One Size Fits All or Customized? – RFID Solution Provider's Decisions

Wenge Zhu*
Henry C. Co
California State Polytechnic University, Pomona, CA, U.S.A.

Today's demand for RFID solution is primarily driven by the RFID mandates. A solution provider may offer products to meet the needs of RFID mandate-driven customers, or to satisfy customers who view RFID as a strategic investment, or both. However, the cost structure of compliance-driven RFID solution and of integrating RFID into business applications differs significantly. The findings of this study provide insights as to when an RFID solution provider should choose a one-size-fits-all strategy, or a customized strategy to offer either a high-end niche product, or a line of products.

*Corresponding Author. E-mail address: zhu@csupomona.edu

I. INTRODUCTION AND LITERATURE REVIEW

We live in the era of *Internet of things*. Just as we *Google* to do a quick search for information on the Internet, physical objects can be linked to the Internet through their digital identities (Glover and Bhatt 2006). With Radio Frequency Identification (RFID), we can haul a pallet past a reader to find out what the items in the pallet are, where and at what specific time they were manufactured, and if we like, the last known location of every other items manufactured within the same hour at a particular location.

Responding to the U.S. Department of Defense (DoD) mandate requiring for passive RFID tagging, Lockheed Martin, Northrop Grumman, GE Transportation, Rolls Royce and Raytheon initiated RFID pilot projects to meet the January 2005 deadline (Symbol Technologies 2005). The DoD is not alone in pushing its suppliers into RFID. Wal-Mart likewise requires its top 100 suppliers to put RFID tags on all cases and pallets by January 2005. Other retailers with similar mandates include Albertsons, Best Buy, Marks & Spencer, Metro, Target, Tesco, etc.

There are three approaches to RFID implementation: (1) *slap-and-ship*, (2) special tagging station, and (3) RFID business-integration. Most current applications in manufacturing are driven by external mandates, and the *slap-and-ship* solution provides the quickest route to satisfying the mandate in addition to providing a valuable testing and learning experience for RFID deployment. The simple *Slap-and-ship* method typically includes a printer, a handheld or fixed RFID reader and the software to print and validate RFID labels. The RFID labels are manually applied just before they get shipped off to customers. For high volume distribution, the special tagging station solution sends the cases and pallets to a specific workstation where they get tagged with RFID labels.

RFID tags make up more than 80 percent of a typical cost of slap-and-ship or special-tagging-station solution. These solutions require little or no backward integration with existing warehouse management applications, thus allowing businesses to avoid making a large capital investment. Market analysis indicates that

slap-and-ship RFID solution costs as little as $25,000 (Shutzberg 2004), at least ten times less expensive than investing on information technology (IT) services and business process reengineering.

Compliance continues to drive most RFID implementations. An AMR Research study shows that Wal-Mart's suppliers do not view RFID as a strategic investment and have patched systems together just enough to meet Wal-Mart's compliance deadline. The study reported that most Wal-Mart suppliers have spent $1M to $3M on RFID, just enough to purchase tags, readers, and minimal software (AMR Research, 2010). However, the *slap-and-ship* and special-tagging-station solutions aren't producing the return on investment (ROI) that would warrant voluntary use of the technology (Katz 2006). As business organizations completed their first wave of RFID pilot projects and mandated compliance efforts, they come to expect a positive return from their initial investments. A survey of U.S. companies by analyst firm ABI Research shows that uncertainty over the potential return on investment (ROI) is the top concern holding up deploying RFID (Collins 2004).

The true benefit of RFID comes from getting the information from those reads to the right place in a usable form. In order to see any significant ROI, users must integrate RFID into their applications, reengineering their business processes, and enabling large volumes of data to be stored and accessed. AMR Research estimates this would cost each supplier $13M to $23M (AMR Research, 2010). RFID business-integration allows for backward integration into a company's core business processes. A Total Economic Impact™ (TEI) analysis by Forrester Research shows that integrating RFID with internal processes can produce positive business benefits in a typical manufacturing and distribution supply chain (Wildeman, Connaughton et al. 2008).

In order to understand the unique challenge that RFID solution providers face when they position and price their products, we identify two streams of research that are related to this study. One of the stream of research is on product development for traditional products, or the production-intensive products (Krishnan and Zhu 2006) for which the costs to provide them are primarily marginal production costs. Readers may refer to (Krishnan and Ulrich 2001) for a comprehensive literature review on that stream of research. Among these research, one of the seminal study (Moorthy and Png 1992) provides great insight in designing a line of traditional products: lower the price of the high-end product and reduce the quality of the low-end product in product line development; either design a single niche product or a product line but never design a one-size-fit-all standard product; always launch the high-end product first. The other stream of related research is on product development for development-intensive products for which the costs to provide them are primarily development costs. The product line development for development-intensive products is different from that of traditional products in many ways, one of which is one-size-fit-all standard product strategy may be a optimal (Krishnan and Zhu 2006). Additional conditions under which product line will be optimal for development-intensive-products are also discussed (Bhargava and Choudary 2008).

This paper contributes to the above streams of literature by investigating the unique challenge for RFID providers: production-intensive nature of the slap-and-ship (providing basic equipments to meet RFID mandate), and the development-intensive nature of the integration capability of the RFID solution (mostly are software package). The mixed production-intensive and development-intensive characteristics of RFID solutions provide additional challenges. For RFID solution providers the optimal product strategy mix is different from what is suggested by either the stream of research mentioned above.

II. QUALITY DIMENSIONS OF RFID IMPLEMENTATION

Today, many RFID solution providers offer products and services for *slap-and-ship* to meet the RFID compliance mandates, but not closed loop solution (a lists of RFID solution providers can be found in http://software.forbes.com/rfid-software, http://www.rfidsb.com, among many others). As organizations are increasingly concerned with the integration of RFID with business processes and applications, RFID solution providers can no longer treat the need for closed loop solution as a peripheral strategy to assist the sales of their RFID hardware. Instead, firms are trying to integrate their RFID compliance strategy and business-integration strategy to achieve higher profit potential.

In this paper, we characterize the dimensions of the solution provider's hardware strategy and business-integration strategy by $Q(q_1, q_2)$. Here q_1 (henceforth referred to as *compliance*) corresponds to the quality of slap-and-ship and special tagging station approaches (open-loop solutions) to RFID implementation. The *compliance* dimension of quality pertains to the quality of the RFID printer, reader, and the software for printing and validating the tags. The cost of providing the compliance quality is primarily marginal production cost.

RFID-enabled business processes are event-driven processes that are dynamic. These processes must respond to events in real time. RFID architecture must be designed in a way that response to these dynamic requirements, and be quickly altered or adjusted as needs dictate. The q_2 (hereinafter referred to as *integration* in $Q(q_1, q_2)$) addresses the business-integration dimension of quality. The q_2 dimension consists of confluence of technologies necessary for closed-loop RFID implementation. It measures the degree of ease and capability to integrate the RFID systems into other IT systems for more advanced applications. This quality dimension impacts the future efforts needed in order to achieve long term goal of RFID applications, such as lean manufacturing and efficient supply chain management. As in Gavin's 8 critical dimensions of quality, the *integration* dimensions of quality consist of integrity, velocity, insight, and capability (Pisello 2006).

The integration dimension of quality is mostly achieved by heavy investment in IT services and business process reengineering. Therefore, the integration quality has development-intensive product characteristics (Krishnan and Zhu 2006), with a cost consisted of primarily fixed development cost and negligible marginal production cost.

III. MODEL AND ANALYSIS

As in (Zhu and Co, 2010), we model a solution provider's quality strategy on *compliance* q_1 and *integration* q_2. Suppose the solution provider's cost of producing *n* quantity of product with quality $Q(q_1, q_2)$ is

$$C(q_1, q_2, n) = nc_1 q_1^2 + c_2 q_2^2 \qquad (1)$$

Note that the cost is a quadratic function of both with q_1 and q_2.

Market Segments

Consider two market segments the RFID solution provider is serving: *high-end* and *low-end* market. Analogous to class A, B, and C in MRP (material requirements planning), the high-end market expects RFID-based solutions to enable lean production and/or agile supply chain management (closed-loop solution of business integration). The low-end market, on the other hand, is simply responding to mandates from customers (open-loop solution of "slap and ship"). High-end customers are more willing and able to invest in closed-loop solution, and thus will provide a much higher budget for RFID implementation than low-end users. We use subscript t (type) $t \in \{H, L\}$ for variables associated with high-end and low-end segment. For example, the size of high-end and low-end market segment is n_H and n_L, respectively. Suppose the customers' willingness to pay (WTP) for RFID product is:

$$U_p(q_1, q_2, t) = v_{t1}q_1 + v_{t2}q_2,\ t \in \{H, L\} \quad (2)$$

Here, v_{t1} and v_{t2} is marginal WTP for dimensional 1 and 2 quality, respectively.

Single Market Segment Benchmark

Suppose there is only one market with n_t number of type t consumers, the RFID solution provider's profit maximization problem is:

$$\Pi_p^F = \max_{q_{t1}\geq 0, q_{t2}\geq 0, p_t \geq 0} n_t(p_t - c_1 {q_{t1}}^2) - c_2 {q_{t2}}^2 \quad (1)$$

$$s.t.\ v_{t1}q_{t1} + v_{t2}q_{t2} - p_t \geq 0 \quad (2)$$

The above problem is a simple quadratic profit maximization problem with a non-negative utility constraint. The constraint is binding in optimal solution. Therefore replace price in (1) from the binding constraint (2) the optimal solutions are found by FOC, and they are described in the following lemma.

Lemma:

The optimal compliance and integration qualities for a homogenous market consisted of n_t type t consumers are called efficient qualities, and they are as follow:

$$q_{t1} = \frac{v_{t1}}{2c} \quad (3)$$

$$q_{t2} = \frac{nv_{t2}}{2c} \quad (4)$$

It is noteworthy that while compliance quality is only related to the users' evaluation of quality and cost, the integration quality is also directly proportional to the market size. Therefore, the degree of RFID adoption directly impacts the RFID provider's motivation to provide integration quality.

Multiple Market Segments Product Strategy

Consider a case in which an RFID solution provider offers two different products targeting the high-end and the low-end market segment, respectively. The RFID solution provider has to carefully design and price the two products so that the customers will self select the product designed for them. The problem of the RFID solution provider in the two market segment is formulated as follows:

$$\Pi_{PL}^F = \max_{q_{H1}\geq o, q_{H2}\geq o, q_{L1}\geq o, q_{L2}\geq o, p_H \geq o, p_L \geq o} n_H(p_H - c_1 {q_{H1}}^2) - c_2 {q_{H2}}^2 + n_L(p_L - c_1 {q_{L1}}^2) - c_2 {q_{L2}}^2 \quad (5)$$

$$S.t.\ v_{H1}q_{H1} + v_{H2}q_{H2} - p_H \geq v_{H1}q_{L1} + v_{H2}q_{L2} - p_L \quad (6)$$

$$v_{L1}q_{L1} + v_{L2}q_{L2} - p_L \geq v_{L1}q_{H1} + v_{L2}q_{H2} - p_H \quad (7)$$

$$v_{H1}q_{H1} + v_{H2}q_{H2} - p_H \geq 0 \quad (8)$$

$$v_{L1}q_{L1} + v_{L2}q_{L2} - p_L \geq 0 \quad (9)$$

The above profit-maximization problem has two sets of constraints. The first set of (6) and (7) are incentive compatibility constraints, which ensure that the different types of customers will self-select the products designed for them. The second set of (8) and (9) are participation constraints, which require all customers have non-negative utility. Since the problem satisfies single cross condition, the constraint (6) and (9) will be binding. In another word, in optimal solution the low-end customers will have zero utility and the high-end customers will be indifference between the high-end and the low-end product. Replace prices in (5) from the binding constraints (6) and (9), the optimal solutions are derived from FOC.

Proposition 1

1. The optimal compliance quality and integration quality for the low-end and high-end product are:

$$q_{H1} = \frac{v_{H1}}{2c_1}$$

$$q_{H2} = \frac{n_H v_{H2}}{2c_2}$$

$$q_{L1} = \frac{v_{L1}(1-R_1)}{2c_1}$$

$$q_{L2} = \frac{n_L v_{L2}(1-R_2)}{2c_2}$$

where $R_1 = \frac{n_H}{n_L}(\frac{v_{H1}}{v_{L1}} - 1)$, and

$R_2 = \frac{n_H}{n_L}(\frac{v_{H2}}{v_{L2}} - 1)$ represent the degree of cannibalization for compliance quality and integration quality, respectively.

2. When the high-end market size is relatively large and/or the high-end consumers' relative evaluation of integration quality is high ($R_2 \geq 1$), the RFID solution provider will offer minimal integration quality to low-end consumer;
3. When the high-end market size is relatively large and/or the high-end consumers' relative evaluation of integration is high ($R_1 \geq 1$), the RFID solution provider will only offer a high-end niche product for high-end consumers.

However, the RFID solution provider may also want to offer a one-size-fits-all standard product for both market segments. In this case the firm's problem is formulated as follows:

$$\Pi_{STD}^{F} = \max_{q_{S1} \geq o, q_{S2} \geq o, p_S \geq o} (n_H + n_L)(p_S - c_1 {q_{S1}}^2) - c_2 {q_{S2}}^2 \quad (10)$$

$$S.t.\ v_{L1} q_{S1} + v_{L2} q_{S2} - p_S \geq 0 \quad (11)$$

The process of solving the above problem is similar to solving (1) in lemma. Comparing the profit of standard product strategy and product line strategy, we have the following results:

Proposition 3

The optimal product strategy for an RFID solution provider is to offer a product line when:

$$R_2 > 1 - \frac{v_{L1} R_1 (v_{H1} - (1-R_1) v_{L1}) c_2}{v_{L2} n_H (v_{H2} + v_{L2}) c_1} \text{ and } R_1 < 1,$$

or, a standard product when:

$$R_2 \leq 1 - \frac{v_{L1} R_1 (v_{H1} - (1-R_1) v_{L1}) c_2}{v_{L2} n_H (v_{H2} + v_{L2}) c_1} \text{ and } R_1 < 1,$$

or, a niche high-end product when:

$R_1 \geq 1$

The proof of proposition 3 is straightforward and therefore omitted.

To sum up, the RFID solution provider's optimal product strategy is to offer a niche product targeting only the high-end customers when market cannibalization is high in compliance quality dimension, offer a standard product for both the high-end and low-end customers when market cannibalization is low in both compliance and integration quality dimensions, or offer a product line with high-end and low-end product each targeting one market segment when market cannibalization is low in compliance quality dimension but relatively high in integration quality dimension. The optimal product strategy mix is illustrated in figure 1.

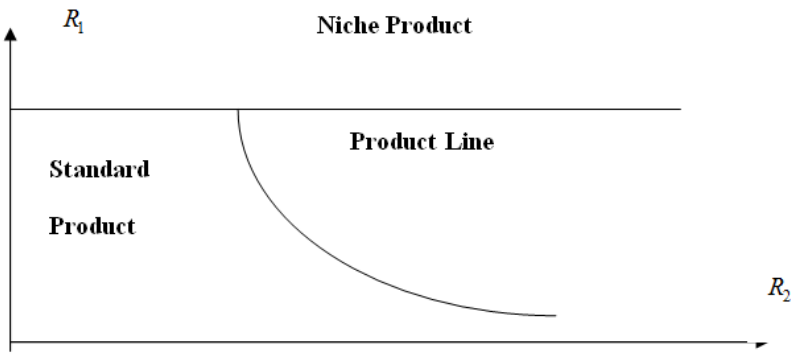

Figure 1. Optimal Product Strategy Region

IV. DISCUSSION

Adoption of RFID in supply chain management is still in the introduction stage of the product life cycle. The growth of the market has been robust, thanks mostly to the mandates set by the world's largest retailer, Wal-Mart, and the U.S. Department of Defense (Leybovich 2010). However, an RFID solution provider in today's market needs the right strategy to position itself in the industry in the future. Although today's demand for RFID solution is primarily driven by the RFID mandates (thus limited to tags, readers, and minimal software), more and more companies are looking for strategic value of the technology through integration of RFID into their supply chain information systems. The integration quality of RFID solution comes from advanced IT services and business process reengineering. A well designed IT-services package in RFID solution will immensely reduce the difficulty in integrating RFID into the company's existing information system and therefore leveraging the RFID potential to achieve competitive advantage.

However, an interesting fact regarding the integration quality of RFID is that the cost of providing the quality is fundamentally different from the cost of providing compliance-driven RFID solution. With negligible marginal production cost and high fixed development cost, the RFID solution provider's motivation to provide integration quality heavily depends on the market size. If there are not enough early adopters for high level integration RFID products, the integration quality of RFID will remain at low level, which in turn impede more adoptions. It is therefore crucial for RFID champions, such as Wal-Mart and the DoD, to understand that there is a need to jump start the market for the integration quality provider.

An RFID solution provider may find it more profitable to engage only the high-end market of consumers interested in the strategic integration of RFID technologies when either there is a relatively large high-end market, or the high-end consumers' evaluation of compliance quality is much higher than the low-end consumers. Unlike a manufacturer of convention product (Moorthy and Png 1992), an RFID solution provider may find it also profitable to offer a one-size-fits-all standard product if the high-end consumers' evaluation of integration quality is not relatively higher enough than the low-end consumers. When there is a significant difference of the evaluation of integration quality between high-end and low-end consumers, the RFID provider will offer a line of products. If the adoption of RFID integration is at the early stage, our finding predicts that an RFID solution provider will offer a product line. However, as compliance-driven adaptors mature and RFID integration becomes the mainstream, our finding predicts that the RFID solution provider will start to offer a one-size-fits-all standard product. A summary table for the

applicability of the optimal strategies is provided as follows:

Product Strategy	Conditions for the Product Strategy Being Optimal
Niche High-end	Dominating high-end market in size, or relatively higher evaluation of compliance quality for high-end customers
Niche Low-end	Never optimal
Standard Product	High-end market not dominating in size, both the evaluation of compliance quality and integration quality are relatively not too high for high-end customers
Product Line	High-end market not dominating in size, the evaluation of compliance quality is relatively not too high but the evaluation of integration quality is relatively high for high-end customers

V. REFERENCES

AMR Research, "AMR Research Finds Wal-Mart Suppliers Spent Only Minimum Required to Comply with RFID Mandate," 2007, from http://www.crm2day.com/content/t6_librarynews_1.php?news_id=EEpFykkEkyTKjZkdGW.

Bhargava, H. K. and V. Choudary, "Research Note: When is Versioning Optimal for Information Goods." Management Science, 54(5), 2008, 1029-1035.

Collins, J., "RFID's ROI tops user concerns," RFID Journal, 2004.

Glover, B. and H. Bhatt, RFID Essentials. Sebastopol, CA, O' Reilly Media, 2006.

Katz, J., "Reaching for ROI on RFID," Industry Week. 255, 2006, 29-31.

Krishnan, V. and K. T. Ulrich, "Product Development Decisions: A Review of the Literature," Management Science, 47(1), 2001, 1-21.

Krishnan, V. and W. Zhu, "Designing a Family of Development-Intensive Products," Management Science, 52(6), 2006, 813-825.

Leybovich, I., "RFID Market Projected to Grow in 2010." Retrieved 12/10/2010, 2010, from http://news.thomasnet.com/IMT/archives/2010/03/radio-frequency-identification-rfid-market-projected-to-grow-in-2010-beyond.html.

Moorthy, K. S. and I. P. L. Png, "Market segmentation, cannibalization, and the timing of product introductions," Management Science, 38(3), 1992, 345-359.

Pisello, T., Shrinking the supply chain expands the return: the ROI of RFID in the supply chain, Orlando, FL, Alinean White Paper, 2006.

Shutzberg, L., Radio frequency identification (RFID) in the consumer goods supply chain: Mandated compliance or remarkable innovation, Industry White Paper Rock-Tenn Company, 2004.

Symbol Technologies, Supplier compliance with the department of defense RFID mandate: who is affected, when, and what to do to comply, Symbol Technical White Paper, 2005.

Wildeman, R. C., P. M. Connaughton, et al., A total economic impact analysis links gains to depth of system integration, ROI of RFID, Forrester Research, Inc., 2008.