing where jobs are accumulating and where they may be against the schedule.

4.3 WM Module

In the WM module, materials are issued against both receipt of materials and issuance of materials against the orders. RFID could play a large part in this module, especially with the automation of the different components of the SAP modules. The main areas in which RFID would benefit are identified as the Display material inventory value and Receive goods sections of the case study. Both of these components would directly benefit from RFID by using the tags to initiate the complete process. Depending on how the system is set up, the information on the RFID tags could initiate the correct screens in SAP to receive materials. This form of autonomation would reduce handling and processing of materials by decreasing the amount of manual entry and manipulation of the system by an employee. As soon as materials entered an area the correct issuances in the ERP would take place without requiring entry by an employee.

4.4 Time Savings

An evaluation in the time it takes to process each of the modules shows where savings can be made in the system by using RFID instead of manual entry. As shown in Poon's work, RFID can reduce data entry times into the system and reduce data entry errors. [8] The SD module was selected as the test case for the time studies due mainly to the level in which RFID would affect the data entry aspect of the module. The SD case study allows for 120 minutes to complete the module. In the run performed for this paper, the user was able to complete the module in approximately 48 minutes. The five components of the SD module that would benefit from RFID are allowed 35 minutes to complete. The run for the paper took approximately 12.75 minutes to complete. Because the process was not able to be automated, it was assumed that RFID should allow a time savings of at least 150%. This would decrease the 12.75 minutes to process the materials to less than 5.1 minutes. The times necessary for each step in the case

study of the SD module are shown in Table 6.The times impacted by the use of RFID are denoted with *. Though the 8 minutes sounds insignificant, it should be understood that companies that have implemented SAP most likely ship many orders per day. Just 50 orders shipped per day would result in a reduced time of over 6 hours of labor allowing for changes in where workers are utilized.

Table 6 Times to Perform SD Module Actions

SD Model Component	Allotted Time	Measured Time	RFID Time
Create new customer	10 min	8.25 min	8.25 min
Create contact person	5 min	1.5 min	1.5 min
Change customer	5 min	2 min	2 min
Create customer inquiry	10 min	5.5 min	5.5 min
Create customer quotation	10 min	6.75 min	6.75 min
Create sales order referencing a quotation	10 min	2 min	2 min
Check stock status	5 min	2.75 min	2.75 min
Display sales order	10 min	3 min	3 min
Start delivery process	5 min	1.75 min	0.7 min*
Check stock status	5 min	1.75 min	0.7 min*
Pick materials on delivery note	5 min	1.5 min	0.6 min*
Post goods issue	5 min	0.75 min	0.3 min*
Check stock status	5 min	1 min	0.4 min*
Create invoice for customer	10 min	4.5 min	1.8 min*
Display billing document and customer invoice	5 min	1.5 min	0.6 min*
Post receipt of customer payment	10 min	2.75 min	2.75 min
Review document flow	5 min	1 min	1 min
Total Time	120 min	48.25 min	40.6 min

4.5 Inventory Valuation

Tables 7, 8, and 9 show the inventory dollar levels associated with inventory turns of 12, 15, and 18 turns per year, respectively.

Table 7 Results of Multipart Stockout Model (Q, r) Calculations for 12 Turns per Year [4]

j	Q_j (units)	$kD_j/(kD_j+h_jQ_j)$ (unitless)	r_j (units)	F_j (Order Freq.)	S_j (Fill Rate)	B_j (Backorder Level)	I_j (Inventory Level)($)
1	36.1	0.666	169.9	27.7	0.922	0.529	2,459.16
2	114.1	0.863	92.1	8.8	0.995	0.022	675.24
3	11.4	0.387	25.9	8.8	0.744	0.778	548.54
4	36.1	0.666	5.0	2.8	0.988	0.014	194.33
				12.0	0.950	1.342	3,877.27

Table 8 Results of Multipart Stockout Model (Q, r) Calculations for 15 Turns per Year

j	Q_j (units)	$kD_j/(kD_j+h_jQ_j)$ (unitless)	r_j (units)	F_j (Order Freq.)	S_j (Fill Rate)	D_j (Backorder Level)	I_j (Inventory Level)($)
1	28.9	0.714	171.6	34.6	0.921	0.466	2,265.44
2	91.3	0.888	93.2	11.0	0.995	0.021	571.88
3	9.1	0.441	26.6	11.0	0.727	0.670	496.27
4	28.9	0.714	5.3	3.5	0.987	0.013	160.99
				15.0	0.949	1.170	3,494.58

Table 9 Results of Multipart Stockout Model (Q, r) Calculations for 18 Turns per Year

j	Q_j (units)	$kD_j/(kD_j+h_jQ_j)$ (unitless)	r_j (units)	F_j (Order Freq.)	S_j (Fill Rate)	B_j (Backorder Level)	I_j (Inventory Level)($)
1	24.1	0.750	173.0	41.6	0.920	0.375	2,154.76
2	76.1	0.905	94.1	13.1	0.995	0.020	504.25
3	7.6	0.487	27.2	13.1	0.714	0.554	468.32
4	24.1	0.750	5.5	4.2	0.987	0.013	139.10
				18.0	0.948	0.961	3,266.44

As the data shows, an increase in the frequency of orders will result in a lower, on-hand inventory level. Because RFID allows for faster updating of information and more accurate data in an ERP system, smaller quantities can be procured while being reasonably certain that the quantities will support the operational needs of the company.

The data also shows that by increasing the number of turns, the fill rate and the backorder levels are reduced. This is interpreted to mean that even as inventory turns are increased and the on-hand inventory levels are decreased, the percentage of orders that can be filled from stock will increase. The large decrease in the backorder level also means that although the on hand inventory level has decreased, there are a smaller percentage of orders that are backordered. This is due to the increase in the number of replenishment cycles and the number of units ordered in each reorder. This shows why it is important for the information utilized in an ERP to be updated quickly and with a high degree of reliability.

From the data it is determined which components of the hypotheses would be rejected. Because there is a decrease in the on hand inventory values the null hypothesis, H_0, and the second alternative hypothesis, H_2, can be rejected. The inventory value fell by approximately $100 for every turn of inventory, though the biggest change occurred between 12 turns and 15 turns, which is believed to indicate an efficiency in the way that the inventory is handled. In this case, there is a failure to reject the first alternative hypothesis, H_1, where RFID will have a beneficial impact on the inventory.

5. Conclusion

The impact of speed and accuracy on the data used in an ERP can be seen through the inventory levels that the system calculates. Though manual manipulation of the data into a system is common, it is simple to see how a technology such as RFID would allow the system to run more efficiently, thereby reducing costs. This paper only looked at the possible time savings in one module in one ERP supplier's system. Through evaluating other modules in this system and the knowledge that many of the ERP/MRP systems that exist all utilize components of the SCOR model, it is possible to understand how large of an impact RFID can have on inventory.

Future work to show more about where RFID could benefit in an ERP/MRP system would be to continue looking at the modules in SAP. The modules that would specifically be targeted would be Materials Management, Production Planning, and Warehouse Management as well as spending more time with the Sales and Distribution module. An actual set up of the SAP system with RFID and a production system modeled after the case studies would show how the inventory costs of the case study would be affected and be a more accurate representation of how the system behaved with RFID. A future study would be to use this information to show how to justify implementation costs associated with RFID.

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