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Prediction of RFID Performance in Supply Chains

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ABSTRACT

This paper discusses the challenges to wide-spread radio frequency identification (RFID) adoption in supply chains using the technology s-curve and the concept of buying hierarchy. A survey on RFID uptake in New Zealand is used in the discussion. We found that early adopters are faced with challenges that can be overcome by considering them early in the development stage of RFID. We look at how this set of challenges can be aligned to the development stage and proposed four issues that require early attention in order for a mass adoption to take place.

Keywords

Buying Hierarchy, RFID, S-Curve, Supply Chain Management.

INTRODUCTION

The use of RFID technology in supply chain management (RFID/SC) has in recent years been increasingly studied and implemented. RFID technology uses radio waves and unique identity systems to manage or communicate information about an object wirelessly. The communications network consists of readers or interrogators and tags or transponders. The combination of wireless communication and unique identification brings the convergence of the information and physical worlds a step closer (Fleisch, 2001). As supply chains are already integrated, or attempting to be integrated, with multiple IT systems such as enterprise resource planning, warehouse management systems, electronic data interchange, billing systems, and freight booking systems, to name a few, RFID systems have and will be an added IT implementation issue to most organisations.

This paper looks at a survey on the uptake of RFID in supply chains in New Zealand and uses the technology s-curve and buying hierarchy to explain how the barriers to RFID adoption could be overcome. For an effective implementation of RFID/SC, we suggest organisations to consider the lessons learned from early adopters of RFID; these lessons are: compatibility of standards, integration with existing systems, tags working with products, ease of use and learning, and usefulness of the data collected to business. This paper is organized as follows. In the next section we have the literature review and research methodology. We then look at the challenges faced by RFID adopters in the survey and discuss what steps are needed to overcome those challenges. The performance of RFID is discussed and plotted using the s-curve and the paper ends with a conclusions section.

LITERATURE REVIEW

There are three aspects that this paper explores. First is the survey on the uptake of RFID in New Zealand supply chains. The survey was intended to find out the different barriers to the adoption of RFID among adopters and non-adopters. Second is the study of the s-curve used by Foster (1986) in "The Attacker's Advantage" and by Christensen (1997) in "The Innovator's Dilemma". The third aspect explored is the buying hierarchy from Windermere Associates (Christensen 1997).

RFID Survey in New Zealand

A survey (Soon & Gutiérrez, 2008) on the adoption of RFID in New Zealand was conducted between 2007 and 2008. The survey aimed at identifying the barriers to RFID adoption and differentiating the adoption criteria between adopters and non-adopters. Sixty-six responses were received in full. Figure 1 shows a breakdown of the respondents with regards to uptake. The survey adoption status is in line with other similar surveys in New Zealand.
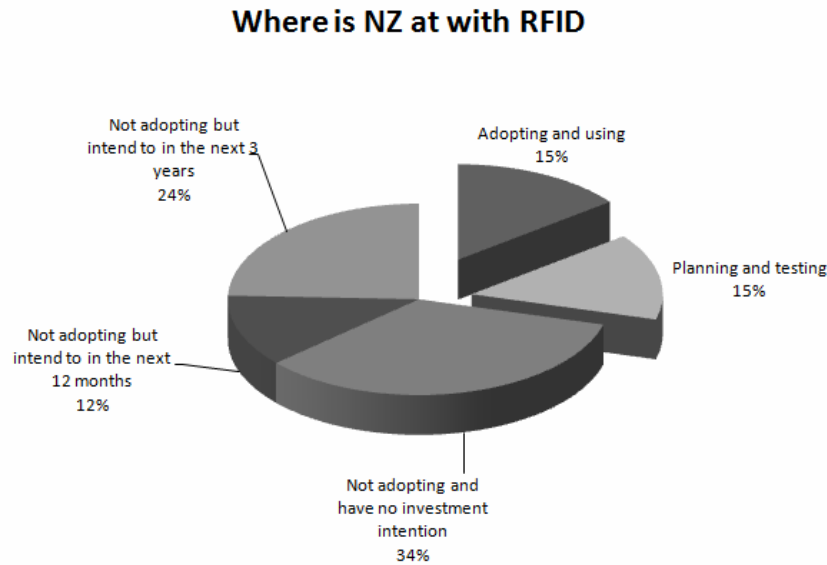

Figure 1. Respondents to RFID Uptake in New Zealand

The survey results show that *better inventory visibility*, *improve labour efficiency*, *product traceability requirement*, and *speed up order fulfilment* were the top reasons for the adoption while *lack of standards (agreement of a common standard)*, *integration*, and *expertise in RFID* were the top reasons for not adopting RFID. Figure 2 shows the reasons for adopting and not adopting RFID. The numbers show the number of respondents.
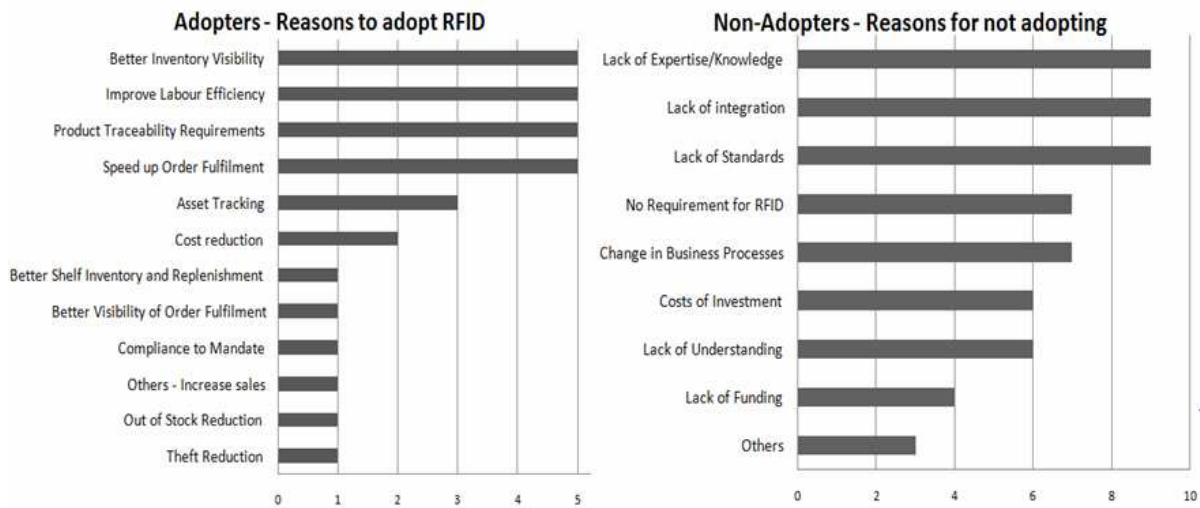

Figure 2. Reasons for Adopting and Not Adopting RFID

The survey also found that the adopters were initially not concerned about the compatibility of RFID with other existing systems. As a result, they were "not satisfied" with the overall integration and investment costs associated with the technology. The non-adopters in contrast were sceptical about issues around compatibility, security, and accuracy of RFID systems. Soon and Gutiérrez (2008) suggest that the adopters were more at ease with RFID technologies as they probably had more knowledge on how RFID could fit into their processes than the non-adopters had. Of interest to this paper is to analyse the results a step further by looking at the challenges faced by the adopters and use the technology s-curve and buying hierarchy to understand where those challenges are; the adopters made up about fifteen per cent of the total respondents.

The Technology S-Curve

The technology s-curve is used to represent the progress of a product or process given the effort to yield or improve the performance of the product or process (Foster, 1986). The product or process starts at a slower pace and gradually improves until it reaches its limit. While there are strategies to sustain a product as it reaches its limit (Christensen, Anthony, & Roth, 2004), the s-curve denotes that at this stage, a discontinuity happens (Foster, 1986). The product gets replaced by its competing products or by an improved version of the product. This can be represented by different s-curves as shown in Figure 3.
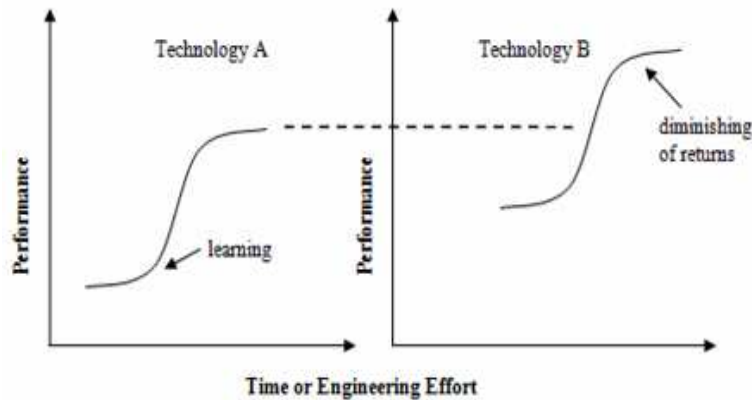

Figure 3. Technology S-Curves representing different set of technologies

Adapted from Christensen (1997)

Foster (1986, p. 106) suggests that the management of technology tends to focus on "efficiency when companies need to be concerned with effectiveness". Effectiveness is referred to as the set of technologies to pursue while efficiency is the efforts in sustaining a strategy. Referring to the S-Curve, effectiveness is the set of technology S-Curves and efficiency is the slope of the S-Curves. Figure 3 shows the different S-Curves. Effectiveness is linked to the pursuit of different technologies such as Technology A and B in the figure. Efficiency is thus the evolution of existing technology or what is known as sustaining technology (Christensen, 1997). According to Foster (1986), the S-Curve describes the learning of a technology as well as the diminishing of returns. At the initial stage of development, it usually takes a considerable amount of effort in learning a new technology and as one reaches the peak of the learning curve, less effort is required to achieve the same amount of progress or performance. Eventually, it will reach a point where each step makes lesser performance improvements when the technology reaches its performance limit.

Technology B shown in Figure 3 could be likened to the disruptive RFID while Technology A could be likened to the incumbent barcodes technology. While barcodes are still gaining wide-spread adoption (Burkett, 1993; Carter, 1991; Ekman, 1992), the capabilities of RFID are helping it to gain popularity in supply chain management. RFID however may at the moment be serving a certain type of market. This can also be represented by the s-curve as Christensen (1997) did to explain the dilemma faced by innovators.

This paper adopts the concept of the s-curve to the different performance levels demanded by members in a supply chain to understand the challenges faced by adopters in *RFID/SC*.

The Buying Hierarchy

The customer buying hierarchy concept by Windermere Associates is used by Christensen (1997) to demonstrate the management of changes in product competition. The basis of this concept is the predictable buying behaviour of buyers in four stages: functionality, reliability, convenience, and price. The concept suggests that when there is no product that satisfies the functionality requirements, consumers would base their choice on the functionality of the product. When the functionality requirements are achieved, consumers would base their choice in the order of reliability, convenience, and price. Christensen (1997) found, in the disk drive industry, that competition was initially based on capacity of the disk drive followed by physical size, reliability and finally price when disk drives became a commodity. He refers these attributes to the customer's demand on performance. While this may be closely related to the product life cycle concept, the simplicity of the buying hierarchy concept is used in this paper to demonstrate the challenges to RFID adoption; most product life cycle literature focus on buyer learning, comparative advantage, competition pressure, to name a few (Day, 1981; Rada, 1999; Tellis & Crawford, 1981) which can be complex. The findings in the New Zealand survey also suggest that the buying hierarchy is a good indicator of RFID adopters' behaviour. Thus, the buying hierarchy is used to explain how the various challenges in RFID adoption could be overcome.

RESEARCH METHODOLOGY

This paper adopts a qualitative approach to gain insight into the finding of the slow uptake of RFID/SC in the New Zealand survey. The survey was sent to the subscribers of a technology forum web site. Sixty-six responses were analysed. The respondents are comprised of suppliers (32 per cent), distributors (15 per cent), retailers (15 per cent), RFID providers (26 per cent), and academics (12 per cent). The questionnaire used in the survey is provided in Appendix A.

We applied the s-curve and the buying hierarchy concepts to the survey findings to determine the reasons for the slow uptake of RFID/SC in New Zealand. The results and assessments are discussed in the following sections.

RFID ADOPTERS' CHALLENGES

In the survey, Soon and Gutiérrez (2008) found that the adopters were initially not concerned with technology issues. However, after implementation, the adopters were "not satisfied" with the compatibility of standards and their overall integration with other systems. They found that the RFID tag did not work very well with some of their products. Although the adopters were somewhat satisfied with the read rate, other research suggests that read rate accuracy is an area of focus for most organisations (Li, Visich, Khumawala, & Zhang, 2006). Thus, there seems to be a disparity among adopters in their demand for RFID performance.

The first stage in the buying hierarchy is functionality. With its unique identification and wireless communication technique, RFID far exceeds the functions expected with its role in supply chain management compared with other identification technologies, such as, barcodes. Thus, functionality is almost not a concern in the RFID buying hierarchy. The second and third stages in the buying hierarchy can be explained together. This is assumed as the point where RFID development accelerates. In the second and third stages, reliability and convenience are a focal point for the organisations. Most RFID literature is focused on these issues. This paper highlights the specific issues to formulate a guideline for RFID researchers and practitioners. In relation to the overall integration, four issues are identified and discussed here. They are compatibility of standards, tags working with products, usefulness of data collected, and learning how to use RFID systems; the former two are related to the reliability and the latter two are related to the convenience in the buying hierarchy. Table 1 shows the satisfaction results for the adopters. The four issues identified fit well into the reliability and convenience stages in the buying

hierarchy. What is not shown in Table 1 is that those who were "not satisfied" with the overall integration were also in the lower continuum towards "not satisfied" for the four "overall integration" issues.

	1 Not Satisfied	2	3 Somewhat Satisfied	4	5 Very Satisfied	Responses
Investment costs within budget	1 (10.00%)	2 (20.00%)	3 (30.00%)	2 (20.00%)	2 (20.00%)	10
Improvement to work performance	0 (0.00%)	3 (30.00%)	2 (20.00%)	4 (40.00%)	1 (10.00%)	10
Overall integration achievement	0 (0.00%)	5 (50.00%)	2 (20.00%)	2 (20.00%)	1 (10.00%)	10
Standards compatibility	0 (0.00%)	4 (40.00%)	2 (20.00%)	3 (30.00%)	1 (10.00%)	10
Security of data meets company's requirements	0 (0.00%)	2 (20.00%)	2 (20.00%)	4 (40.00%)	2 (20.00%)	10
Change to business processes	0 (0.00%)	2 (20.00%)	2 (20.00%)	4 (40.00%)	2 (20.00%)	10
Tags working with my products	0 (0.00%)	2 (20.00%)	3 (30.00%)	2 (20.00%)	3 (30.00%)	10
Scanning accuracy at my site	0 (0.00%)	2 (20.00%)	3 (30.00%)	1 (10.00%)	4 (40.00%)	10
Usefulness of data collected by RFID to company	0 (0.00%)	1 (10.00%)	4 (40.00%)	2 (20.00%)	3 (30.00%)	10
Learning how to use the RFID systems	0 (0.00%)	1 (10.00%)	4 (40.00%)	3 (30.00%)	2 (20.00%)	10

Table 1. Satisfaction Level of the Adopters

While there are global standards for RFID, the issue of compatibility of standards is related to the integration of RFID systems into existing infrastructure. RFID hardware such as readers and tags are required to be compatible to work as a system while the information management systems of RFID, such as, electronic product code information services (EPCIS) requires to be compatible with existing supply chain systems and products. Tags on products present another set of problems. Radio waves are easily attenuated by materials with metal and liquid properties. An example is the case of kiwifruit. Eastpack, a grower owned kiwifruit post-harvest company in New Zealand, was faced with the challenges of reading their trays of kiwifruits tagged with EPC-compliant RFID tags due to the fruit's high water content (Friedlos, 2008). Several trials and electromagnetic interference surveys were conducted to work out a RFID infrastructure that is efficient in the kiwifruit's environment. An efficient application of RFID in New Zealand is the National Animal Identification and Tracking (NAIT) scheme where dairy animals are tagged with RFID for traceability purpose. However, the effectiveness of the system has yet to be tested.

The adopters in the survey indicated that learning to use the RFID systems they implemented and the usefulness of the data collected were "not satisfactory"; in particular for those adopters who reported dissatisfaction with the overall integration. In the IS literature, ease of use and usefulness of a system is important to the success of IS implementation (Davis, 1989). To ensure continuity after implementation, an IS application needs to be used by users to accomplish the tasks it is intended for. It is therefore important for a RFID application to be easy to use. In the case of NAIT, there was suggestion that the use of low frequency tags might not effectively identify animals specially those quicker runners, such as, the deer (Anonymous, 2005). Besides the ease of use, the data collected have to be useful to business, thus enabling the diffusion of the RFID application in the organisation.

PREDICTION OF RFID/SC PERFORMANCE TRAJECTORY

Based on the buying hierarchy, and while researchers are actively studying the reliability of RFID, the convenience of the RFID application should also be considered. Once both reliability and convenience have reached their limits, demand for RFID should increase rapidly driving the prices down as it moves towards the status of commodity technology.

The performance trajectory of RFID/SC is illustrated using the technology S-Curve as shown in Figure 4. The buying hierarchy theory is plotted onto the S-Curve to represent the progress of the performance-demand of the market. In order to reach out to the majority, reliability and convenience issues need to be addressed. RFID/SC will only appeal to the majority when it has been proven in the industry and not just by the early adopters since they are not a good reference to the majority. As such, the majority in the mainstream are likely to be assessing the technology as the industry competes. Competition will increase as more players join the race. This also means that there is intense innovation driving the resulting performance levels. Therefore, reliability and convenience are plotted along the steep slope of the S-Curve.

The trajectory of RFID/SC depends on the effort of the industry players. We believe that once reliability meets the market demand, the adoption of RFID/SC will cross over to the majority and technology diffusion will start to take place. Adoption cost will then fall significantly.
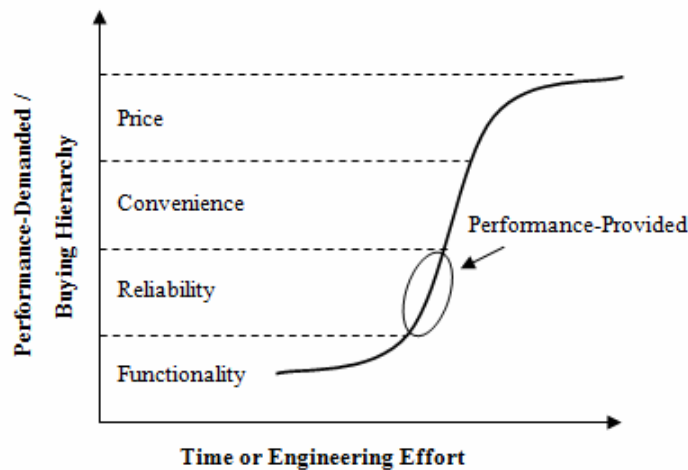
Figure 4. Performance Progression along the S-Curve

CONCLUSIONS

This paper follows on the survey on the uptake of RFID in New Zealand supply chains to explain some of the challenges faced by early adopters. Using the technology s-curve and the buying hierarchy concepts, the challenges are identified so that further research is focused on them in order for a mass adoption to take place. The challenges faced by the adopters are grouped into the reliability and convenience stages in the buying hierarchy. They are namely concerned with compatibility of standards with existing infrastructure, tags working with products, ease of use, and the usefulness of the data collected. We believe that by overcoming these challenges raised by the adopters, organisations wanting to adopt or having to adopt RFID will find a faster route to the implementation of the technology.

This paper is a follow-on qualitative assessment from our earlier work to gain insight into what is needed for a mass adoption to take place. This paper suggests that some technical issues of RFID systems need more development and that while technical issues usually get the attention, the ease of use and usefulness of the systems have to be considered in the early

stage of RFID development. Particular issues that need attention are the compatibility of standards, integration with existing systems, tags working with products, ease of use and learning, and usefulness of the data collected to business.

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APPENDIX A

Questionnaire Form

Part A: Background Information

1. Which industry best describes your organisation?
    (Refer to Part F for industry definitions)

○ Aerospace	○ Export/Import	○ Manufacturing
○ Agriculture	○ Fishing	○ Mining
○ Biotechnology	○ Forestry	○ Retail Trade
○ Business Services	○ Government/Defence	○ Transport/Storage
○ Construction	○ Healthcare	○ Wholesale Trade
○ Education	○ Horticulture	○ ICT
○ Energy	○ Communication/Media	○ Others:

2. Select one that best describes the role of your organisation in a supply chain.

○ Manufacturers/Suppliers/Producers	○ Warehouse/Distributors/Transporters
○ Retailers	○ RFID Solution Providers/Advisors
○ Academic Institutions	○ Others:

3. Which organisation type best describes your organisation?

○ Local Multi-National Corporation	○ Overseas Multi-National Corporation
○ Large Enterprise	○ Small-Medium Enterprise
○ Public/Government Institution	○ Others:

4. Number of employees in New Zealand entity:

○ 1-10   ○ 11-20   ○ 21-50   ○ 51-100   ○ 101-200   ○ Above 200

If you are a User or potential User of RFID for supply chain management (e.g. supplier, distributor, retailer) please proceed to Part B. If you are an RFID solution provider/advisor, please proceed to Part C. If you are from an Academic institution, please proceed to Part D.

Part B: For Users

If you are a user or potential user of RFID, please complete this section.

5. Select one that best describes the status of RFID initiatives in your organisation. Please continue to question 16 if your answer is *not adopting*.

○ Adopting and using

○ Planning and testing

○ Not adopting but intend to in the next 12 months

○ Not adopting but intend to in the next 3 years

○ Not adopting and have no investment intention

6. If you are adopting/using or planning/testing RFID, select **three** primary reasons for the intention to adopt RFID, else go to question 16.

☐ Compliance to mandate (For example: from a supply chain partner)

☐ Better inventory visibility

☐ Better visibility of order fulfilment

☐ Improve Labour efficiency

☐ Asset tracking

☐ Out of stock reduction

☐ Better shelf inventory and replenishment

☐ Theft reduction

☐ Inventory reduction

☐ Cost reduction

☐ Counterfeit reduction

☐ Speed up order fulfilment

☐ Product traceability requirements

☐ Others: _____

7. When planning to adopt RFID, to what extent has each of the following concerns affected your decision? Please indicate the level of concerns with the scale of 1 -5 (1 means *'No Concern'* and 5 means *'Very Concerned'*).

S/N	Concerns	1	2	3	4	5

A	Investment costs would be too high	○	○	○	○	○
B	There might not be much improvement to work performance	○	○	○	○	○
C	Overall integration might not be achieved	○	○	○	○	○
D	Standards might be incompatible	○	○	○	○	○
E	Security of data might not meet company's requirements	○	○	○	○	○
F	Change to business processes might be disruptive	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Difficulty with scanning accuracy at my site	○	○	○	○	○
I	Data collected by RFID might not be useful to the company	○	○	○	○	○
J	Employee might find it difficult to learn how to use the RFID systems	○	○	○	○	○

8. In thinking about your existing or potential investment in RFID, what are your key concerns around further investment?

         a. Concern 1: _____

         _____

         _____

         b. Concern 2: _____

         _____

         _____

         c. Concern 3: _____

         _____

         _____

9. Please rate your level of satisfaction for the following based on the results of your RFID implementation. (1 means *'Not Satisfied'* and 5 means *'Very Satisfied'*).

S/N	Results of Implementation	1	2	3	4	5
A	Investment costs within budget	○	○	○	○	○
B	Improvement to work performance	○	○	○	○	○
C	Overall integration achievement	○	○	○	○	○
D	Standards Compatibility	○	○	○	○	○
E	Security of data meets company's requirements	○	○	○	○	○

F	Change to business processes	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Scanning accuracy at my site	○	○	○	○	○
I	Usefulness of data collected by RFID to company	○	○	○	○	○
J	Learning how to use the RFID systems	○	○	○	○	○

10. At what level is the RFID system integrated within your organisation? Please tick one or more where applicable.

☐ Stand alone RFID system

☐ Integrated with organisation IT infrastructure

☐ Integrated with warehouse management system

☐ Integrated with transport or logistics provider

☐ Integrated with supply chain members

☐ Integrated with other: _____

11. Was the RFID project outsourced?

○ Yes   ○ No   ○ Mixed inhouse/outsourced

12. If outsourced, how effective has the project been in reaching desired objectives?

○ Not Effective   ○ Somewhat Effective   ○ Very Effective   ○ Not Applicable

13. How much was invested in the RFID project thus far (in New Zealand)?

○ Less than New Zealand$20,000   ○ $21K to $50K

○ $51 - $100K   ○ $101K - $200K

○ $201K - $500K   ○ Above $500K

14. If you already have RFID implemented but plan to further invest in RFID in the next 3 years, how much do you intend to invest?

○ Less than New Zealand$20,000   ○ $21K to $50K

○ $51 - $100K   ○ $101K - $200K

○ $201K - $500K   ○ Above $500K

○ No further investment

15. If you are not adopting, select **three** primary reasons for not adopting RFID in the supply chain. Else go to question 18.

☐ Lack of funding

☐ Lack of standards

☐ Lack of integration

☐ Lack of understanding

☐ Lack of expertise/knowledge

☐ Costs of investment

☐ Requirement to change business processes

☐ No requirement for RFID

☐ Others: _____

16. If you are not adopting, to what extent do you think each of the following has an impact when making the decision to adopt RFID? (1 means '*No Impact*', 3 means '*Some Impact*', and 5 means '*High Impact*'). Else go to question 18.

S/N	Results of Implementation	1	2	3	4	5
A	Investment costs would be too high	○	○	○	○	○
B	There might not be much improvement to work performance	○	○	○	○	○
C	Overall integration might not be achieved	○	○	○	○	○
D	Standards might be incompatible	○	○	○	○	○
E	Security of data might not meet company's requirements	○	○	○	○	○
G	Change to business processes might be disruptive	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Difficulty with scanning accuracy at my site	○	○	○	○	○
I	Data collected by RFID might not be useful to the company	○	○	○	○	○
J	Employee might find it difficult to learn how to use the RFID systems	○	○	○	○	○

17. If you are not adopting but have the intention to adopt RFID in the supply chain, how much do you intend to invest in this initiative? Else go to question 18.

○ Less than New Zealand$20,000   ○ $21K to $50K

○ $51 - $100K   ○ $101K - $200K

○ $201K - $500K   ○ Above $500K

○ No further investment

18. What is your **perception** for each of the following when planning on an RFID project? (1 means '*Very Difficult*', 3 means '*Neutral*', and 5 means '*Very Easy*').

S/N	Item	1	2	3	4	5
A	Selecting the right project team members	○	○	○	○	○
B	Selecting the right vendors (RFID, IT)	○	○	○	○	○
C	Learning about RFID	○	○	○	○	○
D	Identifying the areas where RFID can be used	○	○	○	○	○
E	Getting resources and support for the project	○	○	○	○	○
F	Training users	○	○	○	○	○
G	Using of RFID application/device	○	○	○	○	○
H	Usefulness of the RFID application	○	○	○	○	○
I	Overall implementation	○	○	○	○	○

19. What tagging strategy is your organisation planning to deploy or has already deployed in your supply chain? You may select more than one strategy.

☐ Slap and ship (tag with EAN/EPC code after packing)

☐ Maintain separate inventory of tagged and untagged product (Piloting specific products)

☐ Tag at container or truck level

☐ Tag at pallet or case level

☐ Tag at item level

☐ Have not decided yet

☐ Others: _____

20. When evaluating the investment costs, to what extent is each of the following costs a concern? (1 means '*Not Concerned*', 3 means '*Somewhat Concerned*', and 5 means '*Very Concerned*').

S/N	Concerns	1	2	3	4	5
A	Costs of RFID infrastructure setup (For example: reader, wiring, server)	○	○	○	○	○
B	Cost of tag	○	○	○	○	○
C	Cost of application/system integration	○	○	○	○	○
D	Cost of change to business processes	○	○	○	○	○
E	Cost of data management	○	○	○	○	○
F	Cost of maintaining the RFID systems	○	○	○	○	○
G	Cost of upgrading existing infrastructure	○	○	○	○	○

21. At which of the following stages do you think your supply chain is at present?

○ Some sort of electronic integration between yours and your suppliers' systems at departmental level

○ Some sort of electronic integration among departments in your organisation and between your suppliers' systems at departmental level

○ Some sort of electronic communication between yours, your suppliers' and your customers' systems

22. Who do you think benefit most from RFID implementation among the supply chain members?

○ Manufacturers/Suppliers/Producers

○ Warehouse/Distributors/Transporters

○ Retailers

Part C: For RFID Solution Providers/Advisors

If you are an RFID solution provider or advisor please complete this section.

23. Please select the type of RFID solution services your organisation provides.

☐ Software application   ☐ Hardware

☐ Project management   ☐ Process mapping

☐ IT integration   ☐ Others: _____

24. How many RFQ/I (request for quotation/information) has your organisation responded to in the last 12 months that have an RFID requirement?

○ 0-5   ○ 6-10   ○ 11-20   ○ Above 20

25. To what extent would you rate your company knowledge in the following?
    (1 means '*Some Knowledge*', 3 means '*Average Knowledge*', and 5 means '*Expert*')

S/N	Skills	1	2	3	4	5
A	Electronic Product Code (EAN/EPC) compliance	○	○	○	○	○
B	Data management	○	○	○	○	○
C	RFID integration with existing systems	○	○	○	○	○
D	Business process solution with RFID	○	○	○	○	○
E	Understanding user's requirement for RFID	○	○	○	○	○
F	Physical aspects of RFID	○	○	○	○	○

26. Please select three primary reasons to implement RFID in the supply chain.

☐ Compliance to mandate (For example: from a supply chain partner)

☐ Better inventory visibility

☐ Better visibility of order fulfilment

☐ Improve Labour efficiency

☐ Asset tracking

☐ Out of stock reduction

☐ Better shelf inventory and replenishment

☐ Theft reduction

☐ Inventory reduction

☐ Cost reduction

☐ Counterfeit reduction

☐ Speed up order fulfilment

☐ Product traceability requirements

☐ Others: _____

27. To what extent has each of the following concerns been expressed by your customers when asked to implement RFID in their supply chains?
    (1 means '*No Concern*' and 5 means '*Very Concerned*')

S/N	Concerns	1	2	3	4	5
A	Investment costs might be too high	○	○	○	○	○
B	There might not be much improvement to work performance	○	○	○	○	○
C	Overall integration might not be achieved	○	○	○	○	○
D	Standards might be incompatible	○	○	○	○	○
E	Security of data might not meet company's requirements	○	○	○	○	○
F	Change to business processes might be disruptive	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Scanning accuracy at my site	○	○	○	○	○
I	Data collected by RFID might not be useful to the company	○	○	○	○	○
J	Employee might find it difficult to learn how to use the RFID systems	○	○	○	○	○

28. To what extent has each of the following issues been when implementing RFID for your customers?
    (1 means '*Not Difficult*, 2 means '*Somewhat Difficult*', 3 means '*Very Difficult*', 4 means '*Not Applicable*')

S/N	Issues	1	2	3	4
A	Compliance or availability of standards	○	○	○	○
B	Meeting business process requirements	○	○	○	○
C	Integrating with existing systems	○	○	○	○
D	Meeting customer expectations	○	○	○	○
E	Minimising disruption to customer operations	○	○	○	○
F	Training	○	○	○	○
G	Accuracy of tag read-rate	○	○	○	○

| H | Managing RFID data | ○ | ○ | ○ | ○ |

29. To what extent has each of the following business functions been implemented with RFID thus far by your customers?
(1 means '*Not Implemented*', 2 means '*Some Implementation*', 3 means '*Extensive Implementation*', and 4 means '*Not Applicable*')

S/N	Functions	1	2	3	4
A	Tagged at manufacturing process	○	○	○	○
B	Warehouse receiving and put away	○	○	○	○
C	Warehouse picking and shipping	○	○	○	○
D	Warehouse storage	○	○	○	○
E	Warehouse cross-dock operation	○	○	○	○
F	Retail receiving	○	○	○	○
G	Retail on-shelf replenishment	○	○	○	○
H	Product return/recall operation	○	○	○	○

Part D: For Academic Institutions

If you are from an academic institution, please complete this section.

30. Is your institution currently offering a course/paper on the topic of RFID?

○ Yes   ○ No

31. If yes, at what level is the course being offered?

☐ Certificate   ☐ Under-graduate

☐ Diploma   ☐ Post-graduate

32. Is there ongoing research on RFID in your institution?

○ Yes   ○ No

33. If yes, to what extent has each of the following been researched?
(1 means '*Not Extensive*', 2 means '*Somewhat Extensive*', 3 means '*Very Extensive*', and 4 means '*Don't Know*')

S/N	Issues	1	2	3	4
A	Physical aspects of RF - technical	○	○	○	○
B	Manufacturing of RFID hardware	○	○	○	○
C	RFID software application	○	○	○	○
D	RFID data management	○	○	○	○
E	RFID in the supply chain	○	○	○	○
F	RFID in the commercial	○	○	○	○
G	Privacy issues of RFID	○	○	○	○

Part E: Contact Information

Thank you for taking time to complete the survey. Your input is valuable to us. If you would like us to contact you for the Part Two study, please give us your contact information. Your support is appreciated.

34. Your Name: _____
35. Your Role in the organisation: _____
36. Organisation name: _____
37. Contact phone number: _____
38. E-mail address: _____

Part F: Appendices

39. Definition of industry type:

Industry	Definition
Aerospace	Airline operations and engineering
Agriculture	Animal farming, sheep, cattle, deer, etc.
Biotechnology	Application of science and technology to living organisms.
Business services	Providing professional business services, includes technical, computer, legal, accounting, etc.
Construction	Builds, alters, repairs residential and non-residential buildings.
Education	Primary, secondary, and tertiary education services.
Energy	Producing and distributing electricity, gas and petroleum-based energy products.
Export/Import	Exporting, importing and overseas cargo.
Fishing	Fish farming and harvesting.
Forestry	Harvesting forest, planting, replanting.
Government/Defence	Central, local government and defence forces.
Healthcare	Pharmaceutical and health services.
Horticulture	Crop growing, fruits and vegetables.
Communication	Producing and selling of communication product and services.
Manufacturing	Producing goods from raw materials or assembling products from components, includes alcohol and tobacco.
Mining	Extracting of raw materials.
Retail Trade	Selling household and personal goods and services, includes supermarket, bookshops, restaurants, hotels, motels, repairers of household equipments and motor vehicles.
Transport/Storage	Air, ocean, land transport services. Warehousing and distribution.
Wholesale Trade	Selling and reselling of new or used goods to retailers, businesses or institutional.
Others	Other type of businesses not listed in the above.