Antecedents to RFID Adoption: Perspectives of Retail Supply Chain Stakeholders

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Abstract. This paper examines factors antecedent to the adoption of Radio Frequency Identification (RFID) from the perspectives of three key retail supply chain stakeholders: retailers, retailer suppliers, and technology providers and develops a conceptual framework to explore the impact of RFID on retail supply chain performance. Drawing on extant interorganisational information system theory, this research identifies factors likely to impact on the adoption of RFID. Four categories of factors such as technological, economic, organisational and external are identified. The relationship between RFID factors, RFID adoption and retail supply chain performance was developed as a conceptual framework employing Analytical Hierarchy Process (AHP). The proposed framework was validated by the results of two Australian pilot studies and responses from stakeholders of two mini surveys. The study identifies several gaps and proposes that each stakeholder group must be aware of, and agree to the salient factors that effects an RFID adoption decision.

1 Introduction

There has been an increased interest in RFID due to advances in the RFID technologies and improvements in Internet technologies. Equally, a notable reduction in technology and associated costs has triggered a review of RFID capabilities. Organisations within fast moving consumer goods (FMCG) supply chains are now looking to replace barcodes with RFID tags [1]. More importantly, they want to progress from established RFID closed system environments to RFID open system environments [2]. Open systems operate when tags attached to products containing a microprocessor chip are populated with identity information. As a pallet load of products passes a reader, it picks up radio signals from the products and passes information to the organisation's enterprise system. Location information is simultaneously circulated to supply chain partners via the Internet. EPCGlobal is the principal institute involved in developing RFID technology. Currently EPCGlobal is coordinating RFID efforts within the retail industry and endeavoring to provide the infrastructure supporting an open system network [3].

The scope of the paper is restricted to RFID open system technology which has the potential to radically change retail supply chains.

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Increased interest in RFID has resulted in a growth of literature, including books, research articles and articles in trade and business journals [4-6]. However, much of the information is anecdotal and the majority of articles are published in trade journals [7] and newspapers [8]. Robust research of RFID in the context of supply chain management is limited.

Implementation of RFID technologies are likely to result in benefits within supply chains [6, 9, 10]. These benefits include improvements over current barcode technology. For example, RFID technology will provide greater levels of inventory visibility, increased accuracy, and lower labour costs [2, 6, 9]. These benefits provide the incentive to investigate the value of RFID in supply chains. The potential benefits of RFID are summarised in Table 1.

Table 1. Benefits from Adopting RFID.

Authors	Major Benefits
[6]	• Faster processing - increased information • Higher accuracy • Increased tracking capability
[9]	• Increased inventory visibility • Decreased inventory levels • Decreased out of stock
[10]	• Increased inventory turnover
[2]	• Decreased shrinkage • Lower labour costs
[11]	• Minimised bullwhip effect
[4]	• Prevention of counterfeiting
[12]	• Process freedom
[2]	• Improved customer service

To prove the benefits of RFID, Wal-Mart commissioned the University of Arkansas to undertake a scientific study. The results concluded that stores using RFID outperformed stores without RFID [7]. Supply chain measures such as 'on-shelf availability' improved with a 14% reduction in out of stock (OOS) products. Also the stockouts were replaced three times faster, and there was a decrease in manual orders submitted by RFID enabled stores [7]. While the Wal-Mart study confirms some of the benefits, it fails to mention other factors including offsetting costs.

The objective of this paper is to develop a conceptual framework for RFID adoption based on extant literature and validate using responses from retail supply chain stakeholders. This will assist in understanding the relationships between factors impacting on the adoption of RFID and in turn its impact on the retail supply chain performance. The structure of this paper is as follows. Section 2 reviews literature on several interorganisational information systems, RFID, and performance measures of retail business. Section 3 summarises supporting adoption theories and proposes a conceptual framework employing analytical hierarchy process (AHP). Section 4 tests the proposed framework against the perspectives of three key stakeholders using two Australian pilot case studies and qualitative information collected through two mini surveys. The paper is concluded with a discussion on the findings, limitations, and future intentions.

2 Literature Review

2.1 Interorganisational Systems

Interorganisational systems [13] enable multiple organisations to communicate through efficient electronic links. IOS facilitates integration resulting in higher levels of collaboration and coordination [14]. Furthermore, higher levels of collaboration and coordination leads to higher levels of supply chain performance [15]. We discuss two widely researched IOS technologies such as Electronic Data Interchange (EDI) and the Internet due to their prominence in literature [16, 17].

2.2 Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) is defined as the computer-to-computer transfer of information between organisations in a structured format [16]. The primary drivers for implementing EDI are operational gains, competitiveness, and improvements in inter-organisational relationships [18]. Benefits from EDI including, quick response and access to information, improving data control, improving customer service, enhancing competitive capacity, faster inventory turnover, consistent flow of information among trading partners, standardization of procedures, and improving trading partner relationships have been reported in literature [19].

Initially, these reported benefits compelled organisations to consider adopting EDI. However, claims of inevitable wide spread adoption did not eventuate. Apart from fortune 1000 firms, only 2% of organisations in the US have implemented EDI [20]. Factors impacting on adoption include high costs [21], technology complexity [22] and the requirement for close cooperation by supply chain members [23]. Such factors prompted the search for other technologies.

2.3 Internet

Organisations have adopted the Internet technology to conduct electronic business in a dyadic framework [24]. Known as e-business, it has been demonstrated that higher levels of web usage throughout supply chains leads to higher organisational performance [25, 26]. Organisations including Dell, GE, Cisco have claimed significant benefits from the adoption of e-business within their supply chains [27, 28].

It is apparent to businesses that the Internet makes sharing information easier and cheaper [29], reduces response times, simplifies payments, extends supplier bases, reduces the manual paperwork, and eliminates errors [30]. e-business applications have advantages over EDI resulting in organisations switching across [31]. For instance, compared to EDI, internet technology requires lower implementation and operating costs and does not require close coordination between partners. There is also a limited need for adjustments for compatibility [29]. Unlike EDI, the Internet has the advantage of a common protocol (xml) [24] and operates in an open world-wide-web system [32]. Internet is also being combined with technologies such as EDI

[33], electronic trading hubs [34], business process management systems [35], and automatic data capture technologies [36] to create more effective electronic systems. However, studies also identified factors that impact adversely on adoption of e-business. These include technology competence, availability of IT professionals, organisational size, global scope, integration, competitive intensity, and regulatory environment [37]. There are increasing evidences of the Internet merging with other technologies.

Both EDI and the Internet have reported benefits for organisations contemplating adopting either of these technologies. Conversely, both technologies have a number of factors that act as antecedents to adoption. These factors can be grouped into categories: technological, economic, organisational and external. We assume that similar factors will be found when we examine RFID technology.

2.4 RFID

Like EDI and the Internet, RFID is now classified as an interorganisational information system [38]. There are two main reasons for current interest in RFID. Firstly RFID has been designed to enhance the transfer of information between organisations. This is achieved by taking information about a product directly from tags placed on these products without line of sight. Secondly, designers provide a network whereby this valuable information can be shared via the Internet [11].

However, RFID technologies have a number of factors that are currently preventing wide spread adoption. RFID is a new technology and not compatible with many of the existing technologies such as other RFID technologies and Enterprise Resource Planning (ERP) systems [12]. RFID is prone to interference causing errors in reading tags [10]. There are economic reasons as well. RFID is considered too expensive [11]. Infrastructure costs, hardware costs, tag costs are all reasonably high [11]. There are also organisational considerations in the adoption of RFID. Studies indicate that only larger organisations are capable of committing considerable resources required to adopt RFID [9]. Furthermore, there is a need for top management support for successful implementation of RFID [6]. Finally there are factors external to the organisation such as competitive pressures [39] and privacy issues [40]. These factors all act as antecedent to adoption of RFID and will be discussed in the following subsections in more detail.

2.4.1 Technological Factors

According to literature, the adoption of technology innovations is shaped by three factors. If a technology is compatible with existing technology, and is not overly complex, and has some relative advantage, then it is more likely to be adopted [41]. Despite advances in technology, RFID has both compatibility and complexity issues that are currently acting as barriers to wide spread adoption. A substantial effort is underway to overcome existing technological issues. Conversely one reason for current attention in RFID is the relative advantage that RFID tags have over barcodes. A comparison of RFID and barcode technologies results in RFID being considered as superior. A summary of technological factors is presented in Table 2.

Table 2. Technological Factors Affecting RFID Adoption. Source: [6, 10, 12, 42, 43].

Cat.egory	Factors	Major issues
Technological	Compatibility	• Inability to integration with other RFID systems • Incompatible with ERP systems • Incompatible numbering, frequency and power standards
	Complexity	• High levels of false reads • High data volume
	Relative advantage	• Continuous information • More accurate information • Simultaneous tag reads • Read without opening cartons • More data stored on a tag • Active tags can record data such as temperature and humidity • Anti tampering capability • Ability to write to active tags • Operate in harsh conditions • Does not require line of sight

2.4.2 Economic Factors

Our research also identifies economic factors as antecedent to adoption. Although the costs associated with RFID technology are declining, they are still considered unacceptably high [2]. The passive tags, which were used in supply chain trials in 2000, cost around $1.00. These tags can now be purchased for between 15 to 20 cents [44]. Some studies suggest that a target cost of 5 cents is likely to be accepted by industries [45]. Table 3 summaries the major issues concerning costs.

Table 3. Economic Factors Affecting RFID Adoption. Source: [2, 11, 44, 46].

Category	Factor	Major issues
Economic	Costs	• RFID tag costs • Hardware costs • Software costs • System integration costs • Training and consulting costs

2.4.3 Organizational

Literature acknowledges the importance of a number of organisational factors in the adoption of RFID. In particular, the support and leadership of top management and the size of the organisation impacts on the propensity to adopt an emerging technology such as RFID [47]. Although top management support has not received wide coverage in RFID literature, a study by Sweeney [6] highlights the need for management involvement in the deployment of RFID. The size of the organisation is reported to have an impact on RFID adoption. Studies show that at this early stage of RFID implementation, mainly the larger retailers and manufacturers are involved in RFID technology trials [2, 9, 12]. We argue that these organisational factors are critical for the RFID adoption process. A summary of organisational factors are presented in Table 4.

Table 4. Organisational Factors Affecting RFID. Source: [2, 9, 38].

Category	Factors	Major issues
Organisational	Firm size	• Large firms dominate • Small firms not considered
	Top Management Support	• Wide adoption less likely without support

2.4.4 External Factors

The adoption of technology is often shaped by the reaction of competitors, supply chain partners and other stakeholders. A number of external factors such as pressure from competitors, industry readiness, and privacy concern have been linked to the adoption of RFID.

When high levels of uncertainty exist, organisations are often subject to coercion, mimetic and/or normative pressures [48]. For example, Wal-mart has mandated suppliers to adopt RFID. Suppliers are aware that failure to comply may result in lost business [49].

Consumer are disturbed about unwanted access to information held in RFID tags attached to products after they leave the store [40]. The issue of anonymity has caused adverse reaction by consumers who object to the thought of being tracking via these tags. [50]. A summary of external factors is presented in Table 5.

Table 5. External Factors Affecting RFID. Source: [38, 40, 49, 50].

Category	Factors	Major issues
External	Industry readiness	• Retailers and Department of Defence industries
	Competitive forces	• Retailer mandates • Mimetic behaviour
	Privacy	• Consumers action groups against tags

2.5 Retailer Performance

Leading organisations have focused on adopting appropriate performance indicators for supply chain performance [51]. These indicators assist in determining improvements throughout the supply chain.

Retailers have recognised that improvements throughout the supply chain will impact positively on their own performance [52, 53]. In particular, upstream efficiencies will impact positively on product availability. Product availability has become the accepted bottom line performance measure for retailers [52].

Retailers compete by offering a wide variety of products to customers. A typical supermarket may manage as many as 30000 products at one time [54]. One issue with such a large assortment is the likelihood of product being out-of-stock (OOS). A recent world wide study reported that the average OOS is about 8.3%. Furthermore, lost sales resulting from products not being on the shelf are reported to be 3.9% of sales world wide [55]. The majority of OOS occurs due to store mismanagement such as failure to order the product. Since OOS is a major concern when it comes to customer service, it is argued that OOS should be completely eliminated [56].

3 Conceptual Framework

3.1 Adoption Theories

There are a number of theories acknowledging adoption and diffusion of emerging technologies [41, 57, 58]. The adoption process has been recognised in terms of initiation stages (agenda setting and matching) and implementation stages (redefining/restructuring, clarifying, and routinizing) [41]. Initiation focuses on the stages up to an adoption decision and is more relevant to emerging technologies such as RFID. The adoption decision is dependent on an organisation's knowledge about a new technology [41]. Organisations continually scan the external environment for new technology. This technology is then examined in the context of matching a problem noted in the organisation's agenda of problems requiring solutions [41]. Equally, knowledge of an emerging innovation can also lead to an investigation of its value, regardless of problems. However, there is uncertainty with radical innovations due to the considerable amount of knowledge an organisation must acquire[41]. This knowledge reflects an organisation's preparedness and the level of accessibility to antecedent factors.

The decision to implement a new technology results in either acceptance or rejection [41]. However, we propose that the decision may also include adoption postponement. Emerging technologies, such as RFID are continually being developed and as a result, organisations need to access all the latest information about antecedent factors. Thus a feedback loop is required to be added between adoption and organisational preparedness to account for uncertainty. Literature also describes how retail performance is influenced by the effective execution of logistics activities upstream in the supply chain. We have considered the term product availability as the performance indicator to capture these factors. Increased product availability will lead to improvements in retail performance. Our conceptual framework is represented in Figure 1.

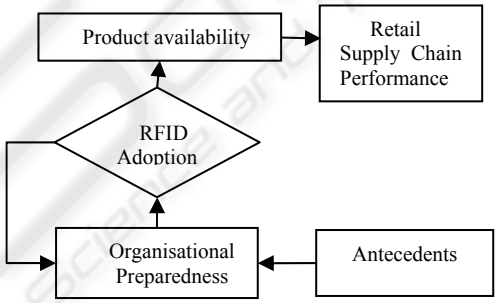

Fig. 1. RFID Adoption Framework.

3.2 Analytical Hierarchy Process

In order to ascertain the managers understanding on factors that affect the successful adoption of RFID, this study develops a conceptual framework using the AHP approach [59].

AHP is a decision-making approach which integrates simultaneously qualitative and quantitative information for prioritising alternatives when multiple criteria must be considered. According to Saaty [59], a decision making approach should have the following characteristics:

- be simple in structure,
- be adaptable to both group and individual decision making environments,
- be natural to human intuition and general thinking,
- encourage compromise and consensus, and
- not require inordinate specialisation to master and communicate.

The decision making process of the AHP is consistent with these characteristics. After comparing five different utility models for determining priorities, Schoemaker and Waid [60] concluded that the AHP was the easiest to use and produced the most credible results. AHP has been used in a recent publications in the field of RFID [61].

3.2 The Modeling Process of the AHP

The modeling process involves four steps:

1. assessment of factors in the adoption of RFID
2. structuring the problem as a hierarchy and building the AHP model
3. collection and compilation of experts' opinions and application of the prioritisation procedure, and
4. determination of critical factors.

The first step involves identification of key factors that influence the level of RFID adoption. Identification and classification of these factors have been discussed earlier and are shown in Table 2 – Table 5.

The structuring step consists of breaking down any complex multiple criteria decision-making problem into a series of hierarchies or set of integrated levels. Generally, the problems are structured in at least three levels given in Table 6.

Table 6. Problem Structure and Definition.

Level		Generic definition	In the study
1	Goal	The overall objective of the decision making process which is placed at the apex of the hierarchy	The goal is to identify the *state of organisational preparedness* based on the level of accessibility of each of the factors.
2	Criteria	Bases on which the alternatives are evaluated	Factors such as technological, economic, organisational and external
3	Alternatives	The outcomes of the evaluation process	Importance of four factors

The goal is to identify the *state of organisational preparedness* based on the level of accessibility of each of the factors. This is shown at level 1 in Figure 2. Level 2 is

represented by the four antecedent categories: technological, organisational, economic and external. Factors within each of these categories (Level 3) requires continous refinement. Frequent advancements update an organisation's knowledge about RFID. For example, industry has been awaiting a 2nd generation of standards anticipating enhanced capability [3]. Our framework indicates a flow from these four categories of factors via updated knowledge to a decision point. The decision node is defined by three outcomes, rejection, acceptance and postponement. While some organisations may have rejected RFID outright, many have postponed their decision pending further information. Postponement is therefore linked back to the state of organisational preparedness. Continual postponement is likely to force organisations to reject RFID altogether. On the other hand, there is considerable evidence that acceptance will lead to significant supply chain improvement. This improvement is represented by product availability. As discussed earlier product availability is now accepted as a bottom line retail performance measure. The conceptual framework for RFID adoption developed using AHP is shown in figure 2. This framework could be used to assess the *State of Organisational Preparedness* using both quantitative and qualitative information. However, in this paper our objective is to validate the proposed framework using only the qualitative information collected from two pilot studies and two mini surveys. The next section examines this validation process.

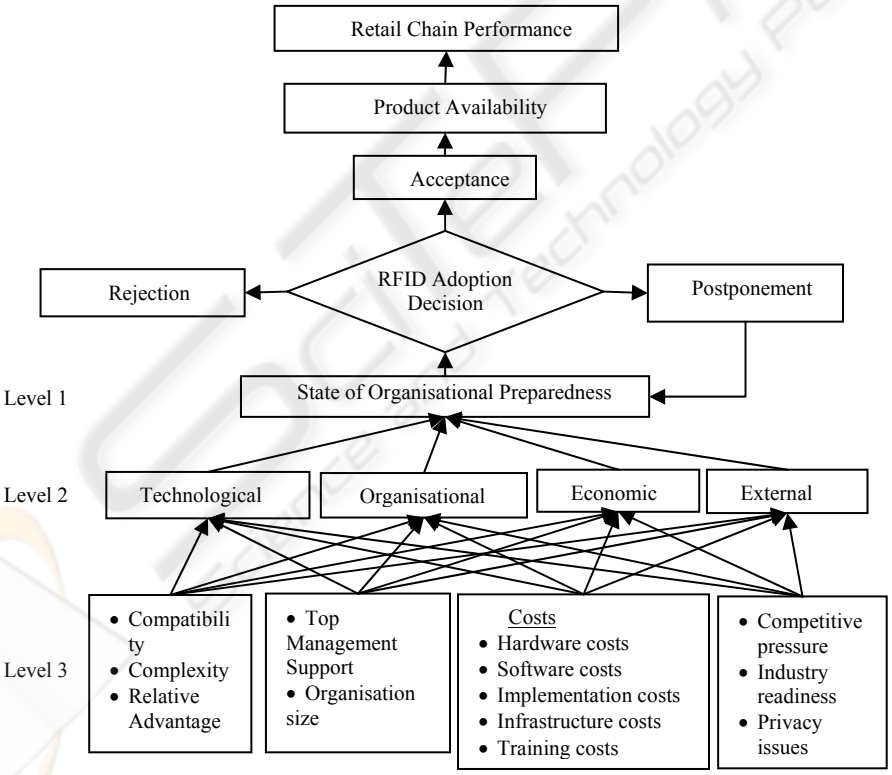

Fig. 2. Detailed RFID Adoption Research Framework.

4 RFID Stakeholder Perspectives

There are a number of stakeholders representing the current RFID environment. Three major parties are retailers, suppliers to retailers, and RFID technology and service providers. In this paper we gathered information from all three sources and compared each stakeholder's view of RFID implementation. This information was obtained from two pilot studies in Australia and two mini surveys undertaken during the latter half of 2005 and 2006.

4.1 Australian Demonstrator Project

The EPC Network Australian Demonstration Project was a trial undertaken in Melbourne during 2006. A consortium of retailers, suppliers, technology providers, transport providers and materials handling organisations in the fast moving consumer goods industry (FMCG) conducted a pilot study of RFID technology.

Supply chain participants including Gillette, Proctor and Gamble, Chep Pallets, Linfox, Metcash Retailer, and technology service institutions such as Commonwealth Scientific Industry Research Organisation (CSIRO), and GS1 Australia. The objectives of the trial objectives were to show that EPC Network could deliver benefits to all members of supply chains through RFID adoption .

The trial also set out to encourage Australian companies to get involved rather than wait for mandates[3]. CSIRO analysed each site and designed the RFID layout. Technology service providers including Verisign and Sun Microsystems provided hardware and software. A subsequent report outlined the results including integration beyond 1st tier suppliers and customers with the adoption of a single set of global standards resulted in higher levels of visibility and real time information. The trial of EPC Network Project provided evidences that such collaborative affords can be successfully applied[3].

This trial provides support for our framework. For example, all the participants of the Network Project are of the opinion that technological factors have serious implications on the adoption of RFID. RF interference, complexity of RFID, failure to link with existing technologies, and false reads are some of the major technological concerns expressed by these companies. Metcash identified the significant amount of resources needed to adopt RFID, alluding to the fact that only larger organisations would be capable of RFID adoption. Metcash also revealed external factors such as the need for all parties to agree to adoption before it could be a success.

Gillette mentioned organisational factors such as top management support, while P&G and Linfox both indicated the difficulty in justifying the return on investment. Among the possible benefits of RFID adoption expressed by the companies are improvement in sharing information (Gillette), process improvement (Capilano and Nugan), improvement in supply chain visibility (P&G), and improvement in tracking capabilities (Chep). Although there was no mention of improvements in product availability, it is suggested that such improvements will invariably impact on the product availability of the entire supply chain [3].

4.2 Patties and Montague's EPC/RFID Pilot Study

Another trial was Patties and Montague's EPC/RFID pilot study. Patties Pies, and Montague Cold Storage are both suppliers to retailer outlets. Together with a number of technology providers they examined RFID technology to determine the reliability and integration capability in a business to business setting [62]. Montague's cold storage facility added a new dimension to the study of RFID technology. One important finding of this study is that tags can be read successfully in sub-zero temperatures. Results also indicated improved visibility, elimination of scanning, reduced labour requirements and overall efficiency of the supply chain [62]. This study also validates our proposed conceptual framework. For instance, technological issue such as RF interference was expressed as a major concern.

4.3 RFID Australasia 2005 and 2006

Two mini surveys were conducted in 2005 and 2006. The first involved respondents from a trade exhibition held in conjunction with 'RFID Australasia 2005' conference in Sydney in August 2005. This venue provided an opportunity to gather information from RFID technology suppliers. Suppliers of RFID technologies included senior level representatives from both local and multinational organisations. These executives were interviewed individually.

The exhibition displayed RFID related technologies which include identification systems, contactless smart cards, middleware, RFID enabled supply chain applications, RFID hardware, RFID software, RFID labels and label printers, RFID readers, transponders and technology consultants. Respondents answered a structured set of open-ended questions aimed at soliciting verbal responses.

The findings support our proposed framework for RFID adoption. Respondents revealed that factors such as technological (infrastructure, standards, interference), economic (costs), organisational (top management support), and external factors (competitive pressures, and mandates) are likely to have profound impact on the adoption of RFID. However, size of organisation was not mentioned as an issue. The possible benefits of RFID expressed by the respondents include labour savings, automation, advantages over barcodes and increased supply chain visibility.

Our 2005 survey was replicated at the 2006 exhibition and found similar results with regards to factors impacting RFID adoption and benefits derived from adoption. However, during this survey we also questioned respondents about changes to the RFID environment in the last 12 months. These responses are summarised in Table 7. It would seem that while some changes could support acceptance of the technology, other responses indicate continuing postponement.

Table 7. Changes to the RFID Environment – 2006 Pilot Study Results.

Acceptance
• Significant improvement in ultra high frequency with generation 2 technology now available
• The ability to read and write to passive tags
• The relaxation of power regulations allowing organisations to gain 4 watt licenses for RFID studies
• Greater levels of education have become apparent
• Consensus on the GS1 standard as the preferred standard for RFID
Postponement
• There has been a slowdown in RFID technology trials
• Decreased hype about the technology
• Significant resources required to undertake such a project
• No open systems have been adopted in Australia
• The two major retailers Woolworths and Coles have not adopted and do not intend to adopt
• RFID in the near future. Both are in touch with USA counterparts (WalMart and Target) and therefore able to monitor this environment.

5 Discussion and Conclusions

First this paper compares extant IOS literature with RFID technology and concludes that the factors that generally impact the adoption of IOS also impact RFID adoption. These were categorised as technological, economic, organisational and external factors. Applying the adoption and diffusion theory [41], we concluded that adoption of RFID would follow similar pattern as other IOS technologies. RFID adoption is dependent on knowledge about the technology, and other antecedent factors. Our research proposes that in the earlier stages of the innovation process involving radical emerging technology there is considerable uncertainty. Thus organisations continually seek the latest information about changes, developments and upgrades. We highlight this point in our framework and define as *'State of Organisational Preparedness'*. We suggest that under these conditions, organisations may decide to accept or reject the technology, as well as postpone adoption.

We employed AHP to develop a conceptual framework for RFID adoption presenting the relationships between the various factors. Three levels are identified in the AHP process. The first level is the goal, characterized by state of organisational preparedness. The second level is factors impacting on the goal, and the third level defines alternatives which represent the importance attributed to factors.

Our research proposes that the organizational preparedness is linked to the RFID adoption decision. Acceptance of RFID is likely to lead to improved supply chain performance in terms of superior product availability.

We test the proposed framework by analysing information from two pilot studies and two mini surveys conducted at RFID exhibitions in Australia. Information was collected from three stakeholders such as retailers, suppliers to retailers, and technology providers. The results from the case studies and mini surveys validated our proposed framework.

It is worthy mentioning that the proposed framework validation process was designed for a preliminary exploratory study. Thus there are two major limitations to this study. First, the trials were localized (in Australia) and did not involve the two major retailers (Coles and Woolworths). Second, the sample size was small and

therefore may not be representative of the retail industry. Further research is required to validate the framework using large sample size and utilizing quantitative data and information.

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