CHAPTER 2
LITERATURE REVIEW

RFID is a generic term for technologies that use radio wave to automatically identify individual items. RFID is a technology that allows data transfer between tags and readers without the necessity of line of light over a distance of up to a couple of 10 meters depending on the type of tag used. For RFID system, the information is being transferred via radio wave, and multiple tags can be read or written simultaneously.

The first use of radio wave to transmit the signals as similar to the RFID technology can date back to World War II when transponder (tags) were put on airplane and used to identify an approaching plane. Interrogators (readers) sent a signal to the transponder on the plane and the signal that is sent back could be used to distinguish between friendly and hostile aircraft. The history of RFID technology development is listed in Table 2-1 (Jeremy Landt, 2001)

<table>
<thead>
<tr>
<th>Decade</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940 - 1950</td>
<td>Radar refined and used, major World War II development effort. RFID invented in 1948.</td>
</tr>
<tr>
<td>1950 - 1960</td>
<td>Early explorations of RFID technology, laboratory experiments.</td>
</tr>
<tr>
<td></td>
<td>Very early adopter implementations of RFID.</td>
</tr>
<tr>
<td>1980 - 1990</td>
<td>Commercial applications of RFID enter mainstream.</td>
</tr>
<tr>
<td>1990 - 2000</td>
<td>Emergence of standards.</td>
</tr>
<tr>
<td></td>
<td>RFID widely deployed.</td>
</tr>
<tr>
<td></td>
<td>RFID becomes a part of everyday life.</td>
</tr>
</tbody>
</table>
2.1 AUTOMATIC IDENTIFICATION SYSTEMS

There are different kinds of technologies existent for Auto ID systems. In terms of applications, cost requirement, and functionality demands, one or a mix of solutions are adopted to fulfill the Auto ID functionality and information collection in the applied systems. A combination of Auto ID technologies is shown in Fig. 2-1. With the cost decline in wireless and GPS technology, Auto ID systems can integrate these high-end technologies with IT systems to offer not only the identification functionality but also value-added information and service in the applied systems. It can greatly improve the information visibility in the system information flow.

![Fig 2-1 Auto-ID systems](image)

- **Barcode Systems**

Barcode is a binary code comprising a field of bars and gaps arranged in a parallel configuration as shown in Fig 2-2. They are arranged according to a pre-determined pattern and represent data elements that refer to an associated symbol. The sequence
made up of wide and narrow bars and gaps can be interpreted numerically and alphanumerically. It is read by optical laser scanning. However, despite being identical in their physical design, there are considerable differences between the code layouts.

The most popular barcode is the EAN (European Article Number) code, which was designed specifically to fulfill the requirements of the grocery industry in 1976. In addition to the EAN code, there are some other popular codes such as Code 39, Code 2/5.

![Fig 2-2 A typical bar code](image)

- **Optical Character Recognition (OCR)**

Optical character recognition (OCR) was first used in the 1960s. Special fonts were developed for the application that stylized characters so that they could be read both in the normal way by people and automatically by machines. The most important advantage of OCR systems is the high density of information and the possibility of reading data visually in an emergency.

OCR is used in production, service and administrative fields, and also in banks for the registration of check (personal data is printed on the bottom line of a check in OCR type). However, OCR systems have failed to become universally applicable because of their high price and the complicated readers that they require in comparison with other ID procedures.

- **Biometric Procedure**
Biometrics is defined as the science of counting and measurement procedures involving living beings. It utilizes the procedures to identify people by comparing unmistakable and individual physical characteristics. In practice, they include finger printing, hand printing procedures, voice identification, and retina (or iris) identification.

**Smart Cards**

A smart card is an electronic data storage system, possibly with additional computing capacity (microprocessor card), which is incorporated into a plastic card as shown in Fig 2-3. The first smart cards in the form of prepaid telephone smart cards were launched in 1984. Smart cards are supplied with energy and a clock pulse from the reader via the contact surface. Data transfer between the reader and the card takes place using a bidirectional serial interface (I/O port). In practice, there are two basic types of smart card based upon their internal functionality: memory card and microprocessor card.

One of the primary advantages of the smart card is the fact that the data stored on it can be protected against undesired access and manipulation. Smart cards make all service that relate to information or financial transactions simpler, safer and cheaper. One disadvantage of contact-based smart card is the vulnerability of the contacts to wear, corrosion and dirt. Readers that are used frequently are expensive to maintain due to their tendency to malfunction. In addition, readers that are accessible to the public cannot be protected against vandalism.

![Fig 2-3 A typical smart card](image-url)
RFID Systems

RFID systems are closely similar to the smart cards. Data is stored on an electronic data carrying device. However, unlike the smart card, the power supply to the data carrying device and the data exchange are achieved without the use of galvanic contacts, but using magnetic or electromagnetic fields. A typical RFID system is shown in Fig 2-4. The technical procedure is drawn from the field of radio and radar engineering. Due to the numerous advantages of RFID systems compared with other identification systems, RFID systems are beginning to conquer new mass market.

Fig 2-4 A typical RFID system

Comparison of Different ID Systems

A comparison of these different identification technologies is shown in Table 2-2 to demonstrate their parameter characteristics and the impact of influence factors against the data reading.
Table 2-2 Comparison of Auto-ID systems

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Barcode</th>
<th>OCR</th>
<th>Biometric</th>
<th>Smart Card</th>
<th>RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Data Capacity</td>
<td>1~100</td>
<td>1~100</td>
<td>16~64k</td>
<td>16~64k</td>
<td></td>
</tr>
<tr>
<td>Data density</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
</tr>
<tr>
<td>Readability by people</td>
<td>Limited</td>
<td>Simple</td>
<td>Difficult</td>
<td>Impossible</td>
<td>Impossible</td>
</tr>
<tr>
<td>Reading speed</td>
<td>Low</td>
<td>Low</td>
<td>Very low</td>
<td>Low</td>
<td>Fast</td>
</tr>
<tr>
<td>Reading distance</td>
<td>0~50cm</td>
<td>&lt; 1 cm</td>
<td>0~2m*</td>
<td>Contact</td>
<td>0~30m</td>
</tr>
<tr>
<td>Cost of readers</td>
<td>Very low</td>
<td>Medium</td>
<td>Very high</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Unauthorized copying / modification</td>
<td>slight</td>
<td>slight</td>
<td>Impossible **</td>
<td>Difficult</td>
<td>Difficult</td>
</tr>
</tbody>
</table>

Influence Factors

<table>
<thead>
<tr>
<th></th>
<th>Very high</th>
<th>Very high</th>
<th>--</th>
<th>Possible</th>
<th>No influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dirt / damp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covering</td>
<td>Totally fail</td>
<td>Totally fail</td>
<td>Possible</td>
<td>--</td>
<td>Very low</td>
</tr>
<tr>
<td>Direction and position</td>
<td>Low</td>
<td>Low</td>
<td>--</td>
<td>Unidirectional</td>
<td>Very low</td>
</tr>
</tbody>
</table>

* It depends on the physical characteristics used for identification. For instance, the distance of voice recognition technology could be up to 1~2m and that of iris technology is only a few centimeters.

** For voice recognition, it could be faked with the tape record.

Alternatively, the comparison in terms of cost and automation level is presented in Fig 2-5. The cost of the technology with active sources is generally higher than those using passive or none sources. However, with the active source to power the electronics devices, they can offer more functions to achieve automation level in the systems. For RFID technology, the system can adopt the tags from passive, semi-active to active ones. It can meet wider customer demands and offer the advantages covering both active and
passive technologies. Meanwhile, with the advance of semiconductor technology and the volume used, RFID technology is gradually being implemented in a variety of devices, products and applications.

![Cost of Auto-ID systems vs. Automation levels](image)

Fig 2-5 Cost of Auto-ID systems vs. Automation levels

### 2.2 RFID COMMUNICATION

In terms of energy and data transmission methods, RFID technology can be generally divided into two types – inductive coupling type and electromagnetic wave type.

#### Inductive Coupling

For the RFID operating at the frequency below 30MHz, the power supply is generally via the inductive coupling between readers and tags. The magnetic filed is generated by the readers and through the inductive coupling, the tag is powered to receive and transmit the data to the reader. Due to the limitation of the coupling magnetic field, its communication range is usually not far away. This kind of RFID is widely adopted in the anti-theft devices and access control.
For the RFID operating frequency higher than 30MHz, it can communicate like the radar systems via the electromagnetic wave. In general, the transmission distance is longer than the inductive coupling type. Meanwhile, its tag size can be minimized to a considerable small one.

2.3 RFID APPLICATIONS

With the read/write capability by the contactless radio wave communication and huge storage capacity, RFID technology is potentially used in a wide rage of applications.
Among the business processes within a company, RFID can be integrated with enterprise systems to improve the process flows. For the cross function tasks, with RFID technology, they can be achieved more efficiently. The relationship among the business processes, enterprise systems and RFID is depicted in Fig 2-8 (Christopher Boone, 2003). It is illustrated based on a top-down layer structure. Obviously, RFID plays as a foundation layer for this layer structure. Enterprise systems handle the influx of data created by RFID and work in conjunction with the middleware in the RFID layer. The business processes will be somewhat different for each company and determined by each company’s strategy. At the core, the enterprise systems will be upgraded or redesigned as the companies change the business processes to take advantage of the introduction of real-time information visibility.

The potential benefits to the business processes are numerous. RFID tags can store a lot of information including details of cost, date of production, date of shipping, expiry date and so on. The human errors in counting and monitoring stock can be eradicated. The box and pallets can be constantly tracked with RFID tags attached. The benefits to businesses are listed in Table 2-3 for some businesses including factories, finished goods warehouses, distribution centers, and in-store handling. RFID technology could not only improve the process efficiency with information visibility but also could create innovative functions to the business processes.
**Fig 2-8** RFID application infrastructure in business processes

**Table 2-3** Benefits of RFID application in businesses

<table>
<thead>
<tr>
<th>Business</th>
<th>Factory</th>
<th>Finished Goods Warehouse</th>
<th>Distribution Center</th>
<th>In-Store Handling / Store shelf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>■ Plant inventory accuracy (Finished goods)</td>
<td>■ Reduced labor costs in receiving, putaway, picking, and shipping</td>
<td>■ Improved efficiencies in receiving and payment for receivables</td>
<td>■ Inventory reduction (backroom, lower obsolescence)</td>
</tr>
<tr>
<td></td>
<td>■ Automatic and verified shipment data reported to finance and inventory systems</td>
<td>■ Proof of ownership during transit</td>
<td>■ Reduction in labor costs</td>
<td>■ Better visibility of back room and on-shelf inventory</td>
</tr>
<tr>
<td></td>
<td>■ Reduction in reverse logistics / Returns and Claims</td>
<td>■ Reduction in reverse logistics / Returns</td>
<td>■ Reduction in reverse logistics / Returns</td>
<td>■ Decrease theft</td>
</tr>
<tr>
<td></td>
<td>■ Improved goods transfer and payment process</td>
<td>■ Reduction in inventory</td>
<td>■ Reduction in inventory</td>
<td>■ Improved on-shelf availability and reduction in out of stock (improved replenishment)</td>
</tr>
<tr>
<td></td>
<td>■ Improved service levels through reduced out of stock</td>
<td>■ Reduction in obsolescence</td>
<td>■ Store labor productivity improvement</td>
<td></td>
</tr>
</tbody>
</table>
In terms of RFID tag applications with time, Fig 2-9 depicts the business opportunities and benefits of RFID in pallet, case and item level applications. Due to the high cost issue in RFID tags currently, the implementation of RFID in pallet and case level is expected to be more feasible than item tagging as the investment in tags is smaller and system complexity is simpler. Companies will be more interested in the introduction of this new technology to their business processes. In the end, the item tagging will be implemented when the tag cost declines to an acceptable price and the technical issues are solved.
The benefits of RFID technology to the business management will vary for the different management functions. It can work alone or integrate with other IT systems to reach the specific goals in the business managements. RFID could be applied in the process management, asset management, security management, storage (Inventory) management and so on. Among these business managements, the supply chain management has the largest amount of items and integrates the widest participants in the value chain. Supply chain management covers the business managements within the organization or externally inter-related ones. For such an open system, its implementation is much complicated and difficult. However, its impact and effect on the business management will be huger ad deeper.

**Supply Chain Management**

One important mechanism for coordination in a supply chain is the information flows among members of the supply chain. These information flows have a direct impact on the production scheduling, inventory control and delivery plans of individual member in the supply chain. Traditional information is sequentially flowed among the members as illustrated in Fig 2-10. One of the well-known drawbacks in the system is Bullwhip effect. Bullwhip effect refers to the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer (i.e, demand distortion), and the distortion propagates upstream in an amplified form. The role of inventory is to act as a buffer to smooth production in response to demand fluctuations.

![Fig 2-10 Information flow in a traditional supply chain](image-url)
According to the study by Hau L. Lee et al (1997), the driving forces to Bullwhip effect include (1) demand signal processing, (2) rationing game, (3) order batching and (4) price variations. Distortion of demand information arises when the retailer issues orders based on her updated demand forecast. As a result, the manufacturer loses sight of the true demand in the marketplace. The distortion effect gets amplified as the number of intermediaries in the channel increase. On clear solution is to grant the manufacturer access to the demand data at the retail outlet. The combination of sell-through data, exchange of inventory status information, order coordination and simplified pricing scheme can help mitigate the bullwhip effect. Table 2-4 lists the contributing factors and counter measures of these causes.

<table>
<thead>
<tr>
<th>Causes</th>
<th>Contributing Factors</th>
<th>Counter measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand signaling</td>
<td><img src="image1" alt="No visibility of end demand" /> <img src="image2" alt="Multiple forecasts" /> <img src="image3" alt="Long leadtime" /></td>
<td><img src="image4" alt="Access sell-thru or POS data" /> <img src="image5" alt="Single control of replenishment" /> <img src="image6" alt="Lead-time reduction" /></td>
</tr>
<tr>
<td>Order batching</td>
<td><img src="image7" alt="High order cost" /> <img src="image8" alt="FTL economics" /> <img src="image9" alt="Random or correlated ordering" /></td>
<td><img src="image10" alt="EDI &amp; CAO" /> <img src="image11" alt="Discount on assorted truckload, consolidation by 3rd party logistics" /> <img src="image12" alt="Regular delivery appointment" /></td>
</tr>
<tr>
<td>Fluctuating prices</td>
<td><img src="image13" alt="High-low pricing" /> <img src="image14" alt="Delivery &amp; purchase asynchronized" /></td>
<td><img src="image15" alt="EDLP" /> <img src="image16" alt="Special purchase contract" /></td>
</tr>
<tr>
<td>Shortage game</td>
<td><img src="image17" alt="Proportional rationing scheme" /> <img src="image18" alt="Ignorance of supply conditions" /> <img src="image19" alt="Unrestricted orders &amp; free return policy" /></td>
<td><img src="image20" alt="Allocate based on past sales" /> <img src="image21" alt="Shared capacity &amp; supply information" /> <img src="image22" alt="Flexibility limited over time, capacity reservation" /></td>
</tr>
</tbody>
</table>

Due to the information invisibility and the time lag of demand signal along the supply chain, the solution to grant the participants access to the information shared on a common platform is clearly a direct and effective counter measure to Bullwhip effect. Fig 2-11 depicts a layered information model on a common platform. In this model, the data is acquired by automatic tracking system, and transformed to the value-added information. Participants in the supply chain can access the instantaneous information through the
secure internet communication. Obviously, information flow lag and distortion condition can be improved, and potential efficiency gains are achievable under this layered information platform. This information flow concept is much different from that in the contemporary supply chain. RFID technology integrated with IT systems can achieve the goal as described in Fig 2-11. Under this information flow structure, data will not only be transmitted in the sequential way but real-time shared under a common platform to the participants.

![Information flow in a new supply chain](image)

**2.5 TECHNOLOGY DIFFUSION MODEL**

Information systems play a critical role in the operation of modern digital firms. In terms of corporative management levels, business functions and work flows are usually interrelated internally within the organization or externally to the suppliers or customers. Information systems not only benefit the process automation in the business flows but also transform the business conduct in the enterprises. With the industrial globalization and market competition, the business economy among firms is getting more complex and
competitive. In order to quick response and obtain the competitive advantages over others, companies intensively establish the information management systems through the IT infrastructure investment.

The information architecture of IT infrastructure in a modern digital firm is depicted in Fig 2-12. With the intelligent system establishment, companies can integrate multiple business functions within the same platform to process the flows. It can greatly reduce the labor force as well as improve the error rate in the traditional labor-intensive work floor layout. Nowadays, IT systems can be deployed in any business functions. Managers make the business decision based upon the information collection and recording by the IT systems. It makes the companies focus on their core value functions and remove the less-margin works by the help of IT systems.

In terms of IT system infrastructure, RFID technology will be taken as an innovative way to access and collect the information from the media. It can be integrated into the existent IT systems to create the value-added functions and service to the firms. Therefore, before the analysis for the factors to the adoption of RFID technology, we should analyze the model or ways for the technology innovation to be adopted and implemented.
IT implementation is an organizational effort directed toward the diffusion of appropriate information technology to support particular tasks within a specific work context. According to the study by Randolph B. Cooper and Robert W. Zmud (1990), the IT implementation can be divided into six steps including initiation, adoption, adaptation, acceptance, routinization, and infusion. Table 2-5 illustrates the detailed process and its product of technology diffusion model.

Due to the uncertainty in the initial stage, the new IT technology could be driven by business demands or could be attracted by its potential benefits to the business opportunities. With the clearness in its risk and the proof in its benefits, the acceptance will gradually be improved in the implementation. The process of new technology implementation is step-by-step diffused into the organization. When the technology can be routinely and smoothly run in the company, maximum potential benefits will be performed to it.
Table 2-5  IT Implementation process model

<table>
<thead>
<tr>
<th>Step</th>
<th>Process</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>Active and/or passive scanning of organizational problems / opportunities and IT solutions are undertaken. Pressure to change evolves from either organizational need (pull), technological innovation (push), or both</td>
<td>A match is found between an IT solution and its application in the organization</td>
</tr>
<tr>
<td>Adoption</td>
<td>Rational and political negotiations ensure to get organizational backing for implementation of the IT application.</td>
<td>A decision is reached to invest resources necessary to accommodate the implementation effort.</td>
</tr>
<tr>
<td>Adaptation</td>
<td>The IT application is developed, installed, and maintained. Organizational procedures are revised and developed. Organizational members are trained both in the new procedures and in the IT applications.</td>
<td>The IT application is available for use in the organization.</td>
</tr>
<tr>
<td>Acceptance</td>
<td>Organizational members are induced to commit to IT application usage.</td>
<td>The IT application is employed in organizational work.</td>
</tr>
<tr>
<td>Routinization</td>
<td>Usage of the IT application is encouraged as a normal activity.</td>
<td>The organization’s governance systems are adjusted to account for the IT application; the IT application is no longer perceived as something out of the ordinary.</td>
</tr>
<tr>
<td>Infusion</td>
<td>Increase organizational effectiveness is obtained by using IT application in a more comprehensive and integrated manner to support higher level aspects of organizational work.</td>
<td>The IT application is used within the organization to its fullest potential.</td>
</tr>
</tbody>
</table>

RFID is an innovative technology to the IT systems. According the IT implementation process model described above, it is just at around the adoption and the adaptation step for most of application cases. Comprehensive deployment of this new technology is not actually realized in the industries. Companies are trying to solve their problems and create new business opportunities with this new technology. Therefore, the effective benefits of this new technology have not been extensively proved. Only some pioneering companies are piloting the test to find the new business model and opportunities with RFID technology.
2.6 KEY SUCCESS FACTORS

The factors to RFID adoption will be analyzed from two perspectives – the driving forces to its adoption and the resistance and issues against it. Though RFID is not a new created technology, it had been used in military industry. However, the application in commercial and consumer industries has not been comprehensively adopted. Companies are exploring the ways to achieve the benefits in the business processes and management through this innovative technology deployment. Therefore, the factors taken into account for firms should be different from those for military application.

First of all, let’s review some of literatures related to the factors to the new IT technology adoption. According to the diffusion of innovation model by Everett M. Rogers (1983), the variables determines the rate of adoption include
1. Perceived attributes of innovations (Relative advantage, compatibility, complexity, trialability, observability)
2. Type of innovation decision (optional, collective, authority)
3. Communication channels
4. Nature of the social system
5. Extent of change agents’ promotion efforts

Premkumar et al. (1994) found that relative advantage and compatibility are predictors of the extent of “adaptation”. Grover (1993), identified five factors that statistically discriminated between firms that have and have not adopted EDI: (1) proactive technological organization, (2) internal push, (3) market assessment, (4) competitive need and (5) impediments.

An understanding of the driving factors is essential in order for practitioners to best implement a new technology. In the following section, the driving forces analysis to the RFID technology adoption is made by dividing the forces into two categories – push forces and pull forces.
For driving forces analysis, we conclude that there are two types of driving forces to the RFID technology adoption. They include the push and pull forces as illustrated in Fig 2-13. The driving forces are described in the following.

**Technology Innovation**

Traditionally, bar codes have been widely used in identifying products for years. They have served their purpose well. However, the bar codes have one big shortcoming: they are line-of-light technology. A scanner has to see the bar code to read it. If a label is ripped, soiled or falls off, there is no way to scan the item. Meanwhile, bar code does not have an unique serial number to identify individual item. Radio frequency identification, by contrast, does not require line of light. RFID tags can be read as long as within range of a reader. Actually, this is a kind of relative advantage thanks to the technology innovation of RFID over bar code solutions.
Compared with the time consumption in data entry via different technologies as shown in Table 2-6, it is found that RFID can save a lot of time and greatly improve the operation efficiency. Financially, this efficiency enhancement thanks to the new technology adoption can directly benefit the operation cost saving. The extent of cost saving increases with the amount of data entry in operation flows. This companies’ adoption is driven by technology innovation. Indirectly, through the RFID adoption, the product and process quality can be improved due to the reduction in entry errors by human operation. Meanwhile, the processes can be reengineering to an optimal level as the labor force can be freed up to perform the more value-added functions.

Table 2-6 Comparison of data entry via different technologies

<table>
<thead>
<tr>
<th>Method</th>
<th>1</th>
<th>10</th>
<th>100</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual entry</td>
<td>10 sec</td>
<td>100 sec</td>
<td>1000 sec</td>
<td>2 hrs 47 mins</td>
</tr>
<tr>
<td>Bar code</td>
<td>2 sec</td>
<td>20 sec</td>
<td>200 sec</td>
<td>33 mins</td>
</tr>
<tr>
<td>RFID</td>
<td>0.1 sec</td>
<td>1 sec</td>
<td>10 sec</td>
<td>1min 40sec</td>
</tr>
</tbody>
</table>

Compatibility is another factor of technology innovation that should be taken into consideration. If the innovation technology can be backward or forward compatible with the existent systems, companies will be more willing to adopt it. They do not need to worry about the waste in technology investment. The risk of technology uncertainty can be mitigated through the system compatibility. In reality, RFID should be taken as a tool to benefit the products or processes with the integration of other IT or management systems. With the relative advantages over the existent solutions, technology innovation can drive the companies or organizations to adopt it.

Government and Standard Organization Influence

Government and standard organization usually have the power to push the extensively adoption of some technologies or systems through the legislation or mandates.
Sometimes, due to the political or economic policy consideration by government and standard establishment among members by standard organization, this kind of forced mandate is a quick way to drive the adoption of technology innovation. The companies will adopt the technology in order to be compliant with standard specification or mandates.

In general, independent organizations will be formed to qualify the products or process according to the standard qualification definition. Through this qualification, the interoperability among the products or processes can be guaranteed among different companies. It plays a critical role when the products or information will be flowed or shared among companies across borders. For instance, the American Department of Defense (DoD) asked their all suppliers to offer the products with RFID tag on the boxes and pallets. This mandate forced the supplier to be compliant with DoD’s RFID standard. Otherwise, the suppliers can not keep on offering the goods. Due to the strong bargaining power of DoD over their suppliers, it is a very efficient way to push the adoption of RFID technology by its suppliers.

Additionally, in the early stage, government and standard organization can play as an advocator of technology innovation. They can sponsor the pioneering plans to demonstrate its potential benefits to the business processes or management flows, and encourage the companies’ adoption through the subsidy or incentive programs. It will share the risk and investment loading from the joint projects between government and companies. Through these actions, the willingness to adopt the new technology can be enhanced as well.

■ Organizational Readiness

Organizational readiness measures whether a firm has sufficient IT sophistication and financial resources to undertake the adoption of RFID technology. IT sophistication means not only the level of technological expertise within the organization, but also assesses the level of top management understanding and support for using IT technology to achieve the organizational objectives. For companies with higher IT sophistication, it
Financial resources are the organization’s capital available for IT investment. Companies with abundant financial resources will be more able to support the adoption of this kind of immature new technology. Specifically, in the early stage when the direct investment return is ambiguous, the risk of technology adoption is statistically higher than the mature ones. Resource support plays a key role in the success of its adoption. By contrast, firms with limited resources will be constrained by the fear of investment failure or have less chance to reach a concrete result due to the interruption of resource support. It will retard the new technology adoption in organizations.

**Inter-organization Demands**

External pressures are the forces to drive the firms thinking about the ways to be more competitive than others. The adoption of RFID technology relates to the ability to maintain or increase competitiveness within the industry. In the industry value chain, there are many collaborative activities in the business processes. The dependency on the trading partner influences the adoption as well. The information flow lag and invisibility incur the problems such as high inventory rate, out of stock situation, poor response to the customer demand, high cost in reverse logistics process and so on. These issues make the participants in the value chain to find the means to improve these situations. Through the collaboration among firms, a foundation can be provided to enable the optimization in product physical flow and information flow. Meanwhile, the JIT (Just in time) delivery can be achieved to allow the average inventories to be substantially reduced to a minimum level. The adoption of RFID technology can improve the business process and management issues occurred in the inter-organizations.

Companies with strong exercised power over other participants in the value chain are able to force the suppliers to adopt the new selected technology to gain the strategically synergy effect or first-mover benefit in the market competition. This kind of new
technology adoption can quickly penetrate the market and push the peripheral companies to support the new technology development. The influence of technology adoption will be quickly made through the network effect among the inter-organizational members. For instance, the retailing giant, Wal-Mart, requests all supplier meet their RFID adoption mandate for the new business process policy. Otherwise, Wal-Mart will reject the acceptance of goods supplied. This is a typical example of the new technology adoption driven by leader companies in the inter-organization structure. Usually, the factors, including the dependency on trading partners, trust and partners’ readiness plays a key role for the success of this kind of new technology adoption.

Alternatively, the adoption of new technology can be driven from the customer side. The customer demands stand for the new business opportunities to the firms. The unsatisfied demands could be existent but there is not an effective way to meet them. Strong customer power can force the companies to adopt the new technology to offer the products or service to improve this situation. For RFID technology adoption, the issues such as product unique ID, accurate real time data in supply and demand, quick responsiveness to the product recall and so on can be achieved to improve the service quality and enhance the customer satisfaction.

■ RESISTANCE AND ISSUES AGAINST RFID ADOPTION

RFID technology used in commercial applications is still in the emerging stage and keeps evolving to a mature one. Many of technical issues, physical problems and application areas are under the way to be proved in industries. Resistances to the adoption are keeping challenge the technology advocators and adopters. However, they also motivate the companies involved to improve the solutions to perform the functions meeting the organization demands and to gain the potential benefits in the practices.

According to the study done by John Fernie (1994) who seeks to identify the impact of EDI and quick response technologies on product identification systems, the barriers to its adoption is illustrated in Fig 2-14 where the barriers can be divided into two categories –
adoption barriers and implementation barriers. For the adoption, most of these barriers should be overcome in the end.

![Fig 2-14 Barriers to technology adoption](image)

Here list the resistance and issues against the adoption of RFID technology.

- **Price Performance Concern**

  As we know, currently in comparison with bar code labels, RFID tags are still much more expensive. The unit cost for bar code label is only few cents and it can even be printed directly to the product package or boxes. However, the passive RFID tags will cost 60~80 cents now. For active RFID tags, the cost could reach few thousand USD dollars. There is a big price gap between these two solutions now. Though RFID has features outperformed the bar code label, tag cost is the major concern for the commercial adoption. Meanwhile, the system implementation costs including the hardware and software investment are a big expense for the firms.

  In terms of business applications, the critical concerns for the adoption are not only the tag price but also its performance it can reach. If the performance and benefits RFID can contribute are indispensable to the business process or product improvement, the cost increase due to the RFID adoption will be covered by its new features or functions. For
instance, the RFID tags used in healthcare or toxic material management can reduce the fatal errors by human operation. The failure cost due to these kinds of errors could reach millions of USD dollars, or even make the unrecoverable errors such as losing lives. Through the RFID adoption, the risk for these errors can be reduced by precisely monitoring the information flow and control. For these situations, companies cannot consider only the tag price but should view from its practical contribution to the business processes or products.

The tag price is anticipated to drop dramatically over time thanks to the advance in semiconductor technology and the volume expansion supported by pioneering industry giants. The resistance to its adoption will be mitigated with the tag price declining to a competitive level and, then companies will pay more attention to its performance and benefits contributed.

Cost and Benefit Justification

Cost and benefit analysis is always the essential concern for companies to adopt a new technology. According to the market survey made by ABI research, the average returned period for RFID investment is anticipated at around 5-7 years. Therefore, the investment in RFID technology is not a quick return. It should be viewed from the long-term prospection. Strategically, through RFID adoption, companies can refine the current processes and redesign the business flow to gain the differentiation benefits. Customer retention to the products and services can be improved with new technology adoption. In terms of capital investment, the RFID adoption can be viewed as an option. The outperformed benefit can be gained through the technology implementation. However, it still exists the risk in this investment.

For short-term perspective, companies who consider adopting RFID technology should focus on the analytical gains first and the production gains later. Though RFID technology adoption can provide a lot of potential benefits to the organizations, focusing on the achievable ones first is the best way to keep on the adoption. Meanwhile, the risk for the project failure can be minimized by the careful scope definition in advance. As a
result, the proposal for the new technology adoption will be more persuasive based upon
the cost and benefit analysis.

- **End User Acceptance**
  As RFID can be used to aid security, it also puts the security under threat. A related
drawback is the consumers’ reaction to the idea of having so much more data about them
stored and available for manufactures’ use. The more data RFID tag holds about the
products, value, and the whereabouts, the easier it is for a rival or criminal with a RFID
reader to access the data remotely and use it detrimentally to the company. Clothes
manufacturer Benetton, for example, announced in 2003 that it would tag all clothes
produced under the Sisley brand and track them through the supply chain to 5,000 stores
worldwide. Privacy groups immediately called for a boycott and the company had to
backtrack the products. So strong, in fact, is the negative feeling towards RFID among
some consumers, that a group called CASPIAN (Consumers Against Supermarket
Privacy Invasion and Numbering) has formed actively to fight against the use of the tags.
One study showed that 78 percent of the public are opposed to RFID on privacy grounds,
objecting to the fact companies will be able to track every product a customer buys, how
much they spend, what happens to the product after purchase, and so on. What
manufacturers also need to think about, though, are the potential drawbacks for
themselves that could come with holding all that data. Companies considering RFID are
encouraged to capture only what they really need to use. Firms should think about the
cost involved.

Effective security mechanisms can provide protection against the described threat. The
security and privacy risks induced by the unprotected tag give reasons to a number of
contributions and protocol propositions. One option would be to “kill” the tag after it has
been used, e.g. at the point of sale. A password protected “destroy” command has also
been integrated into the EPC specifications. There are also proposal for protocols that
authenticate the tag to the reader and protect against tag counterfeiting. Some RFID
systems are able to encrypt and authenticate the data traffic with proprietary protocols.
Interoperability, Interference and Data Overload

Tag and reader incompatibilities still exist among rival manufacturers. Interoperability among different vendors is the problem for companies who consider adopting RFID solutions. The tags and readers might be incompatible for the protocols, functions or operating frequency covered. As a result, the selection for tag and reader is currently not flexible enough for the companies who are interested in adopting the RFID technology. The industry association and standard organization such as the CompTIA, the association of Automatic Identification and Mobility, and EPCglobal are pushing for RFID certification and compliance test in industries. Through the certification mechanism, the certificated tags and readers are interoperable to communicate with each other.

RFID signal can be blocked in some environments (e.g. liquid, mental) and it can be interfered by the wireless signals at the neighboring frequency band. The problem limits the scope and level of RFID applications in industries. For the electromagnetic wave communication, the multi-path interference is always the problem for the wireless communication. This interference issue is one of the problems that should be solved for the comprehensive adoption in all item levels. However, through the floor layout design and the selection and arrangement in tags and readers, the interference impact can be reduced to an acceptable level for the RFID communication. Meanwhile, the signal quality and interference immunity can be improved with the specific coding and error correction method.

RFID systems churn out a flood of data in comparison with the trickle of information in bar code environments. Data volumes vary by business scenario and the depth of deployment. The data might be managed in real-time, post process or both, depending on the requirement of scenario. Data loads produced by RFID systems could overload company systems. The existent systems might be incapable of handling such a large volume of data flood that companies need to upgrade the systems to meet the data processing demands. The investment in system upgrade is a resistance for companies considering the adoption of RFID solutions. Through the data screening, data capture
mechanism design and system layer definition, the data flood generated by RFID can be minimized to an acceptable level for the system processing. The system upgrade should be viewed in terms of the capital investment for long-term benefits and being leveraged for the whole system performance, not for the RFID solution only.

■ Country Specific Idiosyncrasies
For RFID applications, some spectrum bands are not for commercial use in Japan and parts of Europe. For instance, the frequency band at around 900MHz is already allocated for the mobile communication at some countries. The situation resists the interoperability of RFID tags and readers among countries around the world. For the application across the borders, the country specific constraint limits the RFID adoption for commercial use. In the future, through the standard organization’s mandate and the support by governments, the frequency allocation problem could gradually be solved for the comprehensive deployment in industries.