EPCglobal:
A Universal Standard

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EPCglobal

A Universal Standard

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Submitted to the System Design and Management Program in Partial Fulfillment of the Requirements for the Degree of

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Abstract:

This thesis evaluates the likelihood of EPCglobal becoming the universal RFID standard by presenting a framework of ten factors used to analyze and determine if EPCglobal is moving in the right direction. The ten factors are: complexity of application (Supply Chain Management), mandates, privacy policy, member type, EPCglobal standard development process, membership size, intellectual property policy, benefits, system cost, and China. These factors have been used in various analyses and studies that explain the main reasons for the adoption of other technologies and/or standards. Therefore, this thesis not only presents an analysis for the adoption of EPCglobal as the universal standard but also presents the factors that could help EPCglobal achieve its goal.

The results show that five of the ten factors that influence the establishment of EPCglobal as the universal standard have a positive effect for the universal adoption of EPCglobal, two are neutral, and three are negative. Thus, there is a strong likelihood that EPCglobal could successfully become the universal standard for RFID system in the retail supply chain management. Furthermore, if EPCglobal strives to have the two neutral rated factors join the other five positive factors and makes an effort to switch the three negative factors to positive, then EPCglobal would be on the right path to becoming the universal standard.

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INTRODUCTION

Radio Frequency Identification (RFID) is an emerging and very promising technology especially in supply chain management applications. The supply chain application became possible because of the vision of the Auto-ID Center at MIT. The MIT Auto-ID Center envisioned "a world in which all electronic devices are networked and every object, whether it is physical or electronic, is electronically tagged with information pertinent to that object." The Auto-ID Center has created a disruptive RFID architecture capable, in the near future, of placing inexpensive RFID tags in every manufactured item.[1] The disruptive nature of the architecture created by the Auto-ID Center comes from the fact that all previous applications of RFID technology utilized very expensive tags containing a large amount of information. The Auto-ID Center developed the idea of using an inexpensive tag with a unique identifier and storing the specific information of each tag in an external database.

Savings in the supply chain from the use of the Auto-ID Center's technology are proving to be substantial.

The RFID technology allows a 100 percent visibility in the supply chain thus enabling a better understanding of the complexity of the supply chain. This complexity of the global supply chain has increased substantially due to the fact that more than $850 billion a year of products are exported from China to countries all around the world.[2] But the adoption of this new technology has not been as rapid as some experts predicted a few years ago. One of the major hurdles keeping this technology from taking off is the lack of a universal standard.

EPCglobal is the current leader in the development of RFID technology standards in the retail industry but it has not yet been able to establish itself as the universal standard for RFID supply chain applications. But because of the benefits of implementing RFID systems some major retailers have mandated the adoption of EPCglobal RFID systems and standard. However other factors such as intellectual property and cost have slowed down EPCglobal's universal adoption.

How can EPCglobal succeed in becoming the universal standard? This thesis focuses on answering this question and analyzes EPCglobal as the main standard organization

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[1] Dew N., "Incommensurate technological paradigms? Quarreling in the RFID industry", *Industrial and Corporate Change,* 2006, 15 (5), pp. 785–810.

[2] Collins, J., "China Urges Role in EPC Standards", RFID Journal, 2004. http://www.rfidjournal.com/article/articleview/1119/1/1/

driving the creation of a universal standard for RFID in the supply chain applications in the retail industry. Today, there are several challenges and drivers for the adoption of EPCglobal standards and these are discussed in this thesis.

The framework of the analysis of this thesis is based on the following ten challenges and drivers: Complexity of application (Supply Chain Management), Mandates, Privacy policy, Member type, EPCglobal standard development process, Membership size, Intellectual property policy, Benefits, System cost, and China. These factors were selected from various technology and standard adoption studies. The ten factors are shown in the table below and a brief explanation of these factors follows the table.

Factors
Complexity of application (Supply Chain Management)
Mandates
Privacy policy
Member type
EPCglobal standard development process
Membership size
Intellectual property policy
Benefits
System cost

Factors
China

Complexity: The complexity factor has been important in technology standardization when applications are complex. Hypertext Markup Language (HTML) for the Web and the bar code for supply chain are some examples of complex applications where the establishment of universal standards brought interoperability among the different players involved.

Mandates: A mandate or a sponsor, as defined by Katz and Shapiro (1986), is an entity that has property rights to the technology and hence is willing to make investments to promote it. In the case of EPCglobal, its members can be considered "sponsors" of its standards because its members are willing to investment and mandate the use EPCglobal standards

These mandates are a main driver for adoption because they have strategic implications for the use of a universal standard. These strategic implications include: larger volume, lower cost of systems, and innovative applications. On the other hand, mandates can have a negative impact on adoption of a standard if they are not properly handled. An example of mishandling is when a sponsor introduces a mandate to a set of users and does not let them communicate with each other.

Privacy Policy: Privacy policy in the adoption of a standard has proven to be important. Consumers do not want their private information to be known, manipulated, and/or controlled by another individual or group. Many consumers believe that new technologies, such as RFID, provide their private information to companies without their consent. Miller and Tucker (2006), have shown that even if the new technology promises great benefits to the consumer, these privacy concerns can "inhibit network effects in the diffusion process" by discouraging end users from using the new technology because consumers are protesting their use. For example, online shopping is experiencing privacy issues and the adoption has been hindered by its privacy concerns.

Members Type: In the book "Diffusion of Innovation", Rogers states that if a technology or standard is complex then the likelihood for high adoption rate decreases. Complexity, in this case, refers to the difficulty to implement the standard as oppose to the intricacy of the application as explained above. When members are involved in the standard development process, the members can determine how complex the standards are to implement. The members (i.e. the end users and solution providers for EPCglobal) do not want complicated standards because a complicated standard decreases the willingness of end users to adopt the standard. The member type also determines where the standards are adopted (i.e. on a regional or global level). So, geographic location of the members needs to be taken into consideration for the development of standards. If the standards are mainly developed by members of a specific region, then non-members out of this region are alienated. Hence, this alienation decreases the likelihood of these non-members eventually adopting the standard and non-members may instead, in the meantime, create their own standards to satisfy their needs and thus never have a need to adopt a universal standard.

EPCglobal Standard Development Process: The EPC global standard development process is done only by its members and there is no collaboration among other standard organizations until a standard has been ratified. It is only once an EPCglobal standard has been ratified internally that it goes to ISO and other standard organizations for its ratification. The EPCglobal standard development process does not include outside members, it develops the standards and expects the rest of the organizations to adjust and adopt them. This closed development process may alienate non-members and hinder the adoption of the EPCglobal standard.

Membership Size: In the paper "Installed base and compatibility: Innovation, product preannouncement, and predation", Farrell and Saloner described the benefits of having a large number of users deploying the same technology. For example, telephone, Video Cassette Recorder (VCR) recording format, cassette tapes, and many other technologies have benefited from having a large number of users. These benefits are: interchangeability of complementary products, ease of communication among machines and people, and cost savings. Therefore, the membership size is an important factor for the adoption of a technology or standards.

Intellectual Property: The correct handling of intellectual property policy was crucial for the widespread adoption of the bar code. At the initial stages of the bar code technology, intellectual property was the main problem for its adoption. Initially a universal standard did not exist and companies had to develop their own proprietary technology. However, companies realized the importance of having compatible technology to increase the installed base of bar code users that would in turn increase the number of bar code equipment sold. The bar code equipment manufacturers understood that in order to make any money, they would have to increase the number of users printing and reading a particular bar code pattern symbol to increase the sales in the equipment. Today, a particular bar code pattern symbol reference decode algorithm is available for the same cost as the ISO specification but with no royalties, no fees, and no licenses. Therefore, in RFID like in the bar code technology, intellectual property policy plays a critical role in the adoption of a universal standard.

Benefits: In the book "Diffusion of Innovations", Everett Rogers explains the importance of the benefits for the adoption of a technology or standard. When benefits are perceived, by observation and trial, the technology or standard is adopted at a much faster rate. Also, in RFID systems the user's adoption rate not only depends on the perceived benefits of the technology but also on how much better the features of an RFID system are with respect to bar code systems (i.e. the current technology) used to manage supply chain applications.

System Cost: In the paper "Coordination and Lock-In: Competition with Switching Costs and Network Effects" Farrell and Klemperer explain that a high switching cost can also affect the adoption by "lock in" users in a particular technology or standard. In the case of standards, a high switching cost occurs when a technology based on a specific standard is not compatible with other standards and the cost to switch from one standard to another is high. Thus, a high switching cost can "lock in" users to early choices of a particular standard or technology that might not be the best technology for a particular application. Also, a positive ROI in RFID is not easy to determine due to the changing cost, number of users, and applications of the technology. But a positive return on investment (ROI) is a perceived benefit that has proven to be crucial for the adoption of RFID technology.

China: Currently, most retail companies in the U.S. receive a large percentage of products made in China. For example, 70 percent of the products at Wal-Mart are made in China. Wal-Mart's Chinese imports amount to 10 percent to 15 percent of overall U.S. imports from China.[3] If China's economy continues to grow at the current pace then China will become the second largest economy in the world in 20 years.[4] Thus, China has a strong interest in and will have an even greater influence on the development and adoption of future RFID standards. Furthermore, China is also an important factor for the universal adoption of RFID technology due to the high supply chain management (SCM) expenditure in China that accounts for 20 to 30 percent of its gross domestic product. This percentage is relatively high when compared to the 10 percent SCM expenditure in more

[3] "Understanding RFID Adoption in China", RFIDJournal, 2005.

[4] "China's Economic Power: Enter the Dragon", The Economist, 2001.

developed countries such as in the U.S. and the European Community. Chinese suppliers are under constant pressure to decrease their expenditure in supply chain management. RFID systems can be a technology that can reduce this expenditure. Thus, there is a strong Chinese interest in the deployment of RFID systems to reduce the cost of supply chain.

This thesis explains why each of the ten variables was selected and uses them to evaluate EPCglobal's strategy for becoming the RFID universal standard. This thesis is divided into five major sections. Section 1 discusses what RFID is, the history of RFID from its first uses in World War II and the first commercial applications to the creation of EPCglobal as a spin off of the Auto-ID Center created at the Massachusetts Institute of Technology in 2003, and some current applications of the RFID technology. Section 2 explains what standards are, how standards are established, and why they are important for the adoption and development of a technology. Section 2 also discusses some of the problems that can arise with the adoption of a standard. Section 3 summarizes the RFID standards and the current standard organizations involved in the development of RFID standards. Section 3 also explains the structure and products offered by GS1 which is EPCglobal's parent organization, describes EPCglobal's components, and lists its current RFID standards. Section 4 explains in more detail the ten factors described above and uses them to analyze the potential of EPCglobal becoming the universal standard for RFID in the supply chain within the retail industry and to set forth the drivers and challenges EPCglobal is currently facing. Section 5 concludes that EPCglobal could successfully become the universal standard.

Section 1 RFID Technology

1.1. What is RFID?

Automatic Identification and Data Captured (AIDC) technologies are used for the identification of objects by storing and reading a code or other information. This information can be read for tracking goods, security purposes, check-out points, and other processes. The goal of AIDC technologies is to minimize human intervention in the identification of objects. Some AIDC technologies in use today are: bar codes, magnetic stripes, integrated circuits or smart cards, RF remote controls, RFID systems, ultrasound systems, and visual identification.

At this time, Radio Frequency IDentification (RFID) is set to be of the most promising AIDC technologies because it does not need contact or line of sight to identify an object. RFID uses "tags" attached to objects and transmits data to a receiver either when prompted (i.e. passive tags) or by continuously sending an RF signal (i.e. active tags). As mentioned earlier, RFID system's primary advantages over other AIDC technologies are non-contact read and write capabilities, data storage capacity, and hostile environment functionality. RFID uses in today's market include livestock inventory control, container and pallet tracking, identification badges and access control for equipment and personnel, parking lot access and control, and product tracking through manufacturing and assembly.[5]

1.2. The History of RFID

Although RFID technology uses the principles of radio broadcasting and radar technology its history can be traced back to the discovery of electromagnetic theory. This section will focus on the development of radio frequency as a means to transmit and receive a signal to identify an object.[6]

During World War II, the Germans were able to identify friendly aircrafts when pilots rolled their planes in a particular way effectively changing the radio signal transmitted back to the receiving system that originally emitted the signal.[7] In 1939, the British Air Force led by Watson-Watt implemented an "Identification Friend or Foe" (IFF) system. This IFF system used a "passive" radar reflector installed in the aircrafts which

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[5] http://www.activewaveinc.com/applications_overview.html

[6] Landt, J., "Shrouds of Time The history of RFID", AIM publication.

[7] http://www.rfidjournal.com/article/articleview/1338/1/129/

in the presence of a radar system sent back a signal identifying the aircraft as a "friend". [8]

In 1948, Harry Stockman published a paper titled "Communication by Means of Reflected Power". In this paper Stockman suggested the possibility of using the reflective power of radio waves to be used for identification purposes. Stockman also proposed the use of radar technology to go beyond the radar's traditional and simple "yes" and "no" response. Stockman stated that "considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored". The work of Stockman was followed in 1952 by F. L. Vernon. In Vernon's paper "Application of the Microwave Homodyne" he explains the principles of detection of microwaves when derived from the same source of the signal before the modulating process.[9]

In 1960, one of the first patents directly related to RFID passive tag technology was published. Patent 2, 927, 321 assigned to Donald B. Harris reads: "This invention relates to radio transmission systems in which one of the stations in communication is designed to be portable [...] The present invention obviates these disadvantages (weight and bulk of batteries and the high maintenance cost associated to the replacement of the batteries used in fixed stations) by providing means whereby the portable station receives its transmission power by radio from the fixed station."[10] Other significant inventions such as "Remotely Activated Radio Frequency Powered Devices," by Robert Richardson and "Passive Data Transmission Techniques Utilizing Radar Echoes" by J. H. Vogelman occurred in the 1960s. These research and paper publications led to the explosion in RFID applications seen in the 1960s and 1970s.[11]

The commercial RFID applications in the 1960s started with the use of "1-bit" tags for electronic article surveillance (EAS) antitheft technology. In 1973, the patent 3,713,148 issued to Mario W. Cardullo describes an active tag with read and write properties and envisions the use of the technology for preventing car thefts and for a toll system based on mileage to be used in highways.[12] In that same year, Charles Watson invented a card with an embedded passive transponder used to gain access to a door equipped with an RF reader. The transponder transmitted a signal to the reader and if the reader

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8 http://www.vectorsite.net/ttwiz1.html#m5

9 "Application of the microwave homodyne" Vernon, F., Jr., Antennas and Propagation, Transactions of the IRE Professional Group on Volume 4, Issue 1, Dec 1952 Page(s):110 - 116

10 http://www.uspto.gov/

11 Landt, J., "The History of RFID", October/November 2005, IEEE Potentials.

12 http://www.rfidjournal.com/article/articleview/392/1/2/

validated the identity of the transponder the door unlocked. [13] Also, during this decade the Energy and Agricultural departments asked Los Alamos National Laboratory to develop nuclear material and animal tacking systems that would be based in RFID.

In the 1980's, the scientists at Los Alamos National Laboratory who worked in the nuclear material and animal tracking systems formed a company to develop an RFID automatic toll system which was first commercialized and used in Norway in 1987. The United States quickly implemented a similar system at the Dallas North Turnpike in 1989. The exploration and successful application of these toll systems was motivated by the development of integrated circuits and personal computers. These developments allowed the collection and management of data generated by the RFID systems. At the same time one of the first RFID standards emerged. The Association of American Railroads (AAR) started the search for a technology that would track railcars. Previously the AAR was one of the first associations to start using bar codes for an industrial application in the late 1950's. In 1967 the AAR mandated the adoption of the optical bar code which took seven years to label 95% of the AAR's fleet. But for many reasons, the bar code system was a disaster and was abandoned in the late 1970's. Thus, the ARR needed to find a technology that could be use in the rough environment of railcars.[14]

What they found to be the best suited system for the ARR application was radio frequency based identification system. In 1988, the ARR formed a committee to write an Automatic Equipment Identification (AEI) standard. In the early 1990s the AAR approved the AEI standard and voted to make this standard mandatory. By 1994, more that 3.1 million RFID tags were attached to over 95% of the North American rail car fleets and 3,000 readers were deployed in strategic locations across North America.[15]

More toll applications were successfully deployed in the 1990s in the United States and Europe and started to appear in other countries including China, Mexico, and Singapore. Also, the number of companies entering the RFID field increased and other companies such as Motorola, Texas Instruments' TiRiS, and Phillips Semiconductors' Mikron started to experiment with RFID for new applications. These applications included: dispensing fuel, gaming chips, ski passes, and vehicle access.[11] One of the innovative applications in RFID was a system for timekeeping by tagging runners in the 1996 Boston Marathon developed by TiRiS.[1]

[13] http://www.rfidjournal.com/article/articleview/1338/1/129/

[14] http://www.adams1.com/pub/russadam/history.html

[15] http://aeitag.stores.yahoo.net/aeirailhis.htmlaA

Also in the 1990's, the U.S. Department of Defense (DoD) became very active in implementing RFID systems to track containers and their contents after having a logistics problem during the Gulf War. The problem occurred after containers loaded with vital supplies arrived at the war zone and hundreds of personnel had to be assigned to open each container to find out what was actually in it. After this incident the DoD awarded a three year contract to deploy an RFID system to track containers and their content to SAVI Technology. [1]

In the 21st century, the research and development of RFID technology has increased the functionality of the technology leading to new implementations and the replacement of other AIDC technologies (e.g. the bar code and magnetic stripe). This research and development started in academic RFID centers such as the Auto-ID Center. The Auto-ID Center was founded in 1999 by the Uniform Code Council (UCC), Procter & Gamble, and Gillette at the Massachusetts Institute of Technology (MIT) and gained the support of more than 100 industrial partners, the government, and RFID vendors. The Auto-ID Center's main goals were to do RFID research, create standards, and facilitate adoption for RFID technology. The Auto-ID Center research created two interface protocols, the electronic product code (EPC) numbering scheme, and the network architecture for data management of RFID tags over the internet. The Auto-ID Center standards focused on the creation of technical standards. These standards would be "open", developed for the EPC code, and approved by consensus among the Auto-ID Center's membership. Finally, to encourage adoption the Auto-ID center created an educational program to promote widespread diffusion of the EPC code in order to increase the demand of tags which would decrease the tag cost.[1] (The Auto-ID Center no longer exists because it was divided into Auto-ID labs and EPCglobal in October 2003).

To further promote the use of RFID in supply chain applications, the UCC and European Article Number International (EAN International) created a plan for a global tag (GTAG) that would promote a worldwide supply chain standard for RFID in 2000.[16] In 2003, EPCglobal was formed as a joint venture between the UCC and EAN International to create the standards needed for supply chain management and to commercialize its technology. In 2005, Global Standards One (GS1) was created as a joint effort between the EAN International and UCC and EPCglobal was incorporated as one of its product offerings. During this decade companies began to understand the benefits of using RFID in their supply chain management and adopted RFID mandates. For example, Albertsons, Metro, Target, Tesco, Wal-Mart, and the DoD established mandates for their suppliers to use RFID tags in their products.[17]

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[16] http://www.gs1.org/about/media_centre/

[17] http://www.rfidjournal.com/article/articleview/1338/2/129/

1.3. RFID Architecture[18]

Architecture is "a specification that identifies components and their associated functionality, describes connectivity of components, and describes the mapping of functionality onto components."[19] One of the first architectures used for RFID systems is shown in Figure 1-1.[20] This architecture uses two components that are still used in today's RFID systems: a tag and an interrogator or reader.

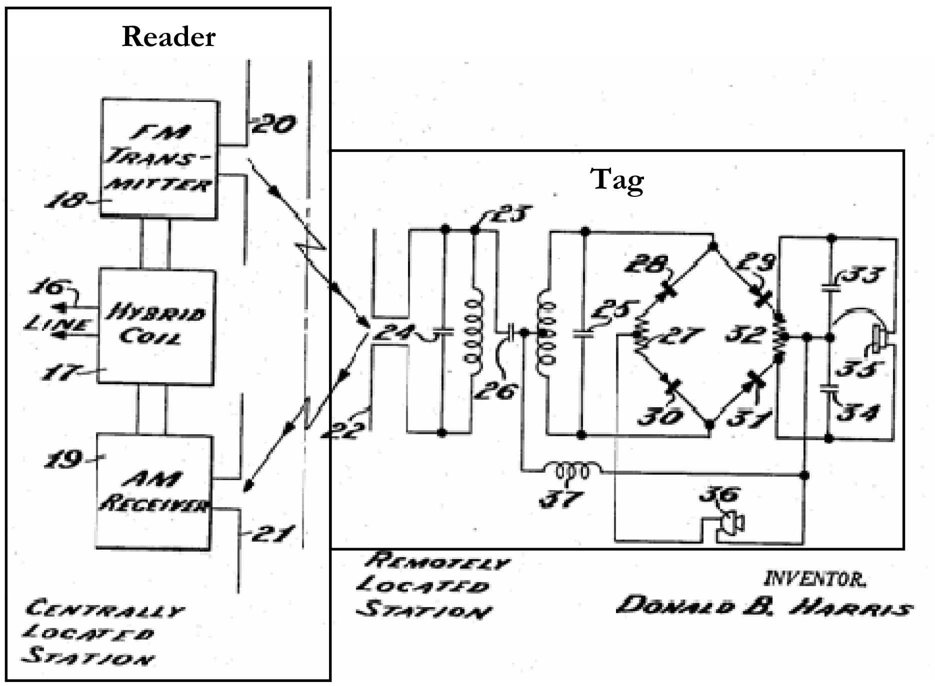

Figure 1-1

Today's RFID systems include other components besides a tag and a reader. These other components include controllers, sensors/actuators/annunciators, hosts and software systems, and communication infrastructures. Figure 1-2[18] shows an illustration of an RFID architecture. Below are descriptions of these components.

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[18] Lahiri , S., "RFID SourceBook", IBM Press, 2005.

[19] http://www.sei.cmu.edu/opensystems/glossary.html

[20] US Patent Office, http://www.uspto.gov Patent: 2, 927, 321.

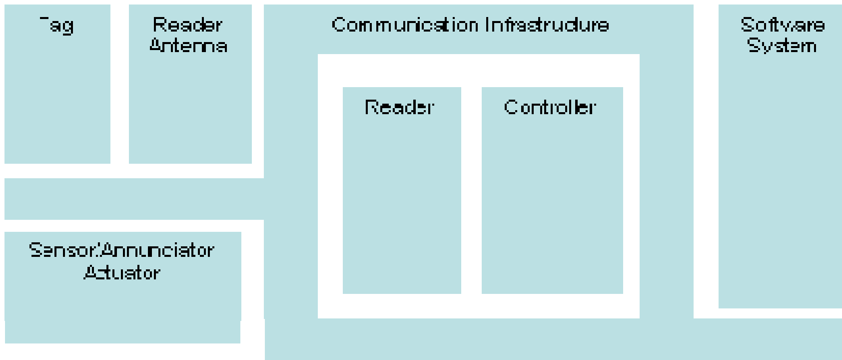

Figure 1-2

Tag: a device attached to an object that stores and transmits information using radio waves. The tag can be in the form of a label, plastic cards and boxes, and capsules and consists of a chip and an antenna (See Figure 1-3 [21]). The chip contains the identifying information and the antenna receives and reflects the radio waves that contain the information.[22] The information transmitted is "read" by a reader or interrogator without any physical contact with the tag. RFID tags are classified as having a power supply (active tags), not having a power supply (passive tags), or how the tags uses a power supply (semi-active tags). Tags can also be classified by their read-write capabilities: read only, write once read many, and read-write tags.

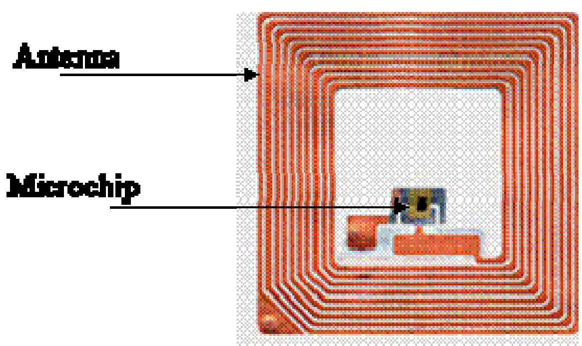

Figure 1-3

[21] http://www.barcode-solutions.com/images/RFID/RFID-Tag-1.jpg

[22] http://www.rfidsb.com/index.php?page=rfidsb&s_ID=16&s_page=4

Passive tags: These types of tags do not use any external power supply to enable any internal functions, instead the tags use the energy emitted by the reader. The energy is used to find the information stored in the tag and to transmit it back to the reader. Passive tags always wait for the reader to start the communication, the reader or interrogator sends a signal and the passive tag, using the power emitted by the reader, responds back. The reading range for this type of tag is from 1 inch to 30 feet.

Active tags: These types of tags use an external power supply, not the energy emitted by the reader. The power supply is used to perform specialized tasks and to transmit information back to the reader. Active tags can start the communication and are actively sending information to the reader or can go to "sleep" in the absence of a reader. The reading distance of these tags can be up to 100 feet or more. The active tag components are antenna, chip, power supply, and electronics. The electronics can be made up, for example, of sensors that can measure temperature and humidity and transmit the information back to the reader or process the information itself.

Semi-active tags: These types of tags use an external power supply for the operation of the tag only. Similar to the active tags, semi-active tags use the power supply to perform specialized tasks but rely on the power emitted by the reader to transmit the information. The reading distance of these tags can be up to 100 feet or more. The semi-active tag components are antenna, chip, power supply, and electronics.

Reader: The reader is the most important device in the RFID architecture. The reader's function is to read or write the information stored in RFID tags and communicate with the rest of the RFID components through the controller

Sensor, Annunciator, and Actuator: These components can be part of the reader as well. Sensors can be used to trigger the use of the reader only when a particular situation occurs. Annunciators are used to provide feedback to the user in case of a bad reading. Finally, actuators add an external functionality or output to the reader in case of a bad reading or a good reading.

Software System: This system is responsible for obtaining and manipulating the data generated by the readers as well as the communication with the rest of the parties involved in an RFID system. Some of the functions performed by this system include control of the reader's behavior and filtering out duplicate readings. Another important component of the software system is the middleware. The middleware is responsible for sharing the data inside and outside the enterprise and efficiently managing the data produced by the readers.

Communication Infrastructure: This system in responsible for the communication of all RFID components using wired and wireless networks with the rest of the world.

1.4. Current Applications of RFID

RFID is replacing older AIDC technology, like bar codes and magnetic stripes and in other cases RFID is creating new applications. For example, real time inventory control, container and pallet tracking, ID badges and access control, fleet maintenance, equipment and personnel tracking, active shelves in retail stores, parking lot access and control, product tracking through manufacturing and assembly, security guard monitoring, blood and water analysis identification, etc. This section explores the following applications where RFID technology is being used today: strategic asset management, supply chain, and payment systems.

Strategic Asset Management:[23] Strategic assets are "assets that either directly generate revenue or are closely associated with revenue creation". Strategic assets include: production, facilities, people, fleets and individual vehicles, and IT systems. It is critical for organizations to manage these assets to maximize utilization to maintain and/or increase revenue. RFID solutions include tracing, tracking, early warning systems, routine maintenance notification, etc. Some asset examples are: animal, equipment, documents and personnel tracking, asset sharing, and theft prevention.

> Tag Used: In most cases active tags are used in this application because of the constant need to monitor the assets and the need to monitor assets that have greater distances between the reader and the tag. The cost associated with the RFID tags is minimal when compared to the cost of the asset itself, thus the return on investment on the higher priced tags can be justified.
>
> Standards: Because this application generally occurs within the boundaries of an enterprise or industry, standards do not need to be universal. This vertical characteristic allows enterprises to establish their own standard. And likewise industry associations create their own standards. For example, the Association of American Railroads (AAR) created the S-918 standard for automatic equipment identification using RFID and the Automotive Industry Action Group (AIAG) has its Tire and Wheel Label and Radio Frequency Identification Standard B-11.

Supply Chain: Supply chain management is the most promising application of RFID systems. The application of RFID technology promises savings in the billions of dollars because of the possibility of having 100% visibility of the product from raw

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[23] "Radio Frequency Identification (RFID) & Strategic Asset Management", Unisys, 2004.

material to the finished product in the hands of the end user. For example, a company's inventory control can be improved by having an accurate level and location of the products on the shelves. Savings will also come from the increase in service levels because there will be less stock outs, less time locating the products in the warehouse, and less human related activities devoted to maintaining the warehouse.[24] Some other advantages of the use of RFID in the supply chain include: streamlining business processes (e.g. more accurate invoices and a decrease in process and delivery errors), improving staff utilization, reduction of counterfeiting and shrinkage, facilitating 'pull' principles, and eliminating the potential for human error.[25]

Because the use of RFID in the Supply Chain significantly reduces the overall cost of operations, Wal-Mart, Target, and Albertsons announced mandates for their top 100 suppliers to start placing RFID tags in pallets and cases by 2005.[26] This mandate has enabled these companies to improve the data quality, item management, asset visibility, and maintenance of material handled. Similarly for the DoD, logistics represents one of the most fundamental activities. In order to improve its supply chain efficiency, the DoD has been actively investing in RFID technology since 1994 and issued a mandate in 2003 that required suppliers to use RFID tags in shipments to the military. [27]

> Tag Used: Passive tags are used in supply chain applications due to their low cost. [28] UHF is becoming the primary choice for supply chain applications due to its read range. UHF uses far field method called passive backscatter which allows read ranges of go up to 15 feet. [22]
>
> Standard: For supply chain applications which are open systems, standards are very important because they ensure the reduction of the technical challenges and increase the interoperability among the RFID equipment. Thus, for the RFID application supply chain mandates to be successful, global standards need to be followed. The DoD and Wal-Mart have specified that their suppliers use RFID tags based on EPCglobal standards.[29]

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24 Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., "Designing and managing the Supply Chain", McGraw-Hill/Irwin, 1999.

25 Garfinkel, S., Rosenberg , B., "RFID applications, Security, and Privacy", Addison-Wesley Professional, 2005.

26 http://www.rfidjournal.com/article/articleview/462/1/1/%20, http://www.rfidjournal.com/article/articleview/802/1/1/, http://www.rfidjournal.com/article/articleprint/819/-1/1/.

27 http://www.rfidjournal.com/article/articleprint/604/-1/1/

28 http://www.rfidjournal.com/article/articleview/1930/1/1/, http://www.symbol.com/category.php?filename=wp-34_supplier_compliance_w_rfid_mandate.xml

29 http://www.acq.osd.mil/log/logistics_materiel_readiness/organizations/sci/rfid/rfid_policy.html

Payment System: RFID technology can also be used to make payments. Payments are automatically deducted from a bank or credit card account once an RFID device has been exposed to a reader. The reader sends the information to a payment system that matches the unique ID of the RFID and completes the transaction. RFID payment systems are simple, efficient, fast, and secure. The secure claim comes from the fact that there is no other person involved in the payment transaction, thus reducing the possibility of a felony. However, other security concerns exist including the possibility of another person having a reader nearby that can obtain the customer's information and use it to 'clone' the RFID tag.

A successful implementation of a payment system based on RFID is speedpass (Figure 1-4[30]) introduced in 1997 by Mobil (later to become Exxon Mobil Corporation). There are more than 10,400 locations equipped to read speedpass devices and more than eight million subscribers in the US, Canada, Singapore, and Japan.[31]

> Tag Used: Passive tags in a small container or credit card type. The frequency used for contactless smart cards is 13.56 MHz. This HF uses a near field technique called magnetic coupling to ensure that the tags only work in close proximity (i.e. within 10 cm) of the reader antenna, thus minimizing any privacy or security concerns.[32]
>
> Standards: In the contactless smart cards industry, as well as other industries, there is a need to control technical challenges and interoperability issues among different parties. Thus, the ISO 14443 A/B has been established as the industry standard. The early establishment of this standard can be attributed to the closed system nature of the industry. In a closed system, there are a small number of companies (American Express, MasterCard International, and Visa) as opposed to an open system where there are a large number of companies involved in the process. In an open system there is also little control over the RFID equipment they use (e.g. supply chain). Thus, standards can be agreed upon and implemented more easily among the different parties. Furthermore, the existing readers used for magnetic stripes can be adapted to become RFID readers.

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30 https://www.speedpass.com/

31 http://www2.exxonmobil.com/corporate/files/corporate/speedpass_fact_sheet.pdf

32 http://svn.gnumonks.org/trunk/presentation/2005/rfid-ccc_ds2005/rfid-datenschleuder.txt

Figure 1-4

As illustrated in the history of RFID and its applications, RFID is an old technology that has found new interest because of its potential impact on supply chain visibility and the creation of new applications. From its inception RFID has had multiple standards most of them specific to any given application. But in applications like supply chain there is a need for a universal standard to ensure compatibility among the different entities involved in the process. Previous RFID applications required expensive equipment so RFID was not considered for supply chain use. When the Auto-ID center developed an inexpensive system for RFID to be used in supply chain management the need of a universal standard became more important.

Section 2 Standards

2.1. What is a Standard?

For the purpose of this research we use the definition of standard given by the Institute of Electrical and Electronics Engineers (IEEE): "a standard is a published document that sets out specifications and procedures designed to ensure that a material, product, method, or service meets its purpose and consistently performs to its intended use."[33] This definition is also consistent with other dictionaries' definition of standards such as: "a standard refers to a basis for comparison; a reference point against which other things can be evaluated." [34]

2.2. Why are Standards Important?

Standards are important because they establish the quality, safety, compatibility, reliability, productivity, and efficiency levels of the products. By the use of standards, trade among different industries and countries is possible. By determining uniform solutions to technical challenges and ensuring interoperability of the products standards create a unified communication method for manufacturers and end-users that ultimately reduces the cost of products.

The use of standards is voluntary unless safety concerns and/or regulations exist. [35] Hence, standards can be imposed through regulation. In some instances regulations can determine the future of a technology. For example, in 1953 the Federal Communications Commission (FCC) approved the television broadcast standard created by Radio Corporation of America (RCA).[36] This standard forced the rest of the television industry to use RCA's design.[37] In addition, technological standards can also be established without a formal promulgation of the standard (i.e. *de facto* standards). This is the case of the Japan Victor Company (JVC) establishment of the VHS video cassette recording device as the industry standard. JVC followed a "strategic maneuvering" business model which consists of forming alliances across the industry.[38] While the business model of the losing competitor, Sony Beta VCR, consisted of avoiding any alliances. [38] This "strategic maneuvering" led to the establishment of the

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33 http://standards.ieee.org/stdsdev/index.html

34http://wordnet.princeton.edu/perl/webwn?s=standard

35 http://www.asme.org/Codes/About/FAQs/Codes_Standards.cfm

36 http://en.wikipedia.org/wiki/RCA

37 Utterback, J., "Mastering the Dynamics of Innovation", Harvard Business School Press, 1996.

38 Cusumano, M., Mylonadis, Y., Rosenbloom R. S., "Strategic Maneuvering and Mass-Market Dynamics: Triumph of VHS over Beta", Harvard Business School, Cambridge, Mass., 1991.

JVC's VHS as the standard technology for video cassette recording without any involvement of standard or regulatory organizations.

Most technologies go through the following development phases. These phases are:[39]

1. Inventors file patents.

2. Competitors enter the market developing products.

3. There are a number of non-compatible products available in the market which in turn has a negative effect on the adoption of the product.

4. Standards are considered in order to increase adoption.

5. Government and big corporations mandate the technology and its standards.

6. A universal standard emerges.

7. All users can now acquire standardized products from many suppliers.

8. A new technology appears.

As illustrated above, in order for a technology to succeed a universal standard needs to emerge. In the case of supply chain application, RFID currently is between stages five and six. There have been number of standards ratified by different standard organizations but a universal standard has not emerged. Therefore, the ultimate success of RFID is still to be determined.

2.3. Why can Standards be a Problem?

Standards, in some cases, can result in the establishment of an inferior technology in the marketplace or have a negative impact on the adoption of a technology. Problems with standards can be due to: "lock in" effects, multiple standards, poorly developed standards, or the bad timing of standards. [40]

A "lock in" effect occurs when a number of users of a technology reaches a critical mass. The necessary number of users depends on the technology and the total number of potential users of the technology. In some instances standards are established by

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[39] "Global RFID Standards Market", research study by Frost and Sullivan, 2004.

[40] http://www.asme.org/Codes/About/FAQs/Codes_Standards.cfm

network effects which might lead to the establishment of an inferior technology from among all the technologies available in the marketplace; this is called "lock in" effect.[41]

This "lock in" effect increases the switching cost from the standard technology to an alternative technology and causes developers of related products to conform to the already established standard used by the majority of users. For example, the operating system developed by Microsoft in the 1980s, DOS, became the standard in the personal computer market due to the popularity of IBM personal computers and the low price strategy followed by Microsoft.[42] In this case, this DOS operating system was inferior to the operating system developed by Apple. However, the lock in effect took place establishing the inferior technology as the ultimate standard.

Another problem can occur when the standardization effort happens too early in the development cycle. This early standardization effort leads to multiple standards for the same technology. These multiple standards create confusion among users and inconsistencies among the different technologies. Thus, the users wonder which standard provides the most accurate result for their application leading to a decline in the adoption rate of the technology since some companies wait until a universal standard has been established. One example is the current migration occurring in the retail industry from Electronic Data Interchange (EDI) systems to eXtensible Markup Language- based (XML-based) alternatives. But because there are more than 100 XML variations available companies are waiting to investigate the business benefits of a particular XML before committing to a full XML implementation, thus not adopting the technology yet.[43] Something similar can occur between bar code and RFID systems.

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41 "Network effects or network externalities represent the benefit that a consumer derives from the use of a good when there are a large number of other consumers purchasing compatible items." Katz, M. and Shapiro, C. "Technology Adoption in the Presence of Network Externalities", The Journal of Political Economy, Volume 94, Issue 4, 1986.

42 Wonglimpiyarat, J., "Standard competition: Is collaborative strategy necessary in shaping the smart card market?", Technological Forecasting & Social Change 72, 2005, 1001–1010.

43 Borck, J., "EDI redux: Early adoption of substandard standards may leave costly legacy pains", Inforworld, 2005. http://www.itworld.com/AppDev/1494/IW010305opborck/

Section 3 RFID Standards

3.1. What are the types of standards for RFID?

There are four main types of standards relevant to RFID: 1) technology, 2) data, 3) conformance, and 4) application. [44]

Technology Standards: These standards deal with the technological features of RFID technology. In particular, these standards cover the air interface communications format and data exchange protocols that have to be agreed upon to ensure compatibility or interoperability in systems produced by different manufacturers or systems providers. The technology standards mainly address tag-reader communication. The tag-reader communication standards include: physical characteristics of the radio communication, structure of commands and responses, and an anti-collision algorithm. The latter is a method of detecting and communicating with only one tag when more than one tag is present.

The typical RFID frequencies used to develop technical standards are: LF (Low Frequency), HF I (High Frequency), HF II (High Frequency), UHF (Ultra High Frequency), and Microwave.

Type	Range	Regulation	Range	Data Speed	Use
LF	129 KHz	Basically unregulated	< 1m	Low	Animal identification and factory data collection
HF I	13.56 MHz	Industrial, Scientific and Medical (ISM) band, differing power levels and duty cycle	< 1m	Low to moderate	Popular frequency for I.C. Cards (Smart Cards), Libraries
HF II	433 MHz	Non-specific Short Range Devices (SRD), Location Systems	1 – 100 m	Moderate	Container Security and Tracking. Asset tracking for U.S. DoD (Pallets) – Active

[44] http://www.rfidsb.com/index.php?page=rfidsb&s_ID=16&s_page=2

Type	Range	Regulation	Range	Data Speed	Use
UHF	860-960 MHz	ISM band, increasing use in other regions, differing power levels and duty cycle	2 – 5 m	Moderate to high	MH 10.8.4 (RTI), AIAG B-11 (tires), EPC (18000-6C), DoD Passive
Microwave	2.45 GHz	ISM band, differing power levels and duty cycle	1 – 2 m	High	IEEE 802.11 b/g, Bluetooth, cordless telephones

Table 3-1

Data Standards: These standards describe how information is to be structured and stored on an RFID tag. These standards ensure compatibility and interoperability of the information transmitted among different parties.

Conformance Standards: These standards provide agreements that specify how a device is to be evaluated to ensure that it complies with a standard. The standards include a set of instructions that outline how a system needs to perform with respect to a particular performance or operational criteria.

Application Standards: These standards establish the agreements on how products are used in a particular application. In most closed system, application standards are not difficult to implement because all the parties are controlled by a single entity. Thus, this single entity can ensure in closed systems that the different parties involved comply with the standard. Most open systems require application standards because the system is used by different parties at different stages of the process with no central or single control. The application standards ensure that the systems used are compatible and useful by anyone involved in the application described by the standards. Application standards may incorporate technical, data, and conformance standards.

3.2. Organizations Developing Standards for RFID

A standard organization is any entity whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise maintaining standards that address the interests of a wide base of users outside the standards development organization. A standard organization can be classified by its role, position, and the extent of its influence on the local, national, regional, and global standardization arena. Figure 3-1[45] shows the principal standard organizations, categorized by the extent of their influence involved in setting RFID standards:

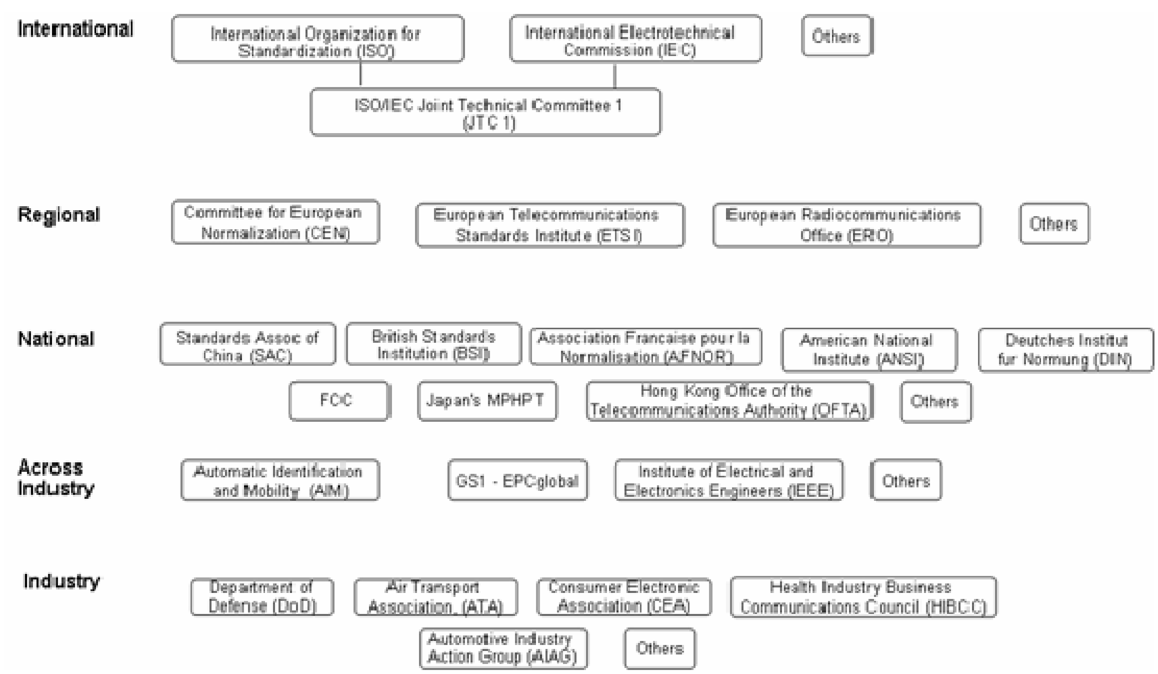

Figure 3-1

ISO and GS1-EPCglobal are the main organizations developing standards for supply chain management applications (see appendix 2 for a full explanation on ISO's involvement in RFID technology standards). The use of RFID in supply chain promises 100% visibility by tracking products from the warehouse, transportation, distribution centers, and retailers. This visibility has the possibility of preventing out of stock, counterfeiting, and shrinkage of inventory. This thesis will focus primarily on GS1-EPCglobal efforts towards developing a universal standard for supply chain applications.

A. GS1

GS1's main activity is the development of the GS1 System. GS1 System is a series of standards and solutions designed to improve the efficiency and visibility of supply and

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[45] Menges, K., "RFID Standards and Trends" and Harmon, C. K., "Cooperation Between ISO, AIM/REG, and IEEE", 2006

demand chains globally and across sectors. The GS1 system of standards is the most widely used supply chain standards system in the world. GS1 allows companies all around the world to globally and uniquely identify physical things.[46]

The GS1 system is composed of four key product areas: 1) BarCodes, 2) eCom, 3) GDSN, and 4) EPCglobal.

I. BarCodes

The bar code was invented by Woodland and Silver in 1952 (US patent 2,612,994 (Figure 3-2[47]). The bar code was commercialized in 1966 when the National Association of Food Chains (NAFC) reached out to equipment manufacturers for check out systems that would speed the process. In 1967 one of the first scanning systems was installed at a Kroger store in Cincinnati. While the bar code implementation helped speed up the checkout process there was a problem with the code Kroger's use, it was not a standard code recognized by all its suppliers. Because multiple codes needed multiple scanners, the industry recognized that they would have to agree on a standard coding scheme open to all equipment manufacturers to use and to be adopted by all food producers and suppliers. But it was not until 1973 when the U.S. Supermarket Ad Hoc Committee, formed in 1970, recommended the adoption of the Universal Product Code (UPC) symbol as we know it today .[48] The UPC made its first commercial appearance on a package of Wrigley's gum sold in Marsh's Supermarket in Troy, Ohio in June 1974.[49]

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[46] http://www.gs1.org/about/visionmission.html

[47] http://www.uspto.gov/

[48] http://www.adams1.com/pub/russadam/history.html

[49] Varchaver, N., "Scanning the Globe", Fortune Magazine, 2004.

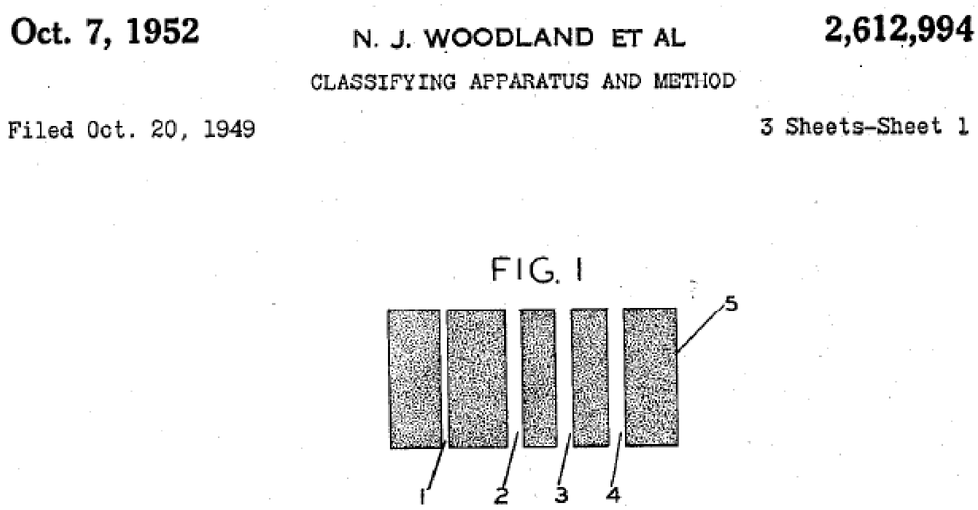

Figure 3-2

Since the development of the UPC symbol there have been a number of different bar codes with different functionalities. Table 3-2 describes and shows the different bar codes offered by GS1.

Type	Visual Description	Attributes[50]
EAN/UPC	5 012345 678900	• Are specified for retail Point-of-Sale (POS) because they are designed for the high volume scanning environment • Used at POS and in logistics must be printed larger than the "target" size to accommodate logistics scanning • Limited to carrying GS1 Keys and special identifiers for restricted applications like variable measure trade items and internal numbering

[50] GS1 Keys are non-significant, secure, and global unique numbers that support the identification of items, services, locations, logistic units, and returnable containers. The GS1 Keys are: identify trade items (GTIN), locations/trading parties (GLN), logistic units; Serial Shipping Container Code (SSCC), individual assets (GIAI), returnable assets (GRAI), service relationships (GSRN), and document types (GDTI).

Type	Visual Description	Attributes[50]
Reduce Space Symbology (RSS)	(01)00012345678905	• A family of symbols that can be scanned at retail point-of-sale (POS), are smaller than EAN/UPC and can carry additional information such as serial numbers, lot numbers of expiration dates • A subset of RSS bar codes designed for use at POS are being considered by a GS1 Board Task Force for future adoption because RSS can carry all GS1 Keys and attributes and do so in a smaller space than EAN/UPC • RSS bar codes are already approved for global use on healthcare items that do not cross POS
GS1-128	(01) 0 0012345 67890 5	• GS1-128 (UCC/EAN-128) bar codes can carry all GS1 Keys and attributes but cannot be used to identify items crossing POS
ITF-14 Interleaved 2 of 5 and 14 digits	00012345678905	• ITF-14 bar codes can only carry GTINs, can be printed directly on corrugated cartons, but cannot be used to identify items crossing POS
Data Matrix		• Data Matrix is the only "2D Matrix" symbol specified for use by GS1 and is becoming increasingly the symbol of choice for many in healthcare • Because Data Matrix requires camera based scanners it is currently specified for healthcare items not crossing POS and direct part marking

Type	Visual Description	Attributes[50]
Composite Component		• Composite Component is the only "2D linear" symbol specified by GS1 • It is called a component because it is only used with a linear bar code like GS1-128 or RSS

Table 3-2

The bar code has generated considerable saving in different industries. For example, UPS (United Parcel Services) projects that bar code technology will save it $600 million a year when the system is fully installed in 2007.[49] The savings come from the monitoring of packages and the planning of routes according to the package's final destination. For other companies the bar code has enabled them to create an efficient supply chain and inventory management. In the case of Wal-Mart this efficiency has allowed it to keep costs and prices down. Other retailers like Stop & Shop and The Home Depot have used the bar code technology to create self-checkout lines which allow customers to scan and pay items for themselves.

II. eCom

This GS1 product provides global standards for electronic business messaging that allows rapid, efficient, and accurate automatic electronic transmission of agreed business data between trading partners. This electronic transmission occurs irrespective of their internal hardware or software types. eCom is based on two components: GS1 EANCOM (European Article Number Communication) and GS1 XML (eXtensible Markup Language).[51]

Figure 3-3[52] represents the flow and parties involved in the exchange of information that the EANCOM standard supports while making trade transactions.[53]

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51 XML (Extensible Markup Language) allows information and services to be encoded with meaningful structure and semantics that computers and humans can understand. XML is great for information exchange, and can easily be extended to include user-specified and industry-specified tags. Source: www.orafaq.com/glossary/faqglosx.htm

52 http://www.gs1.org/productssolutions/ecom/eancom/technical/

53 Adapted from http://www.gs1.org/productssolutions/ecom/

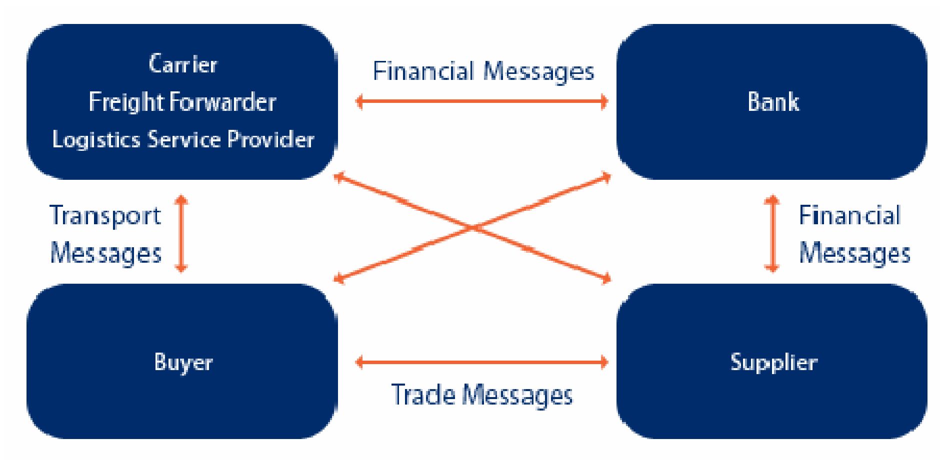

Figure 3-3

III. GDSN [54]

The Global Data Synchronization Network (GDSN) is an internet-based interconnected network of interoperable data pools and a global registry (the GS1 Global Registry) that enables companies around the globe to exchange standardized and synchronized supply chain data with their trading partners. GDSN assures that data exchanged between trading partners is accurate and compliant with universally supported standards. GDSN consists of trading partners (suppliers and retailers), data pools (services that hold and process trading partner data), and the GS1 Global Registry (Figure 3-4[55]). The GS1 Global Registry is a worldwide directory that helps locate data sources and manage ongoing synchronization relationships between trading partners.

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[54] "GDSN what you need to know", www.GS1.com

[55] http://www.gs1.org/productssolutions/gdsn/overview/index.html

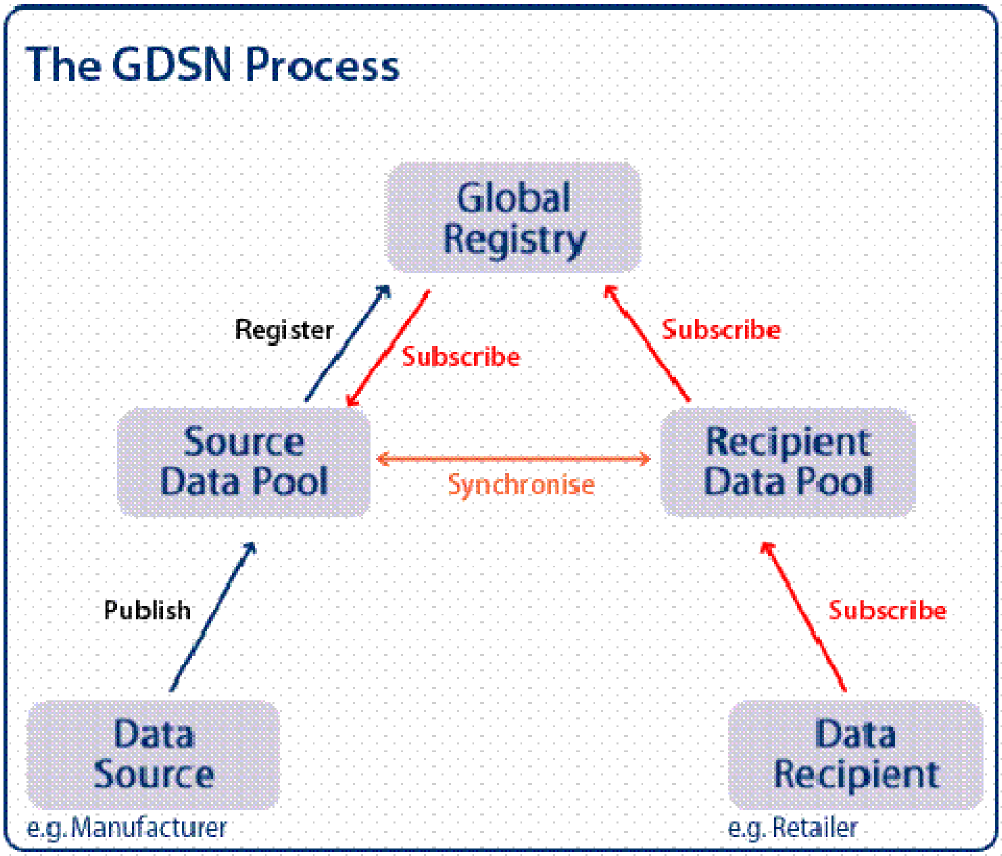

Figure 3-4

IV. EPCglobal[56]

As previously mentioned, EPCglobal has its origins at the Massachusetts Institute of Technology (MIT). The Auto-ID Center at MIT had the vision of "a world in which all electronic devices are networked and every object, whether it is physical or electronic, is electronically tagged with information pertinent to that object." In 2003, the Auto-ID Center became EPCglobal. EPCglobal is a global standards organization committed to increasing supply chain effectiveness for the benefit of organizations and consumers across all industry sectors. The standards created by EPCglobal have the following objectives: 1) facilitate the exchange of information and physical objects between trading partners, 2) foster the existence of a competitive marketplace for system components, and 3) encourage innovation. EPCglobal network consists of the following elements: EPC code, EPC tag and reader, EPC middleware, EPC discovery

[56] http://www.epcglobal.org

services (e.g. object name services (ONS)), and EPC information services (EPCIS). See Figure 3-5.[57]

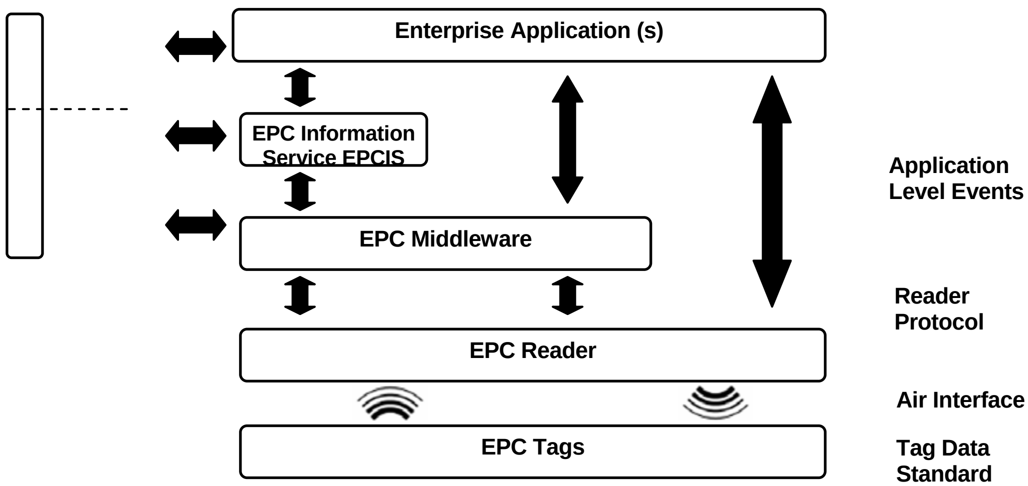

Figure 3-5

EPC Code: David Brock, a principal research scientist at MIT, suggested the use of a unique number to identify an object and using the network to download the information of the object. From this idea, the EPC code became the identification scheme for universally identifying physical objects via RFID and other means.[58] The EPC code has four key attributes that enable the unique identification of any item: header, EPC manager number, object class, and serial number of the object. See Figure 3-6 for a 96-bit format.[59]

[57] Thiesse, F. and Michahelles, F., "An overview of EPC technology", Sensor Review, 26/2, 2006, 101–105.

[58] "EPCglobal Tag Data Standard TDS Version 1.3", www.GS1.com

[59] A 96-bit format is the most common in supply chain application and would be fully represented by the following number: 48 3 5 0614141 000734 203886. Image source: Thiesse, F. and Michahelles, F., "An overview of EPC technology", Sensor Review, 26/2 (2006) 101–105.

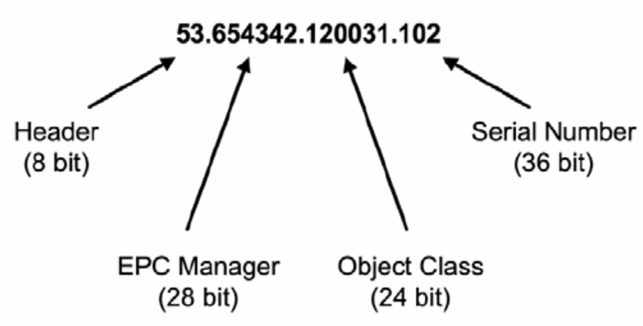

Figure 3-6

The EPC code is compatible with other GS1 keys like GTIN, GLN, and SSCC as well as other legacy systems including the Unique Identification (UID) code from the DoD. There are mappings guidelines that enable the transition from one numbering scheme to another. For example, to convert from an EPC code to GTIN, see Figure 3-7.[60]

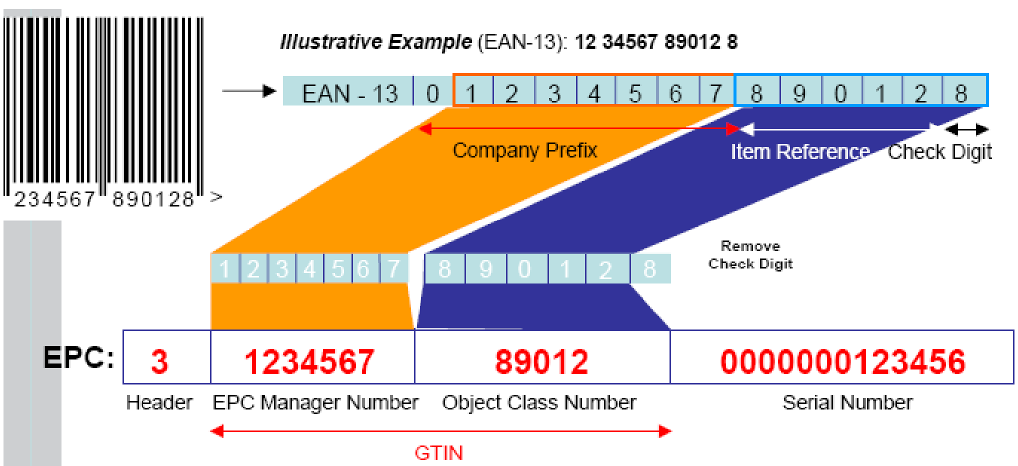

Figure 3-7

The EPC codes can be from 64 bit to 256 bit. The 96 bit format is the most common format in supply chain application due to it ability to generate a very large quantity of unique numbers. For example, the 96 bit code can provide unique identifiers for 268

[60] Barthel, H., "Standards for collaborative Commerce", presentation, 2004. https://www.centr.org/docs/2005/02/centr-ga25-barthel-epcglobal.pdf

million companies. Each company can have 16 million object classes and 68 billion serial numbers in each class.[61]

EPC Tags and Readers: The different classification of tags allows users to choose different tags with different functionality at different costs. Also, by creating standard readers and tags, end users do not have to buy all the equipment from the same supplier which promotes competition among the different vendors to create better products at a lower cost. The following Table 3-3 shows the classification used by EPCglobal for its tags:[25]

EPC Device Class	**Tag Classification**	**Feature**	**Programming**
Class 0	"Read only" passive		Programmed by the manufacturer
Class 1	"Write once-read many" passive		Programmed by the customer; cannot be reprogrammed
Class 2	Rewritable passive	A passive tag with up to 65 KB of read-write memory	Reprogrammable
Class 3	Semi-passive	Similar to a Class 2 tag but with a built-in battery to support increased read range	
Class 4	Active	An active tag that transmits and runs its chip's circuitry with the use of a built-in battery.	
Class 5	Active	An active tag that can communicate with other Class 5 tags and/or other devices or tags.	

Table 3-3

61 http://www.rfidjournal.com/faq/23 and RFID Sourcebook.

The current "Class 1 Generation 2 UHF Air Interface Protocol Standard" or "Gen 2" is a technical standard that specifies the air-interface-protocol for a class 1 tag that uses a passive-backscatter, Interrogator-talks-first (ITF), radio-frequency identification (RFID) technology operating in the UHF frequency. This standard covers readers and RFID class 1 tags. The Gen 2 standard has several advantages over its predecessor (i.e. Gen1 standard) including: faster read rates, smaller chip size, higher reliability, and increased security. Furthermore, the Gen2 standard has incorporated the frequency and performance needed to be used world wide.[62] The latter has enabled the ISO's ratification of the EPCglobal Gen 2 RFID standard in July 2006 as an extension to Part 6 of ISO's 18000 standard. This ratification promises to further promote the adoption of the EPCglobal Gen 2 standard by allowing customers to specify products that conform to the standard.[63] In addition, the Gen2 standard was written by a committee as opposed to the Gen 1 Class 0 standard which was based on one company's technology, that of Symbol; and the Gen 1 Class 1 standard which was based on the Auto-ID Center technology.

EPC Middleware: This component is what connects readers to the enterprise information systems. The middleware ensures that the handling of data is efficient and useful. For example, without the middleware the information transmitted from the readers to the information systems would include double reads from the same or multiple readers, thus creating an enormous amount of information. The middleware is responsible for reader coordination, data handling, and process management.[64]

> Reader coordination: Configures and monitors the readers by issuing commands to the readers.
>
> Data Handling: Ensures data accuracy and prevents data redundancy. The middleware handles a large volume of data by providing a buffer for filtering and compression of data. In addition, the middleware controls the distribution of information to differentiate the various business applications used in the process.
>
> Process management: Monitors data based on business rules. For example, the middleware is capable of alerting the systems when an unauthorized product movement or unexpected inventory level occurs. In addition, the middleware is responsible for sending notifications about low or out-of-stock levels of inventory to inventory management system.

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[62] "The Gen 2 Standard: What Is It, and What Does It Mean?" by Lori Porter, Monarch Products and Services.

[63] https://www.arcweb.com/txtlstvw.aspx?LstID=bee27d5b-12a2-43df-8fb6-53334d561fdd

[64] Mousavidin, E., "RFID Technology: An Update", ISRC Technology Briefing Series, 2004.

Discovery Services: The discovery services are in charge of providing access to the EPC data generated by the tags and readers. The Object Name Services (ONS), part of the discovery services, is a global database lookup that works in a manner similar to the Domain Name System (DNS) used for the internet. The ONS looks up the information about a product and services and relates it to the EPC Code.[18] The ONS translates the EPC codes directly to an Internet Protocol (IP) addresses, see Figure 3-8.[65] The ONS enables the communication among the different computer systems and determines the location of the information referred to in each EPC code embedded in the RFID tag. In 2004, EPCglobal awarded Verisign a contract to run ONS in its servers.[66]

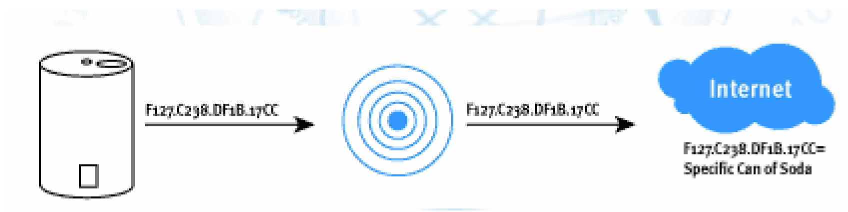

Figure 3-8

EPC Information Services (EPCIS): EPCIS is the information that trading partners share to gain more insight into what is happening to physical objects in locations not under their direct control. EPCIS information can be divided into two categories: static data which does not change over the life time of the product and transactional data which constantly changes over the life of the product. The information from the EPCIS is extracted in the form of Physical Markup Language (PML).[67]

a. EPCglobal Membership

In order to implement the EPCglobal standards companies must become subscribers. There are two types of subscribers: 1) end users and 2) solution providers. The annual cost of becoming a subscriber depends on the company geographic location, the company's revenue, and, in the case of end users only, on the number of EPC codes it plans to use in one year. For example, the subscription fee for an end user in North America with annual volume sales of between $500 million to $1 billion is $50,000. For

65 http://alpha.edtinger.at/docs/autoid/slides.html

66 http://www.forbes.com/manufacturing/2004/06/29/cx_ah_0629rfid.html

67 The PML is a modular toolset that provides the building blocks needed to construct complex descriptions of physical objects, as well as commercial and industrial processes. PML is a variation of the more commonly known Extensible Markup Language (XML) and is designed specifically for the EPC Network. Source: Auto ID Labs.

a solution provider with the same annual sales the subscription fee is $75,000.[68] The group currently has over 1,000 subscribers.[69]

A subscription to EPCglobal is the first step to gaining access to the EPCglobal Network. A subscription includes:

- Assignment and maintenance of EPC Manager Numbers in the Object Naming Service (ONS registry).

- Training and education on implementing and using the EPC and the EPCglobal Network.

- Participation in the ongoing development of business-driven use cases and standards for the EPCglobal Network.

- Access to EPCglobal Network components, software specifications, and the published reference implementations of middleware and Physical Markup Language (PML).

- Continued influence (through EPCglobal Action Groups) on the future direction of research by Auto-ID Labs.

- Access to best practices regarding consumer privacy and public policy.

- Access to certification and compliance testing.

- Links with other subscribers to create pilots and test cases.

b. EPCglobal Standards Development Process [70]

The EPCglobal standard development process (SDP) is a user driven process for the development of Technical Standards. As of March 8, 2006, the EPCglobal SDP consists of a total of nine steps divided into two main tracks: Submission and Standards. See Figure 3-9. [70]

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[68] EPCglobal, "Subscription Fee Schedule for US Headquartered Companies".

[69] http://www.epcglobalinc.org/about/media_centre/press_rel/EPCglobal_Inc_1000th_sub_press_release.pdf

[70] EPCglobal, "Standards Development Process", Version 1.2, March 8, 2006

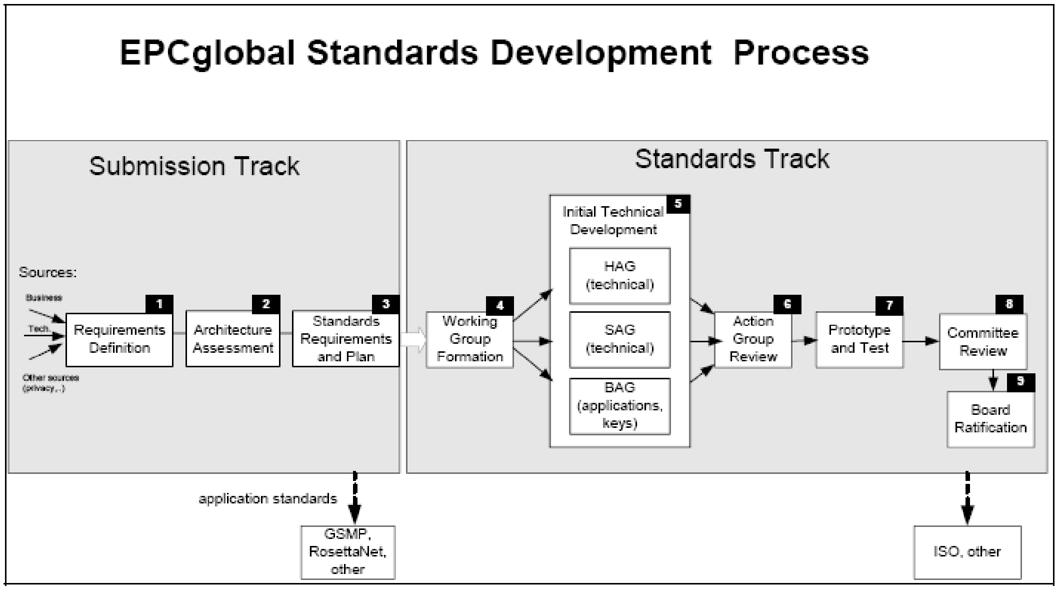

Figure 3-9

Submission track: The submission track is designed to ensure that all business requirements are captured and validated against the EPCglobal reference architecture and the requirements for standards are properly documented. The EPCglobal reference architecture is the set of principles, guidelines, and strategies governing the implementation of the EPCglobal Network and related RFID technologies.

Step 1 - Requirements definition: The purpose of this step is to gather and assess business and technical requests from multiple sources that include business, technical, and privacy/legal groups or from Auto-ID Labs to develop requirements.

Step 2 - Architecture Assessment: The purpose of this step is to assess a proposal and determine the impact on the supply chain architecture, EPCglobal reference architecture, and other standard development organizations. This track feeds into the standards track within the EPCglobal SDP as well as to the appropriate standard organizations (e.g., EAN.UCC GSMP or RosettaNet) if applicable.

Step 3 - Standards Requirements and Plan: The purpose of this step is to identify and define areas requiring standardization, present them as standards requirements, and specify where they would be incorporated. In addition, a technical plan for the specific solution would be developed.

Standards track: This track is designed to accommodate the creation of technical standards.

Step 4 - Working Group Formation: The purpose of this step is to form intellectual property (IP) neutral environment groups to work towards the creation of the standard.

Step 5 - Initial Standards Development: In this step, the SDP is confidential and open only to the members of the working group. The working group meets to turn the business requirements contained into a technical approach that can become a final specification.

Step 6 - Action Group Review: In this step, a draft document is posted for the review of the two action groups (i.e. Hardware Action Group (HAG) and Software Action Group (SAG)). After this review period the working group resolves, corrects, and reposts all the comments. Finally, the action group votes to decide whether the document advances to candidate specification status or not.

Step 7 - Validation Prototype and Test: In this step, a real prototype is built to demonstrate that the specification is feasible. Software and hardware prototypes must be produced and demonstrate they are capable of meeting the required specification.

Step 8 - Steering Committee Review: In this step, the Business Steering Committee (BSC) reviews the proposed specification along with the prototype results. At the same time the Technical Steering Committee (TSC) determines if the technical specification is complete and workable.

Step 9 - Board of Governors Ratification: This is the last step of the SDP. The purpose of this step is to seek ratification for the specification to become an EPCglobal standard. The process starts with the President of EPCglobal who determines whether due process was followed. Then the results and the recommended specifications are presented to the EPCglobal Board for ratification. If the specifications are ratified then they achieve the highest maturity status and become EPCglobal Standard Specifications.

c. Intellectual Property (IP) policy [71]

The EPCglobal IP policy states: "As a user-driven organization that works with retailers, manufacturers, and hardware, software, and integration solution providers to create and share intellectual property that will benefit the entire subscriber base. […]

[71] Adapted from EPCglobal Intellectual Property Policy, EPCglobal.org

The EPCglobal Intellectual Property (IP) Policy ensures that all companies subscribing to the organization have open, neutral access to EPCglobal Network technology and standards. The agreement guarantees that the technology remains non-proprietary for the benefit of industry as a whole." Under EPCglobal IP policy participants make the necessary intellectual property available for license. Thus, EPCglobal obtains a licensing commitment from the participants who developed each specification. This licensing commitment is offered either royalty free or reasonable and non-discriminatory (RAND).

By having a royalty-free licensing of "necessary" IP policy, EPCglobal hopes to avoid the creation of monopolies and to encourage the development, exploitation, and independent development of intellectual property based on EPCglobal Specifications. Necessary IP covers only those things which a participant owns and is fundamental to a specification. Only under extraordinary circumstances (i.e., when a working group is unable to find an alternative to the use of such intellectual property) an alternative to royalty free licenses can be used. In this case, the participant is required to identify the intellectual property, the reasons why the intellectual property is necessary to a specification, and to commit to a reasonable and non-discriminatory (RAND) licensing plan.

d. EPCglobal Privacy Guidelines[72]

EPCglobal has set a number of guidelines to address privacy concerns. These guidelines apply to goods with EPC tags that are under the control and use of consumers. The consumer guidelines are:

1. Notice: Consumers will be given clear notice of the presence of an EPC tag on the product they are purchasing. This notice will be given through the use of an EPC logo or identifier on the product or packaging. See Figure 3-10.[73]

Figure 3-10

[72] Adapted from "Guidelines on EPC for Consumer Products", EPCglobal.org

[73] Image Source: www.printronix.com and www.rf-it-solutions.com

2. Choice: Consumers will be informed of the choices that are available in order to discard or remove EPC tags from the products. Most products carrying EPC tags should have a disposable packaging or other efficient, cost effective, and reliable alternatives to disable EPC tags.

3. Education: Consumers will have the opportunity to easily obtain accurate information about EPC and its applications. Companies using EPC tags at the consumer level will cooperate in appropriate ways to familiarize consumers with the EPC logo and to help consumers understand the technology, its benefits, and any privacy concern they might have.

4. Record Use, Retention, and Security: The Electronic Product Code does not contain, collect, or store any personally identifiable information. As with conventional bar code technology, data which is associated with EPC will be collected, used, maintained, stored, and protected by the EPCglobal member companies in compliance with applicable laws. EPCglobal members are expected to take effective security measures to prevent any unauthorized access to information related to EPC use.

EPCglobal states that it is committed to follow these principles for dealing with RFID evolution and implementation to ensure the privacy of consumers. EPCglobal identifies privacy, in the EPCglobal Network, as an essential element for adoption of RFID technology.

e. What are the Current RFID Standards of EPCglobal?

Table 3-4 summarizes the current RFID technological, data, and conformance standards used in supply chain for EPCglobal.

Table 3-4

Standard's Body	Standard	For	Status	Scope
EPCglobal - EPCglobal, Inc.				
	EPC Tag Data Specifications (Interface)	TDS1.27	EPCglobal Ratified standard	Defines the overall structure of the Electronic Product Code, including the mechanism for federating different coding schemes, defines specific EPCglobal coding schemes for each EPCglobal coding scheme, and defines binary representations for use on RFID tags, text representations for use within information systems (in particular, at the ALE level and higher in the EPCglobal Architecture Framework), and rules for converting between one representation and another.
	# EPC Radio-Frequency Identity Protocols Class-1 Generation-2 UHF	UHFC1G2 V1.09	EPCglobal and ISO Ratified standard	Communicates a command to a tag from an RFID Reader, communicates a response from a tag to the RFID Reader that issued the command, provides means for a reader to singulate individual tags when more than one is within range of the RFID reader, and provides means for readers and tags to minimize interference with each other.
	RFID Reader (Protocol)	RP1.1	EPCglobal Working Draft	The Reader Protocol provides the means for software to control all aspects of RFID Reader operation, including all capabilities implied by features of the Tag Protocols. In particular, the EPCglobal Reader Protocol is intended to provide complete access to all capabilities of the UHF Class 1 Gen 2 Tag Protocol including modulation formats, data rates sessions, and passwords, as well as reading, writing, locking, and killing tags.

Standard's Body	Standard	For	Status	Scope
	Reader Management Interface (Interface)	RM1.0	EPCglobal Ratified standard	As the specification of this interface evolves to fully exploit features of the UHF Class 1 Gen 2 Tag Protocol, it is expected that it will gain additional responsibilities including providing means to manage readers to prevent reader-to-reader collisions and facilitate “scouring” to find tags. This includes management of power levels, carrier frequencies, “sessions” (as that term is defined in the UHF Class 1 Gen 2 Tag protocol), and protocol parameters.
	Application Level Events (ALE) Standard	ALE1.0	EPCglobal Ratified Standard	Specifies an interface through which clients may obtain filtered, consolidated Electronic Product Code™ (EPC) data from a variety of sources. Chiefly applies to middleware, other methods of filtering EPC data.
	EPCIS Capture Interface, Data Specification and Query Interface	EPCIS1.0	EPCglobal Working Draft	EPCIS encompasses both interfaces for data exchange and specifications of the data itself. The EPCIS Data Specifications provide a precise definition of all the types of EPCIS data, as well as the meaning of “event” as used above. Provides a path for communicating EPCIS events generated by EPCIS Capturing Applications to other roles that require them, including EPCIS Repositories, internal EPCIS Accessing Applications, and Partner EPCIS Accessing Applications. Provides means whereby an EPCIS Accessing Application can request EPCIS data from an EPCIS Repository or an EPCIS Capturing Application, and the means by which the result is returned.
	Object Naming Service (ONS) Standard	ONS1.0	EPCglobal Ratified Standard	Specifies how the Domain Name System is used to locate authoritative metadata and services associated with the SGTIN portion of a given Electronic Product Code™ (EPC). Target audience is developers who implement ONS resolution systems for applications.

Standard's Body	Standard	For	Status	Scope
	Tag Data Translation Schema (Core Service)	TDT1.0	EPCglobal Working Draft	Encodes in machine-readable form all of the rules that define how to translate between EPC encodings defined by the EPC Tag Data Specification
	Security (EPC IS Security Profile)	V1.0	EPCglobal Working Draft	

Section 4 RFID EPCglobal - A Universal Standard

Figure 4-1 shows a 2005 survey about the deployment challenges for a successful implementation of RFID.[74] The number one reason for having issues in the deployment of such systems is the lack of a universal standard.

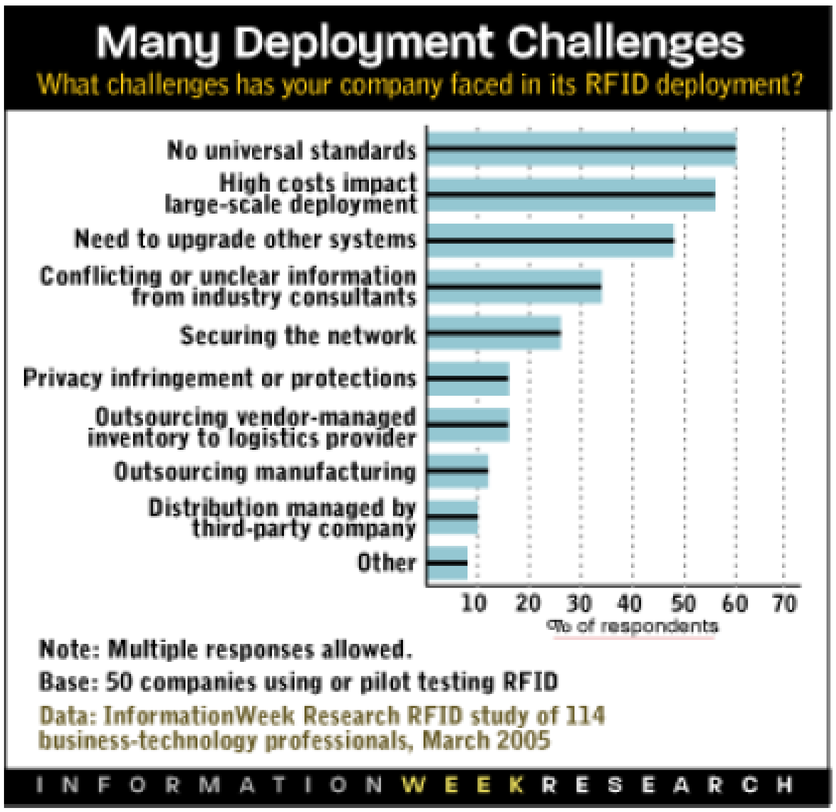

Figure 4-1

Factors that have a positive or negative impact for the adoption of a universal standard are: Complexity of application (Supply Chain Management), Mandates, Privacy policy, Member type, EPCglobal standard development process, Membership size, Intellectual property policy, Benefits, System cost, and China. These factors were selected from various technology and standard adoption studies. In this section, I will analyze these factors for standard adoption to evaluate EPCglobal's possibilities of becoming the universal standard for RFID supply chain applications.

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[74] Information Week Research, RFID study, March 2005.

4.1. Analysis

A. Complexity of application –Supply Chain Management

For purpose of this analysis, supply chain can be defined as: "a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandize is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements."[24]

Technology standardization in complex applications such as Hypertext Markup Language (HTML) for the Web and the bar code for supply chain have allowed the establishment of universal standards that have brought interoperability among the different players involved.[75] Complexity in a system can be defined as "having many interrelated, interconnected or interwoven (a variety of) elements and interfaces. Complexity can manifest itself as the interfaces between elements or modules are defined. Hence, a complex system requires a great deal of information to specify (its function)." [76]

Complexity can be measured by adding the number of players, type of players, connections, and type of connections of a system. The Equation 4-1 is shown below:

$$C = Nplayers + Ntypes\_of\_players + Nconnections + Ntypes\_of\_connections$$

Equation 4-1

Where Nplayers= Number of players, Ntypes_of_players = Number of types of players, Nconnections = Number of connections among players, and Ntypes_of_connections = Number of types of connections. [76]

A typical supply chain is shown in Figure 4-2.[77]

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75 http://www-03.ibm.com/autonomic/industry_wsdm.html

76 Crawley, E., "System Architecture Class", Fall 2006, ESD.34.

77 http://www.theprogressgroup.com

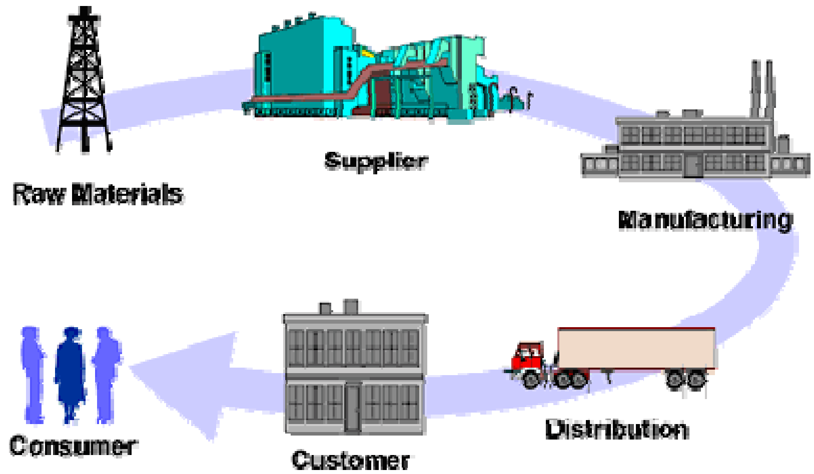

Figure 4-2

Each player (i.e., raw material, supplier, manufacturer, distribution, customer, and consumer) in the chain is responsible for the interchange of either product or information with one or more players. In a supply chain the number of players, types of players, and connections among players, are high. For example, Table 4-1 compares the complexity between a closed system (i.e., toll system) and an open system (i.e., supply chain). [78] The complexity of the closed system is low when compared to supply chain.

Variable	Toll System	Supply Chain
Number of players	Low	High
Number of types of players	Low	High
Number of connections[79]	High	High
Number of types of connections[80]	Low	Low
Complexity	Low	High

Table 4-1

Therefore, by the measure proposed above and by general knowledge we can state that a supply chain is inherently complex.[81] EPCglobal's universal standard goal is to

[78] Author's assessment on the level of the different variables involved in toll systems and supply chain applications.

[79] Number of connections = a tag used in the system is one connection.

[80] Number of types of connections = tag to reader is one type of connection.

manage this complexity to better forecast, deliver, and order the correct number and type of products at the right time. EPCglobal is the only organization that has developed a complete suite of solutions for the implementation of RFID systems to be used in supply chain applications. EPCglobal provides a set of standards that ensures the interoperability of the hardware components (i.e., the tags and readers), compatibility of information (i.e., EPC code), and the information flow (i.e., ONS) among the different players. Thus, the complexity in supply chain applications has a positive impact for the adoption of EPCglobal as the universal standard.

On the other hand, if this complexity is not well managed by EPCglobal the outcome could be similar to the computer systems. In complex computer systems, compatibility is very difficult to obtain because of the number of layers in the hierarchical structure. Each layer must have its own architecture and these architectures must be integrated into a larger network. Furthermore, computer systems require rules and protocols to introduce, process, store, move, and retrieve information at every layer. Thus, EPCglobal needs to control the complexity of the system by ensuring compatibility among all of the layers involved in the supply chain process.

B. Mandates

A sponsor, as defined by Katz and Shapiro (1986), is an entity that has property rights to the technology and hence is willing to make investments to promote it. In the case of EPCglobal, its members can be considered "sponsors" of its standards because its members are willing to investment and mandate the use EPCglobal standards. Some EPCglobal members, such as Wal-Mart, Target, and other retailers along with the U.S. DoD, have established mandates for the utilization of EPCglobal standards in their RFID system deployment. These mandates are a main driver for adoption because they have strategic implications for the use of a universal standard.[82] These strategic implications include: larger volume and lower cost of RFID systems, innovative applications to prevent inventory shrinkage, 100% product visibility, new and merchandising strategies.[83] Furthermore, these mandates force suppliers to comply with and become members of EPCglobal.

In some cases though, mandates can have a negative impact on adoption of a standard if they are not properly handled. An example of mishandling is when a sponsor

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81 Wilding, R., "The Supply Chain Complexity Triangle: Uncertainty Generation in the Supply Chain" International Journal of Physical Distribution and Logistics Management, Vol. 28, N0. 8 pp. 599-616

82 Katz M., and Shapiro, C., "Technology adoption in the presence of network externalities", Journal of Political Economics, 1986, 94, 822-841.

83http://www.directionsmag.com/article.php?%20article_id=629&trv=1&PHPSESSID=%20a942fc54a33502601eb2cbbec3fced74

introduces a mandate to a set of users and does not let them communicate with each other.[84] In the case of Wal-Mart, its mandate to its suppliers does not allow them to share information about their RFID deployment in order to gain some strategic advantage over other retailers. EPCglobal tries to minimize this competition by creating a sharing environment for its members where they develop and publish their own RFID case studies. These case studies outline the benefits and the deployment strategies followed for a successful implementation of RFID systems.

Another negative factor that affects the adoption of EPCglobal standards that comes from the issuing of mandates is the fact that initially, some EPC data derived from one RFID systems was only used within a specific retailer's supply chain. Wal-Mart created a "closed system" supply chain by not letting its suppliers share any information from its RFID systems with other retailers (e.g. Wal-Mart products' data was in a different format than the data used for Target products). But in 2005, Wal-Mart and Target announced that they would share the EPC data with some of their suppliers, thus creating a favorable environment for the adoption of EPCglobal as the universal standard for an open system supply chain application. [85]

C. Privacy Policy

The threat to privacy through the use of information technology is due to the ability to save and link information about individuals.[86] Consumers today do not want their private information to be known, manipulated, and/or controlled by another individual or group. Many consumers believe that RFID will provide their private information to companies without their consent. These privacy concerns (i.e. the person who buys an individual product with an RFID tag) are having a negative impact on the adoption of EPCglobal. Even if the technology promises great benefits to the consumer and retailers (e.g., no out-of-stock items, less employee theft, and lower cost) these privacy concerns can "inhibit network effects in the diffusion process" by discouraging retailers from using RFID technology because consumers are protesting their use.[87]

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84 Grover, V., and Segars, A. "Introduction to the Special Issue: Electronic Commerce and Market Transformation." International Journal of Electronic Commerce, 3, 4, 1999, 3. and Riggins, F.J., and Mukhopadhyay, T., "Interdependent benefits from Interorganizational systems: Opportunities for.", Journal of Management Information Systems, 1994. 11(2): p. 37.

85 http://www1.rfidjournal.com/article/view/1928/

86 Culnan, M., Bies, R., "Consumer Privacy: Balancing Economic and Justice Considerations", 2003, Journal of Social Issues 59 (2) 323–342.

87 Miller, A. and Tucker, C., "Privacy, Networks Effects and Electronic Medical Record Technology Adoption", 2006.

Privacy concerns are not particular to RFID applications. They are also holding back the adoption of other technology applications. For example, online shopping is experiencing privacy issues where sixty-one percent of the U.S. online consumers are hesitant to divulge their credit card information online and 50% voice concern about creating a personalized profile on a portal site.[88]

Although currently most consumers are not familiar with RFID, tags in individual products are the major privacy issue for consumers.[89] Currently case and pallet tagging do not generate any privacy concern to the consumer. However, item tagging does generate privacy concerns. Privacy concerns in the case of item tagging include: profiling, surveillance, and how personal information might be used.[25] For example, in 2003 Benetton, a global up-market clothing brand, planned to use RFID tags in individual items of clothing. The implanted devices would enable Benetton to improve its supply chain management by uploading inventory information more quickly and easily to its tracking system. Nevertheless, concerns about the possibility of tracking individuals and matching their credit card information once an RFID tagged product was purchased were raised. This concern and consumer protest led to Benetton not using RFID tags for its clothing.[90]

Another example of consumer protests over privacy issues regarding RFID tags is the case of Gillette razors. Gillette has been alleged to have implanted "spy chips" within their RFID tagged products. Consumers have formed a website calling for the boycott of Gillette products until RFID tags are removed. The site http://www.boycottgillette.com/ has the following statement: "RFID "spy chips" have been hidden in the packaging of Gillette razor products and in other products you might buy at a local Wal-Mart, Target, or Tesco - and they are already being used to spy on people." See Figure 4-3.[91] Although Gillette denies such allegations the fear of privacy invasion remains in the minds of consumers. Unfortunately in the minds of some consumers RFIDs have become associated with spy tactics and intrusive invasions of privacy.

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88 Anderson, E., "Consumers Need Education About Privacy And Security", Forrester Research, 2004.

89 A survey by Capgemini and the National Retail Federation found that 770 of 1000 consumers were not familiar with RFID and from those consumers that were aware of RFID, 42% had a favorable perception of the technology, and 31% had no opinion.

90 http://www.epic.org/privacy/rfid/

91 http://www.boycottgillette.com/

Figure 4-3

A number of privacy concerns emerge from the fact that RFID tags can be read with a wireless device. Consumers fear that with the product in their possession they will be tracked in their homes and place of business. But currently passive RFID tags (which are the tags that are used in the majority of supply chain applications) can only be read within short distances and with specific devices. However, if technology advancements allow larger read ranges for RFID passive tags then policies and laws have to be implemented to reduce the privacy concerns.

EPCglobal ensures the privacy of consumers with its privacy policy and recognizes that handling privacy concerns is an essential element for the adoption of RFID technology and its standards. Table 4-2 presents some concerns with the EPCglobal privacy policy.

Table 4-2

Guideline	Description	Critique
Notice	Consumers will be given clear notice of the presence of an EPC tag on the product they are purchasing. This notice will be given through the use of an EPC logo or identifier on the product or packaging.	The EPCglobal notice assumes that all products will have enough room to display the EPCglobal logo or that the logo will make sense to all consumers.
Choice	Consumers will be informed of the choices that are available in order to discard or remove EPC tags from the products. Most products carrying EPC tags should have a disposable packaging or other efficient, cost effective, and reliable alternatives to disable EPC tags.	Retailers might have return policies in place to accept only items with RFID tags functioning properly. These policies might discourage consumers to "kill" the RFID tag and leave it alive in the products.
Education	Consumers will have the opportunity to easily obtain accurate information about EPC and its applications. Companies using EPC tags at the consumer level will cooperate in appropriate ways to familiarize consumers with the EPC logo and to help consumers understand the technology, its benefits, and any privacy concern they might have.	The question in this case is how the education is going to take place and what will organizations with concerns about RFID (e.g. CASPIAN Consumer Advocacy) do to inform consumers about the privacy concerns of RFID?
Record Use, Retention, and Security	The Electronic Product Code does not contain, collect, or store any personally identifiable information. As with conventional bar code technology, data which is associated with EPC will be collected, used, maintained, stored, and protected by the EPCglobal member companies in compliance with applicable laws. EPCglobal members are expected to take effective security measures to prevent any unauthorized access to information related to EPC use.	EPCglobal does not talk about the possibility of its members misusing the information generated by RFID tags. For example, in the event that the information is sold to a third party.

At this point in time, the fact that EPCglobal is already addressing consumer privacy concerns has a positive effect for the adoption of RFID technology. However, it is likely that EPCglobal will have to further enhance its privacy policy as the advancement of the technology enables item level tagging.

D. Member Type

The members developing the standards determine the complexity of the features. The complexity of the standards then determine whether the standard will be adopted and if so on a regional or global level. If the standard's features have a high degree of complexity, the effort required to implement the standards increases, thus creating a negative impact on the adoption of the standards.[107] Also, if the standards are mainly developed by members of a specific region, then non-members out of this region are alienated. And this alienation decreases the likelihood of these non-members eventually adopting the standard. Furthermore, non-members may instead in the meantime create their own standards to satisfy their needs and thus never have a need to adopt a universal standard.

EPCglobal is "a subscriber-driven organization comprised of industry leaders and organizations focused on creating global standards for the EPCglobal Network." EPCglobal subscribers are 59% end users and 41% solution providers from 36 different countries. See Figure 4-4

Figure 4-4

As seen in the figure above, EPCglobal is a user/solution provider driven organization. So, by having more than half of its members being users, EPC global is trying to ensure that the difficulty in the user implementation, which comes from the development of complex standards, is minimized.[108] So, if an organization involves users in the standard development process, then an easy implementation of the standards can encourage users to take advantage of all the benefits driven by the use of standards. In turn, this increases the adoption of the standard when members perceived that the usefulness of the technology has increased. On the other hand, having an organization heavily composed of users can also be counterproductive. This is due to the fact that users might not be in a position to provide meaningful technical requirements for the standard development process because of a lack of the necessary technical experience.[92] Therefore, there can be an increase or decrease of the adoption rate by having a standard organization with a large end user group.

Another factor within the membership type that can affect the adoption rate of EPCglobal standards is the number of countries represented in its membership. Currently there are 36 countries represented in EPCglobal. Figure 4-5 presents a breakdown of the countries represented by region.

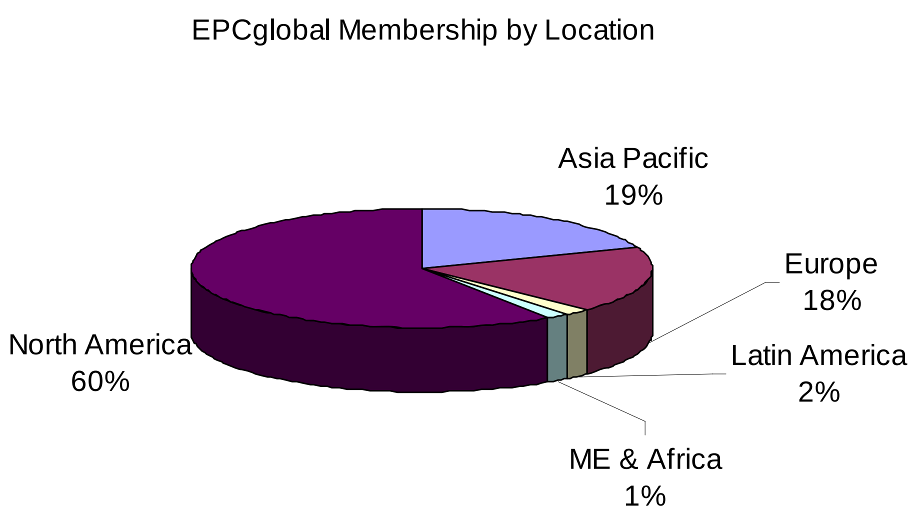

Figure 4-5

As seen in the figure above, EPCglobal membership is heavily concentrated in North America. This can have a negative effect in the adoption of EPCglobal as the universal

[92] Jakobs, K., Procter, R., Williams, R., "User Participation in Standard Setting - The Panacea?", StandardView, Vol. 6, No. 2, June 1998.

standard. For example, China, which can be considered the manufacturing capital of the world, is not represented in EPCglobal's membership.[93] Furthermore, China is hesitant to adopt EPCglobal standards due to the way information is handled through the ONS system, intellectual property of the technology (e.g., Intermec, an EPCglobal member, holds 13 RFID patents that greatly enhance the functionality of Gen2 tags), and the EPC code as the unique identifier which is in hands of other countries.[94] If China does not adopt EPCglobal and moves towards only international standards then China might encourage other countries to do the same thing and not adopt EPCglobal standards.[95] Thus, multiple standards across multiple regions can emerge that would have a negative impact for the adoption of EPCglobal as the universal standard.

E. EPCglobal Standard Development Process

The EPC global standard development process is done only by its members and there is no collaboration among other standard organizations until a standard has been ratified. Figure 4-6 illustrates that once an EPCglobal standard has been ratified internally then it goes to ISO and other standard organizations for its ratification. The EPCglobal standard development process does not include outside members, it develops the standards and expects the rest of the organizations to adjust. This closed development process alienates non members. And with only 36 countries represented in EPCglobal membership it does not reflect the global requirements of a universal standard. Therefore, EPCglobal's process has a negative effect for EPCglobal to become a universal standard.

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[93] Clampitt, H., "RFID and China", 2005, RFID Journal, 1758/1/128

[94] For example, the ONS is managed by Verisign, a U.S. firm.

[95] http://www.aimglobal.org/members/news/anmviewer.asp?a=407&print=yes

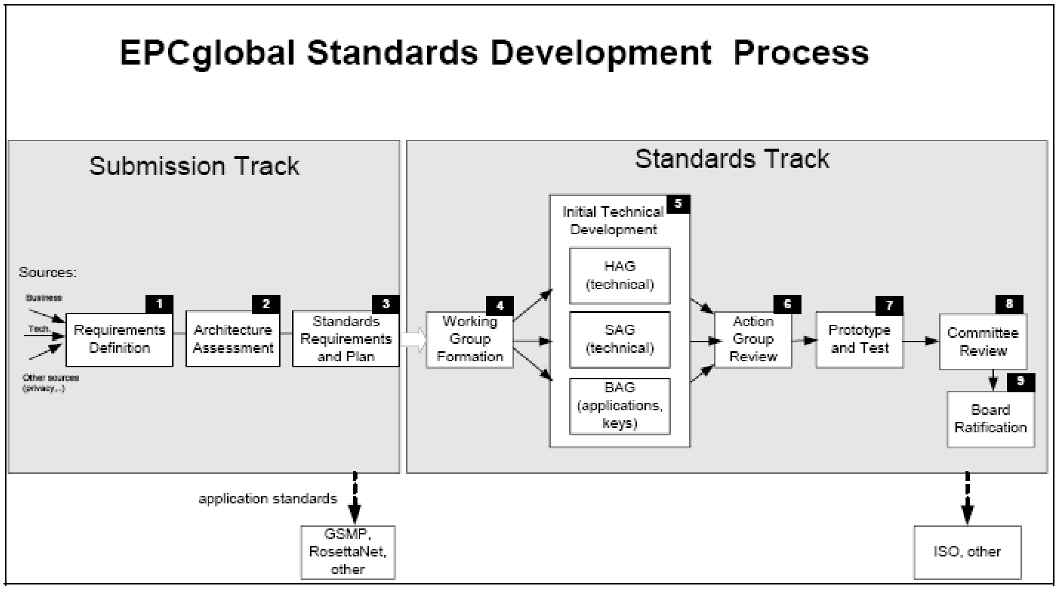

Figure 4-6

Nevertheless, EPCglobal states that it is committed to collaborating with ISO in areas where the collaboration benefits its members.[96] EPCglobal is part of the external ISO liaisons. These liaisons are organizations that make an effective contribution to the work of the ISO technical committee and vice versa. These liaisons may nominate experts to participate in a working group. ISO appointed Steve Halliday from SC31 to work with EPCglobal. Similarly, EPCglobal appointed Henri Barthel to work with ISO's SC31. Such organizations are sent copies of all relevant documentation and are invited to meetings, see Figure 4-7.[96] So, EPCglobal is trying to monitor the work and assess opportunities for collaboration between EPCglobal and ISO SC31 much earlier in the standard development process. Therefore, the current activities for collaboration between ISO and EPCglobal have a positive effect on the adoption of EPCglobal as a universal standard.

[96] Presentation on EPC Global by Henri Barthel technical director of EPCglobal and GS1, 26 September 2006, Graz, Austria.

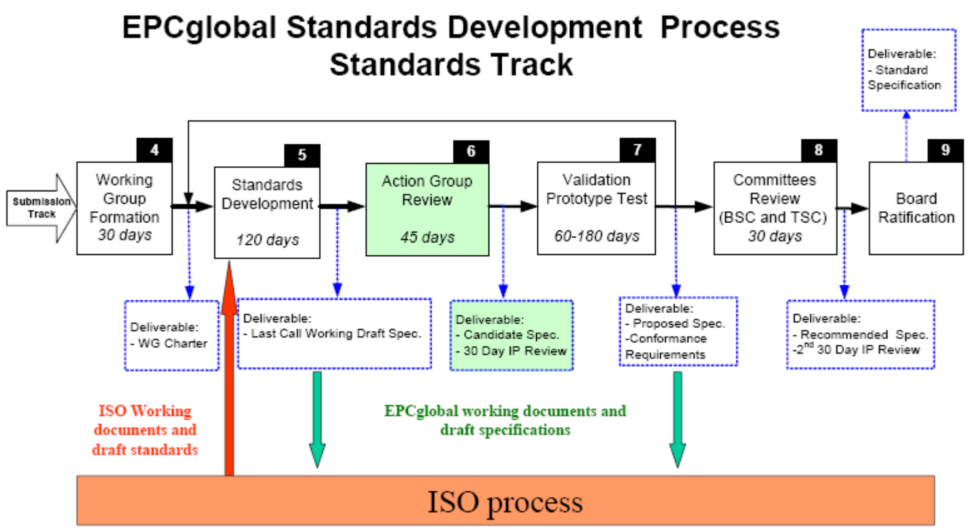

Figure 4-7

An example of this collaboration between ISO and EPCglobal is the ratification of the Gen2 standard. The Gen2 standard incorporates the frequency and performance so that it can be used world wide. This worldwide compatible standard enabled its ISO's ratification in July 2006 as an extension to Part 6 of ISO's 18000 standard.[62] This ratification promises to further promote the adoption of the EPCglobal Gen 2 standard by allowing customers to specify products that conform to the standard all around the world without the requisite of being EPCglobal members.

Through their development process EPCglobal creates specific standards. This is another factor that encourages the adoption of EPCglobal standards. For example, EPCglobal standards prescribe the physical implementation of the tags and readers, rather then specifying their generic characteristics as ISO standards do.[97] This creates simpler standards to be used in specific applications (e.g. retail).

F. Membership Size

The membership size for the adoption of a standard is an important factor. In the paper "Installed base and compatibility: Innovation, product preannouncement, and predation", Farrell and Saloner described the benefits of having a large number of users deploying the same technology. Telephone, VCR recording format, cassette

[97] Gerst, M., Bunduchi, R., "Current Issues in RFID Standardization", University of Edinburgh.

tapes, and many other technologies have benefited from having a large number of users. These benefits are: interchangeability of complementary products, ease of communication among machines and people, and cost savings. Thus, there have to be many users of EPCglobal standards for its membership to benefit from the use of RFID technology in supply chain.

Currently, EPCglobal has more than 1000 members in 36 countries. This number, although impressive for the three years that EPCglobal has existed, is small in comparison to the members in GS1 which are 1.1 million in 140 countries.[98] When joining GS1, EPCglobal tried to leverage the number of members in GS1 to become EPCglobal member, but EPCglobal has not been able to influence them. Currently with only 1000 members EPCglobal does not to have the sufficient number of members needed to capitalize the benefits that will ensure the adoption of EPCglobal standards.

In order to determine the time it would take EPCglobal to reach the size of GS1, this author uses an S-Curve forecasting model. The S-Curve emerged as a mathematical model and has been applied to a variety of fields including physics, biology, economics, and technology and standard adoption. The information represented in an S-curve is comparable to the cumulative distribution of a normal or Gaussian distribution. Hence, the S-curve yields valuable insight about the time it would take for users to adopt EPCglobal standards. See Figure 4-8.

Table 4-3[99] shows the EPCglobal membership from 2003 to 2006 and Equation 4-2 shows the Pearl curve equation used to forecast the number of members joining EPCglobal in the next 20 years. See Appendix 1 for a full analysis and explanation of the S-Curve model.

Year	EPCglobal New Subscribers
2003	100
2004	398
2005	709
2006	1012

Table 4-3

[98] http://www.rfidconsultation.eu/docs/ficheiros/EC_Workshop_EPCglobal____Hogan.pdf

[99] Various EPCglobal presentations and http://www.epcglobalinc.org

$$y = L / [1+ a*\exp(-bt)]$$

Equation 4-2

Where y is the number of EPCglobal members, L is the saturation level or maximum number of adopters, a is the location coefficient, b is the shape coefficient, and t is the time.

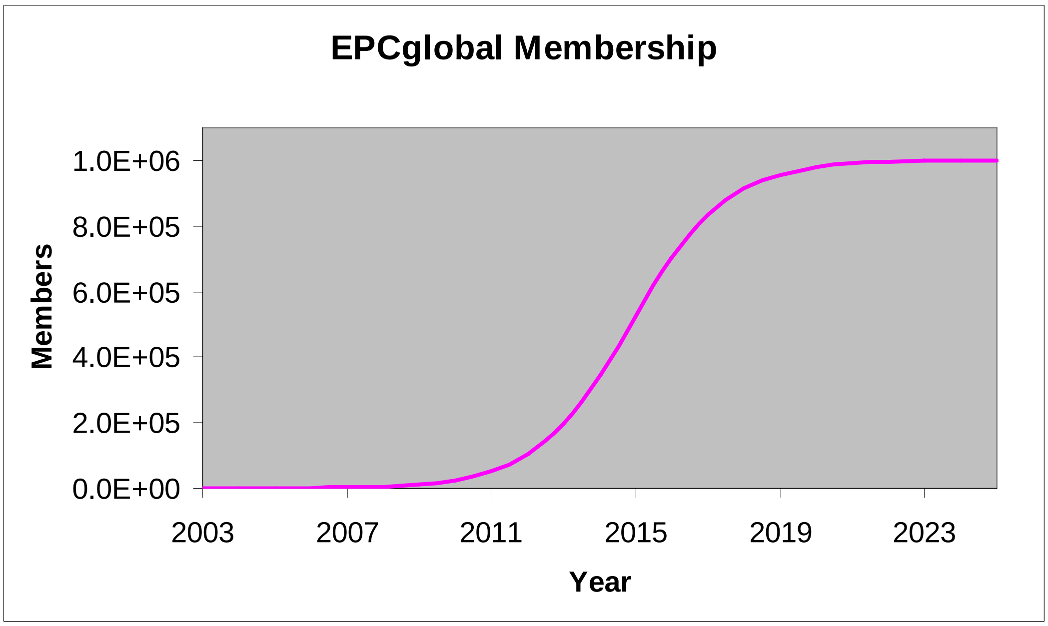

Figure 4-8

At the current membership growth rate, EPC global would be reaching the one million members GS1 currently has by 2020. If EPCglobal wants to accelerate this adoption level it needs to grow at a much faster pace. For example, for EPCglobal to have one million members by the year 2015 the number of members joining in 2007 would have to be 4,500. See Figure 4-9 for a comparison between the two plots. Gaining 4,500 new members in one year currently represent a challenge for EPCglobal. Thus, the current membership size and joining rate have a negative effect on the adoption of EPCglobal as an international standard.

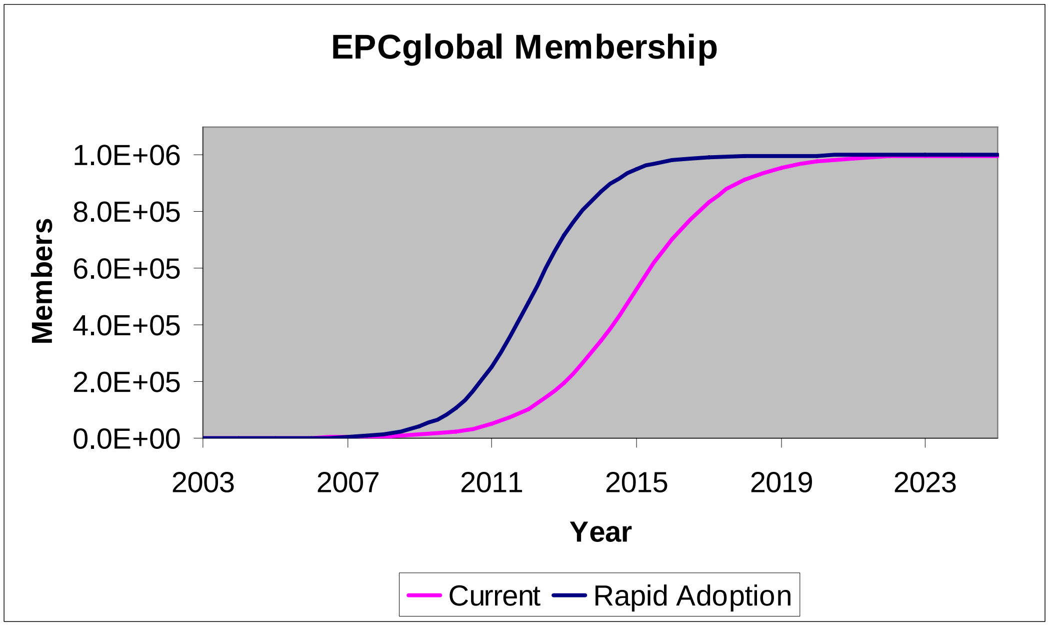

Figure 4-9

Although the S-curve is a useful model to predict the adoption of a technology or a standard within an industry, there are some issues that arise when using the S-curve to predict the future. These issues arise because of the standard's future dependence on the development stage, the introduction of a new sustaining or competing standard, the data collection time frame, and other uncertainties that can affect the final outcome of the adoption. The purpose of the S-curve model used is to illustrate the need of EPCglobal to increase the number of new members that will in turn generate a faster adoption rate.

G. Intellectual Property Policy

At the initial stages of the bar code technology, intellectual property was a main problem for its adoption. Initially a universal standard did not exist and companies had to develop their own proprietary technology. However, companies realized the importance having compatible technology to increase the installed base of bar code users that would in turn increase the number of bar code equipment sold. The bar code equipment manufacturers understood that in order to make any money, they would have to increase the number of users printing and reading a particular bar code pattern symbol to increase the sales in the equipment. Today, a particular bar code pattern symbol reference decode algorithm is available for the same cost as the ISO specification but with no royalties, no fees, and no licenses. Therefore, in RFID like in the bar code technology, intellectual property plays a critical role in the adoption of a universal standard.[100]

The EPCglobal intellectual property policy ensures that all companies subscribing to the organization have open, neutral access to EPCglobal Network technology and standards. The agreement guarantees that the technology remains non-proprietary for the benefit of industry as a whole. Under EPCglobal intellectual property policy participants make the necessary intellectual property available for licensing. This license is offered either on a royalty free or reasonable and non-discriminatory (RAND) basis to only EPCglobal subscribers.

EPCglobal's goal is to have all the "necessary" intellectual property needed for the compliance of its standard to be royalty-free. With this royalty free approach, EPCglobal hopes to avoid the creation of monopolies and to encourage the development, exploitation, and independent development of intellectual property based on EPCglobal specifications. Necessary intellectual property covers only those things which a participant owns and is fundamental to a specification and only under extraordinary circumstances (i.e., when a working group is unable to find an alternative to the use of such intellectual property) an alternative to royalty free licenses can be used. In this case, the participant is required to identify the intellectual property, the reasons why the intellectual property is necessary to a specification, and to commit to a reasonable and non-discriminatory (RAND) licensing plan. ISO on the other hand only requires a RAND agreement for a technology to be used as part of its standards.

However, there have been a number of issues with EPCglobal intellectual policy implementation. For example: [101]

- Intellectual property holders that have agreed to license their technology on a royalty free basis are not required to honor this to non EPCglobal members.

- EPCglobal itself holds a number of patents, most of which have neither been filed nor declared royalty free.

- There are many holders of fundamental IP that are not EPCglobal members, thus they are not required to offer their IP royalty free or in a RAND basis.

- Intermec, an EPCglobal member, will no longer offer 13 of its RFID patents on a RAND basis.[102]

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[100] "Global - EPC and IP: Look Back, Move Forward", RFID Connections, July 2004.

[101] Harmon, C., "Defining Global Interoperability", RFID China Forum Spring 2005.

The latter has generated a large debate mainly because of the implications of Intermec's decision to not RAND license its proprietary technology. Initially Intermec donated five of its patents on a royalty-free basis and agreed to license an additional 13 patents on a RAND basis. However, the cancellation of Intermec's intellectual property agreement with EPCglobal came after EPCglobal's law firm stated that none of Intermec's patents were necessary for Gen2 compliance. Thus, Intermec is under no obligation to provide its patents on a royalty free or RAND basis and would have to negotiate licensing arrangements with individual technology companies interested in its technology.

Although the Intermec's patents are not necessary for complying with the Gen2 standards without them functionality and/or performance of the RFID system might be inferior. For example, Intermec holds a patent that covers frequency hopping spread spectrum for RFID. This patent is not essential for tags and readers to comply with the Gen2 standard but it improves their performance in noisy environments.[103] On the other hand, the ISO ratification of the Gen2 standard means Intermec has to make its intellectual property available on a RAND basis.[104] But RAND licensing agreements do not guarantee that royalties will be low, it only guarantees that licensing fees are transparent and the same for everyone. For example, a semiconductor manufacturer developing microchips based on the Gen 2 spec would have to pay Intermec a royalty of between 2.5 to 7.5 percent of the unit sold. [105] Therefore, even though Intermec's withdrawal from any license agreement from EPCglobal had a negative effect on the adoption of EPCglobal standard the ISO ratification helped minimize this effect.

A positive outcome of Intermec's intellectual property position is that if companies do not want to pay royalties to Intermec then these companies need to develop a technology that is superior to the one Intermec currently owns. For example, Texas Instrument, Philips Electronics, Symbol Technology, Zebra Technology, and others have agreed to pay royalties to Intermec for every Gen 2 product they make.[106]

In order to avoid paying royalties companies instead will try to develop superior technology. The quest for superior technology is beneficial to the advancement of the

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102 Roberti, M., "Intermec Withdraws IP Licensing Plan", RFID Journal, 2005.

103 AIM Global, "Intermec IP: Good News or Bad?", 2005. http://www.aimglobal.org/members/news/templates/rfidinsights.asp?articleid=300&zoneid=24

104 Collins, J., "Intermec Announces Licensing Plan", RFID Journal, 2005. http://www.rfidjournal.com/article/articleview/1579/1/1/

105 http://www.rfidjournal.com/magazine/article/1555

106 Durig, R., "Let the RFID Cycle Begin", 2006. http://www.durig.com/rfid_report.html

technology. For example, when bar code's reference decode algorithms standards were published by AIM Global, the intention was only to set a foundation for the development of much more robust decoders. So, by following AIM standard the bar code reader would perform very poorly in comparison with other commercial decoders.[103] Therefore, analogous to the development of the bar code the Gen2 standard can serve as a reference for more robust and advanced technology to be developed.

H. Benefits

User's rate of adoption is enhanced when users can perceive, by observation and trial, the benefits of a technology or standard. Furthermore, the user's adoption of RFID depends on how much better the RFID system is with respect to the current technology used to manage supply chain applications. [107]

The benefits of deploying an RFID system in the supply chain are mainly derived by the promise of having 100% visibility throughout the supply chain process which allows the reduction of out-of-stock items, inventory, labor in distribution centers, and counterfeiting, etc. A study of an RFID system deployment using EPCglobal standards in 12 Wal-Mart stores by the University of Arkansas found a 16% reduction in out-of-stocks, 63% decrease in the time it takes to replenish out-of stock-items, and a reduction in excess inventory when compared to the current technology used.[108] Currently without the use of RFID, more than six percent of spending on the supply chain is lost because of a lack of or poor visibility in the supply chain.[25] RFID technology and EPCglobal standards benefits are clear and most users can observe them. Hence, the users' observed benefits of the technology and EPCglobal standards over the current technology have a positive impact for their adoption.

EPCglobal standard adoption also depends on the ability to verify and quantify the benefits and determine how easily its features can be assessed without commitment of financial or human resources.[107] Unfortunately, RFID systems require heavy investments for their deployment. In order to achieve a 100% visibility, the flow of the EPC RFID tagged products needs to be monitored throughout the entire distribution process. Thus, in the case of a Wal-Mart supplier, the tagging and reading must occur continuously and around the world. This means that to comply with Wal-Mart's mandate, each case or pallet must have an EPC RFID tag, there must be readers placed in strategic locations, and the middleware needs to be installed, etc. Thus, it is estimated that the cost of deploying such a system is in the order of nine million

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[107] Rogers, E.M., "Diffusion of Innovations", 1962.

[108] http://66.195.41.11/index.php?option=com_content&task=view&id=1034&Itemid=88

dollars in the first year to comply with this mandate.[109] At this cost, many users would prefer to wait and ensure that the technology and its standards will not change. Hence, the high cost for the deployment of an RFID system that could ensure a 100% visibility in the supply chain has a negative impact on the adoption of the RFID technology and EPCglobal standards.

I. System cost

One major hurdle in the way of speedy and universal adoption of the EPCglobal standard is the cost of the RFID equipment as it currently stands. Although the prices of tags are falling, the tags are a significant part of the overall cost in an RFID system. The present cost range of passive tags is from $0.08 to $0.15 depending on the features and quantities.[110] A reader costs between $1,000 and $3,000.[111] Middleware licenses cost between $50,000 and $100,000 for a distribution center depending on the number of antennae or development licenses.[112] For example, an RFID deployment in a consumer packaged goods manufacturer would cost between $13M to $23M for shipping 50 million cases per year. See Table 4-4.[113] Therefore, the cost of implementing an RFID system is not trivial. And because of the high cost, it is difficult to ensure a positive return on investment before committing to this new technology.

Costs for Shipping 50 Million Cases per Year	
Tags and readers	$5M to $10M
System integration	$3M to $5M
Changes to existing supply chain applications	$3M to $5M
Storage and analytics of the large volumes of data	$2M to $3M

Table 4-4

A study presented to the Grocery Manufacturers of America shows that the relationship between the necessary adoption level and tag cost needed in order to

109 Rothfeder, J., "What's Wrong With RFID?" CIO Insight, 2004.

110 http://www.rfidjournal.com/article/articleview/1887/1/1/

111 http://www.rfidproductnews.com/issues/2006.05/newprod/readers.php

112 http://www.rfidjournal.com/article/articleview/1232/1/14/

113 Asif, Z., Mandviwalla, M., "Integrating the Supply Chain with RFID: A Technical and Business Analysis", Communications of the Association for Information Systems, Volume 15, 2005.

achieve a positive return on investment is significant.[114] For example, Figure 4-10[114] shows that for a tag cost of $0.05 the adoption in the retail industry has to be at least 50 percent to generate a positive return on investment. Industries have agreed that if a tag were 5 cents then RFID deployment would be feasible. Industry experts have claimed that the tag price will drop to 5 cents for a number of years. However, the tag price has not dropped this low. But because of this claim to the tag price dropping many companies have waited to implement RFID systems until the price does drop. Unfortunately no one is sure as to when the tag price will drop and so there are many potential buyers that are waiting on the side line and not considering if they would currently still get a positive return on investment even with the higher tag price. Therefore, the perception that the 5 cent level is when a positive return on investment will occur has a negative effect on the adoption of EPCglobal as a universal standard.

The study summarizes 24 business cases from large North American Consumer Package Goods (CPG) companies. Positive return in investment is the result of the improvements versus the expenses generated by implementing an RFID system across the supply chain. These improvements focus on four specific areas: 1) reduced out of stocks, 2) reduced inventory, 3) reduced credit and claims, and 4) reduced distribution center labor and costs; and the expenses focus on two: 1) installation and 2) maintenance cost for tags, readers, infrastructure and software integration. The study uses normalize data of the actual cost and benefits of cash flows around a common case volume to help eliminate distortions caused by different company sizes and the tag costs at various levels and time period.

The assumptions that played a critical role in the determination of the relationship between the necessary adoption level and tag cost are: the cost of tags and tag application incurred by the manufacturers, tagging occurs in pallet and case level only, a 100 percent tagging of pallets and cases occurs in three to five years, estimates were not made for manufacturing or supply side related benefits, and the installation of readers in store and door back rooms occurs in retailer warehouses.

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[114] "A Balanced Perspective: EPC/RFID Implementation in the CPG Industry", prepared by A.T. Kearney and IBM for the Grocery Manufacturers of America.

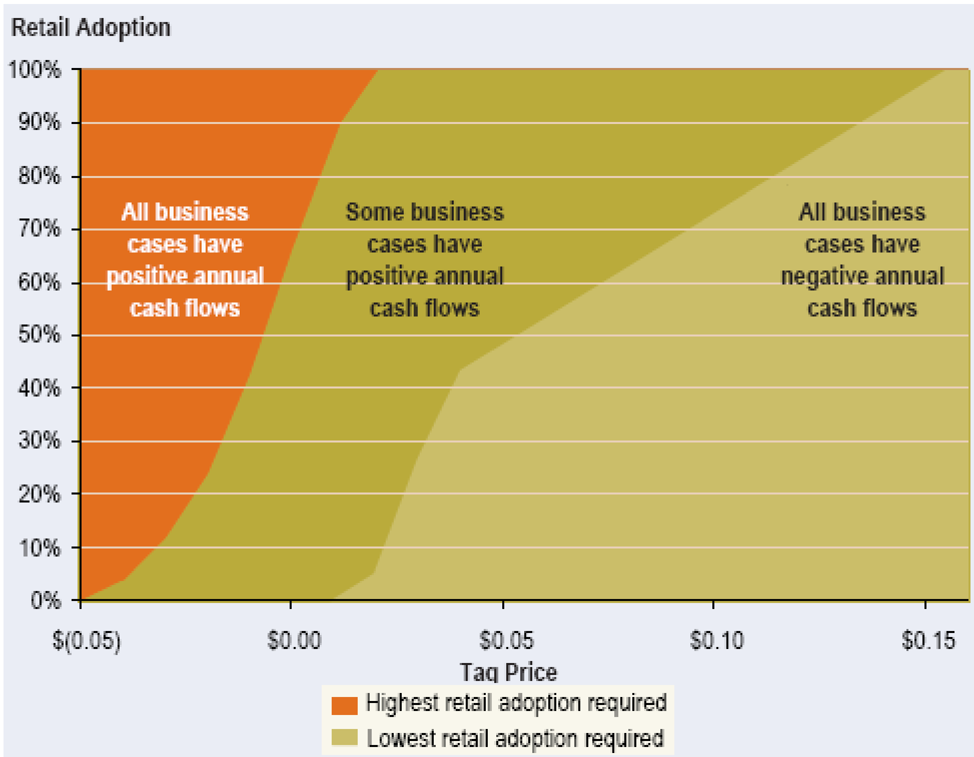

Figure 4-10

A high switching cost can also affect the adoption of the standard. In the case of standards, switching cost occurs when a technology based on a particular standard is not compatible with other standards. Switching cost can lock in users to early choices of a particular standard or technology that might not be the best technology for a particular application.[115] So, EPCglobal compliant manufacturers need to make sure that the different EPCglobal standards are compatible with each other. In fact, compatibility of RFID equipment becomes a competitive advantage for manufacturers when the cost to upgrade a system to the next generation is low to nothing. For example, to upgrade Thingmagic Mercury4 reader from EPCglobal Gen 1 to Gen 2 standard takes place by just installing new firmware. This compatibility among EPCglobal standards plays a key role in the development and adoption of EPCglobal standards. If in the future EPCglobal ratifies a Gen3 standard, then EPCglobal needs to ensure either backward compatibility or an easy conversion method from any of its previous standards to the Gen3 standard. Hence, compatibility among EPCglobal

[115] Farrell, J., Klemperer, P., "Coordination and Lock-In: Competition with Switching Costs and Network Effects", Oxford University, 2006.

standards means that end users switching costs are minimized which increases their confidence in adopting EPCglobal standards.

J. China

Supply chain management expenditure in China accounts for 20 to 30 percent of its gross domestic product as opposed to only 10 percent in more developed countries such as in the U.S. and the European Community.[116] Hence, Chinese suppliers are under constant pressure to decrease their expenditure in supply chain management. Thus, there is a strong Chinese interest in the deployment of RFID systems to reduce the cost of supply chain.[117]

China already has some world class manufactures and it is a manufacturing center delivering products all around the world. Currently, most retail companies in the U.S. receive a large percentage of products made in China. For example, 70 percent of the products at Wal-Mart are made in China. Wal-Mart's Chinese imports amount to 10 percent to 15 percent of overall U.S. imports from China.[118] If China's economy continues to grow at the current pace then China will become the second largest economy in the world in 20 years.[119] Thus, China has a strong interest in and will have an even greater influence on the development and adoption of future RFID standards.[120]

The influence that the Chinese government has in the standard adoption is illustrated by its impact on the establishment of the Radio Frequency standard for mobile phones. In China there were two standards competing for the mobile Chinese market: 1) Global System for Mobile communication (GSM) and 2) Code Division Multiple Access (CDMA). The GSM standard is a European digital standard supported by Nokia and Ericsson and other European vendors, while the CDMA is supported by U.S. vendors. Currently, 85 percent of China's mobile phone users have GSM devices and only 15 percent have CDMA. The virtually universal adoption of the GSM standard in China is mainly due to the involvement of China in the GSM standard development process as well as in the production of the GSM technology, while the CDMA vendors did not share information with either Chinese vendors or

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116 "Look for Breakthrough Points for China's RFID Industry Chain", China eWeek, 2005.

117 Lai, F., Hutchinson, J., Zhang, G., "Radio Frequency Identification (RFID) in China: Opportunities and Challenges", 2005.

118 "Understanding RFID Adoption in China", RFIDJournal, 2005.

119 "China's Economic Power: Enter the Dragon", The Economist, 2001.

120 Lai, F., Hutchinson, J., Zhang, G., "Radio Frequency Identification (RFID) in China: Opportunities and Challenges", 2005.

government. Since there is no intrinsic superiority in the GSM standard, we can conclude that it is largely due to the European venders open development process, that the GSM standard, with 375 million GSM mobile phone users, has become the de facto standard in China. [121]

The Standardization Administration of China (SAC) is the government organization in charge of the oversight and development of RFID standards in China. And in 2004, the RFID national standard working group was established.[122] China has become more interested in the adoption of international standards however the adoption rate is low. For example, ISO and IEC have 17,910 international standards and only 6,364 of them have been transformed to Chinese national standards. [123] The adoption rate is only 35.3%. This low adoption rate can be attributed to China's interest in developing its own standards instead of adopting international standards. If China develops its own standards, then it holds the rights of the intellectual property and can mandate the compliance of Chinese standards to foreign companies. For example, the standard for the Wireless Local Area Network (WLAN) Authentication and Privacy Infrastructure (WAPI) was developed by the China Broadband Wireless Internet Protocol Standard Group, and in 2003 the Chinese government announced a mandate requiring all wireless devices sold in China to include WAPI support. Furthermore, foreign companies were forced to partner with one of 24 Chinese firms in order to have entrance into the Chinese market, because only these 24 Chinese firms have access to the implementation information of the standard.[124]

Another factor that explains the motivation of China towards developing its own standards is the cost of the intellectual property when not own by Chinese companies. The compliance with international standards can drive up the cost of manufacturing goods and reduce the competitiveness of Chinese products in global markets. For example, to comply with DVD standards there is a high cost for the intellectual property which is not own by Chinese vendors. This has forced more the 90 percent of Chinese manufacturers to stop the export of DVD equipment.[117] So, the Chinese government has become active in the development of standards to avoid intellectual property issues.

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121 http://www.itfacts.biz/index.php?id=P777

122 Zhao, S., "China RFID Standards", Global Forum 2004, Malmo Sweden.

123 Standardization Administration of China, "Adoption of International Standards", http://www.sac.gov.cn/english/adopt/index.asp

124 ANSI, "Intellectual Property Rights Policies in Standards Development Organizations and the Impact on Trade Issues with the People's Republic of China", Patent Group, 2004.

Most international standards have consistent patent policy approaches that ensure that all holders of essential patent claims license their patented technology to all parties using the standard under terms that are reasonable and non-discriminatory (RAND). However, the compliance to this policy does not mean that the license fees are inexpensive, thus the fee can significantly contribute to the overall cost of a product. For example, as previously stated Intermec wants charge between 2.5 to 7.5 percent of the units sold to any semiconductor manufacturer developing microchips based on the Gen 2 spec, a cost that China can avoid by developing its own RFID standards.

There are other issues that prevent China from adopting EPCglobal as its standard. According to the Chinese government the membership fees to obtain EPC codes, which can add up to $200,000, do not add any value to the Chinese RFID systems because China has its own code, the National Product Code (NPC). This code could be used instead of EPCglobal's EPC code. Also, China considers its data and communications to be a national security issue.[125] So, if China wants to have ownership of the database, then China will not likely support EPCglobal because EPCglobal has signed an agreement with Verisign, a US based company, to manage the EPC Network's root directory (i.e., the system that points computers to each company's ONS). Finally, the lack of involvement from Chinese manufacturers or standard organizations in the development of EPCglobal standard has caused the Chinese government not to adopt the EPCglobal standard.

Counterbalancing the fact of China's lack of involvement in the EPCglobal standard development process is China's slowness in developing its own RFID standards. Because of its own lack of a universal standard many Chinese suppliers are having to use EPCglobal standards, since many U.S. suppliers require RFID tags in their products and will not waive this requirement. The need to have RFID tags in products combined with EPCglobal's aggressive involvement in China could turn EPCglobal standards into de facto standards. For example, in 2006 EPCglobal Hong Kong launched its EPCglobal Industry Support Program (EISP), to lend financial, technological, and implementation support for EPC adoption in enterprises across Hong Kong and Southern China.[126]

A factor that can diminish the strength of China in the standardization process is the fact that the Yuan may eventually be untied from the U.S. dollar. If and when the Yuan becomes freely traded in the international monetary market it will rise in value against the U.S. dollar and other world currencies. If this happens, China will lose some of its economic leverage and retailers' suppliers will seek other countries with

125 Harmon, C. K., "Radio Frequency Identification (RFID)- Making the Right Choices", 2005.

126 "The RFID Market in China: Assessment of Chinese RFID Market Opportunities and Regulatory Issues", ABI Research, 2006.

lower manufacturing cost. Thus, the economic leverage China currently has as the manufacturing capital of the world may be diminished.

To encourage RFID adoption and advancement of RFID technology in China, the Chinese government has started the "Golden Card Project". This project deploys RFID systems in banks, public transit, and other government services to accept smart cards containing RFID tags as a form of payment. The project expects 300 million consumers to use smart cards in 400 cities within 10 years.[127] Although, this project is not directly related to supply chain management, the deployment of such a system in China improves its technical and practical expertise in the field of RFID as well as consumer awareness.

[127] http://www.rfidjournal.com/article/articleview/1758/1/128/

Section 5 Conclusion

Five of the ten factors that influence the adoption of a universal standard have a positive effect for the universal adoption of EPCglobal, two are neutral, and three are negative. See Table 5-1.

Table 5-1

Factors	Impact on EPC global adoption
Complexity of application (Supply Chain Management)	Positive ↑
Mandates	Positive ↑
Privacy policy	Positive ↑
Member type	Negative ↓
EPCglobal standard development process	Positive ↑
Membership size	Negative ↓
Intellectual property policy	Positive ↑
Benefits	Neutral ↔
System cost	Negative ↓
China	Neutral ↔

The factors that have a positive impact on the adoption of EPCglobal are: complexity of application (Supply Chain Management), mandates, privacy policy, EPCglobal standard development process, and intellectual property policy.

The factors that show the weaknesses of EPCglobal are: member type, membership size, and system cost. To address the membership type and size issues and to encourage adoption, EPCglobal needs to diversify more its membership not only by having offices all around the world but by actively recruiting, changing its membership policy, and providing other benefits to its members. To deal with the promise of a five cent tag which would seem to solve the system cost EPCglobal should educate suppliers of the current stage of the technology and predict an accurate timeline for the availability of less expensive tags so that potential buyers do not wait for an indefinite and potentially non-realistic date.

The factors that have a neutral impact on the adoption of EPCglobal standards are: benefits and China. These two factors were negative in the past but now are in the transition to become potentially positive factors. In terms of benefits it is because of EPCglobal actions that this factor might become a positive factor in the adoption of EPCglobal standards. EPCglobal is sharing RFID implementation case studies with all its members, thus allowing EPCglobal members to assess the capability needed to ensure a successful deployment of an RFID system without incurring significant costs. Although China would like to have its own national RFID standard it has been unable to rapidly implement such a standard. Thus, in the meantime EPCglobal standard has been used by Chinese suppliers. The high switching cost of RFID systems will discourage those Chinese suppliers who have implemented EPCglobal to switch to a future Chinese standard. Hence, EPCglobal has been able to get a foothold in the Chinese market despite China's aversion to a non-national standard.

With the assumption that the ten factors carry a similar weight there is a strong likelihood that EPCglobal could successfully become the universal standard for RFID system in the retail supply chain management. As described above the two neutral rated factors could join the other five positive factors because of EPCglobal actions and the current necessity for an already established standard in the world market place. It is a matter of time and concerted efforts on the part of EPCglobal for the three negative factors to become positive. Therefore, it is important to track all the factors to ensure the positive factors continue toward having a positive impact on the adoption and that the necessary actions are in place to change the neutral and negative factors to positive position. Further research for this thesis should include a system dynamics model that determines the weight, relationship, and sensitivity of the factors to understand their importance and impact on the adoption of EPCglobal as the universal standard. This model could also provide a time frame of when EPCglobal could become the universal standard.

APPENDIX 1[128]

The S-Curve emerged as a mathematical model and was afterwards applied to a variety of fields including physics, biology, and economics. Many biological systems follow this structure (e.g. population growth, carrying capacity), as well as product life cycles and technology and standards evolution. The information represented in an S curve is comparable to the cumulative distribution of a normal or Gaussian distribution. The S-shaped curve has three characteristic phases: slow birth, steep growth, slow decline. The S-curve can predict the by defining the most important performance parameters of a standard from its conception to its current state and then plotting the performance parameters versus time needed to make the progress, the S curve can yield valuable insight about the future of the standard.

For the forecast of EPCglobal membership the Pearl equation was used. The Pearl curve is frequently used to estimate or forecast the rate of adoption of a technology or standard over time. The Pearl curve is represented by the function:

$$y = L / [1+ a*\exp(-bt)]$$

where y is the number of EPCglobal members, L is the saturation level or maximum number of adopters, a is the location coefficient, b is the shape coefficient, and t is the time.

So, by defining the following variables:

$$Y = \ln(L/y - 1)$$
$$a = \ln(a) \quad \text{so that} \quad a = \exp(a)$$
$$b = -b \quad \text{and} \quad b = -b$$

the non-linear logistic function is transformed to the following linear function:

$$Y = a + b\,t$$

Hence, given the number of members joining EPCglobal since its creation the values are transformed to Y-values and standard linear regression is used to estimate the constants a and b for a given L.

128 Lawrence, S.R., "S-Curve Forecasting", 1998.

APPENDIX 2

International Organization for Standardization (ISO)

ISO was created in 1946 at the Institute of Civil Engineers in London from the union of two organizations: International Federation of the National Standardizing Associations (ISA) and United Nations Standards Coordinating Committee (UNSCC). ISO officially began operations on February 23rd, 1947. ISO members are national standards institutes of 156 countries. ISO only accepts one member per country (e.g. ANIS in the United States), nevertheless ISO maintains other international organizations in liaison with its technical committees. For example, ISO technical RFID committees maintain communication with the Association for Automatic Identification and Mobility (AIM) and GS1 (ISO liaison organizations can participate actively in the development of standards but these organizations do not have voting rights). ISO is non-governmental organization and because of this ISO occupies a special position between the public and private sectors. ISO combines the interests of its member institutes because some are part of the governmental structure of their countries while other members are part of the private sector.

Since 1947 ISO has published more than 15,000 international standards. These standards range from traditional activities, such as agriculture and construction, mechanical engineering, medical devices, and the newest information technology developments, such as the digital coding of audio-visual signals for multimedia applications.

To create, coordinate, and implement some of its international standards, ISO collaborates with the following partners: International Electrotechnical Commission (IEC) and International Telecommunication Union (ITU). This collaboration exists for the creation of standards for "Automatic Identification and Data Captured (AIDC) techniques". AIDC standards are covered by ISO and IEC. ISO and IEC have established a Joint Technical Committee (JTC-1) to address technology standards, including those for AIDC. Standards that are developed by JTC-1 are subsequently published as joint ISO/IEC standards. Within JTC-1, Subcommittee 31 (JTC 1/SC 31), ISO has 28 countries that actively participate in standards development including China, Korea, and Japan. In addition, this committee has other regional and international organizations with which it cooperates in liaison.

The Work Group 4 (JTC-1 SC31/WG4) deals with RFID for item management. The goal of this group is: "to provide standards for interoperability of wireless, non-contact omni-directional radio frequency identification devices capable of receiving, storing, and transmitting data while operating at power levels that are in freely available international frequency bands in the area of item level identification and management across the supply chain such as finished good asset management, raw material asset management, material traceability, inventory control, electronic article surveillance, warranty data, production control/robotics, and facilities management." The following subgroups exist within JTC-1 SC31/WG4:

- SG1 Data Syntax: Develops a technical paper of what should be in the final standards on functions of syntax in a data flow reference model and provides a technical paper outlining a search/append/solution for RF tags.

- SG2 Unique ID of RFID Tags: Makes the appropriate research and submits a draft proposal for standards addressing the unique identification of RFID tags

- SG3 Air Interface (18000 - Air interface standard)

- Application Requirements Profiles Group

- Regulatory Issues

There are a variety of other ISO committees that address other RFID applications. For example, the Technical Committee 104 (TC104) has issued a standard for RFID on maritime containers and the Joint Working Group of ISO TC122 and TC104 is working on a set of generic RFID application standards.

a. ISO Standard Development Process

The inclusion or creation of an international standard occurs as an agreement among the member bodies of ISO. Furthermore, ISO follows established rules and engages all member countries in voting and commenting during the development of standards. The ISO standard development process (SDP) consists of six steps, see Figure A2-1:

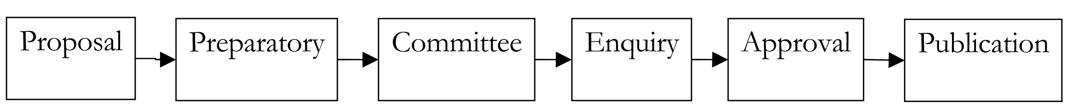

Figure A2-1

Step 1 - Proposal: During this step, confirmation of the need of a new International Standard occurs. Also, a proposal is submitted for vote by the members of the relevant technical committees (TC) and subcommittees (SC) to determine whether to continue with the process.

Step 2 - Preparatory: The purpose of this step is to develop a working draft describing the best technical solution to the problem being addressed. This first draft is developed by a working group of experts and forwarded to the working group's parent committee to be considered for the next step.

Step 3 - Committee: The purpose of this step is to register and distribute the first draft for comments. In some instances voting is required among the TC and SC members in order to reach an agreement on the technical content of the document. Once consensus has been attained, the text is finalized for submission as a draft international standard (DIS).

Step 4 - Enquiry: The purpose of this step is to circulate the DIS to all ISO member bodies for voting and comment. It is approved if two thirds of the TC and SC votes are favorable and if no more than one quarter of the total number of votes cast is negative.

Step 5 - Approval: In this step, the final draft is circulated to all ISO member bodies for a final Yes/No vote. If there are any comments received during this stage, they are no longer considered, but they are registered for consideration during a future revision of the standard. Voting rules are similar to the ones in the previous step.

Step 6 - Publication: Once the final draft has been approved, only minor editorial changes can be included into the final text. The final text is sent to the ISO Central Secretariat which publishes the International Standard.

In some instances, standards might omit some stages and go directly to approval or other later stages. This "fast track" is possible when the document submitted to ISO has a certain degree of maturity (e.g. a standard has been developed by another standard organization).

b. ISO Intellectual Property Policy

International standards under the ISO umbrella may contain provisions which are covered by patent rights. To ensure that the standards can be applied and used worldwide on a fair and equitable basis statement, ISO and IEC need to receive a guarantee from the owners of such rights, that they are willing to grant licenses to applicants worldwide on reasonable and non-discriminatory term (RAND).

c. ISO Privacy policy[129]

ISO defines security as the "provision of protection against threats to people, physical assets, infrastructure, information and information technology assets including electronic networks and facilities, and to the movement of people and goods and related facilities." To ensure that security is considered while developing standards, ISO and IEC have created an advisory working group that provides guidance to standards developers on security issues. The working group is called ISO/IEC Strategic Advisory Group – Security Working Group (ISO/IEC SAG-S WG) and has the directive to:

1. Have a strategic direction and coordination on security.

2. Provide guidance on consideration of security by all standards developers and integration of security in standards.

3. Provide a common security vocabulary, concepts and principles.

This directive ensures that personal information for service delivery and commerce is in protected databases and while in transit and requires an identity management system as an enabler of privacy protection and service delivery.

d. What are the Current RFID Standards of ISO?

The Table A2-1 summarizes the current RFID technological, data, and conformance standards used in supply chain for ISO.[130]

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[129] Sturgeon, A., "Security and the Global Economy – Contribution of International Standards: Security as a prime mover in ISO's work", 2005.

[130] http://www.rfidsb.com/index.php?page=rfidsb&c_ID=180 and http://www.iso.org

Table A2-1

Standard's Body	Standard	For	Status	Scope
ISO International Standards Organization				
	ISO/IEC 15418	Data Specifications	Reaffirmation	Information Technology, Automatic Identification and Data Capture Techniques – EAN/UCC Application Identifiers and ASC MH 10 Data Identifiers and Maintenance
	ISO/IEC 15434	Data Specifications	Published	Information Technology, Automatic Identification and Data Capture Techniques – Syntax for High Capacity ADC Media
	ISO/IEC 15459	Data Specifications	Published	Information technology — Unique identifiers for item management — Part 1: Unique identification of transport units Part 2: Registration procedures Part 3: Common rules for unique identification Part 4: Unique item identification for supply chain management Part 5: Unique Identification of Returnable Transport Items (RTIs) Part 6: Unique identification for product groupings in material lifecycle management”

Standard's Body	Standard	For	Status	Scope
	ISO/IEC 15961	Data Protocol	Published NP Filed for revision	Information Technology, Automatic Identification and Data Capture Techniques – Radio frequency Identification (RFID) for Item Management – Data Protocol: Application Interface Part 1: Application interface Part 2: Registration of RFID data constructs Part 3: RFID data constructs
	ISO/IEC 15962	Data Protocol	Ballot approved	Information Technology, Automatic Identification and Data Capture Techniques – Radio Frequency Identification (RFID) for Item Management – Data Protocol: Data Encoding Rules and Logical Memory Functions
	ISO/IEC 15963	Data Specifications	Published	Information Technology, Automatic Identification and Data Capture Techniques – Radio Frequency Identification for Item Management – Unique Identification for RF Tags
	ISO/IEC 18000	Air protocol	Various	Part 1: Defines the foundation for all air interface definitions in the ISO/IEC 18000 series Part 2: Parameters for air interface communications below 135kHz Type A (FDX): 125 kHz Type B (HDX): 134.2 kHz Part 3: Parameters for air interface communications at 13.56 MHz Part 4: Parameters for air interface communications at 2.45 GHz Part 6: Parameters for air interface communications at 860 to 960 MHz Type A and type B with the primary difference being the anti-collision algorithm used Part 7: Parameters for active air interface communications at 433 MHz

Standard's Body	Standard	For	Status	Scope
	ISO/IEC TR 18001	Item Management	Published	The result of three surveys identifying the applications for RFID in an item management environment, and the resultant classification of these applications based on various operational parameters, including operating range and memory size.
	ISO/IEC TR 18046	Device Performance	Various	Information Technology, Automatic Identification and Data Capture Techniques – Radio Frequency Identification Device Performance Test Methods Part 1: Test methods for system performance Part 2: Test methods for interrogator performance Part 3: Test methods for tag performance
	ISO/IEC TR 18047	Test Methods	Published	Information Technology, Automatic Identification and Data Capture Techniques – Radio Frequency Identification Conformance Test Methods – Part 2: Test Methods for Air Interface Communications below 135 KHz Part 3: Test methods for air interface communications at 132.56 MHz Part 4: Test methods for air interface communications at 2.45 GHz Part 6: Test Methods for Air Interface Communications at 860-960 MHz Part 7: Test Methods for Active RFID Air Interface Communications at 433 MHz
	ISO/IEC 24729	Implementation guidelines	In progress	Information technology — Radio frequency identification for item management — Implementation guidelines Part 1: RFID-enabled labels Part 2: Recycling and RF tags Part 3: RFID interrogator/antenna installation

Standard's Body	Standard	For	Status	Scope
	ISO/IEC NP 24791	Software/ Middleware		Information technology, Automatic Identification and Data Capture techniques — Radio frequency identification (RFID) for item management — Software system infrastructure — Part 1: Architecture Part 2: Data management Part 3: Device management Part 4: Application interface Part 5: Device interface Part 6: Security

GLOSSARY

Air-interface-protocol: This is the communication between a reader and a tag that can occur as follows: modulated backscatter, magnetic coupling, transmitter, or transponder type.

Backscatter: This communication applies only to passive and semi-passive tags. The communication starts with the reader sending a continuous wave of radio signal containing alternating current (AC) power and a clock signal. This type of communication is called Interrogator-talks-first (ITF). The passive and semi-passive tags in this case depend on the reader's power to communicate data.

Magnetic coupling: In this communication the reader provides a magnetic field which is used to power the micro chip inside the tag. The strong magnetic field only exists in the proximity of the readers' antenna. Magnetic coupled RFID systems are sometimes called "proximity RFID" due to its operational ranges of less than 10cm. Common frequencies for such magnetically coupled RFID systems are 125 kHz and 13.56 MHz. [32]

Transmitter: This communication applies to active tags that send in regular intervals a radio signal irrespective of the presence or absence of a reader. This communication is also called Tag-talks-first (TTF)

Transponder: This communications occurs when active tags go into a "sleep" mode if there is no interrogator emitting a radio signal. In this case the "sleeping" tags send a signal in predetermined intervals to find out if there is a reader close by. Once a reader receives a signal from the tags, the reader sends a "wake up" instruction for the tags to resume the transmission of data.

Anti-collision: A general term used to cover methods of preventing radio waves from one device from interfering with radio waves from another. Anti-collision algorithms are also used to read more than one tag in the same reader's field.

Closed Systems: A closed system is when all relevant data regarding the attributes of the object is stored in a common data base. It usually refers to a system under the control of a single owner or authority.

Controller: A device that controls the transfer of data from a computer to a peripheral device and vice versa.

Middleware: Defined as the software layer that lies between the readers and the applications on each site of the system. The middleware is responsible for the following functions: hiding distribution, hiding the heterogeneity of the various hardware components and communication protocols, providing uniform, standard, high-level interfaces to the application developers and integrators, and supplying a set of common services to perform various general purpose functions, in order to avoid duplicating efforts and to facilitate collaboration between applications.[131]

Modulation: The methods of modulating or altering the carriers in order to carry the encoded information are quite varied. They include amplitude modulation (AM)/ phase modulation (PM), frequency modulation (FM), frequency shift keyed (FSK), pulse position (PPM), pulse duration (PDM) and continuous wave (CW). In some cases, different modulating techniques are used in each direction (to and from the tags).

Open System: Application in which reader/writers do not have access to a common data base.

Protocol: The special set of rules for communicating that the end points in a telecommunication connection when they send signals back and forth.[132] Protocol can also be defined as the language spoken among computers that helps them exchange information.[133]

Radio Frequency: an electromagnetic wave whose frequency lies between 30 Hz to 300 GHz. RFID frequencies is usually between 30 KHz and 5.8 GHz. Thus, RFID can be classified as: low frequency or LF (30 – 300 KHz), high frequency or HF (3 – 30 MHz), ultra high frequency or UHF (300 MHz – 1 GHz), and microwave frequency (1 GHz – up).

Read Rate: The maximum rate at which data can be read from a tag expressed in bits or bytes per second.

Read/Write: Many applications require that new data or revisions to data already in the Tag, be entered into the Tag, while it remains attached to its object. Tags with this capability are said to be reprogrammable and are called read/write tags, memory cards or memory modules.

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131 http://middleware.objectweb.org/

132 http://www.lanyon.com/support/Glossary/Glossarye-p.htm

133 http://www.liv.ac.uk/webteam/glossary/

Tag: The transmitter/receiver pair or transceiver plus the information storage mechanism attached to the object is referred to as the tag, transponder, electronic label, code plate and various other terms. Although transponder is technically the most accurate, the most common term and the one preferred by the Automatic Identification Manufacturers is tag.

Write Rate: The rate at which information is transferred to a tag, written into the tag's memory and verified as being correct. It is quantified as the average number of bits or bytes per second in which the complete transaction can be performed.