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Factors affecting selection decision of auto-identification technology in warehouse management: an international Delphi study

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Selecting an automatic identification and data capture (auto-ID) technology, for example RFID and barcodes, is a long-term investment, and it contributes to improving operational efficiency, achieving cost savings and creating opportunities for higher revenues. We identified the set of factors that affect the technology-selection decision for warehouses through a literature review. Then, to investigate the critical factors, and their relative importance to the decision-making process, we conducted a modified two-round Delphi study with a worldwide panel of experts (107) including academics, industry practitioners and consultants in auto-ID technologies. The results show that there are 54 key factors under six categories: organisational factors, operational factors, structural factors, resources, external environment and technology. We verified the results of the Delphi study with interviews carried out with 19 experts across the world. Based on the Delphi study and the interviews' findings, we developed a multi-stage selection framework for auto-ID technology.

Keywords: auto-identification technology; RFID; barcode; warehouse management; decision-making process; Delphi study

1. Introduction

In a supply chain, a warehouse is an essential component linking all chain parties. The performance of warehouse operations, which are either labour- or capital-intensive, not only influences the productivity and operation costs of a warehouse, but also the performance of the entire supply chain (Gu, Goetschalckx, and McGinnis 2007). Deciding on the type of auto-identification (auto-ID) technology is a key aspect of strategic decision-making for warehousing companies or manufacturers operating large warehouses. The optimum auto-ID technology may offer and sustain the competitive advantage of the company. There is a wide range of factors potentially affecting the decision to use auto-ID technologies. The number of warehousing companies considering auto-ID technology continues to increase (Sarac, Absi, and Dauzère-Pérès 2010).

Previous studies have investigated the critical factors influencing auto-ID decisions in a supply chain (Sarac, Absi, and Dauzère-Pérès 2010; Laosirihongthong, Punnakitikashem, and Adebanjo 2013; Pfahl and Moxham 2014). They have examined these factors separately to help decision-makers to obtain the optimum auto-ID technologies in a supply chain. However, the literature on auto-ID selection decision in the warehouse environment is limited, with few studies that discuss the factors recognised in auto-ID selection decisions in a warehouse context (Chow et al. 2006; Karagiannaki, Papakiriakopoulos, and Bardaki 2011; Poon, Choy, and Lau 2011). Therefore, this research aims to investigate empirically the auto-ID technology-selection process and to determine the factors and their relative importance in the warehouse context.

Warehouse operations are no longer confined to inventory storage and protection of goods; they might include various operations, ranging from receiving, put away, order picking, packaging of items and after sales services to light assembly and inspection (Poon, Choy, and Lau 2011). Auto-ID technologies are a wide category of information collection techniques that are used to automatically identify objects, humans and animals, retrieve information carried by the objects, and enter information into a database (Waldner 2008). Major auto-ID technologies are: barcode, optical character recognition (OCR), voice recognition, biometric systems, smart cards and radio frequency identification (RFID)

To understand the auto-ID technology-selection process in a warehouse environment, it is important to take heed of all key factors that may potentially influence this decision. Although there are some papers that explored the criteria of the auto-ID selection decision in a warehouse (Porter, Billo, and Mickle 2004; Vijayaraman and Osyk 2006; Van De Wijngaert, Versendaal, and Matla 2008; Poon et al. 2009; Karagiannaki, Papakiriakopoulos,

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and Bardaki 2011; Osyk et al. 2012), those factors have been examined separately. The choice of barcode or RFID is not a single choice, but a number of issues influence the selection that is comprised of a series of decisions (Ilie-Zudor et al. 2011). Warehouse managers should follow several steps before any auto-ID technology is selected for implementation (Pero and Rossi 2014). This paper defines a conceptual framework to examine and collectively understand the key factors that may potentially influence the technology-selection process in a warehouse environment and their relative importance, because it is a long-term investment contributing to cost savings and affecting service levels.

This paper is organised as follows. In Section 2, factors and sub-factors affecting auto-ID selection decision in warehouse management are identified. A description of the research design and methodology is given in Section 3. Findings of the Delphi study and the interviews are presented and discussed in Section 4. Finally, Section 5 is devoted to concluding remarks and implications for future research.

2. Factors relevant to auto-ID selection decision in the warehouse environment

Warehouse needs are key factors that may have a significant effect on auto-ID decisions (Liviu, Ana-Maria, and Emil 2009). Technological perspectives have received considerable attention since the late 1950s, but less have been undertaken from other perspectives such as an organisation and environment level when firms make an auto-ID selection decision (Sarac, Absi, and Dauzère-Pérès 2010). However, warehouse contextual factors such as structure, workflow and resources are major considerations in many RFID selection decisions (Karagiannaki, Papakiriakopoulos, and Bardaki 2011). In this regard, the most efficient RFID solution in a warehouse environment can be formulated by studying the actual physical and internal environment of a warehouse first and then analysing various RFID technologies (Poon et al. 2009). Technological factors are more notable than strategic factors such as network structure, business processes and management components when firms decide to use auto-ID technology in their supply chain (Ilie-Zudor et al. 2011).

The key factors affecting auto-ID selection have not been studied as a whole. For this purpose, we used the technology–organisation–environment (TOE) framework (Tornatzky and Fleischer 1990) as the theoretical basis to categorise the factors identified through the literature review and organise them into six categories: organisational, operational, structural, resources, external environmental and technological. For each category, we identified the key factors that may affect auto-ID decision-making based on a combinatorial synthesis and an analysis of the literature on IS implementation in supply chain management and warehouse management.

2.1. *TOE framework*

Some of the key IS theories on technology adoption are technology acceptance model (TAM) (Davis Jr 1986), theory of planned behaviour (TPB) (Ajzen 1985), unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al. 2003), diffusion of innovation (DOI) (Rogers 1995) and TOE (Tornatzky and Fleischer 1990). In this research, we discuss only the DOI and the TOE because they are at the firm level, while TAM, TPB and UTAUT are at the individual level (Oliveira and Martins 2011).

According to the TOE, a technological innovation adoption is based on factors in the technological, organisational and environmental contexts (Tornatzky and Fleischer 1990). The technological context refers to internal and external technologies relevant to the firm. The organisational context refers to descriptive measures about the organisation such as the firm's structure and resources, scope (the horizontal extent of a firm's operations), size, top management support and complexity of its managerial structure. The environmental context is the arena in which an organisation conducts its business. This includes the industry, competitors and dealings with the government.

Warehouses can be categorised with respect to their processes, resources and structure (Rouwenhorst et al. 2000; Bhuptani and Moradpour 2005; Karagiannaki, Papakiriakopoulos, and Bardaki 2011). Products arriving at a warehouse are taken through a number of steps called processes or operations. Resources include all means, equipment and staff needed to operate a warehouse. Finally, warehouse structure consists of a set of physical and internal environmental factors considered when starting-up a new warehouse or renewing/adding to an older one.

The TOE framework is consistent with the DOI theory where technological characteristics, individual characteristics, and both the internal and external characteristics of the organisation are antecedents to any adoption decision (Zhu, Kraemer, and Xu 2006). These are similar to the technology and organisation context of the TOE framework; however, the TOE framework also has the environment context that includes constraints and opportunities for IT innovations (Oliveira and Martins 2011). Therefore, the TOE framework makes the DOI theory better able to explain intra-firm innovation adoption (Hsu, Kraemer, and Dunkle 2006). For this reason, the TOE framework provides a good starting point when analysing and considering appropriate factors for understanding the technology adoption (Wang, Wang, and Yang 2010). RFID and barcode are enabled by technological developments and automated identification driven by organisational factors such as top management support and affected by environmental factors related to business partners and competitors (Oliveira and Martins 2011). These factors are presented in Table 1.

Given the pre-mature level of auto-ID research in warehouse management, the Delphi method is also well suited for research in areas where theory is not yet well developed (Skulmoski, Hartman, and Krahn 2007) and thus, it enhances the external validity of this research design. Moreover, compared with surveys or case studies, which usually depart from a certain perspective, a Delphi technique offers a much wider perspective because it can use an open question as a starting point, which then can be developed into a set of issues (Seuring and Müller 2008).

3. Research design and methodology

The research design relied on two phases, as shown in Figure 1. After reviewing and analysing the existing theory, a modified (mixed-methods) two-round Delphi study using a worldwide panel of 107 experts in the first phase was used to identify important factors that influence auto-ID selection decision in warehouse management.

The second phase incorporated follow-up interviews, both face-to-face and telephone, using 19 experts across the world. The objective was to discuss in-depth, verify and confirm the results of the Delphi study. The two-round Delphi study and the follow-up interviews were sufficient for providing enough data to develop a comprehensive framework for the selection process of auto-ID technology in warehouse management.

3.1. *The Delphi approach*

A Delphi study is a systematic, iterative process, with controlled anonymous judgments and systematic refinement, to extract a consensus view from a heterogeneous panel of experts from different backgrounds (Linstone and Turoff 1975). The Delphi approach uses a representative group of experts to produce a more accurate and more informed judgement than is obtainable from one individual. It is different from other group judgment techniques, such as brainstorming or opinion polls in that it avoids group interactions of individuals, which may result in induced responses. The Delphi method helps to reduce the effect of dominant individuals and to generate a consensus of expert opinion on subjective issues (Green and Price 2000). The following subsection provides the details of the Delphi process followed in this research, including the selection of panel, pilot and actual Delphi studies, followed by the analysis of data collected.

3.1.1. *The Delphi panel*

For the first round, we selected experts from different fields to obtain a variety of insights from researchers with both theory-based and practice-based background (Table 2). The largest group of panellists (40.1%) were from the field of auto-ID technology, followed by supply chain management (24.5%), warehouse management (14.4%), logistics (13.6%) and operations management (7.4%). The panellists were based in Western Europe (UK, Italy, France, Germany and Portugal, 49.4%), North America (US and Canada, 42%), Asia (China and India, 5.6%), Australia (1.9%), and South America (Brazil 0.9%). The panel members consisted of 39 academics, 36 industry practitioners and 32 auto-ID consultants. Eighty-eight of the panel members were male, and 19 were female. The majority (105) held a PhD or a Master's degree.

The invited experts, with a theory-based background, were all first or second authors on high impact papers in the field of auto-ID technology in supply chain management and warehouse management, published between 2000 and 2012. Database searches in Science Direct, Sage, Scopus and Emerald were performed to identify experts and to examine reference lists from relevant papers, book chapters, review studies and conference abstracts. The experts with a practice-based background were selected on the basis of their publications, but also using the snowball sampling approach (Goodman 1961), where each member of the responding experts was asked to nominate names of important experts in the field. This resulted in an initial list of 135 experts who were invited by email to participate in the Delphi survey, 8 respondents refused to participate, 7 did not respond. So, the total number of experts who agreed to participate was 120 (88% response rate). However, the actual number of experts who has participated in this research was 107 (79% response rate), because there were 13 experts who agreed to participate, but then did not.

3.1.2. *Pilot Delphi study – round 1*

A questionnaire was developed based around the factors and sub-factors presented in Table 1. It was first pre-tested with 10 postgraduate colleagues to check for clarity and consistency and ensure appropriate changes were made. Then, a pilot study of the questionnaire was conducted on 10 December 2012, with 12 people, that is, 10% of the expert sample size (Baker and Risley 1994). Four academics, six practitioners and two auto-ID consultants participating in the Delphi study were selected randomly and invited to the pilot study to receive comments and feedback. The pilot study was closed on 24 December 2012. Participants made valuable contributions to the development and improvement of

Table 1. Factors and sub-factors organised under the TOE framework.

Major factors	Sub-factors	Considered by
Warehouse structural factors	• Warehouse size; • number of aisles; • number of racks; • mechanisation level; • departments layout; • product carrier of the stock keeping unit (SKU) (pallet, case or item); • product type; • temperature; • humidity; • noise; • dust and dirt; • pressure; • E-Plane (electric field); • H-Plane (magnetic field).	• De Koster, Le-Duc, and Roodbergen 2007 • Gu, Goetschalckx, and McGinnis 2007 • Arooj, Mufti, and Jamal 2011 • Bhuptani and Moradpour 2005 • Karagiannaki, Papakiriakopoulos, and Bardaki 2011
Warehouse operational factors	• Receiving • put away • forward reserve allocation • picking • order accumulation and sorting • zoning • batching • routing • shipping • storage assignment policy.	• Rouwenhorst et al. 2000 • Karagiannaki, Papakiriakopoulos, and Bardaki 2011
Resources-related factors	• Storage units • storage systems • warehouse management system • material handling equipment • warehouse staff members (labour) • storage space capacity	• Rouwenhorst et al. 2000 • Karagiannaki, Papakiriakopoulos, and Bardaki 2011
Organisational factors	• Top management support • IT knowledge capability • warehouse internal needs.	• Hwang et al. 2004 • Liviu, Ana-Maria, and Emil 2009 • Laosirihongthong, Punnakitikashem, and Adebanjo 2013
Technological factors	• Technology costs • deployment costs • line-of-sight; labour • visibility • accuracy • reliability • item level tracking • traceable warranty • product recalls • quality control • tag data stora • information properties • tag weight • tag read/write capabilities • operational life • memory • communication range • multi-tag collection • security • privacy • environmental sensitivity • interference	• Huber, Michael, and McCathie 2007 • Sarac, Absi, and Dauzère-Pérès 2010 • Poon, Choy, and Lau 2011 • Fosso Wamba and Ngai ahead-of-print 2013

(*Continued*)

Table 1. (*Continued*).

Major factors	Sub-factors	Considered by
	• ongoing innovations • ease of use • established standards • performance • Return on Investment (ROI).	
External environmental factors	• Government pressure; • competitive pressure; • customer pressure; • technology provider support.	• Hwang et al. 2004 • Wang, Wang, and Yang 2010 • Quetti, Pigni, and Clerici (2012)

Table 2. Demographic characteristics of the Delphi panel members.

Characteristics	Frequency (N = 107)	Percentage (%)
Age		
Below 25 years	0	0
26–35	5	5
36–45	33	31
46–55	58	54
56–65	11	10
Above 65 years	0	0
Gender		
Male	88	82
Female	19	18
Highest qualifications		
PhD	101	94
DBA	4	4
MBA	2	2
Occupation		
Academics	39	36
Industry practitioners	36	34
Auto-ID consultants	32	30

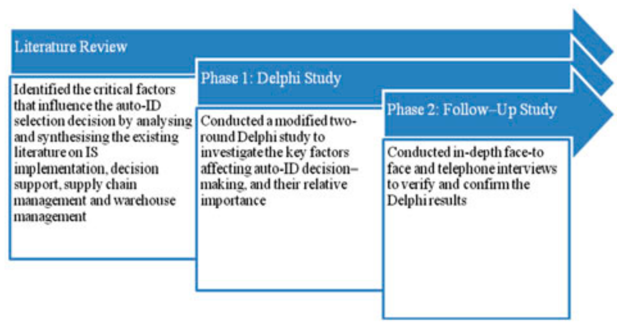

Figure 1. Research design.

the questionnaire. The pilot study allowed ambiguities to be highlighted and some sub-factors to be grouped, rearranged or removed. Six major factors and 65 sub-factors were identified for consideration in the actual first round of the Delphi study.

3.1.3. *Actual Delphi study – round 1*

The initial round of the Delphi study was sent out to the panellists on the 06 January 2013, and the round was open until the 10 February 2013. The email included detailed information on the study aim and procedure, as well as a link referring them directly to the first-round questionnaire. Non-responders received a reminder email after the 3-week response period had expired. As a result, 21 additional responses were received after the reminder. The first-round questionnaire consisted of two parts. The specific issues addressed in Part A of the questionnaire were:

- The motivations of warehouses that seek to use auto-ID technology;
- The key steps in the selection process of auto-ID technology in warehouse environment;
- The most difficult problem in making an auto-ID decision; and,
- The ways to overcome the problem.

Part A consisted of four open-ended questions, which allowed respondents to provide and express their opinions or add information freely and independently. The qualitative data were analysed manually using a content analysis approach. The results of the contents analysis were presented quantitatively and converted into frequencies, because it offers easy comparison with other studies undertaken within a similar framework (Bryman 2012).

Part B of the questionnaire focused on the relative importance of major factors and sub-factors affecting auto-ID selection decisions using a five-point Likert scale. The descriptive statistics were used to analyse the quantitative data using SPSS (Statistical Package for Social Sciences) version 18.0. Later, the second round of the study was conducted to get feedback, comments and to arrive at a consensus regarding the results of the first round of the Delphi.

3.1.4. *Pilot Delphi study – round 2*

After the first round, responses were gathered and analysed, the second round questionnaire was developed and pre-tested with 8 postgraduate colleagues to check for clarity and consistency; then, suitable changes were made. Next, a pilot study of the questionnaire was conducted on 25 February 2013 and continued until 09 March 2013 with 10 experts. The respondents were three academics, four industrialists and three auto-ID consultants who made valuable contributions to the development and improvement of the questionnaire, for example some ambiguities were clarified.

3.1.5. *Actual Delphi study – round 2*

In the actual second round, an interim report was sent back to the first-round participants on 10 March 2013, to get feedback and comments and also to arrive at a consensus regarding the results. The second round was closed on the 10 April 2013. The interim findings were presented in tabular form. Participants were invited to make comments on any aspect of the interim findings, to record their agreement or disagreement, to suggest revisions, clarifications or to add further information. A reminder letter was sent to all panellists who had not replied, after the two-week response period had expired and this produced 17 additional responses. A total of 102 panellists replied to the second round, yielding a response rate of 75% for the second round.

3.1.6. *Delphi data analysis*

Measures of central tendency (mean, mode, median) and dispersion (standard deviation, interquartile range) have been used to measure the consensus in Delphi studies. For the evaluation of the second-round responses, the mean and the standard deviation (SD) were calculated to represent group opinion and consensus, and, a mean of 3.50 or greater showed agreement (*agree* to strongly *agree)* within the panel members on a certain item. The SD for each item was also calculated and an SD of ≤1 showed that the panel had a strong consensus while, a SD of >1 showed that there was a wide range of opinion, and therefore, a low consensus amongst the panel members.

The responses from the second round demonstrated strong agreement on the results. Most feedback was concerned with the priorities of the factors and sub-factors from the first round. A number of specific items, comments and additional factors relevant to particular contexts have been added by the panellists. Overall, it was felt that a third round of the study would not add to the understanding provided by the first and second round. Thus, at this stage, the Delphi study has been concluded and the follow-up interviews have been started.

3.2. ***Interviews***

For the verification of the Delphi results, a follow-up study in the form of interviews (Skulmoski, Hartman, and Krahn 2007; Hasson and Keeney 2011) was conducted. The results of the Delphi study were discussed in-depth with the experts through two face-to-face and 17 telephone interviews to validate the results of the Delphi study on the factors affecting the auto-ID selection in warehouse management.

3.2.1. *Selection of participants for the interviews*

Participants of the interviews were 19 experts across the world. The largest group of participants (42.12%) were experts in the field of auto-ID technology, followed by supply chain management (26.34%), warehouse management (15.79%), operations management (10.53%) and logistics (5.26%). Interview participants were based in Western Europe (UK, Italy and Germany, 52.63%), North America (US and Canada, 26.34%), Asia (India 5.26%), Australia (5.26%) and the Middle East (Egypt and Lebanon, 10.53%). The participant group consisted of seven academics, eight industry practitioners and four auto-ID (RFID or Barcode) consultants. Sixteen of the panel members were male, and three were female. The majority (15) held a PhD or a Master's degree. Similar to the first phase of the research, the experts were selected through purposive and snowball sampling. Consequently, 19 experts, nine of whom were among the Delphi panellists, accepted to participate in the interviews.

3.2.2. *Interview process*

The preparation for interviews started on 25 March 2013, and the interviews were conducted by the first author over the telephone between April and May 2013. The panellists were given detailed information about the purpose of the study via e-mail. The interviews were recorded using an audiotape and transcribed so that the data could be analysed later. In addition, the researcher took notes during the interviews. Face-to-face interviews lasted about an hour, and telephone interviews lasted 20–40 min. After having read the transcripts multiple times (Creswell 2002), the data were coded according to the questions posed in the interviews, as well as the codes used in the Delphi study. Then, the data were explained and interpreted.

3.3. ***Trustworthiness of the study***

To provide content validity in this research, the researchers carried out a comprehensive literature review and benefited from the views of some other experts throughout the study (Morgan et al. 2007). Moreover, the Delphi process has been modified to achieve the research aim and to verify the content and the face validity (Heimlich, Carlson, and Storksdieck 2011). For example, different types of questions (closed-ended/open-ended) and analysis (qualitative/quantitative) have been used in each round of Delphi process (Skulmoski, Hartmanm and Krahn 2007).

Due to the nature and manner of the data being collected (PhD research), only pre-tested and internal consistency reliability measures were considered applicable in this research. Internal consistency (Cronbach's α) was checked to establish inter-item reliability for the constructs and measures that have been adapted and amalgamated from previous studies (Tomasik 2010; Bhattacharya et al. 2011). Cronbach's α scores were computed independently for both rounds of the Delphi process (Table 3).

Cronbach's α value should be 0.70 or above to be considered a sufficient indicator of reliability (Nunnally, Bernstein, and Berge 1967). In this study, Cronbach's α scores were higher than this suggested threshold for both rounds.

4. Findings and discussion

The main aim of this research was to investigate empirically the auto-ID technology-selection process and to determine the factors that influence this decision in warehouse management. Using the modified Delphi method and follow-up interviews, the researchers leveraged the knowledge and experience of worldwide panel of experts who are actively involved in auto-ID technologies and their applications in warehouse management. Motivations, factors and reasons for using auto-ID technologies have been examined. Also, the key steps that should be followed in making auto-ID technology-selection decision have been identified. The findings and their significance are presented and discussed below separately for each of the four questions. The corresponding tables summarise the frequencies (*F*), means and SDs of the responses in the first and second rounds of the Delphi study.

4.1. *Motivations of warehouses that seek to use auto-ID technology*

Table 4 shows that the largest number of the panellists identified the major motivation for warehouses to use auto-ID technology as *optimising operational performance* ($n = 100$). Other important reasons highlighted were the ability to achieve enhanced customer service ($n = 67$), improved resource management ($n = 64$), improved security ($n = 25$) and increase and sustain competitive position advantage ($n = 19$). The findings lend support to other studies which suggest that warehouses are driven by a variety of motives when they decide to use auto-ID technologies (Chow et al. 2006; Bhattacharya et al. 2007; Poon et al. 2009; Wang, Wang, and Yang 2010).

In the second round, the panellists tended to agree with the above findings. For example, *optimising operational performance* was rated as the most important motivation for warehouses to use auto-ID technology, which had already a top placement in the first round. Also, the second ranking category from the first round remained among the largely agreed categories, that is enhanced customer service, but it is topped by improved resource management and increased and sustained competitive position and advantage. Again, improved security ranked the last in the list both in the first and in the second round, and thus, it is the lowest important motivation of warehouses that seek to use auto-ID technology.

Nevertheless, some panellists stated that the motivations depend on the type of warehouse needs and problems, type of business, and the nature of the business environment. The ability to achieve improved security, for example enhancing physical control and security of people and objectives, preventing or decreasing the level of theft in the storage area especially at night, is a key reason for choosing auto-ID in finished goods warehouses, because the availability of finished goods makes it a prime area for theft (Banks 2007). Moreover, the ability to strengthen security against product counterfeiting (counterfeit drugs) with RFID is vital in the pharmaceutical industry for protecting public health (Wyld 2006). In addition, two panellists highlighted that some warehouses use auto-ID technologies because they are mandated from customer(s) downstream in the supply chain. Southall et al. (2010) supports this view, noting that many industries focused exclusively on RFID technology through retailer mandates rather than the business benefits.

Table 3. Cronbach's α for both rounds of the Delphi process.

Category	Cronbach's α Round 1 (# of items)	Cronbach's α Round 2 (# of items)
Organisational sub-factors	0.789 (3)	0.842 (3)
Operational sub-factors	0.777 (10)	0.943 (10)
Structural sub-factors	0.851 (14)	0.933 (9)
Resources-related sub-factors	0.773 (6)	0.877 (6)
External environmental sub-factors	0.750 (3)	0.870 (3)
Technological sub-factors	0.758 (28)	0.951 (23)

Table 4. Warehouse management motivations for using auto-ID.

	Round 1 ($N = 107$)	Round 2 ($N = 102$)			
				Consensus Level (%)	
Motivations	Frequency N (%)	Consensus Mean	SD	Agree	Disagree
Optimising operational performance	100 (93.46)	4.95	0.217	100	0
Enhanced customer service	67 (62.62)	4.79	0.430	99	0
Improved resource management	64 (59.81)	4.89	0.312	100	0
Improved security	25 (23.36)	4.73	0.491	98	0
Increase and sustain competitive position and advantage	19 (17.76)	4.80	0.423	99	0

4.2. *Key steps in the selection process of auto-ID technology in a warehouse environment*

The study has highlighted five key areas in the technology decision-making process in a warehouse context. There was strong consensus on the steps identified in the technology-selection process over the two rounds of the study. The following steps presented in Table 5 are a summary of the preferred or expected procedure in making auto-ID selection decisions in warehouse management:

The above stages identified develop and extend those noted in other studies (Poon et al. 2009; Ilie-Zudor et al. 2011). Decision-makers should start with gathering information relevant to different auto-ID solutions (possibilities and limitations) with regards to the internal problems, needs, requirements and objectives of the warehouse. Such information may be both tangible and intangible. Because of the differences between barcode and RFID, it is essential that separate scenarios should be made for analysing both auto-ID systems. An analysis can be made about how the existing barcode technology works, and if, and how, it can be changed to meet the new requirements. New and different possible solutions should be created with a complete new auto-ID system, or some kind of hybrid system, where various auto-ID technologies are used together. Several methods are suggested to analyse different solutions, such as cost-benefit analysis and return on investment (ROI) analysis, in order to find a preliminary best solution. However, decision-makers should ensure that all factors (qualitative and quantitative) are evaluated for each auto-ID solution in order to select an appropriate system.

Consistent with other studies (Angeles 2005; Sarac, Absi, and Dauzère-Pérès 2010), the findings have emphasised the importance of the pilot test part of the system in the actual warehouse environment to discover problems in an early phase. However, this study has also highlighted the importance of reviewing the pilot test in order to identify strengths, weaknesses as well as additional opportunities to deploy the system. Weaknesses and problems might be the accuracy and interference problems of RFID, organisational problems like people/workers, and the integration complexity with existing systems (WMS/ERP).

Although it seems that the decision-making process is the last step, it is actually an ongoing process in order to get to the final decision. Auto-ID systems in the warehouse management are of strategic importance, because high risks are involved and they are relatively expensive to implement.

There was strong consensus on the steps identified in the technology-selection process over the two rounds. However, some specific and relevant comments emerged in the second round. One comment was that these steps are appropriate only for large warehouses, because small- and medium-sized warehouses may not have sufficient resources or budgets to follow the steps when considering auto-ID choices. On the other hand, this study has also found that the selection decision process is complex and requires a whole series of decisions over a long period, and also, all the relevant people should be involved in the process. Nixon (1995) and Ilie-Zudor et al. (2011) support this view, indicating that the more complex a decision becomes, the less financial influences there will be in the decision. Moreover, the respondents have mentioned that top management should be directly involved in the decision process where a series of decisions have to be made. It was also noted that the step ‘requirements definition for the technology’ especially, RFID, is linked to process flows that warehouse managers want to improve. Specific comments indicated the steps that ‘educate workers as to why the company is moving to the new system’ and ‘train those workers in new system operations’ are very important in succeeding in terms of the implementation of RFID technology in a warehouse, but they are not important for the selection process of auto-ID technology; unless the step, ‘training those workers in new system operations’, is aiming to educate the people on the technology so they can be more knowledgeable in the selection process.

Table 5. Key steps in the auto-ID selection process.

Step	Consensus mean	SD	Consensus level (%) Agree	Disagree
1. Organisational issues				
1.1. Secure top management support for the initiative	4.84	0.392	99	0
1.2. Absolute clarity of the internal problems, needs and requirements	4.96	0.195	100	0
1.3. Make clear the objectives for the overall business both in the short and long term	4.95	0.217	100	0
1.4. Setting reasonable expectations and understanding the warehouse manager's perceptions of auto-ID's capabilities	4.86	0.346	100	0
1.5. Educate workers as to why the company is moving to the new system	4.83	0.375	100	0
1.6. Train those workers in new system operations	4.52	0.656	95.1	0
2. Warehouse environment specifications				
2.1. Understanding key operations and processes of the warehouse and determining points to be improved	4.94	0.236	100	0
2.2. Evaluate the overall business process design/re-design	4.89	0.312	100	0
2.3. Defining company's preferred process flow and the system requirements necessary to implement that process	4.75	0.460	99	0
2.4. Evaluate the overall warehouse management system design/re-design	4.95	0.217	100	0
2.5. Overall definition of the IT infrastructure	4.83	0.400	99	0
2.6. Overall evaluation of warehouse resources	4.88	0.353	99	0
2.7. Amount of metal and liquid	4.76	0.530	97.1	0
2.8. Other types of RF devices in the area	4.69	0.545	96	0
3. External environment study				
3.1. Consider your customer	4.88	0.380	98	0
3.2. Check provider's support	4.95	0.259	99	0
3.3. Define the industry competitors	4.64	0.577	95.1	0
3.4. In-country service support	4.91	0.285	100	0
4. Technological analysis				
4.1. Requirements definition for the technology (necessary and optional)	4.73	0.470	99	0
4.2. Analysis of the different auto-ID solutions (possibilities, and limitations)	4.93	0.254	100	0
4.3. Think about adopting a hybrid and/or integrating various auto-ID technologies	4.92	0.336	98	0
4.4. Initial cost-benefit analysis/return on investment (ROI) analysis/feasibility	4.93	0.290	99	0
4.5. Pilot test part of the system in the actual warehouse environment	4.95	0.259	99	0
4.6. Review the pilot test to identify strengths, weakness and as well as additional opportunities to deploy the system	4.80	0.423	99	0
4.7. Final cost-benefits analysis/ROI including both quantitative and qualitative factors	4.96	0.195	100	0
5. Decision–making				
5.1. Select and get buy in from all the relevant people involved in the process	4.91	0.375	99	0

4.3. *Challenges in making an auto-ID decision in a warehouse environment*

This question generated a variety of opinions in the first round. The panellists identified many problems that may arise in the auto-ID selection decision process, as shown in Table 6. The largest number of the panellists (73) identified the most difficult problem in making an auto-ID decision in warehouse environment as *the technological issues*. Other difficult problems highlighted were the decision process, information, management issues, people and customers. These issues are noted in a number of studies (Angeles 2005; Spekman and Sweeney 2006; Sarac, Absi, and Dauzère-Pérès 2010; Kim and Garrison 2010; Poon, Choy, Chan, and Lau 2011).

In the second round, one panellist noted, from some projects he participated in, that the 'Planning for 99% read accuracy' means 100 miss reads per day, and, he suggested that the planning should be for 100% read accuracy (Schuster et al. 2004). In addition, it was suggested by some of the panellists and has also been noted by scholars (Bendavid and Cassivi 2010) that warehouse managers and IT managers are not geared for evaluating the multi-faceted aspects of auto-ID technology if they are alone, though they are good at working together. Three panellists noted that the 'quality of information, experience of the analyst, and available time' are very important and could lead to major problems in the selection process. It was also noted that combinations of qualitative and quantitative factors influence the decision-making process significantly and make the selection process complex (MacCarthy and Atthirawong 2003).

4.4. *Recommendations to address the challenges*

The panellists recommended a variety of ways to overcome the different types of problems mentioned above. The key recommendations identified that may help in addressing different problems in auto-ID decision-making suggested from the first round are as follows: prudent evaluation process (1); specialist advice/expertise (2); techniques/tools (3); develop appropriate incentives scheme and relevant organisational structures (4); and movement towards international standards (5). These recommendations are presented in Table 7.

The panellists did not argue with these findings in the second round; however, some further comments emerged and added on to some of these issues. For example, it was noted that educating a team and training IT and operations people on the auto-ID technology so they can participate in the selection process vs. relying on specialist advice and/or consultants as one possible solution (Attaran 2012). A specific comment was that

Table 6. The most difficult problem in selecting an auto-ID technology.

	Round 1 (N = 107)	Round 2 (N = 102)			
				Consensus level (%)	
Category	Frequency (%)	Consensus mean	SD	Agree	Disagree
1. Technological issues	73 (68.2)				
1.1. Cost-benefit analysis/ROI analysis	30 (28.04)	4.96	0.195	100	0
1.2. Changing the practices and processes to suit auto-ID technology, or, adapt the technology to facilitate practices	20 (18.69)	4.89	0.312	100	0
1.3. Evaluation of the technology without assistance from others	10 (9.35)	4.93	0.352	99	0
1.4. Integration complexity with existing systems (WMS/ERP)	4 (3.74)	4.93	0.290	99	0
1.5. How to leverage the system across internal processes and external partners	3 (2.80)	4.78	0.459	98	0
1.6. Missing standardisation	2 (1.87)	4.62	0.527	98	0
1.7. Competing with other internal projects	2 (1.87)	4.65	0.591	94.1	
1.8. Stability/low maintenance costs	1 (0.93)	4.50	0.625	95.1	0
1.9. Planning for 99% read accuracy	1 (0.93)	4.30	0.715	87.2	0
2. Decision process	17 (15.9)				
2.1. Decision process is complex, and many factors are involved in it, for example benefits, costs, expected risks, ROI, complexity, social needs	17 (15.9)	4.90	0.330	99	0
3. Information	15 (14.00)				
3.1. Quality of information about a system integrator, hardware and software providers	5 (4.67)	4.93	0.290	99	0
3.2. Missing overview of a technology provider(s)	4 (3.74)	4.52	0.656	95.1	0
3.3. Comparison of alternatives	3 (2.80)	4.60	0.618	97.1	0
3.4. Missing best practices	3 (2.80)	4.55	0.623	97.1	0
4. Management Issues	13 (12.1)				
4.1. Limited knowledge capabilities on auto-ID technology	7 (6.54)	4.91	0.375	97	0
4.2. Lack of skills to address the underlying problem	3 (2.80)	4.83	0.489	95.1	0
4.3. Diversion of warehouses' managers from the evaluation process by the 'shiny objects' of technology that does not meet its objectives	2 (1.87)	4.70	0.559	95.1	0
4.4. Warehouse managers and IT managers are not geared for evaluating the multi-faceted aspects of auto-ID technology	1 (0.93)	4.38	0.718	88.3	0
5. People	7 (6.5)				
5.1. Ability and/or rationality of decision-maker	4 (3.74)	4.80	0.488	98	0
5.2. Experience of the analyst	2 (1.87)	4.83	0.424	98	0
5.3. Available time	1 (0.93)	4.84	0.392	99	0
6. Customer	3 (2.8)				
6.1. Understanding the customer needs and ensuring that they are the real issues	3 (2.8)	4.74	0.486	98	0

these issues reflected a large warehouse perspective. Another believed that 'physics experts' are not the only ones that will recommend the best hardware and configuration; they may help in designing the solution/configuration, but not the hardware (Attaran 2012). Four panellists were not in agreement on these issues, indicating that the approach would depend on the motivations of the warehouse managers.

4.5. *The ranking of major factors influencing auto-ID selection decisions in a warehouse*

In Part B of the questionnaire, panel members were asked to rate the importance of the major factors and their sub-factors in the auto-ID selection decision, using a five-point Likert scale. In the first round, the panellists were asked to rate the importance of six major factors for auto-ID selection decisions. The importance mean ratings of these factors are presented in Table 8 (1 – not at all important to 5 – extremely important).

Organisational factors are ranked highest among all major factors. Operational, structural, resources-related, external environmental and technological factors are also significant factors highlighted, in decreasing order. It is also apparent that the ratings for all these factors are very close to one another and all are rated relatively highly. In the second round, very few comments were made on the relative rankings of the six factors. Three panellists suggested that the importance of each factor may vary from one situation to another and would depend on sectors or market types. In addition, it was noted by two panellists that 'technological factors' should rank more highly.

4.6. *The ranking of sub-factors*

The relative importance of sub-factors was also investigated in Part B of the questionnaire for each of the major factors mentioned above. In this research, a mean of 3.50 was adopted as a cut-off point (Budruk and Phillips 2011). Only the factors that had a mean of 3.50 or above were fed back to panellists in the second round for the re-evaluation and comments. Fifty-four (54) sub-factors were deemed important with their means exceeding 3.50. In the second round, panellists were asked to comment on the importance rankings of each of these sets of sub-factors. In general, there was agreement across the panel members on the ranking order of sub-factors.

4.6.1. *Organisational sub-factors*

The results from the second round revealed that the majority of the panellists agreed with the importance order of the organisational sub-factors and no valuable additional comments were made (Table 9).

Overall, organisational factors are the most important factors highlighted in this study. Deciding on the type of auto-identification technology (barcode or RFID) is a key aspect of strategic and logistical decision-making for warehouses (Sarac, Absi, and Dauzère-Pérès 2010). The significance of organisational factors is noted in a number of studies (Hwang et al. 2004; Lin 2009; Wang, Wang, and Yang 2010). Warehouse internal needs were ranked in the top of the organisational sub-factors in this study and were suggested by others (Angeles 2005).

4.6.2. *Operational sub-factors*

Operational factors are regarded as one of the most important factors in deciding about auto-ID technology in warehouse management (Table 10).

In the second round, a small number of panellists argued against the importance ranking of these sub-factors, with reasons such as 'the ranking order and importance depend on the products if they have already arrived tagged at the warehouse'. Shipping and receiving operations are necessary to bring products from suppliers to warehouses and to deliver products to markets as quickly and reliably as possible, enabling warehouses to reduce total cycle time effectively. Therefore, many warehouses seek to apply auto-ID systems for achieving superior customer responsiveness (Poon et al. 2009). However, this study found that the importance of the operational sub-factors depends on the products and if they have already arrived tagged at the warehouse. For instance, receiving operations were suggested to be the most important issue, particularly for supplier pre-tagged products. This means that the warehouse can only have a reader that would be able to read those tags, enabling swift and more flexible communication with the supplier.

4.6.3. *Structural sub-factors*

Table 11 displays the relative importance of the structural sub-factors obtained after Round 1. Product type is ranked highest among all the structural sub-factors. This is followed by a number of other significant structural sub-factors, including mechanisation level, E-plane (electric field), departments layout, warehouse size, number of racks, H-plane (magnetic field), product carrier of SKU (pallet, case or item) and number of aisles. It is also apparent that the ratings for all of these sub-factors are very close to one another and all are rated relatively highly. However, the structural sub-factors that had a mean below 3.50 such as, humidity, temperature, dust and dirt, pressure and noise were not fed back to the panel members in the second round for comments.

Table 7. Recommendations to overcome problems in auto-ID technology selection.

Category	Round 1 ($N = 107$) Frequency (%)	Round 2 ($N = 102$) Consensus mean	SD	Consensus level (%) Agree	Disagree
1. Prudent evaluation process	67 (62.62)				
1.1. Empower cross-functional team(s) to serve on the project in a warehouse and to work with supply chain partners	18 (16.82)	4.99	0.99	100	0
1.2. Building a thorough and rigorous business case methodology	15 (14.02)	4.97	0.170	100	0
1.3. Comprehensive and accurate information	10 (9.35)	4.98	0.139	100	0
1.4. Careful analysis of all impacts of the technology, including overall SCM	5 (4.67)	4.94	0.236	100	0
1.5. Good planning and screening of the market	5 (4.67)	4.94	0.275	99	0
1.6. Technology selection and deployment must be strictly based on need alone	3 (2.80)	4.92	0.390	98	0
1.7. Process of reviewing the best practices of class warehouses	3 (2.80)	4.88	0.405	99	0
1.8. Visit to conference and exhibition on auto-ID	3 (2.80)	4.91	0.348	98	0
1.9. Continuous decision process based on good involvement of warehouse's executives	2 (1.87)	4.93	0.290	99	0
1.10. Requirement for a demonstration	1 (0.93)	4.77	0.443	99	0
1.11. Install an experimental setup/mini pilot	1 (0.93)	4.89	0.342	99	0
1.12. Visit similar installations	1 (0.93)	4.93	0.254	100	0
2. Specialist advice/expertise	35 (32.71)				
2.1. Employ qualified consultants and/or professional advisors to investigate and pull all stakeholders together at the beginning of the auto-ID selection process	24 (22.43)	4.74	0.506	97.1	0
2.2. Strong understanding of auto-ID physics by having physics experts who can support and recommend the best hardware and configuration	11 (10.28)	4.38	0.845	85.3	2.0
3. Techniques/Tools	30 (28.04)				
3.1. Advanced numerical models for cost-benefit analysis	11 (10.28)	4.65	0.591	96.1	0
3.2. Comprehensive and robust ROI calculations including quantitative and qualitative factors	9 (8.41)	4.94	0.236	100	0
3.3. Multi-analysis tools	6 (5.61)	4.64	0.559	98	1.0
3.4. Multiple testing stages	4 (3.74)	4.82	0.432	98	0
4. Incentives	4 (3.74)				
4.1. Develop appropriate incentives scheme and relevant organisational structures to improve the quality of information and help in decision-making process	4 (3.74)	4.73	0.529	98	0
5. Standardization	3 (2.80)				
5.1. Movement towards international standards for the technology, especially, RFID products	4 (3.74)	4.78	0.500	98	1.0

Table 8. The importance of the major factors.

Major factors	Round 1 ($N = 107$) Importance mean (SD)	Round 2 ($N = 102$) Rank	Consensus mean (SD)	Consensus level (%) Agree	Disagree
Organisational factors	4.72 (0.453)	1	4.92 (0.305)	99	0
Operational factors	4.52 (0.556)	2	4.95 (0.259)	99	0
Structural factors	4.43 (0.798)	3	4.73 (0.600)	94.1	1
Resources-related factors	4.40 (0.645)	4	4.74 (0.596)	96.1	2
External environmental factors	4.34 (0.578)	5	4.80 (0.468)	97	0
Technological factors	4.27 (0.567)	6	4.83 (0.582)	96.1	3

Table 9. The relative importance of the organisational sub-factors.

Sub-factors	Round 1 (N = 107) Importance Mean (SD)	Round 2 (N = 102) Rank	Consensus Mean (SD)	Consensus Level (%) Agree	Disagree
Warehouse internal needs	4.93 (0.344)	1	4.93 (0.352)	99	0
Top management support	4.62 (0.526)	2	4.81 (0.593)	96	0
IT knowledge capability	4.62 (0.488)	3	4.82 (0.534)	97.1	0

Table 10. The relative importance of operational sub-factors.

Sub-factors	Round 1 (N = 107) Importance mean (SD)	Round 2 (N = 102) Rank	Consensus mean (SD)	Consensus level (%) Agree	Disagree
Shipping	4.76 (0.431)	1	4.86 (0.468)	95.1	0
Receiving	4.75 (0.478)	2	4.88 (0.380)	98	0
Storage assignment policy	4.72 (0.491)	3	4.78 (0.538)	94.1	0
Picking	4.57 (0.616)	4	4.63 (0.561)	96.1	0
Zoning	4.49 (0.572)	5	4. 54 (0.640)	92.2	0
Routing	4.48 (0.555)	6	4.47 (0.640)	91.2	0
Put away	4.44 (0.586)	7	4.33 (0.708)	90.2	0
Batching	4.37 (0.607)	8	4.42 (0.696)	90.2	0
Order accumulation and sorting	4.30 (0.633)	9	4.42 (0.710)	89.2	
Forward reserve allocation	4.30 (0.586)	10	4.44 (0.654)	91.1	0

In this study, the product type (liquid/metallic objects) is an increasingly critical issue and is found to be significant in many studies (Porter, Billo, and Mickle 2004; Clarke et al. 2006; Mercer et al. 2011), as it affects the reliability and accuracy of the reading performance of the technology. In deciding to use auto-ID, it is also necessary to investigate the warehouse mechanisation level (manual, semi-automated or automated), because in a highly automated warehouse, there is less need for auto-ID than in a warehouse where a large number of tasks are performed manually (Karagiannaki, Papakiriakopoulos, and Bardaki 2011). Not only must warehouses consider the product type, they must also consider the E-plane (electric field) and H-plane (magnetic field), as they have a negative effect on the reading performance of auto-ID tags (Poon, Choy, Chan, and Lau 2011). E-plane is 'the plane containing the electric-field vector and the direction of maximum radiation,' and H-plane is, 'the plane containing the magnetic-field vector and the direction of maximum radiation' (Balanis 2011).

This study has also noted that warehouse size, departments' layout, number of racks, number of aisles and product carrier of SKU (pallet, case or item) are increasingly important when considering the auto-ID in warehouse management. In fact, the more complex the warehouse, the more beneficial is the specific auto-ID implementation in terms of reduction in labour, increase in utilisation and time savings (Karagiannaki, Papakiriakopoulos, and Bardaki 2011). In practice, warehouses need to study their actual environment thoroughly and determine their specifications before making auto-ID decisions (Bhuptani and Moradpour 2005). This is because the warehouse layout design and structure (physical and internal environmental factors) vary among different companies.

There was a high degree of consensus on these findings in the second round of the study. However, it was argued that the importance of 'warehouse size and number of aisles' should be ranked more highly. Importantly, it was noted that in addition to the E-plane (electric field), 'H-plane (magnetic field)' is also a critical issue in auto-ID selection decisions in a warehouse and they should rank more highly, as it directly affects the operational performance of the technology.

4.6.4. *Resources-related factors*

Table 12 presents the relative importance of the sub-factors of resources-related factors obtained after Round 1. This study has highlighted the general importance of resources – related factors and their sub-factors that should not be ignored when investigating auto-ID decisions in warehouse management (Chow et al. 2006). In

Table 11. The relative importance of the structure sub-factors.

	Round 1 (*N* = 107)	Round 2 (*N* = 102)			
				Consensus level (%)	
Sub-factors	Importance mean (SD)	Rank	Consensus mean (SD)	Agree	Disagree
Product/material type	4.76 (0.596)	1	4.88 (0.380)	98	0
Mechanisation level	4.64 (0.650)	2	4.86 (0.468)	97.1	0
E-plane (electric field)	4.48 (0.781)	3	4.76 (0.632)	92.7	0
Departments layout	4.41(0.921)	4	4.59 (0.603)	94.1	0
Warehouse size	4.38 (0.809)	5	4.33 (0.680)	92.1	2.0
Number of racks	4.34 (0.951)	6	4.34 (0.605)	93.2	0
H-plane (magnetic field)	4.23 (0.808)	7	4.32 (0.720)	89.2	2.0
Product carrier of SKU (pallet, case, or item)	4.16 (0.716)	8	4.29 (0.623)	91.1	0
Number of aisles	3.97 (0.946)	9	4.26 (0.659)	88.2	1.0
Humidity	2.65 (0.790)	Not considered as they are below the threshold			
Temperature	2.45 (0.717)				
Dust and dirt	2.10 (0.900)				
Pressure	2.08 (0.837)				
Noise	2.07 (0.918)				

the second round of the study, most panellists agreed with the ranking of the sub-factors in Table 12. Not surprisingly, however, there was a significant emphasis by some panellists that the warehouse management system (WMS) should be ranked in the top position of all components, as integration complexity with existing systems (WMS/ERP) is one of the top concerns of warehouses implementing RFID (Vijayaraman and Osyk 2006).

It was argued that the storage systems, storage units and storage space capacity should be ranked highly. The storage space capacity is a critical issue when considering auto-ID decisions in a warehouse environment, and, it was demonstrated that RFID technology can be effectively applied to enhance the utilisation of the space capacity in a warehouse (Wang, Chen, and Xie 2010; Karagiannaki, Papakiriakopoulos, and Bardaki 2011).

4.6.5. *External environmental factors*

Auto-ID decisions in warehousing are also affected by external environmental factors. Not surprisingly, the customer pressure/mandate was found to be the most significant factor that affects decision-makers when deciding on auto-ID technology in a warehouse (Li et al. 2010). Many powerful companies, such as Wal-Mart, the US Department of Defence, Metro and Tesco, have recently exerted strong pressure on their suppliers to implement RFID (Wu et al. 2006; Ngai et al. 2008). As shown in Table 13, technology provider support, competitive pressure and government pressure are very critical when considering the use of auto-ID in warehousing, and, were also found to be significant in many studies (White, Johnson, and Wilson 2008; Lin and Ho 2009; Li et al. 2010).

The results from the second round revealed that most of the panellists clearly agreed with these issues and their relative importance. However, two panellists noted that the 'government pressure' is more important than the 'competitive pressure' in some countries or sectors (Wang, Wang, and Yang 2010).

4.6.6. *Technological sub-factors*

In the second round, the means of all 22 items were greater than 3.50 (Table 14), indicating agreement with SD ≤ 1. However, return on investment (ROI), deployment costs, reliability, performance, technology costs and accuracy received more emphasis in auto-ID choices and the study has suggested that these factors are equally important at a high level. Four panellists suggested that the 'labour, ease of use, item level tracking and established standards' should be ranked more highly. Moreover, it was commented by some of the panellists that the relative importance of these issues would depend on the type of the business and also on the objectives and strategic motivations of the warehouse, for example 'security, privacy and item level tracking' are critical issues in some applications, while they are not important in others.

Technological factors such as accuracy, visibility, quality control, traceable warranty, product recalls and labour have also been highlighted in this study as key factors in the decision-making process. For instance, RFID systems enhance visibility by providing an accurate picture of inventory levels in real-time and locating warehouse resources easily and therefore enhancing warehouse productivity and reducing the labour and operational costs of warehouse (Poon et al. 2009). On the other hand, barcodes are manual systems and thus

Table 12. The relative importance of resources-related sub-factors.

	Round 1 ($N = 107$)	Round 2 ($N = 102$)			
				Consensus level (%)	
Sub-factors	Importance mean (SD)	Rank	Consensus mean (SD)	Agree	Disagree
Material handling equipment	4.77 (0.524)	1	4.83 (0.564)	95.2	2.0
Warehouse management system (WMS)	4.74 (0.634)	2	4.87 (0.460)	97.1	1.0
Warehouse staff members (labour)	4.48 (0.781)	3	4.67 (0.635)	95.1	2.0
Storage systems	4.30 (0.703)	4	4.34 (0.638)	92.1	2.0
Storage units	4.13 (0.616)	5	4.45 (0.623)	93.2	2.0
Storage space capacity	4.00 (0.614)	6	4.84 (0.685)	89.2	0

Table 13. The relative importance of external environmental sub-factors.

	Round 1 ($N = 107$)	Round 2 ($N = 102$)			
				Consensus level (%)	
sub-factors	Importance mean (SD)	Rank	Consensus mean (SD)	Agree	Disagree
Customer pressure	4.91 (0.292)	1	4.96 (0.195)	100	0
Provider/supplier support	4.87 (0.366)	2	4.91 (0.401)	96.1	0
Competitive pressure	4.35 (0.551)	3	4.77 (0.579)	94.1	1.0
Government pressure	3.80 (0.818)	4	4.74 (0.644)	93.2	2.0

Table 14. The relative importance of the technological sub-factors.

	Round 1 ($N = 107$)	Round 2 ($N = 102$)			
				Consensus level (%)	
Sub-factors	Importance mean (SD)	Rank	Consensus mean (SD)	Agree	Disagree
Return on investment (ROI)	4.97 (0.166)	1	4.93 (0.290)	99	0
Deployment costs	4.83 (0.376)	2	4.89 (0.370)	98.1	0
Reliability	4.82 (0.384)	3	4.87 (0.363)	99	0
Performance	4.81 (0.392)	4	4.66 (0.497)	99.1	0
Technology costs	4.79 (0.413)	5	4.51 (0.558)	97	0
Accuracy	4.75 (0.436)	6	4.31 (0.563)	95.1	0
Visibility	4.64 (0.664)	7	4.21 (0.569)	92.1	0
Security	4.56 (0.703)	8	4.24 (0.583)	92.2	0
Privacy	4.36 (0.745)	9	4.19 (0.609)	91.1	1.0
Quality control	4.35 (0.646)	10	4.22 (0.574)	92.1	0
Product recalls	4.27 (0.667)	11	4.18 (0.636)	89.2	1.0
Multi-tag collection	4.17 (0.707)	12	4.32 (0.616)	92.2	0
Labour	4.15 (0.611)	13	3.80 (0.664)	73.6	5.0
Ease of use	4.12 (0.544)	14	3.84 (0.689)	75.6	4.0
Item level tracking	4.11 (0.555)	15	3.98 (0.660)	79.4	2.0
Traceable warranty	4.03 (0.574)	16	3.98 (0.645)	80.4	1.0
Interference	4.00 (0.644)	17	4.20 (0.564)	92.2	0
Established standards	3.94 (0.580)	18	4.09 (0.599)	86.2	0
Communication range	3.94 (0.529)	19	4.07 (0.618)	84.3	0
Tag read/write capabilities	3.74 (0.619)	20	4.32 (0.616)	92.2	0
Environmental sensitivity	3.72 (0.595)	21	4.23 (0.628)	89.2	0
Line-of-sight	3.57 (0.754)	22	4.23 (0.612)	90.2	0
Information properties	3.51 (0.732)	23	4.23 (0.612)	90.2	0
Ongoing innovations	3.03 (0.746)	Not considered as they are below the threshold			
Operational life	2.78 (0.744)				
Tag data storage	2.51(0.781)				
Memory	2.40 (0.781)				
Tag weight	2.20 (0.693)				

Table 15. Motivations of warehouses that seek to use auto-ID technology.

Motivations	Quotes from interviews
Mandate/compliance	'Nowadays, RFID is driven by mandate compliance such as, mandate from buyers, government departments and department of defence (e.g. the warehouse of the retail store … so, the retailer who puts the mandate on the suppliers, but not the other way round and this is what exactly Wal-Mart did'. *[Professor in Information Systems and Operations Management & RFID Consultant]* 'There are still some employers in the industry making mandate … so; warehouses do not think because of mandate, but not all of them.' *[Professor in Operations Management & RFID consultant]*
Improved operational performance	'I would say that the main reason behind auto-ID technology is to increase the efficiency of the warehouse operations (i.e., reduction in operating and labour costs, increase the speed of delivery; quality; higher productivity, higher performance …). RFID helps warehouses to automatically record data about objects received into computer systems and this automation enhances efficiency and improves performance provided if it is used prudently. The higher cost of technology will be easily compensated by high productivity'. *[Professor in Logistics and Supply chain Management & RFID consultant]* 'The most important factor in a workhouse environment is accuracy of despatches leading to stock integrity. As a warehouse, you will decide by yourself if you will use RFID or not, there were two surveys 2009, the first by auto-ID Research and the second by RFID Journal showing that in 2008–2009 there was like a turning point and most of the companies are adopting RFID because of business processes improvement, but not because of mandate'. *[Professor in Operations Management & RFID consultant]*
Improved warehouse visibility	'All companies struggle to maintain accurate data about what is in their warehouses and where it is located. As a result, items go missing and it often takes a long time to find items. RFID helps you to track and trace your resources accurately and in real-time, so it provides the visibility into what is in the warehouse, and where'. *[Founder & editor of RFID Journal, RFID Consultant]* 'In any warehouse, effective inventory control and stock location management are very important because both the precise quantity and the precise storage location of the items are crucial to a warehouse to be operated efficiently'. *[Professor in Operations Management and Supply chain Management]* 'Need for part-level visibility in the supply chain, RFID is justified only in cases where visibility is important. Installing RFID for warehouse operations alone may not be a prudent decision (e.g. in case an original equipment manufacturer (OEM) is keen to track a part from the warehouse till it is sold to the consumer, and then, RFID is the only answer)'. *[Chief Operating Officer, Logistics and Supply Chain Management]*
Enhanced customer responsiveness	'Warehouses want a fast, efficient way to find items stored, pick the right items and ship the right items to their customers. RFID can be used to confirm pick accuracy, reducing missed shipments'. *[Assistant Professor in Supply Chain Management]* 'I think one of the reasons for using auto-ID technologies is to improve quality of customer service and satisfaction through more accurate and time delivery of goods, and better tracking information that provides customers with visibility as to movements of those goods'. *[Assistant Professor in Logistics, Operations Management]*
Enhanced Security	'In a warehouse environment, theft in the storage area is very common, but this can be avoided by item level tagging with readers installed on racks which will allow 24 h security control. However, objects can be stolen by truck drivers and this is 'in-transit theft' which can only be prevented or decreased by careful counting of the number of items in the receiving process. Therefore, RFID technology can be implemented to effectively automate the inspection and checking processes and to avoid human errors both in receiving and as well as in shipping processes where theft can also be existed'. *[Chair of Materials Handling and Warehousing, Managing Director of Operations & RFID Consultant]*

they are labour-intensive. Barcode systems provide limited visibility because they are unable to update daily operations of inventory level, locations of forklifts and stock keeping units (SKUs) in real-time, or, to provide timely and accurate data of warehouse operations, resulting in high operational costs for the warehouse (Poon et al. 2009). Moreover, quality control cannot be very accurate using a barcode as it has restricted traceability and product recalls across a supply chain, while RFID technologies provide an accurate quality control because they have traceable warranties and product recalls across a supply chain (Huber, Michael, and McCathie 2007). RFID tags can also monitor shock and temperature levels to ensure the quality of the end product (Wyld 2006).

Other key technological factors, including multi-tag collection, interference, communication range, tag read/

Table 16. Key steps in the selection process of auto-ID technology in a warehouse environment.

Step	Quotes from interviews
1. Organisational analysis	'If your warehouse is running pretty well, then you have no interest in RFID. However, if there is a high level of theft, high labour costs, or shipping inaccuracies, then you start to look at auto-ID technologies to solve these problems. You might also see an opportunity to add value for customers by providing data on location of products or inventory levels. Thus, you must not be blinded by the technology; you must first focus on the business problems and objectives'. *[Warehouse Manager & RFID Consultant]* 'Training and education of the team that will be involved in the project is essential and not only relying on consultants and vendors. Unfortunately, few budgets are available for this portion of the project and the training usually costs are planned once a solution has been implemented. The team will serve on the project and identify how their work units (processes) could utilise the technology system. Then the team members need to identify and work with supply chain partners who can take advantage of the new technology system. Here you want collaborative partners who you are going to share information with'. *[Professor in Operations Management & RFID consultant]*
2. Warehouse characteristics analysis	'It is very important to do a site survey which is to have a look at the physical infrastructure and understand the processes/operations, and then you try to see if there are any interferences and physical problems such as, metal, engine (e.g. warehouses that deals with liquid/metallic objects may not be as receptive to auto-ID implementation vs. a warehouses that deals with other types of objects since liquid/metal may necessitate additional expenses or result in high read-rate errors). Also, you have to check how easy is it to revamp (any/necessary changes to) the processes? Since auto-ID may eliminate some, add some, as well as shuffle some processes. After that, then you justify if there is a big problem or not. Today, 2013 we can say that the technology has been improved so much and physical problems are not a big issue anymore'. *[Professor in Information Systems and Operations Management, RFID Consultant]*
3. External environmental analysis	'Defining the set of spectrum frequency allocated for RFID is very important because this varies in each country (e.g. in the USA 900 MHz, in Europe is 842 MHz), so depending on that the reader can be decided and selected and also the wireless line infrastructure, the tags can be created'. *[Industrial Engineer and RFID consultant]*
4. Technological analysis	'Warehouses should consider and examine different auto-ID systems available from different vendors and then compare the hardware capabilities to match their objectives and requirements. Warehouses should also think about adopting a hybrid solution (RFID and barcode) which is very common in supply chain (e.g. sometimes, the actual barcode solution cannot resolve your problem or RFID is not able to get a good spectrum to catch and read because of the location of the warehouse). Then properly check the feasibility/ROI/cost-benefit analysis of the technology. After that, pilot test part of the system, by using real-world scenarios, in your actual warehouse environment and if the pilot is successful then go select and roll out the technology'. *[Industrial Engineer and RFID consultant]*
5. Decision-making	'Selection decision of the technology should be based on joint effort and collaboration among IT team, warehouse managers, experts, stockholders, and vendors, because selecting and implementing a solution that based on one person's views always fails … It is very important to determine the openness of all stakeholders to consider/implement auto-ID and to check if there is any resistance. Also, it is important to investigate the synergies across other divisions/groups of the firm, for example auto-ID implemented at warehouse may be beneficial at the manufacturing shop floor or supply chain …!' *[Managing Director & RFID Consultant]*

write capabilities, environmental sensitivity, line-of-sight and information properties, were highlighted in this study. Multi-tag collection is a key technological factor because some RFID systems can scan a thousand tags from a single reader, for example active RFID, while passive RFID systems can only scan a hundred tags within 3 metres from a single reader (Domdouzis, Kumar, and Anumba 2007). That is because different RFID tags have different communication ranges and different read/write capabilities. RFID systems allow automatic non-line-of-sight scanning (multiple tags can be read simultaneously) and updating of tag information. Barcode systems, by contrast, require optical line-of-sight scanning (it can only be read individually and with alignment), and, the barcode information cannot be updated during scanning (Wyld 2006; Huber, Michael, and McCathie 2007). In addition, RFID can operate in harsh environments such as in dirty, dusty and moist conditions, which deteriorate the performance of barcodes (Li et al. 2006). Therefore, warehouse managers should consider all these technological factors in order to select the most appropriate auto-ID technology, which will enhance the operational efficiency of their warehouses (Poon et al. 2009; Poon, Choy, and Lau 2011).

Table 17. Problems in auto-ID selection decisions and recommendations to overcome them.

Problems/Recommendations	Quotes from interviews
Information/Prudent analysis	'One of the big problems with auto-ID systems in general is the vendors. Let us say that you have two big choices of the vendors: for example Motorola & Alien, they have very good solutions, but they are more expensive than some training companies that have very good solutions, but no reputation. As a buyer do I go to the choice with a good reader and technology and have a risk of that company is not reliable! OR just I pay more! So this is a kind of questions that warehouses asking themselves today: What kind of these choices we need to choose! So, what they do, a lot of them go to RFID Journal Life OR RFID World, but RFID Journal Life has the main conferences and exhibition centres … Conferences provide the opportunity to meet all the vendors in the industry … and this is part of the process of selecting and buying the technology right now and which is very important'. *[Professor in Operations Management & RFID consultant]*
Technology/Standardisation	'Few years ago, 2003–2006 and 2007, there were no unified standards so, the same tags you are using in Canada you cannot use them in the UK, but right now tags can be used at the same frequencies in different countries and the same for the readers … they are able to read tags at different frequencies so they can command the whole supply chain without any problems'. *[Professor in Operations Management & RFID consultant]* 'You are a warehouse and you have suppliers and different customers … the suppliers use specific technology and you only can have a reader that would be able to read the tags. This means that you can just have the same technology/standard technology in order to be able to communicate with your supplier … within the supply chain, there is no way to implement the technology alone … you need to adopt a standard technology that can talk together, not only on the RFID level, but on the Information Technology (IT) level'. *[Professor in Supply Chain Management & auto-ID consultant]*
Technology/Techniques and tools	'The most difficult part is estimating the impact of the technology and translating that impact into measurable value … it can be hard to prove a clear ROI. So, warehouses need to determine the overall costs … whether such costs justify the benefits envisaged! Therefore, advanced numerical models for the technology analysis (cost-benefit/ROI) and comprehensive information about the technology will assist estimating its impact on the business processes and good ROI proving'. *[Assistant Professor of Supply Chain Management]*
Management/Consulting and training	'One of the problems is that the warehouses managers especially, the managers of small companies are not familiar with the technology and they are ready to pay … let us say 10,000 dollars just to implement the technology, so they lose a lot of money in order to have anything … Warehouses should have consultants who will not just provide them with a solution, but also with training … When they are educated they can join the decision with any vendor'. *[Professor in Operations Management & RFID consultant]* 'There are a lot of companies who go in many directions and cannot make the technology decision because they are not educated on the technology … That is why the training is essential in order to be educated on the technology and gently decide what type of the technology is the best for your warehouse environment'. *[Technology Engineer and RFID consultant]*

Problems/Recommendations	Quotes from interviews
Information/Prudent analysis	'One of the big problems with auto-ID systems in general is the vendors. Let us say that you have two big choices of the vendors: for example Motorola & Alien, they have very good solutions, but they are more expensive than some training companies that have very good solutions, but no reputation. As a buyer do I go to the choice with a good reader and technology and have a risk of that company is not reliable! OR just I pay more! So this is a kind of questions that warehouses asking themselves today: What kind of these choices we need to choose! So, what they do, a lot of them go to RFID Journal Life OR RFID World, but RFID Journal Life has the main conferences and exhibition centres … Conferences provide the opportunity to meet all the vendors in the industry … and this is part of the process of selecting and buying the technology right now and which is very important'. *[Professor in Operations Management & RFID consultant]*
Technology/Standardisation	'Few years ago, 2003–2006 and 2007, there were no unified standards so, the same tags you are using in Canada you cannot use them in the UK, but right now tags can be used at the same frequencies in different countries and the same for the readers … they are able to read tags at different frequencies so they can command the whole supply chain without any problems'. *[Professor in Operations Management & RFID consultant]* 'You are a warehouse and you have suppliers and different customers … the suppliers use specific technology and you only can have a reader that would be able to read the tags. This means that you can just have the same technology/standard technology in order to be able to communicate with your supplier … within the supply chain, there is no way to implement the technology alone … you need

(*Continued*)

Table 17. (*Continued*).

Problems/Recommendations	Quotes from interviews
	to adopt a standard technology that can talk together, not only on the RFID level, but on the Information Technology (IT) level'. *[Professor in Supply Chain Management & auto-ID consultant]*
Technology/Techniques and tools	'The most difficult part is estimating the impact of the technology and translating that impact into measurable value … it can be hard to prove a clear ROI. So, warehouses need to determine the overall costs … whether such costs justify the benefits envisaged! Therefore, advanced numerical models for the technology analysis (cost-benefit/ROI) and comprehensive information about the technology will assist estimating its impact on the business processes and good ROI proving'. *[Assistant Professor of Supply Chain Management]*
Management/Consulting and training	'One of the problems is that the warehouses managers especially, the managers of small companies are not familiar with the technology and they are ready to pay … let us say 10,000 dollars just to implement the technology, so they lose a lot of money in order to have anything … Warehouses should have consultants who will not just provide them with a solution, but also with training … When they are educated they can join the decision with any vendor'. *[Professor in Operations Management & RFID consultant]* 'There are a lot of companies who go in many directions and cannot make the technology decision because they are not educated on the technology … That is why the training is essential in order to be educated on the technology and gently decide what type of the technology is the best for your warehouse environment'. *[Technology Engineer and RFID consultant]*

4.7. *Validation of the Delphi study results with interviews*

Following the Delphi study, the results of the study were discussed in-depth during face-to-face and telephone interviews by the first author. After each interview, the author reviewed notes and transcripts to identify potential difficulties or problems. Only in two cases was it necessary to contact the respondents for clarification.

To avoid bias, the analysis of the interview results was conducted after all the interviews had been completed. Then, due to the manageable amount of qualitative data, the authors analysed the data manually using a thematic content analysis approach (Hasson, Keeney, and McKenna 2000; Braun and Clarke 2006). Thematic analysis was chosen because it offers an accessible and theoretically flexible method for analysing qualitative data (Braun and Clarke 2006).

4.7.1. *Major motivations for warehouses to use auto-ID technologies*

At the start of each interview, respondents were asked to describe the motivations of warehouses that seek to use auto-ID technology. The motivations included: mandate compliance (mandate from buyers, government departments or from the department of defence); improved operational performance, improved warehouse visibility, enhanced customer responsiveness and enhanced security (Table 15).

From Table 15, motivations mentioned in the interviews are similar to those found in the Delphi study; however, mandate compliance, such as mandate from buyers, government departments (the food and drug administration) and from the department of defence, has received more emphasis as a motivation for warehouses to use auto-ID technologies (Li et al. 2010).

4.7.2. *Key steps in the selection process of auto-ID technology in a warehouse environment*

Panel members were asked about the key steps in auto-ID selection process in warehouse management. Table 16 gives a summary of the expected procedure in making an auto-ID selection decision in warehouse management.

From Table 16, we can see that the main steps of the technology-selection process are similar to those which have been identified in the Delphi study. Five stages/aspects are crucial in the selection process of auto-ID technology in a warehouse environment. The organisational, warehouse characteristics analysis, external environmental analysis and technological analysis are part of this decision process. Once the organisational analysis has been conducted, an analysis for warehouse characteristics should be started in order to have a look at the physical infrastructure and understand the processes/operations and resources as well as to see if there are any interferences and physical problems engine (Poon et al. 2009). External environmental analysis should be started after conducting the organisational and warehouse characteristics (operational, structural, resources) analysis. For example, the set of spectrum frequency allocated for RFID should be defined because this varies in each country. After that, warehouses should consider different auto-ID systems available from

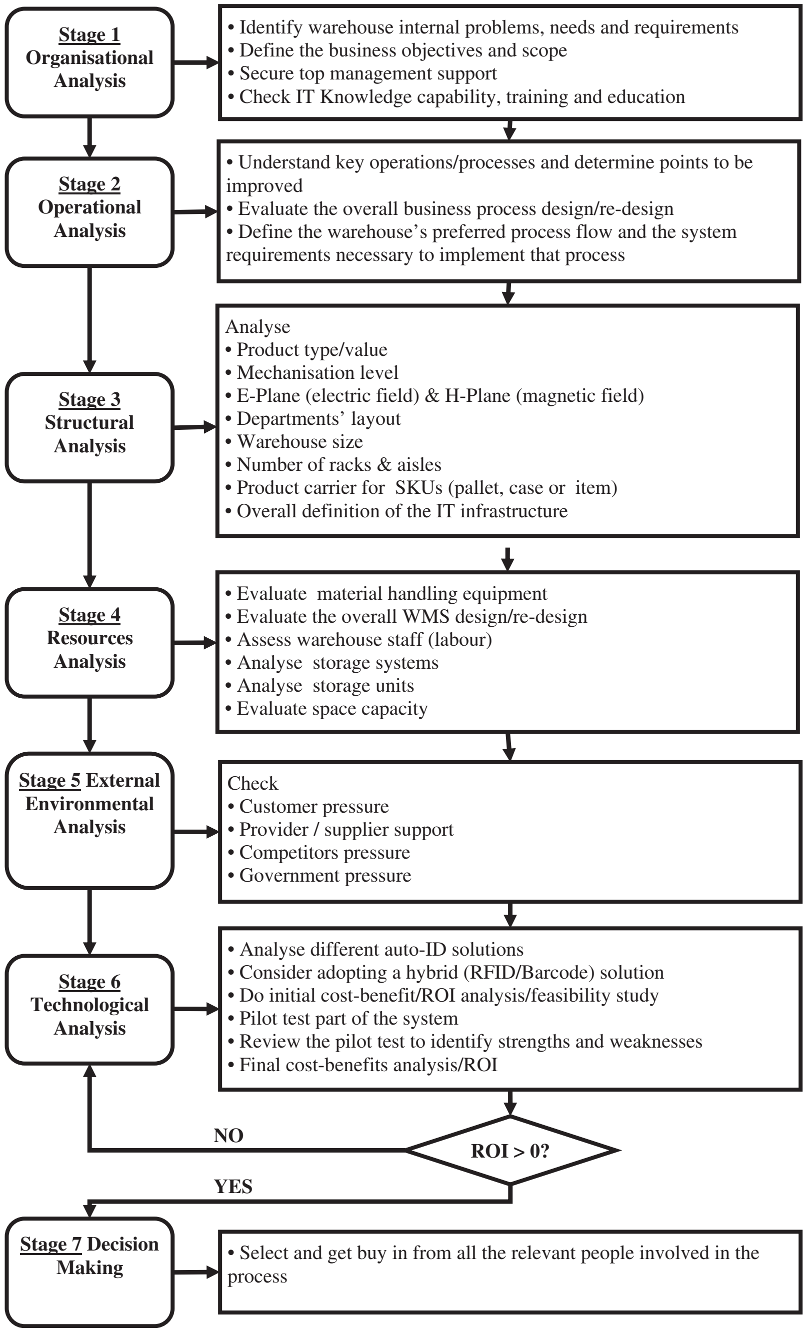

Figure 2. Auto-ID selection decision process in warehouse management.

different vendors, think about adopting a hybrid solution (RFID and barcode together), check the feasibility/ROI/-cost-benefit analysis of the technology, and, pilot test part of the system in their actual warehouse environment. After conducting all the above activities and if the final cost-benefits analysis/ROI analysis is successful, then warehouse managers should select and roll out the technology.

4.7.3. *The most difficult problem in making an auto-ID decision in warehouse environment and recommendations to overcome the problem*

Finally, panel members were also asked about the problems involved in the auto-ID selection decision in a warehouse and the recommendations they put forward to overcome these problems. Some problems relevant to the information, technology and management have been highlighted. Warehouses should employ a variety of ways to overcome these problems, including prudent analysis, standardisation, advanced techniques and tools, and consulting and training. Table 17 gives a summary of representative responses to this question.

One of the big problems with auto-ID systems, in general, is the information about vendors. However, warehouses can overcome this problem by conducting prudent analysis of the vendors in the industry, for example attending conferences and exhibition centres, which will help warehouses to select the best technology vendors. Another difficult problem that has been highlighted by the panellists was estimating the impact of the technology and proving a clear return on investment (ROI) analysis. Adopting advanced techniques and tools for the technology analysis (cost-benefit analysis/ROI) and comprehensive information about the technology will assist in estimating its impact on the business processes and ensuring a good ROI (Sarac, Absi, and Dauzère-Pérès 2010). The final important problem in making an auto-ID decision was that the warehouses managers, especially the managers of small companies, are not familiar with the technology. Therefore, the warehouses should have consultants who will not just provide them with a solution, but also provide them with training as well. As a result, they can join the decision with any vendor of the technology and can decide what type of technology is best for their environment.

In summary, the data from the interviews presented a similar trend to that found in the Delphi study: the selection process of auto-ID is crucial and warehouses should do it before implementing the technology. Based on the Delphi results and the interviews findings, a comprehensive framework for a multi-stage auto-ID-technology selection process has been developed (Figure 2). There are seven key stages involved in this framework:

(1) organisational analysis;
(2) operational analysis;
(3) structural analysis;
(4) resources analysis;
(5) external environmental analysis;
(6) technological analysis; and,
(7) decision-making.

Pulling together the insights obtained in the Delphi study and the interviews, the researchers of this study found that the selection decision of auto-ID technologies in a warehouse management is complex and needs support and closer collaboration from all stakeholders involved in the process, such as the IT team, warehouse managers, top management, functional managers, experts, stockholders and vendors/technology providers. Therefore, warehouses should do this process for collaboration before adopting the technology in order to reduce the high risks involved and achieve successful implementation. This conclusion strongly supports the view of the auto-ID selection process as a sequence of stages, in which related steps and activities occur (Ilie-Zudor et al. 2011). Also, the more complex a decision becomes, the less financial influences there will be in the decision (Nixon 1995).

The general conclusion from this research must be interpreted and generalised with care. The results from this study are applicable to only barcode and/or RFID because they are pretty much the only auto-ID technologies that are widely used in warehouse management applications. In addition, the objectives and strategic motivations of warehouse, size of warehouse, location, type of business, nature of the business environment, sectors, market types, countries and characteristics of items (cold chain) in the warehouse would alter the results, because they affect the relative importance of the identified major factors and sub-factors in the auto-ID selection decision.

5. Concluding remarks and implications

This study aimed to investigate and identify critical factors in the auto-ID selection decision. The Delphi approach has been employed to capture and consolidate expert knowledge and opinion. The relative importance of the identified factors and sub-factors obtained from the first round was reported. The six major factors that influence the auto-ID selection decisions in warehouse management are: organisational, operational, structural, resources, external environmental and technological factors (in order of importance). In addition, the key sub-factors (54) identified from the list of each of the major factors have been presented and ranked in decreasing order of importance.

Follow-up interviews were conducted to discuss and verify the Delphi results. Based on the Delphi results and the interviews findings, a comprehensive multi-stage framework for the auto-ID selection process was developed (Figure 2).

It is anticipated that the results of this research will help both practitioners and academicians with auto-ID selection in warehouse environments. Academically, this study provides a holistic multi-stage framework that explains the critical issues within the decision-making process of auto-ID technology in the warehouse management. Moreover, it contributes to the body of auto-ID and warehouse management literature by synthesising the literature on key dimensions of auto-ID (RFID or barcode) selection decisions in the warehouse field. This study also provides a theoretical basis upon which future research on auto-ID selection and implementation can be built. Practically, the findings provide valuable insights for warehouse managers and executives associated with auto-ID selection, and, advances their understanding of the issues involved in the technology-selection process that need to be considered. The power of this framework is in the provision of a simple step-by-step approach that can be leveraged to define, present and manage auto-ID selection activities by all of the participants in the selection process.

As with other survey approaches or any Delphi-type study, the results reported in this study must be interpreted and generalised with care. This study provides broad and subjective views on critical factors influencing the auto-ID decision-making process in warehouse management. The panel members were not chosen randomly, but they were selected based on their experience and knowledge concerning the topic being surveyed and on their willingness to participate. The Delphi technique provides a better understanding of complex problems than other survey methods.

Promising avenues for future studies on auto-ID selection in warehouse management are hereby proposed. First, future studies may want to replicate this study using a fuzzy Delphi method, or, a two-step fuzzy Delphi and the fuzzy multi-attribute decision-making (MADM) method. The fuzzy Delphi method, which is an integration of the fuzzy concept and the Delphi approach, requires only a small survey sample to achieve objective and reasonable results. With this method, time and costs of collecting questionnaires and gathering data can be reduced, the data to be presented by fuzzy numbers instead of crisp numbers, and, opinions of experts' panel can be kept as they are without being twisted (Maskeliūnaite, Sivilevičius, and Podvezko 2009).

Second, the findings reported in this study should provide a useful basis for other studies seeking to improve understanding of factors influencing auto-ID selection decisions in warehouse environments. The Delphi method is not designed for advanced statistical analysis and does not, in itself, present relationships and interactions among factors. Further research using other methodologies, such as detailed case studies, is advocated to take the subject forward. Currently, the researcher is conducting a case study in order to evaluate the usefulness of the proposed framework of this auto-ID selection process in a real-world warehouse.

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