Market Research for RFID Real-time Cold-chain Monitoring System

Master of Science Thesis

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Stockholm 2010-11-18

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Thesis Number: TRITA-ICT-EX-2010:296
Abstract

With the surging of cold-chain logistics industry, people pay more and more attention to the quality of cold-chain control. There emerge many approaches monitoring the dynamic situation along all the phases of the whole cold supply chain including processing, storage, transportation and selling.

Here in iPack Center, KTH, a RFID real-time cold-chain monitoring system is presented. The system is aiming to track and monitor the situation of goods in-transit in real-time including the position, temperature, relative humidity as basic monitoring issue, gas concentration and shock parameters as optional. To know in which way and toward whom this product can position itself, a deeper investigation and knowledge of the current cold-chain logistics industry is essential.

Some field interviews are conducted towards companies that are involved in cold-chain logistics industry at different segmentations majorly in pharmaceuticals and foods. The companies are chosen elaborately that they are considered that they can represent the market environment of cold-chain monitoring to some extent. The real thought and expectations from them are valuable as a useful reference to improve iPack’s own RFID tracking system in some detail or specification way as well as identify the real business opportunity, deduce the business model towards different parties that involved in this industry for the future work.
Acknowledgement

The work of this thesis was performed at iPack Center in the School of Information and Communication Technology, KTH. I am grateful to the iPack Center for enabling me to pursue my thesis for such an interesting topic.

During my last four years studying in KTH, I have gotten tremendous help and support from numerous kind people. Now I would like to use this opportunity to express my very deepest gratitude to all of you and in particular to the following persons:

**Professor Lirong Zheng.** I’m so grateful that you grant the opportunity for me to pursue my study in KTH. The gracious help that you offered in the later years include this thesis work is also appreciative. You are such an inspiration as a scientist, an entrepreneur and a friend. Your enthusiasm in science, entrepreneurship as well as the way of life is truly contagious. Thanks a million for everything!

**Dr. Chen Qiang** and **Pang Zhibo**, thank you so much for providing me this thesis opportunity that timely. The kind help along the whole process till now is beyond words. I really appreciate the kind guidance you gave and the valuable time you bestowed. I’m much obliged to you for always being there supporting and edifying me.

For the people that shared their valuable time to be interviewed, I will also express my greatest thankfulness to all of you, for your kindness and selfless help. Without you, the process of this thesis would not be this smooth. The people who contributed in the interview is: **Per Norman** from Billerud AB, **Andreas Kjällander** from World Courier (Sweden) AB, **Malin Schäfer** from Ewerman AB, **Bengt Petersén** from SABA Fresh Cut AB, **Mrs. Liu** from Sinopharm Logistics Co., Ltd, **Ren Zijun** from HAVI Logistic Services (Beijing) Co.Ltd, **Wang Li** from Guangzhou Nanland Air Catering Co. Ltd, **Mr. Yu** from NT Pharma Group, **Wang Huaiqing** and **Liu Xingyu** from Sinotrans Group.

For my dearest friends in Sweden, thank you for all the happy memory you gave me and the time we shared together. It is a great period and experience to have you accompany me for the life in Sweden. Among those, I would like to express my distinguished appreciation to **Dr. Cheng Qing**. Thanks for the lucky chance to have you to be my closest friend, all the memory with you is truly impressive. Thank you for always bestowing encouragement and “supervision” to me, and always taking considerate care of my life. Wish I could realize the “blueprint” to proceed this delightful friendship with you in Sweden. Meanwhile, a special thank to **Jacob Bartoletti**, my very best Swedish friend, thank you for always keeping me in mind.
and being my comprehensive Swedish Wikipedia. It is really enjoyable and appreciated to have you in my life for the past couple of years.

**My dearest parents and grandparents,** the greatest thankfulness should be conferred to you, for doing your utmost to bring me up. For my dearest grandpa and grandma, from the day I was born, you dedicate all your love and energy to foster me. I will bear these in mind forever and ever. For my dear mum and dad, the gratitude is beyond words for supporting me not only in the economic way, but also to be my best friends of life. Thanks for your timely help and consideration no matter what problems I encountered. There is still a long journey for us to go, I’ll make all of you feel proud of me!
Table of Contents

1. Introduction .................................................................................................................. 3
   1.1 Background of cold-chain monitoring ..................................................................... 3
   1.2 Introduction of RFID cold-chain monitoring system ............................................. 4

2. Research methodology .................................................................................................. 6

3. Real market study and interviews summary ............................................................... 7
   3.1 World Courier Management Inc. ............................................................................. 7
      3.1.1 Company briefing (www.worldcourier.com) ...................................................... 7
      3.1.2 Interview summary ......................................................................................... 9
   3.2 Sinopharm Logistics Co., Ltd. ................................................................................ 13
      3.2.1 Company Briefing (www.sinopharmlog.com) .................................................. 13
      3.2.2 Interview summary ....................................................................................... 19
   3.3 Allfrukt & Ewerman AB ......................................................................................... 21
      3.3.1 Company briefing (www.ewerman.se) ............................................................ 21
      3.3.2 Interview summary ....................................................................................... 23
   3.4 HAVI Logistic Services (Beijing) ........................................................................... 25
      3.4.1 Company briefing .......................................................................................... 25
      3.4.2 Interview summary ....................................................................................... 26
   3.5 Guangzhou Nanland Air Catering Co. Ltd. ............................................................ 31
      3.5.1 Company briefing ......................................................................................... 31
      3.5.2 Interview summary ....................................................................................... 31
   3.6 Saba Group ........................................................................................................... 34
      3.6.1 Company briefing (www.saba.se) ................................................................... 34
      3.6.2 Interview summary ....................................................................................... 35
   3.7 NT Pharma (Group) Co. Ltd., ............................................................................... 37
      3.7.1 Company briefing ......................................................................................... 38
      3.7.2 Interview and studies .................................................................................... 38
   3.8 Jointown Pharmaceutical Group Co., Ltd. ............................................................. 42
   3.9 Sinotrans Air Transportation Development Co., Ltd. .......................................... 43
      3.9.1 Interview summary ....................................................................................... 43

4. Analysis ....................................................................................................................... 45
   4.1 Market demand analysis ......................................................................................... 45
      4.1.1 End-user demand analysis ............................................................................. 45
      4.1.2 Customer demand analysis ........................................................................... 45
   4.2 Michael Porter’s Five Forces Analysis .................................................................. 47
      4.2.1 The threat of substitute products .................................................................... 47
      4.2.2 The threat of the entry of new competitors ..................................................... 48
      4.2.3 Current Intensity of Competitive Rivalry ....................................................... 48
      4.2.4 The bargaining power of customers ............................................................... 49
4.2.5 Bargaining power of suppliers

5. Conclusion

References

Appendix
  A. Information matrix of interviewed person
1. Introduction

1.1 Background of cold-chain monitoring

The term of “cold-chain logistics” is a systematic procedure that refers to the comprehensive management for ambient sensitive products that demanding controlled environment along the whole supply chain including phases of producing, storage, transportation/delivering and selling to ensure the quality of the products meanwhile slashes the cost from preventing the dispose of degraded products. Cold-chain not only means to keep products chilly, but it also can be something need hot temperatures or high/low humidity etc. Among the four major phases, transportation/delivering process is the most vulnerable due to the potential great change of ambient and the limitation of technology to monitor and control the goods’ condition in-transit. The risk of occurrences of quality degradation due to temperature change is relatively higher. In this way, it’s really essential and stringent to find a proper and efficient approach to track the status of goods in-transit.

In the conventional way, digital data loggers or chart recorders will be mounted in trailers or containers with goods, as well as time temperature indicators (TTI) that may be stuck to the packages of goods. At some certain checkpoints of the cold-chain, the loggers will be inspected manually and the temperature history may be downloaded to the companies’ ERP system for delivering to the customers as well as analyzed by themselves. The result of some elaborate experiments shows that even though the trucks are equipped with state-of-art cooling devices, the temperatures are still varied by several degrees at different positions within a truck container [1], that’s to say a monitoring sensor at a fixed single point with whole-load environmental recording task in common use today is not efficient and accurate enough to measure the real goods’ temp appropriately. A more accurate and efficient monitoring method for in-transit goods at a granular package level is on demand. Meanwhile the requirements of obtaining real-time information of the goods are also surging.

Thus an innovative technology to realize the real-time and more accurate tracking of the cold-chain transportation status is introduced by the invention of active RFID tags with embedded sensor and on-chip memory, working jointly with GPRS/CDMA network module. It’s now being adopted by more and more companies which are somewhere involved in some process of the cold supply chains of high value products such as clinical trials, special pharmaceuticals, blood samples, expensive foods, some rare species flowers as well as precision electronics etc, especially for the long-haul transportation with many turning points.

Nowadays, there are some companies which engaged in providing IT solutions or in the field of developing traditional data loggers have already launched research in this
RFID tracking technique and some of the companies which involved in the cold-chain logistics have adopted this customized system to some extent. Even though these RFID tracking system are used in some certain niche markets with a small scale now, it is still considered to be very promising for the future development of the cold-chain logistics monitoring. This set of system will most likely go to mass market later on when the technology is more mature and cost of those tags are reduced.

1.2 Introduction of RFID cold-chain monitoring system

Based on the trend and real requirement from the industry, adding on the expectation of offering customers with add-value service from Billerud AB, a global cold-chain monitoring and tracking service is presented, in which a set of primary environmental conditions for transportation of environmental sensitive goods, including global position, temperature, relative humidity, concentrations of CO₂, O₂ and ethylene gases and 3-axis acceleration (represent vibration or shock occurrence during the transportation), is collected through mobile and remotely controllable wireless sensor nodes. Real-time monitoring, tracking, alarming, close-loop controlling and information sharing could therefore be provided to the customers as WEB services with service oriented architecture.

The proposed service in managed by an Operation Center (OC), which controls all the sensor nodes, databases and provides all services to users. Services are accessible through kinds of terminals covering from complicated enterprise resource planning (ERP) system to personal laptop and mobile phone. Typical user interface comprises a web based data analysis and visualization tool, a GoogleMap™ compatible route tracking tool and a Short Message Service (SMS) based alarming and query tool for mobile phone users.
Figure 2. The packaged master and slave sensor node

The temperature and relative humidity data will be sampled by the sensors inside the slave sensor nodes (SSN) deployed with high density all over the cargo container according to the frequency set by the customer. The sampled data will then be sent to the master sensor node (MSN) by the RFID component in the SSN. The measurements of concentrations of CO\textsubscript{2}, O\textsubscript{2} and ethylene gases and 3-axis acceleration are conducted by the MSN. From MSN, the data can be forwarded to the end-users via commercial telecom network, thus the real-time tracking and monitoring function is realized. Meanwhile, an alarming mechanism can also be enabled by the customer, which means the end-user or the truck driver could get alarm SMS, if the data being observed exceed the set-value range. Thus, the close-loop control can be triggered.\textsuperscript{[2]} Besides of real-time monitoring, the final whole record/report will also be an essential reference for the goods receivers to make a right judgment of whether the goods are acceptable.
2. Research methodology

The main aim of this thesis research is to gain knowledge from the real market about how the cold-chain monitoring approaches are implemented in different segmentations of cold-chain industry thus to fulfill investigation of the potential markets environment, and to know how is companies’ thought and expectation about the cold-chain management to identifying the business opportunity for such monitoring system etc. Based on these real feedbacks, some conclusion can be extracted to provide opinions and suggestions to improve the functionality and elaborate the detail of operability of the existing system, thus to make it more competitive when launching in the real market.

To achieve the above purpose, plenty of real interviews with the responsible persons from various companies have been conducted either by telephone or by on-site visit. The target companies were chosen carefully after collecting relevant information from internet about the business scale of companies and their current methods that serving customers. They are majorly famous ones in the pharmaceutical as well as food industry either in China or Sweden with high reputation in the relevant fields of their own cold-chain management experience. Their opinions or expectations will be very valuable and meaningful for the system making improvement or marketing decisions.

The interviews are designed more or less based on the following issues:
- Get to know the company’s main business and its work flow.
- Their on-going approaches for monitoring the goods in warehouses and in-transit.
- The requirements from their customers regarding the cold-chain quality control.
- Their own feelings and opinions about the current system.
- Plan of making any changes regarding the cold-chain management issue.

The criteria may vary depending on the diversified situation in different industry fields and companies.

Afterwards, the demand of market will be summarized from the real thought of those companies. The competitors’ analysis will also be conducted in the form of Michael Porter’s Five Forces Analysis.
3. Real market study and interviews summary

3.1 World Courier Management Inc.

3.1.1 Company briefing (www.worldcourier.com)

World Courier is the world leading company that offers the specialty logistics services for the medical and bio-pharmaceutical communities, it had successfully transported the first human heart tissue for transplant in 1984. Today, World Courier is utilized in approximately 80% of the world’s clinical trials requiring the use of a specialty courier service. With experience in managing the logistics of over 7,500 clinical trials worldwide, World Courier is the well-known expert in handling temperature-sensitive specimen and drug distributions. World Courier is also the only specialty courier with a truly global presence, having established over 140 offices throughout the world. The other specialty courier services are forced to subcontract the majority of their work to various third party vendors around the world, due to their absence of the global office infrastructure. In this way, World Courier is confident to provide their customers same level of high quality service no matter where the customers are located.\textsuperscript{3}

The rigorous standard in quality assurance “ISO 9001-certified” is granted to every World Courier office. It is the only specialty courier whose SOPs and systems meet the strict requirements of this independent certification.\textsuperscript{21} Meanwhile, as a courier company in the bio-pharmacy field, the internationally-recognized standards “GxP” including such as GMP (Good Manufacturing Practice), GSP (Good Storage Practice) and GDP (Good Distribution Practice) etc. used as World Courier’s compliance that guide them to ensure that the storage and distributions are safe. Among those “GxP” guidance, GDP is considered to be the most essential for World Courier business, since most of the missions that World Courier takes are transporting the clinical trials together with pharmaceuticals. GDP governs the proper distribution of medicinal products for human use and regulates the movement of products from the manufacturers’ premises (or other central point) to the end user (or other intermediate point). As such, World Courier’s Good Practice policy is based on, but not limited to, the following guidance documents that deal with GDP:

- Health Canada Guidelines for Temperature Control of Drug Products during Storage and Transportation, 2005
- Irish Medicines Board Guide to Control and Monitoring of Storage and Transportation Temperature Conditions for Medicinal Products and Active Substances, 2006
- USP chapter <1079> Good Storage and Shipping Practice
- EU Guidelines on Good Distribution Practice of Medicinal Products for Human Use (94/C 63/03)

Although GDP compliance is defined as the main driver for the company’s GxP policy, World Courier also embraces elements of GMP (Manufacturing), GSP (Storage) and GCP (Clinical) as they relate to World Courier’s core transportation business. [3]

At World Courier, every shipment containing biological specimens, investigational drugs, vaccines, etc. is handled on an individual basis by the trained and experienced employees. To do this, every shipment can be ensured arriving on time and in perfect condition. The comprehensive clinical trial services include but not limited to:
- Being a local site resource. By working closely with investigator sites to review logistics protocols, they eliminate a major source of potential problems during the study.
- Providing cold chain management expertise including strict SOPs on 2°C-8°C handling.
- Individual shipment monitoring from pick-up to delivery, including real-time online tracking with protocol and site-specific details.
- Dry ice and gel pack replenishment as well as in-transit temperature monitoring. [19]

World Courier’s experts recommend and provide appropriate packaging and refrigerants to guarantee the safety of customers’ temperature-controlled shipments. They can also design customized packaging to meet the unique requirements. All packages are strictly tested and qualified under a variety of conditions that may occur during transit. Refrigerants are routinely checked and replenished during transit as required. [20]

The cold-chain logistics service features of World Courier are generally as follow:
- In-Transit Temperature Monitoring for Controlled Ambient, 2-8°C, etc.
- Comprehensive Guidance with Country Specific Import Requirements
- Global SOP’s for All Temperature Ranges
- Consultation on Specialty Packaging Solutions
- Refrigerated Trucking Services
- GMP Compliant Depot Storage Facilities in Argentina, Australia, Brazil, Chile, China, Colombia, India, Mexico, Peru, Russia and South Africa. [21]

World Courier is proud of their most advanced data management system known as Bio-STAR℠, with which World Courier can proactively anticipate and prevent costly transportation problems that are so often unavoidable when conducting studies.

Bio-STAR℠ majorly engaging in: [22]
Market Research for RFID Real-time Cold-chain Monitoring System

- Coordinate site logistics to minimize transit time.
- Effectively manage changes in protocol and site information during the course of the study.
- Provide customers and staff with real-time access to protocol and site-specific details.
- Supply customers with a variety of automatic email alerts.

This management system also offers access to the customers to track their shipments. The information is initialized since the goods was picked up from the customer, an email notification containing complete flight details and the expected delivery time can be generated and sent to the customer. Using a secure intranet system that links World Courier offices worldwide, the customer will know exactly where the shipment is throughout transit. The email auto-alert function can also be programmed to provide instant delivery notification including the time/date of delivery and the name of the individual who signed for the shipment.  

3.1.2 Interview summary

Based on company’s pharmaceutical courier’s leading position as well as consider the technology of cold-chain tracking and management in such company, an on-site interview with Andreas Kjällander the network manager from the department of cold-chain development & compliance in World Courier Sweden has been conducted.

World Courier Sweden site doesn’t engage itself in the goods storage service, there are no depots in Sweden, so the questions regarding their cold-chain management are all based on the issues that involved in the goods transportations.

- The general workflow and the assortment of customers:

The general workflow:
The pharmaceutical manufactures or hospitals will inform about the shipments to World Courier quite in advance, they will provide all the address of the receivers and their requirements for different kind of goods. World Courier will register and save this information in the Bio-STAR system, and prepare studies will be done carefully for those upcoming shipments. At the time of real shipping, World Courier will pick up the goods from clients either with their own packages that designed specially according to the goods and clients’ requirements or the goods have already been wrapped up by the clients. After that, the goods will be loaded on the earliest flight to the destinations thus to achieve the most prompt delivery. The partner airlines to different destinations are elaborately assessed by World Courier as they want their goods can be taken in very good care during flights.

World Courier’s customers are companies from big pharma to small pharma, as well as hospitals and clinics all over the world.
Current temperature monitoring method along the cold logistics chain:

They don’t have any warehouses/depots to store the specimen or pharmaceuticals in Stockholm site.

For the monitoring approach during the way of transportation is that they are using different kinds of temperature monitors (brand like Sensitech, Elpro etc.) to record the history of temperature along the way. The monitors are placed inside the packages together with the goods themselves, they are not be placed among the gel-pack or dry ice. So the temperature of the goods is accurately recorded. The temp recording is initialized by press the “start” button of the monitors. Many temp inspections will be conducted manually by open the packages and read the data on the monitor’s screen and take a record at every checkpoint along the whole journey (eg.when receiving from clients, before loading on the flight, after taking off the flight, in the store room at the transferring airport and at the time of delivering to receiver.). So far this temp statistics gotten at every checkpoint will not be tracked by the customers on-line, unless the staff from World Courier who is doing the inspections found something wrong with the temp, he/she will then immediately report the situation to the customer for them to make a decision of either taking a remedial operation or retrieving the whole batch of goods and discard them. If there is no temp error detected at the checkpoint inspection, the customer will be offered a PDF format temp history graphic by E-mail after delivering the goods to the receivers.

The temp monitors that World Courier is using have various kinds. The old version monitor doesn’t have USB port, when the shipment is concluded, the monitors must be taken to World Courier’s office and read the data by a special interface. The clients and the receivers need to wait for a while for getting the graphics by E-mail. The new version monitors are equipped with USB port, the temp history can be generated as a PDF file when connecting the monitors to a laptop, and thus the receiver can get the temp log instantly at the point of accepting the goods.

These temp monitors have been calibrated very rigorously both by the manufactures and World Courier. Some of them can be used for many times, the others are only capable to be used for a single shipment. Even though the single-used monitor cost generally around 30~35 Euro each, it is still negligible when comparing with the value of the goods. The owner of such high value goods just need their goods to be delivered the safer the better.
The temp monitors in general have 2 different level of accuracy, one can be accurate to 0.55°C, and the other is accurate to 0.22°C for more sensitive goods. The sampling frequency for every monitor is configurable by World Courier. There is a sticker on the backside of every monitor, which records the information of the expire date, interval of sampling (eg. 5 minutes or 10 minutes), monitoring temperature range (eg. 2 °C-8 °C), capable working duration (eg. 13 days or 50 days). As Andreas said, not every shipment’s temp need to be monitored, some goods are tolerant to a wide range of temp. But some goods can be very sensitive to temp. If the agreed temp range is 2°C -8°C, a slightly temp increase above 8°C may cause the whole batch turn into spoilage. So World Courier will chose the most suitable temp monitors for each shipment based on both their own experience and the customers’ requirements.

Regarding the temp monitors retrieval issue: there is an unique ID for every monitor, the sticker with the ID is adhered to the monitor. Normally, the goods will be delivered by the staff from World Courier’s local office, the staff must follow the instructions to take the monitors and sometimes also the packages back. Even though in some cases, the final delivery work is subcontracted to other company, the drivers also must follow the agreement with World Courier to take the required thing back.

The opinion of adopting RFID monitoring system:

According to what Andreas said, they are not using any RFID solution at the moment. But in order to offer their customers better service, they have to step further on the way of monitoring the temperature of the goods during shipments. They show great interests on the RFID tag with embedded sensors to be their new monitoring device. Recently they are looking to find different manufactures that providing RFID
solutions (for example the US company “SensorLogic”).

As in Andreas’ opinion, most of the companies engaging in the pharmaceutical business are interested in the RFID solutions used in monitoring cold-chain. Since comparing with the conventional temp logger, RFID tag’s size is much smaller, it’s very essential to have a smaller device that can be placed right and closer to the goods in the package to get a more accurate data. Sometimes, the temp logger is way too large to be inserted in the box, close to the goods. In addition, currently the inspection of temp at the checkpoint needs to open the packages and take out the logger for collecting data. By doing this, the possibility of damaging the goods as well as violating the agreed temp range will arise. If the temp data can be collected without opening the package, the goods might be protected better. Meanwhile, the real-time and remote tracking functions are also considered to be interesting and useful.

But there also arises problems, since most of World Courier’s service is operated by aircrafts on which the GPS or GPRS as well as active RFID is strictly prohibited by International Air Transport Association (IATA) due to safety reason. Andreas also revealed that there is an US company who has developed a device that integrate temp sensor, RFID as well as GPRS together. The GPRS function can be turned off automatically when it on-board of a flight. This product is now under test by IATA. This device so far is much bigger than the normal active RFID tag, and the cost of it is really high.

- The potential scale of the RFID monitoring system when the company adopts it.

Andreas reveals that the scale or the quantity of such RFID tags is still hard to figure out, but World Courier is a company with more than 140 offices globally. Once this method is introduced, the scale won’t be too small.

- The general commend about the future RFID cold-chain monitoring system.

  - The RFID tags must be as small as possible but robust. As the goods they send are with various package sizes from 10cmx10cmx10cm up to a big pallets.
  - The devices must be calibrated carefully, certain accuracy of temperature must be achieved.
  - The signal that emits from the active RFID tag must be receivable through liquid, since the goods are always surrounded by gel-packs or dry ice at every side of the packages. The signal must be strong enough to go through those liquid materials and received by the handset out of the package.
To work stably under low temp is also expected.

If the RFID solution provider can also develop a system/database that specifically used for saving temp data in unified format after collecting, easily making comparison between different shipments will be more than welcomed. Recently, World Courier doesn’t have special database for saving the temp data, all the temp graphics are saved in PDF format, shipment by shipment. The original temp data format that generated by the monitor is not compatible between different brands of monitors.

3.2 Sinopharm Logistics Co., Ltd

3.2.1 Company briefing (www.sinopharmlog.com)

Sinopharm Logistics Co., Ltd was established in May 2004, with registered capital of 3 hundred million RMB, it is the wholly-owned subsidiaries of Sinopharm Group Co., Ltd. It establishes increasing numbers of modern chain pharmaceutical distribution centers in big cities, among those, the 5 biggest ones in Shanghai, Beijing, Tianjin, Guangzhou and Shenyang are considered to be the bases of the whole distribution network that covers nearly the whole country’s area. (The whole network covers over 30 provinces, 300 secondary cities, more than 10,000 hospitals, 100,000 clinics and pharmacies) The company in total owns around a hundred thousand square meters warehouses, 230 trucks for transferring goods among those 30 are refrigerated trucks. In the year 2009, the company has transferred goods that worth over 50 billion RMB. [23]
All of the logistics centers within the company implement a unified operating standard and centralized operation data system to ensure the coordination and efficiency of the whole network. The company is using a comprehensive web-based warehouse management system (WMS) to deal with various operating command. This system is easily compatible with the other ERP (Enterprise Resource Planning) or MHE (Material Handling Equipment) systems that in used by the company. Thus, comprehensive and complete logistics information can be achieved both by the company itself as well as their customers. The share of such information via web service will connect all the parties involved in the supply chain together in harmonious. The company carries out tracking and monitoring activities in every step that they are in charged in order to offer their customer with more than satisfied logistics service.

Their core services include:

- **Warehousing service**: The company is capable to offer customers with GSP (Good storage practice) qualified and other special ambient requirement warehousing service. For example, the cold-chain management service for the vaccine products etc.

- **Delivery service**: The delivery network covers most of big hospitals, pharmacies and clinics in the country.

- **Distribution processing service**: re-packaging, re-processing and other value-added services.[5]

The logistics solution embraces.[24]

- **Multi-warehouse operating mode**:

  The advantages:

  - Orders that come from the area that close to the distribution center will be confirmed in 24 hours.
  - The transportation duration is strictly controlled in 48 hours, which to a great extent keep the pharmaceuticals’ package and quality free from external violations.
  - There are 2 out of 3 portions of delivery are handled by trucks, which save the logistics cost effectively compare with delivered by other means.
  - If system crash or disasters occur at one of the distribution centers, the system will automatically dispatch goods from the other nearest depot. Thus to reduce
the risk of delivery failure.

- **Cold-chain service:**
  - **Special packaging:**
    - The goods will be placed inside a special polyfoam box with dry ice or frozen gel-packs wrapped around.
    - The package must be validated for temperature controlled between 2°C to 8°C for 48 hours.

![Figure 6. Polyfoam box](image)

![Figure 7. Gel-pack](image)

**Cold-chain transportation:**

- Refrigerated trucks with independent cooling system, the in-transit temperature control and printing functions are also introduced.
- Routinely maintenance and temperature validation.
- Skillful staffs that can offer coordinated dispatching service for 8 hours per day, 5 days per week.
- The order confirmed on the first day, will be delivered together in the coming morning, and 48 hours delivery guarantee is issued after the order confirmation.
Temperature monitors:

- One temperature monitor will be placed inside the truck for each shipment to record the temperature along the whole delivery honestly.
- At both the goods receiving and delivery point, the temperature graphics must be printed out, in order to get approved by the random inspection or the whole batch of goods must be returned due to the abnormal temperature history.
Vehicle mounted GPS receiver and visual management system:
- The condition and position of the truck in-transit can be visualized and tracked remotely via the system.
- The timely information about the truck in-transit will be sent to the customers in order to facilitate their receiving work.

Cold—chain validation system:
Due to the temperature sensitivity of the goods being transferred, a comprehensive
and strict validation for all aspects of the cold-chain must be conducted, it includes the following issues:

- Warehouse temperature validation
- Refrigerated trucks’ dynamic temperature validation
- Cold-chain packaging validation
- Temperature validation during different seasons
- Special ovens that used for simulating various temperatures ambient

![Figure 14. Packaging](image)

Vaccine logistics service:

- Comprehensive vaccine control process:
  - The company has developed a comprehensive and rigorous vaccine quality control system and regulation.
  - 18 management rules and 8 detailed operation standards are implemented specially for the logistics of vaccine products. The routinely validation and record of transportation vehicles and warehouse devices is conducted. The staffs are also get regular training.
  - Achieved recognition from big vaccine suppliers GlaxoSmithKline and Sanofi-Aventis.

![Figure 15. Temperature graphic (Generated by Elpro’s temp monitor)](image)

3.2.2 Interview summary

Based on the descriptions above, an interview with distribution manager Mrs. Liu from Sinopharm Logistics Co., Ltd’s Beijing distribution center was conducted.

According to Mrs. Liu’s introduction and answer to the questions, the current cold-chain management situation that goes on with company is elaborated as below:

- General introductions of Beijing distribution center:

  Beijing distribution center covers an area about 27,000 m², with warehouses area 20,000 m². The pharmaceuticals are stored inside cooling warehouses as well as refrigerated warehouses with storage positions in AS/RS (Automated storage and retrieval system) depots, heavy goods depots and scattered goods depot. The center owns more than 10 refrigerated trucks and connects with over 1,500 hospitals and company clients inside or around Beijing. As a 3rd party pharmaceutical logistic company, the center is qualified with the national GSP standards, and successfully introduced the gold standards of quality control “ISO-9001 certified”
Current monitoring approaches for the cold-chain:

Inside the warehouse, the temperature is monitored remotely in-real time by the sampled data from the sensors fixed inside the warehouses. The alarming mechanism has also been adopted, when the temperature goes out of the setting range. The alarm notification will not only be shown on the screen in the monitoring room, but also can be sent to the responsible person’s mobile phone which the number has already registered in the system. When the person who get the alarming SMS reply “Y”, the information in detail about which warehouse’s temperature went wrong, how much is the current temperature etc. will be sent back.

On the way of delivery, all the trucks have to be inspected and validated carefully. The temperature inside the truck is controlled strictly depends on the requirements of the certain shipment. The delivery service has a time-guarantee which is 4 hours for delivery inside Beijing area, and 48 hours for the delivery out of Beijing. Every truck is equipped with GPS module and the temperature inside the truck container is measured by an inner fixed sensor. The GPS information together with the temps data will be sent back via GPRS network by a customized frequency (currently is per 15
minutes a transmission), in this way the company can monitor the trucks condition remotely in real-time. In addition, every shipment will take a temp logger among the goods on board which the temp’s history will also be recorded more accurately by this logger. When the goods arrive at clients, the temp’s history graphic can be printed out by the handset and shown to the clients as an evidence for them to make decision of acceptance.

- The consideration of RFID monitoring system for the cold-chain:

Mrs. Liu tells that the way they’re monitoring the cold-chain is more or less edified by NT-Pharma Co., Ltd which is considered to be the best of cold-chain management within the pharmaceutical logistics field. NT-Pharma has already used RFID solutions to monitor their cold-chain since 2008. As Liu said, the current GPS + fixed sensor real-time monitoring system is satisfied so far. Meanwhile, Liu also told that from the logistics companies like them receive medicines from the manufactures to the delivery to the end users, the only criteria that they will check and be responsible for is the damage of the medicine’s packages. The test of the medicine’s quality will only be conducted either by the manufactures or by the end-user. But the temperature records are so important that they can be the indispensable evidence to make disclaimer if the batch of goods are tested to be contaminated.

The bigger advantage of using RFID is that a more accurate and comprehensive temp data can be achieved due to Liu’s opinion. But she also cares much about the cost of not only the single RFID tag, but also the whole systems. She wondered about the capability of retrieving the RFID tags back after a delivery, also the tags must work stably at a freezing cold ambient and how to make sure that the tags are sensing the real medicine for all the time not gel-packs’ temp is also an operation detail that she took into account.

### 3.3 Allfrukt & Ewerman AB

#### 3.3.1 Company briefing (www. ewerman.se)

Ewerman AB, Allfrukt in Stockholm AB together with Satotukku Oy are subsidiary companies belong to STC Green Food which is part of STC Group. They are engaging in the fruits and vegetables trading business. These companies specialise on purchasing, import, wholesaling and distribution domestically in Sweden and Finland.

In Sweden, STC Green Food is the largest independent importer, wholesaler and distributor of fruits and vegetables. The companies in STC Green Food offer a complete range of products to customers in the wholesale, foodservice and retail segments. Another strong competitive factor is the company's logistics know-how,
which entails that quality is maintained throughout the supply chain, ensuring that fresh and high-demand products are always delivered to the right customers at the right time.\[6\]

Based on STC GreenFood’s background, the Ewerman AB was chosen to be a representative that a deeper look at their cold-chain management issue will be carried out.

The Ewerman AB not only works as a fruits and vegetables wholesaler and distributor, but also as a food producer. So they have accountability to regulators, customers and consumers to produce safe food.

To do this, there is a comprehensive legislative and administrative control that is responsible for ensuring that laws and regulations. There are also requirements that the company has a proprietary control system in place that shows the company regularly check themselves.

Ewerman AB has decided to make an improvement in their work by inviting a 3rd party company (Procanitas certification AB) certify Ewerman AB’ service based on the BRC Global Standard. This standard is a tool that ensures all the bits that need to be in place to produce safe food, is actually in place.\[8\]

The standard addresses 10 fundamental requirements that are divided in areas such as human resources, process management, product management, construction requirements, quality management and establishment of HACCP plans. It sets great requirements on the cleaning and hygiene, traceability, training of staff and the internal audit work in the BRC standard.\[7\]

BRC standard focuses on the persistence of successful practices throughout the year and not just at the time of certification. Thus it is not that "urgent" to prepare for the certification, rather than that the company pays more attentions to the existence of cleaning protocols, regular audits, etc. throughout the year.

Food safety is an essential part of the company’s efforts to create trust for the customers. It is important that the customers believe in the products and trust them. The company keeps their products safe, manufactured and transported in a manner which can live up to the customers’ agreed requirements, their own internal standards and regulatory requirements.\[8\] In addition, they set supplier controller that constantly assess and select new suppliers and traders focus both on the price and the quality. They also control the quality of their fruits and vegetables supply chain. When the goods arrive at their warehouse, the temperature and quality will be inspected. They strive for a high turnover of stock and the current inventory is constantly checked.
To ensure that the goods are stored and transported in right way, they carry out continuous temperature control. A small temperature card is sent with the goods which the customer will return back when they have received the goods. The temperature statistics will then be downloaded in to computer, so that the fluctuation during the transportation can be recognized.

### 3.3.2 Interview summary

According to the brief ideas gotten from the company’s webpage, some questionnaires are developed to be answered by the logistic manager: Malin Schäfer which helped a lot in the process of getting knowledge of the monitoring methods adopted and the real situation in their company.

The interview is based upon the following aspects:

- The workflow of the company and the general duration for the inventories’ turnover. The responsible party for the delivery-to-customer processes:

  The company purchases fruits and vegetables from suppliers that approved all around the world. Most of the goods come directly from the places where they are cultivated. The company’s main clients are other wholesalers within food supply field as well as retailers, caterings and food service companies. Ewersman AB is famous for the various assortments of fruits and vegetables. The fruits and vegetables are stored in the warehouses normally for around 1-3 days (sometimes the turnover could be longer, depending on what kind of goods it is).

  The delivery processes are completely handled by the 3rd party logistic companies. The Ewerman AB doesn’t own any trucks for delivery.

- At the goods receiving point from suppliers, the quality control is done in the following approach:

  At the receiving point, a visual quality control and temperature check will be conducted by the staff. In some cases the temperature log will be asked to provide by the suppliers to show the temp history during the transport that the suppliers were responsible for. Meanwhile the sweetness of the fruits will be sampling tested.

- The current methods for Ewerman AB to manage their inventories and the involvement of manual operations to record the goods information:

  They are currently using barcode labels and 4 digit labels to be the ID for inventories stored in their warehouses. To record the goods information the 4 digit code needs to be manually registered into the warehouse management system. They are now
Market Research for RFID Real-time Cold-chain Monitoring System

expecting to the completion of establishment and installation of the new high-bay automatic warehouse (AS/RS), which by then the scanners will read the barcode automatically. So far the company hasn’t adopted any RFID solution yet.

● The current approach to monitor the goods temperature during transportation and the quantity and density of temperature card used each time. The expectation and thought about monitor the temperature or the position (Using GPS) of the goods remotely in Real-time:

The temperature card is placed inside the fruits and vegetables’ box/carton and sent together with the goods to the clients. The clients will then return the cards back to Ewerman AB, so that the staff can download the statistics recorded in the cards to see how the temperature has changed during this transportation. Normally only one card per truck will be placed. Regarding the real-time temperature monitoring methods, the interviewee Malin shows great interest on that. She considered it would be superb to monitor the temperature in real-time together with GPS.

● The order of the inventory turnover:

Just like most of other food companies, Ewerman AB is also adopting the First in First out regulation.

● The current approach to monitor the goods’ conditions in warehouse. The distribution of sensors in warehouse. HACCP or other food safety certification’s role in Ewerman AB:

So far the company just monitors the temperatures of the inventories in the warehouses, no relative humidity or gas concentration has been taken into consideration. The temperature of the warehouse is real-time monitored by the cooling system. Sensors are adequately distributed in the warehouses. Also an alarming mechanism is in use. HACCP is requiring that Ewerman AB evaluate risk of contamination of the goods.

● The commends or thoughts about the importance of monitoring the goods status in real-time. Customers’ requirement to get the temperature record when hand over the goods to them:

Ewerman AB believes it is very important to store and monitor the goods in a good manner so that they can ensure a top quality to their clients. The clients do not require a temperature record as long as they are satisfied with the quality.

● The self commends on the current condition and monitoring approach:

Ewerman AB is about to invest in a new cooling system which will also enable them to monitor their warehouses more accurately and efficiently. The interviewee
expressed that they are not so satisfied with the current system and they are looking forward to next year when the new system is in place.

3.4 HAVI Logistic Services (Beijing)

3.4.1 Company briefing

At the mention of HAVI Group, the mystic partnership between her and McDonald's Corporation must be introduced. HAVI Group has taken the role of the exclusive 3rd party logistics partner for McDonald's worldwide for over 30 years.

McDonald's puts quality and food safety control as their first priority, this guiding principle has permeated to every suppliers on the whole supply chain. Not only the food manufactures but also the logistics companies have to comply with McDonald's comprehensive regulations and under their strict supervision.

For example, during the bread manufacturing process, McDonald's requires its suppliers to keep a firm hand in every step, such as every barrel use for containing wheat flour mustn’t be in white color in order to distinct the debris from the flour powder. McDonald's has adopted HACCP (Hazard Analysis Critical Control Point) system for over 20 years, they conduct inspections on every critical point of the food supply chain. Like the last process before bread can be served to the customers is to pass a metal detector to make sure there’re no metal materials in the bread. Meanwhile, for the transportation, McDonald's asks its carrier to equip with 8 tons volume refrigerator truck which cost around 80,000$ each, and keep the refrigerator installations up and running along the whole delivery. The cost is increased to the extent of almost 200% when compare with other traditional method. But since the sensitivity of food quality control and the increasing demand of food safety from customers, low cost competition will obviously devastate the whole supply chain. A more favorable quality contest will take place. McDonald's is just willingly to put more effort to the aspect or details that others may feel regardless of.[9]

Based on this quality principle from McDonald's, HAVI Group is honored to be their exclusive 3rd party logistic partner owning to the high standard, customized and seamless logistic service it provides. (Besides, HAVI is also partner with Starbucks coffee company etc.) It supports McDonald's not only for basic food transportations, but also other service such as information management, inventory control, manufacturing and quality control etc. Even though these sort of add-value services add on cost, they enhance the competitive strength of McDonald's own service in the same time.

Nowadays, HAVI Group China has established food distribution center in Beijing, Shanghai and Guangzhou as well as some subsidiary centers or delivery stations in
Shenyang, Wuhan, Chengdu and Xiamen. Together with the centers in Hong Kong and Taiwan, HAVI Group China invests huge to build the service network all over the country.

HAVI Logistic Services Co. Ltd establishes a world leading multi-temperature food distribution center in Beijing which covers the area of 12,000 square meters and costs more than 55 million RMB. Among those, 3 different temperature range warehouses are in use. The warehouses for storing the non-temperature requirements supplies such as different kinds of disposable cups, paper packages take the volume to 2,000 tons, temperature is kept between 5°C ~25°C. The frozen storage warehouses can hold over 1,100 tons of frozen food such as French fries, Pies and meat. The warehouses are kept running with -23°C~20°C all day round. The refrigeration warehouses contain over 300 tons of food such as lettuce, eggs which chilling temperature is needed, temperature is kept constantly between 1°C ~3°C. All the equipments in warehouses are installed delicately, in order to keep everything to the greatest extent of freshness. Some isolation areas that are equipped with automatic gates are built in between warehouses with different temperatures, in order to prevent the interference of warm air. The set of customized loading and unloading platforms are adopted, that the refrigeration truck can be seamlessly connected to the warehouses which the dust and warm air from outside can be avoided from invading the warehouses and the foods. HAVI Logistic Services Co. Ltd Beijing branch is equipped with more than 40 refrigeration trucks, that each can take 5-20 tons of goods. So far, the distribution center in Beijing has already delivered more than 10 million cartons of goods to the McDonalds’ restaurants in their service range.[9]

Regarding the highest priority of food safety and quality, HAVI logistic implements two essential principles in the whole supply chain management, one is the HACCP which has already been widely adopted in the food industry, it emphasizes on the inspection and surveillance at the critical points along the supply chain, in order to control the whole process, in this way, the quality is ensured not only depend on the final control but more on the quality of the arrangement in advance. The other is the QIP (Quality Inspection Program) which defines customized quality standard for every supply and provide in depth inspection guidance when receiving the goods from suppliers, it is considered to be the extension and complement of HACCP. Together, they ensure the food safety in the whole supply chain to the highest standard in every detail.[10]

3.4.2 Interview summary

An interview with Mr. Ren Zijun--Manager from department of transportation in HAVI Logistic Services (Beijing) Co. Ltd has been conducted.

The questionnaires are mostly around the company’s workflow and their current method to monitor the temperature along the cold-chain logistics.
The interview is briefly as follow:

- The general service workflow of HAVI logistics for McDonald’s:

HAVI’s distribution center provides McDonalds’ restaurants not only delivery service, but also order supplies, storage and transportations. It functions as a heart that pumps out “fresh blood” to every McDonalds’ restaurants in every second. It connects and coordinates all the suppliers with the restaurants smoothly and harmoniously. At the restaurant side, the managers of procurement also have to be trained specially in the prediction of the quantity of sales, procurement and inventory. The procurement cycle is one week. Managers will predict for a safe inventory quantity, and send out orders to the dispatching center in HAVI. McDonalds’ allows neither to order too much foods nor too little. Too much inventory in the restaurant will increase cost and make the cash flow retardant, degrade the quality of the foods. Too little inventory will directly decrease the turnover and profit, meanwhile the cost for an urgent order will be relatively high.

At the site of HAVI distribution center, there is a certain department that works out the prediction of the demand of different kind of food and consumable supplies of McDonalds’ restaurants in their responsible range in advance based on their years of experience. The orders then will be sent out to the corresponding suppliers for manufacturing. When the goods are all ready, they will be delivered to HAVI distribution center and stored in their warehouses until the orders from restaurants are confirmed by HAVI, the goods will be shipped up without any delay.

- The service range of HAVI Logistic Services (Beijing) Co. Ltd and delivery-time requirement:

The distribution center in Beijing is responsible for a really wide service area, which almost covers the whole north and northeast China (include Beijing, and provinces of Hebei, Shandong, Inner Mongolia, Jilin, Liaoning and Heilongjiang etc.). Recently, with the soaring number of restaurants in northeast China, a subordinate distribution center is established in Shenyang to facilitate the long-haul distribution work from Beijing to the three northeast provinces.

There is no special restriction about the delivery-time set by McDonalds’, but normally under the recent HAVI’s own SOP (standard of operations), after confirming the order from restaurants, the number of trucks for dispatching and the optimized routes and delivery-time will be calculated and figured out by HAVI’s inner transportation management system. All the goods in ordered will be received by restaurants within only one day, no matter how far the restaurant is, as long as it is still in the service area. The punctuality of arriving will be precisely controlled within the range of 30 minutes to the stipulated time.

- The warehouse and supply chain management issue and the warehouse condition monitoring method:
Recently, the whole supply chain within McDonalds’ from the upmost raw material suppliers to the end restaurants still manage the inventories by the normal labels which all the information of the product is printed by characters and can be read by human eyes. No barcode labels or digit labels are adopted, the reason is that the categories of the foods and other supplies are neither so many nor complicated. McDonalds’ implement their own rule of numbering the goods, it’s uniform and recognizable to all the parties involved in McDonalds’ supply chain.

The high bay automatic warehouses have been used, but still a lot of information for the inventory management need manually input to the system.

The inventory management in McDonalds’ also simply complies with the first-in-first-out order.

![AS/RS depot of HAVI Logistics](http://www.havi-logistics.asia/SC/Content/TOPNavigation/Services/Storage_and_Handling.asp)

Figure 19. AS/RS depot of HAVI Logistics


Accessed on 2010-10-08 )

● The stringent specification of the temperature / quality controls in food storage and transportations from McDonalds’ and the approaches that HAVI implements to meet the requirements.

McDonalds’ stringent specification of the cold chain logistics covers many processes, such as temperature recording and tracking, refrigerating equipment monitoring, goods inspections, temperature checkpoint setting as well as the SOP stipulations of the operation process. Thus, even for the very detailed process, there is still a standard to make guarantee. For instance, a normal refrigeration truck with load capacity of 8 tons must be loaded or unloaded within 5 minutes.

McDonalds’ requires every party involved in the supply chain record correctly and accurately in every step they conduct. For delivering and receiving goods, some certain process and regulations must be obeyed. For example, when delivering the goods to restaurants, the placement of different kind of goods must depend on their sensitivity of temperature, from most inside to outside will follow the order like apple pies, fish, chicken, beef, French fries etc. On the other hand, when receiving the goods from the upstream suppliers, the following issues must be conducted: check in
advance that the temperature in the frozen and refrigeration warehouses is proper, record the accurate time and place of receiving the goods, check the documents’ completeness, randomly inspect the goods’ temperature at that time-point, check the expire date and anticipate whether the date is long enough for the goods to be used, look over the packages to detect damages and contaminations, examine the pressure of CO$_2$ gas containers, the last step is the verification of the quantity of different categories of the goods and confirmed with signature.

To substantiate it, the situation in HAVI Logistic Services (Beijing) Co. Ltd is described as follow:

HAVI samples the temperature by electronic thermometers into the food packages at the point receiving goods from the suppliers and initiates the temperature record from then on. The suppliers also will take a reverse inspection of the temperature of HAVI’s truck before the goods are loaded. During the storage process in HAVI’s warehouses, the refrigeration monitoring system is functioned as real-time monitors running non-stop 24 hours every day, the staff can monitor the warehouses’ conditions remotely in the surveillance room, the temperature is sampled by sensors rationally deployed and fixed in the certain places in the warehouses.

During the transportations, the advanced multi-temperature refrigerating trucks are in use, which means there are three different temperature areas in a single truck, in order to transport different sort of goods in an optimized approach. The frozen foods such as ice-cream, fried chicken and frozen meat are placed nearest to the refrigerator. Then a movable isolation board with a fan that blows the cold air to the cooling area will be mounted. Afterwards, the food need cooling condition such as milk, sauce and vegetables will be loaded. Finally, out of the second isolation board is the normal temperature area, loaded with supplies like staff uniform, tray and none-temperature needed food such as dry bread etc.

Several temperature data loggers are placed in the truck to record the history of temperature of different areas along the whole journey. But this is not a real-time monitoring approach. To enhance the temperature controllability and traceability, a real-time monitoring system is in use. The temperature of the goods is sampled by some sensors that are fixed in the certain places inside the container of the truck. These data are not only displayed on the control panel in the cab of the truck to facilitate the drivers to take actions when it runs out of range, but also the data are transmitted to the surveillance room in the distribution center through the GRPS communication system by the frequency that set up by the staff in distribution center. In addition, the GPS module mounted on every truck will collect the position statistics together with the temperature data send back by GPRS network. The transmission frequency is set diversely for different kinds of goods that are transported. In consideration of the data transmission costs, the rate is normally set to be per 10 minutes a sending. When the temperature being monitored goes out of alarming range,
an alarm will be triggered. The alarming signal is not only displayed on the control panel to call for attention from the drivers but also the alarming message will be sent by GPRS network to the remote distribution center, thus the staff there can coordinate with the drivers in field to detect and eliminate the problems promptly.

When trucks arrive at McDonalds’ restaurants, the staff in charge of quality control will take an inspection and records of the foods’ temperature. The temperature fluctuation history curve diagram along transportation period can be printed out from the data logger on request. After handing over the goods, the data loggers will be taken back and the data is downloaded into HAVI’s logistic management system and saved for periodical analysis.

As Mr. Ren mentioned, at the time in 2008 that Beijing holds Olympic Games, HAVI Logistic Services (Beijing) Co. Ltd was honored to be the officially authorized catering logistic company. BOCOG (The Beijing Organizing Committee for the Games of the XXIX Olympiad) is the distinguished customer during that period. Their demands of the food quality are far stricter than McDonalds’, even though McDonalds’ is already at world leading position in the food industry. The Olympic Games has the utmost important global influence, all the service for the event must be qualified to zero fault or deficiency. During the event, every process of HAVI’s original operation was enhanced to a higher level. For example, when the truck is loaded, a RFID belt will be bent across the lock, if the truck is opened with human interference or by accident on the delivery way before arriving at the destination, the operator/driver will know simultaneously. The whole truck must return back promptly. A new batch of goods will be dispatched instead. Thus, the temperature control and monitor become more essential in this certain condition. BOCOG requested HAVI adopt the RFID temperature real-time tracking system provided by a Singaporean IT company. Instead of fixed sensor, the RFID tags are adequately deployed inside the food’s package. By doing this, the accurate temperature can be achieved. BOCOG assigned some staff together with some from HAVI, together installed the system and trained to use it. The system is removed after the events.

By far, according to Mr. Ren’s point of view, the recent technology that adopted is sufficient to satisfy McDonalds’ requirement of the cold-chain logistics. In addition to the temperature tracking system mentioned above, there is another recording system developed by Tsinghua University installed inside each truck. It works as a “black-box” on the airplane, it records not only the truck’s position and speed, but also the condition of the trucks. The information can be downloaded afterwards, thus the time of start and stop the engine as well as how did the refrigeration equipment functioned can be easily obtained. For example, a 8 tons normal refrigeration truck cost 70,000$, it requires an overall maintenance after running for 500 hours. In this circumstance, if the refrigeration is just up and running for several hours in the beginning and in the end, the goods can also be approved by the temperature inspection by the receiving restaurant. No one will know the story on the way. Both
the cost of maintenance and oil-consumption will be saved to a great extent. But the black-box system together with the real-time GPRS tracking system, this shoddy work can be eliminated.

The recent tracking and recording systems are not so costly compare with adopting RFID technology. But the RFID solution can be an option if the customer set a special request just like BOCOG. All in all, the approaches that HAVI use are appropriately based on customers’ demand.

### 3.5 Guangzhou Nanland Air Catering Co. Ltd

#### 3.5.1 Company briefing

The company was established in 1989 by joint venture from China Southern Airlines and France Servair Co. Ltd. It locates close to the new Guangzhou Baiyun Airport, covers the area of 42,000 m², equipped with over 30 trucks with elevating system specialized for delivering food for the airplanes. The automatic high-bay warehouses system has the capacity to contain more than 1,400 tons of inventories. The total refrigeration warehouses covers area around 4,300 m². The company is capable to produce over 50,000 set of on-plane catering daily. It provides food and other ground services for the flights from over 20 airline companies (Mainly is the China Southern Airlines) both domestic and international. Meanwhile, as a food processing company, the company has already gotten the international quality system certifications of ISO9001 and HACCP.[11]

#### 3.5.2 Interview summary

- General work flow:

  During the procurement of raw material and semi-finished ingredients for food, the safety qualification of the suppliers must be checked and approved by the quality-control department of the company. Meanwhile, some sampling inspection must be conducted before confirm the receiving. After that, the materials go to the process of cleaning and initial handling. Then they will be transferred to different kind of warehouses for storage.

  The airline companies usually submit the orders with passengers’ information and the required food pattern to Nanland 2 days before the corresponding airplane departure. The control and plan department will calculate and figure out the quantity of different sort of food in order and hand over the number of different categories to the cooling-dish, warm-dish and cake bakery workshops respectively. Then they will
calculate how much materials they need to produce the corresponding amount of food and pick properly from the warehouses. (In order to keep the freshness of the materials, the quantity of goods taken from warehouses at one batch must be predicted to be cooked into ready-food within 45 minutes.) After the frozen goods are picked up from the warehouses they will enter into a warmer warehouse for defreezing, and then these materials must be cooked strictly within 45 minutes after they leave the refrigerated environment. The final product will be transferred and stored in a special cooling warehouse with temperature 0°C-5°C temporarily before they deliver to the plane. This batch of food will be assorted and placed in every platter, loaded on trucks, delivered to the airplane apron and finally loaded on the airplane 2 hours earlier than the departure.

In the case of severe delay of the flight, the plan department of Nanland will dispatch the ready food to the flights that just going to departure. A new batch of food will be processed according to the new departure time for that flight. The aim is just to assure the freshness of the food.

- Warehouse management and cold-chain monitoring

  ➢ Warehouse management
  Raw materials and semi-finished food (Require refrigerated environment):

  The management in such warehouses is still using manual approach to register the inventories’ entering date, expire date, suppliers’ information and the position in the warehouse on paper cards etc. The FIFO regulation is also adopted there.

Other supplies for the flight:

These supplies include different kinds of beverage and some disposable supplies such as plastic spoon and tissues. The warehouse to store this non-refrigeration need supplies is a cutting-edge automatic high-bay warehouse (AS/RS), with height of around 20 m and the capacity for more than 1,400 tons.

When receiving a new batch of goods, the warehouse management staff will make barcode tags for each package and stick them to the package. These barcodes are only internally recognized within the company. The name and quantity for different sorts of goods as well as the placement with their pallet ID for the corresponding goods will be registered in the warehouse management system. When the goods are ordered to be taken out of the warehouse, the staffs only need to input the goods’ name and quantity, the system will comply with the FIFO regulation to dispatch the goods from the certain pallet automatically, no manual manipulation during this process is required. After the barcode scanning at the gate of the warehouse, the goods will be loaded on the trucks that waiting out of the warehouse and be transferred directly to the sub packaging group to combine with the foods.
Ready-food: The ready food temporarily stored in the refrigerated warehouse before they loaded on trucks for delivery. In this step, the registration is not done by cards or barcode labels, but just simple paper forms which record the time and temperature when entering and exiting the warehouse, quantity, and the responsible person etc.

➢ Cold-chain monitoring
In the refrigerated warehouses:

The monitoring approach that Nanland company adopts is combination of the automatic system with human surveillance.

All the refrigerated warehouses’ condition within the company’s range can be monitored remotely in the control center via LAN with 24×7 on-board staff. If there occurs abnormal temperature in any warehouse, an alarming signal will be displayed on the screen in the control center. The staff on-board will then soon contact the warehouse caretaker who is close to the alarming warehouse to take an on-the-spot inspection and repair. The area of each warehouse is not that large, it takes around 30~40m², every warehouse equipped with only one temperature sensor that collects the data.

Meanwhile, there are also screens fix on the wall outside of each warehouse that shows the inner temperature, when the warehouse caretakers are patrolling around, they can check the screen and enter into the warehouses to get an accurate statistics manually, thus the mal-function that the remote monitoring system or the temperature sensors may encounter will be eliminated.

In the transportation:

During the transportation, the duration normally takes only 1-2 hours from the food loaded on the trucks until they loaded on the flight. So far there is no specific monitoring and tracking approach/equipments being adopted at this step. (However, recently Nanland company is intending to deploy GPS positioning system for their trucks). The interviewee considers that it is sufficient to keep the food at a satisfied temperature during the delivery by the dry ice packs that placed inside packages together with the trucks refrigerating system.
3.6 Saba Group

3.6.1 Company briefing (www.saba.se)

Saba Group is the leading importer and distributor of fruit, vegetables and flowers in Scandinavia. The group consists of three subsidiary companies: Saba Frukt & Grönt och Blommor, Banan-Kompaniet and Saba Fresh Cuts. They import fruits, vegetables and flowers from over 70 countries worldwide. From year 2005, they are owned completely by the world’s largest fruit and vegetable company Dole Food Company Inc. [12]

- **Saba Fresh Cuts:**
  Saba Fresh Cuts is a processing industry for fresh-cuts sale, it produces Dole pre-cut salad. The products are distributed in a closed cold-chain to the Swedish, Danish, Finnish and German market. They are sold and marketed by Saba Frukt & Grönt. The manufacturing plant in Helsingborg is one of most modern in Europe, it meets the most recent requirements for fresh food processing on technology, hygiene, food quality and safety.

  To assure the foods’ best quality, Saba carries out rigorous screening rules to entitle a grower to be their supplier. It is also very essential to have the raw material cooled promptly after harvest and kept refrigerated throughout the whole supply chain from farm to the shelf in supermarket. Dole offers Saba grocery refrigerators that are specially adapted to store the pre-cut salads. These refrigerators guarantee the right temperature that the products can retain the freshness for longer time.

  Meanwhile, according to Saba’s own SOP (standard operating procedure), all vegetables need to be rinsed three times in 2°C water after harvest. The packaging materials are designed specially that can breathe. By doing this, the salad’s freshness and durability can be extended. [12]

- **Saba Frukt & Grönt och Blommor:**
  Saba Frukt & Grönt och Blommor is a trading company that buys and sales fruit, vegetables, flowers and pre-cut salads which produced by Saba Fresh Cuts. During different seasons, the goods will come from different origin countries. However there are always around 500 species of products in stock. The products are delivered to shops, supermarkets and other wholesalers throughout Sweden, Denmark, Finland and Germany. The major distribution center is in Helsingborg, Sweden.

  Rigorous quality control permeates the work of the company’s business. They record carefully of all steps in the supply chain, from cultivation and transportation to reception, storage and handling. All documentations are used to guarantee the goods’ safety that the customers are entitled to demand. According to the company’s years of
experience, fruits and vegetables have different ideal storage temperatures to retain its flavor and freshness. Low temperature slows down the respiration naturally present in fruit and vegetables, thus delays their aging process. So the company pays much attention on the maintenance of an unbroken cold-chain.\textsuperscript{[12]}

3.6.2 Interview summary

Due to the nature of the company’s business and the relationship between cold-chain management and their affair, an in-depth research about their cold-chain control issue has been conducted.

The interviewee Bengt Petersén works as quality manager mainly for Saba Fresh Cuts (SFC) and also sometimes for Saba Frukt & G"{o}nt (SFG). The interview is unfolded regarding the following issues:

- The company’s workflow. The normal turnover of the inventory. The major customers.

SFC buys all products in Europe. They contract with different growers in different seasons. During summer, they pick suppliers from Sweden and Denmark while Spain and Italy in the winter. Raw materials are normally stored for 1-4 days before processing. Their main customer in Sweden is ICA Group. Other customers are Max Hamburgerrestauranger and Burger King and Kesko Corporation in Finland just to name a few.

SFG procures products also outside EU. Products with small volume are procured through agents in Holland. Raw materials store in their warehouses up to one week before delivered to clients. The main customer is Axfood AB which is one of the largest food retailers in Scandinavia. Other customer is Servera AB.

- Temperature control and relative humidity measurement at the goods receiving point.

SFC always conducts controls on the temperature at receiving. If the temperature by that time is over the agreed limitation, the transportation company has to provide the temp history from loading.

SFG also has the control of arrival temperature. If there arise problems, they will also go and check the transportation company’s record.

Both companies don’t have the relative humidity inspections at the acceptance point.

- Order of turning over the goods from warehouse.

For SFC, generally the daily production is delivered at the same day or one day after.
For SFG, they adopt first in first out (FIFO) in general, but also depend on the maturity of the goods or special customer requirements.

- Condition monitoring approach of the fruit and vegetable in warehouse. Compliance regarding the food safety issues that must conform to.

In SFC, the temperature in warehouse is controlled during the process control. The temperature inside the warehouse and processing workshop will be shown on data screen. The data is obtained by the fixed thermo sensors.

In SFG a real-time temperature monitoring system is adopted, which the temperature of every warehouse can be seen remotely. The sensors were fixed at certain point in the warehouse as well. The alarming mechanism will be triggered if the temp exceeds the setting range. In most cases, it’s enough to measure warehouse’s temp. Sometimes the manual sampling measurement of the products’ temp must also be implemented to ripening critical or temp sensitive products. The thermometers that are in use have the precision of ±0.5°C, and the accuracy is 0.1°C.

Figure 20. Manual inspection of the products’ temperature

The monitor of the humidity and gas concentration haven’t been taken into their consideration so far.

They also comply with the HACCP requirements when dealing with the cleaning and the involvement of manual handling of the fruit and vegetable.

- Temperature monitoring approach during the transportation.

The transportation service is handled by a 3rd party logistics company. SFG generally doesn’t have monitoring approach during the transportation, but sometimes they test the temperature before loading manually with temp logger.
SFC generally experiences the same situation as SFG. But the treatment is different depends on the different requirements from various customers. Sometimes more inspection and record is demanded. In that way SFC is using data loggers to record the temperatures for the shipments, each logger will be put inside an envelope with stamps, initialized before delivery and placed inside the fruit or vegetables’ package, sent together with the goods to customer. The customers suppose to send the temp loggers back to SFC directly when they receive the goods. SFC will be responsible for the data analysis and give feedbacks and the temp graphics recorded to the customers afterwards. One of such clients is Burger King, which requires data logger on every shipment. But in this way, as Bengt revealed that the loggers' loss rate is relatively high, almost 3 out of 10 loggers may be lost on their way back. Reasons for this are complicated, since many parties have been involved in this operation.

- Commends on the current monitoring system. Any planned improvement of current cold-chain monitoring method.

For the moment Saba Group doesn’t have any planned changes to the current system. They feel satisfied with the approaches they have adopted. To supplement, they will probably increase measuring times and occasions with the same system and devices that are used today.

### 3.7 NT Pharma (Group) Co. Ltd.

From the knowledge gained from web, media as well as from the expert in the field of pharmacy logistics, NT Pharma (Group) Company Limited is never be more recommended as an excellent example as a leading pharmaceutical 3PL (3rd Party Logistics) in China. Many other large scale pharmacy logistic companies in China set NT Pharma’s management and monitor method as a good reference or standard to establish their own. In order to provide their customer matchless service as well as take high responsibility to the pharmaceuticals’ end users, NT Pharma has set up comprehensive and up-to-date SOP (Standard Operation Procedure) in order to meet the GSP (Good Supplying Practice) qualification enacted by the national government in 2008 as well as enhance the degree of satisfaction of customers. They have gotten cooperation with the NEC Corporation, which customized an IT solution for them to utilize RFID tag with embedded temperature sensors to monitor the pharmaceuticals’ temperature in real-time not only in warehouses but also on the way of distribution. Thus NT Pharma can get the comprehensive and prompt information about the goods, meanwhile customers will also benefit from the accurate temperature records. So far by now, NT Pharma has already adopted this system for over 2 years.

As a real case of how this RFID system has been used in the real industry for cold-chain management, a deeper look at NT Pharma’s case is meaningful.
3.7.1 Company briefing

NT Pharma (Group) Co. Ltd was established in 1995 with the head-quarter in Hong Kong. It is majorly responsible for the import and distribution for the foreign pharmaceutical manufactures in China. It has been granted as the exclusive distribution partner of GlaxoSmithKline (GSK)’s vaccine products in China and one of the three main distributors for Pfizer®’s prescription medicine products. It is the first enterprise that introduces the seamless vaccine cold-chain management system into Chinese market and it is by far standing in the leading position of the quality of cold-chain logistics management owning to the cutting-edge innovative technology it adopted. The company has been a loyal long-term partner of many well-known pharmaceutical manufacturers, such as GSK®, Pfizer®, Wyeth®, Bayer® and Astellas®. Nowadays, the company owns many GSP (Good Supplying Practice) certified distribution centers that cover over 50 major cities, more than 400 big hospitals in China as well as a GMP (Good Manufacturing Practice) certified pharmaceutical factory that produce their own medicine.[13]

3.7.2 Interview and studies

Seeing that NT Pharma is renowned for its cold-chain monitoring methods and adoption of the RFID monitoring system, it is found quite related to the thesis’s main topic. In this way, the study and interview to this company is more oriented and focused on the operation detail of their current RFID monitoring system. Mr. Yu the manager from Cold-chain control department in NT Pharma Shanghai office offered his gracious help for the interview.

Within NT Pharma’s business range, the transportation and storage of vaccine products account for the majority proportion. As a special kind of biological product, vaccine is extremely sensitive to temperature, they can only live at a certain temp range. By this mean, the temperature along the whole supply chain from manufactures through warehouses and delivery trucks to the end users must be kept in the appropriate range strictly, the cold-chain cannot tolerate any broken phase. This is also highly demanded by the end users.

Since year 2003, NT Pharma established a set of comprehensive vaccine cold-chain management system, they adopted the real-time ambient monitoring method in warehouses and data loggers recording along the transportation. Even though the data loggers faithfully record the temp’s fluctuation and they also implement the company’s own SOP to regulate the staff on-board checking the goods condition in time, it’s still highly expected to get real-time information about the goods in-transit. If that can be realized, the customers will receive faster and more reliable information about the batch of goods they ordered, meanwhile the staff in NT Pharma can also
take more efficient remedial measures when something goes wrong with the goods rather than passively accept the discards.

From year 2008, the company has gotten technical support from the world leading IT solution company NEC Corporation, which provides an RFID real-time monitoring solution to realize NT Pharma’s expectation, thus to protect their vulnerable cold-chain. The deployment and operation of this monitoring system is more or less the same as the thesis’ aiming system: When the goods are stored in warehouses, the RFID tags with embedded sensors and memory will be placed inside the pharmaceutical’s packages, the temperature inside the packages will be recorded and saved. Meanwhile, the temp data will also be transmitted to the receiver fixed in every warehouse which equipped with ADSL network, thus the data can be monitored in real-time remotely. \[26\] NT Pharma use the RFID tags not only recording the temp data, but also they will be registered the goods information. When the folk truck take the goods pass through the gate of the warehouse, the temp info together with the batch info will be read and transmitted directly by the receiver without any manual operation and all these info is simultaneously available in the company’s management system.

During the transportation, NT Pharma uses both RFID tags together with GPRS and digit temp loggers jointly monitor and record the temp, in order to provide customers with more reliable statistics. The RFID tags also will be insert in some packages, in order to achieve the more accurate temp compare with sensed by fixed sensors in the truck. The data will be collected by a truck-mounted receiver which also equipped with GPRS module. Thus the condition of the vaccine will be tracked by NT Pharma’s quality assurance staff in real-time through the network based TeMS (Temp Management System) which is also developed by NEC. This kind of RFID tag is reusable for 3 years. The alarming mechanism has been introduced. If temp goes out of range, SMS notification will be triggered to send out both to the truck driver as well as the responsible person in the office. When deliver the goods to customers, the temp history data can be read and printed out by the handset without open the packages. The customers rely upon the result to judge the quality of temp control. \[25\]
Meanwhile, the traditional temp loggers will also be mounted on trucks to work together with the fancy RFID tags. The results read out from the loggers are also considered to be an important source to evaluate the quality of the goods. Generally the temperature sampling interval set to be 10 minutes. In the future, NT Pharma plans to enable the access to the TeMS system for their customers to track the in-transit goods’ status on-line.\[25\]

The brief workflows with RFID in different phases are displayed as follow:
- **Entering warehouse:**
  When the goods arriving at NT Pharma’s warehouses, the caretaker will scan or input the orders number which contains the info of this batch of goods into the warehouse management system. The system will print out barcode labels depending on its own rules. The staff needs to stick those labels to every package. RFID tags will then be
placed inside some of the packages for recording. Before they are put in the packages, the staff will register the RFID tags’ ID for the corresponding batch of goods in the system. Meanwhile the information of the goods will also be programmed into the tags. Thus, the temp of the goods can be retrieved from the TeMS system at a single package level.

Figure 23. Workflow with RFID in the phase of entering warehouse

● Delivering:
According to the order for delivery, corresponding inventory will be picked and piled up together. Every barcode on the package will be scanned as well as the number on the order sheet, thus to make the inventory match along with the order. Before insert the RFID tags for monitoring, their ID will also be scanned together with the order number to establish the correspondence relationship between every package of inventory being monitored and the data from the monitoring RFID tags. When this preparation work is completed, the inventory is ready for shipment, and the RFID system is triggered for recording.

Figure 24. Workflow with RFID in the phase of delivering
(Figure 23-24 refer to: http://www.necsl.com.cn/solution/RFID/livestock/index.shtml Accessed on 2010-10-10)

● Temperature’s history inquiry mechanism:
The temperature of the goods that is monitored within the logistics range of NT Pharma stores all at package level. When staff inquiring the entire temperature history of any package, the temp graph or data that labeled with the package’s barcode ID will be retrieved from the database. The graph or data is generated by the combination of the statistics that recorded at different segments of the cold-chain both in warehouses and in-truck. Meanwhile, the trucks’ ID will also been shown together with the temp of that period in order to clarify the responsibility of every segments.

The temp history of the transferring period can also be inquired by the order’s number. After inputting the order’s number, the general info of this order together with the highest temp, lowest temp, time of abnormal temp as well as the duration of
transportation will be shown. Detailed information is also accessible by simply click on the buttons of the name in the list of all the goods in this order. Then the batch list of this certain goods together with their highest temp, lowest temp, time of abnormal temp will be displayed. Furthermore, the detail button in the form after each batch number will lead to the information of every package with that batch number. Thus, the temp info of a certain package of goods can be inquired.

Regarding some operational detail, Mr. Yu also revealed that: In some cases, in order to make a more accurate temp record, some package of the goods will be rived off to insert in the RFID tags. Otherwise, the tags will be fixed at the right place that they shouldn’t touch the dry ice or gel-pack. When delivering to the customer, it’s a must to offer them with the temp history that is printed out by the handset RFID reader on-site to get signature for acceptance. The record must be taken back to the company for backup and analysis. Normally, 1-2 tags will be placed inside each truck. But in some cases, the quantity can be more according to the company’s SOP for different kinds of goods as well as the customers’ special requirements for a certain shipment. All the portable monitoring device must be taken back by the drivers follow the instructions they get before shipping.

3.8 Jointown Pharmaceutical Group Co., Ltd.

In a similar condition, Jointown Pharmaceutical Group also adopts NEC’s RFID solution for their cold-chain tracking and management issue. The Group is the third largest pharmaceutical wholesaler and distributor in China. It owns 34 distribution centers in China which distributes pharmaceuticals to hospital, pharmacies and even individual customers. Recently, it becomes one of the fastest growing pharmaceutical dealers with a 47% increase of sales per year.[14]

Also being influenced by the new GSP standards, Jointown Group needs to make improvement on the accuracy and continuity of temperature data along the cold-chain, especially during the transportation process for their high end-value pharmaceuticals such as vaccine and blood products.

From the case study of costumer portfolio of NEC Group, some knowledge has been gained regarding Jointown’s adoption of the RFID solution: There are two companies bidding for this project. The reason that Jointown decided to chose NEC as their service provider is that they can offer a better performance of service for over long distance communication and the accuracy of data acquisition. After starting system development, NEC reassured their solution by carefully announcing any problems they have encountered, including the compatibility of Jointown’s existing system. Finally, they delivered a comprehensive tracking system with a sophisticated database and totally compatible with the company’s old systems and meet the rigid requirement of temp monitoring.[14]
Jointown substantially launched the system from December of 2009. On the first step, for the following 2 years, they just planned to adopt 1,500 RFID tags for a small scale use for transportation monitoring of the expensive pharmaceuticals. The operation flow of this system in Jointown is slightly different from the one in NT Pharma—Jointown hasn’t introduced the GPRS module for real-time monitoring. They just attached the tags in the package of the goods before shipment. When arriving at customers, the data are read by a handset reader in a few seconds and printed out for the customer’s confirmation of acceptance. Later on, the data will be categorized and saved in the company’s temp analysis database.[14]

The senior logistics manager Mr. Qu Yong from Jointown also revealed that, they are getting preparation for launching the expanded monitoring system with real-time tracking functionality through GPRS network at the end of 2010. He also admitted that, it’s difficult to produce a noticeable effect with partially introducing this kind of system, the coordination of temp data throughout the whole distribution process will improve quality and ensure the reliability of the cold-chain. Thus, their future prospective is to let NEC establish a framework which can involve all the essential parties along their logistics chain, from suppliers of more than 4,200 pharmaceutical manufactures and over 58,000 dealers to the downstream customers. This indicates a very promising future of this RFID monitoring solution.[14]

3.9 Sinotrans Air Transportation Development Co., Ltd

3.9.1 Interview summary

Sinotrans Air Development was made from the assets reconstructing of the high-quality air freight business of Sinotrans Group, of which the core businesses include air freight forwarding and express business, and the international freight forwarding business has stably ranked No.1 in the domestic industry.[15]

To know something more about the freight logistics business, an interview was issued with Liu Xingyu, Manager of marketing in the Department of international freight operation. Even though they are not representatives in the cold-chain industry, but they are still representative experts as freight forwarders. General knowledge can be gained about normal air freight logistics, thus some assessment can be done to judge whether it’s a promising market for RFID monitoring system to be targeted. Or in which way, the monitoring system can step in this big market.

According to Mr. Liu’s words, general workflow of normal international air freight forwarders can be abstracted as below:
Customer ➔ Forwarder ➔ Airport ground service company (GS) ➔ Airlines ➔ GS ➔ Custom's supervised depot ➔ Forwarder’s depot (After Custom inspection)
When the goods once picked up from customers, certain contract will be signed with the customer. After assisting customer for declaration to Custom, the goods can be shipped out to the airport, where they will be handed over by the airports’ ground service companies. At the handing over point, only the amount of goods and completeness of the packages will be checked up. This regulation will also be carried out when the ground service company handing over the goods to the airlines. When arriving at destination, local ground service company will unload the goods from airplanes, and drive them to the depots which belong to the airport. Then they will be transferred to the custom supervised depots either inside or outside of airport, waiting for the inspection. During this period, the local freight forwarder will help customer to declare to the local custom. After inspection, the goods will be taken out and transferred into forwarder’s depots waiting for customer to pick up or direct delivery to customers.

During this works flow, Mr. Liu also revealed that the staff who is dealing with the real goods will never know information on the freight note. Vice versa, the staff that is responsible for assisting declaration will never see how the real goods look like.

Regarding the insurance claims:
Normally there is insurance to protect the customer from getting lost or damage of their goods. The value declaration must be done before shipment. But in most cases, due on the much higher cost of freight after declaration (over 10 % of the goods value they have declared), people chose to take risk when signing the contract with forwarder. If there is something unexpected happen, the airline company can just be claimed within 14 days after they handing over the goods to the ground service company, and they just pay claims on the weight base regulation. This is under the protection of the Warsaw Treaty. In this way, Mr. Liu said that it can be very welcomed to have some devices for recoding the history of the transportation to identify whose responsibility it is.

In the cases of their customers:
They are seldom involved in cold-chain demanded freight, but just in some cases dealing with temperature sensitive glue for electronic use. Under that circumstance, the customer will tell them in the contract to replenish dry ice for how much and at which certain time. For monitoring the goods condition, the customer will put data logger inside their goods, and checked by themselves at arrivals to know the environment changes at transportation, and judge the quality of the goods in first step.
4. Analysis

4.1 Market demand analysis

4.1.1 End-user demand analysis

End-user here indicates the parties who really consume the pharmaceuticals or foods which has been transported, for instance, the McDonalds’ restaurant, the ICA supermarket, Axfood, as well as the hospitals just to name a few.

- Demand of knowing the history of transportation condition

As the end-user, they have get rights to know how their goods be treated before they accept them. This is considered to be very essential for the pharmaceutical or clinical trials consumers, since the goods can be extremely sensitive to environment, and it may be too hard for naked human eyes to identify whether they are degraded or not. So the accurate and continuous temperature record is the most important reference for them to confirm the acceptance and be fully responsible for their own customers. For example, from the interviews, it can be known that the Burger King’s restaurant requires temp loggers for every shipment and World Courier sometimes use disposable temp monitors which cost even 40 euro each just want to make their customers feel safer of their goods. It’s according to these end-users’ demand to adopt or improve the way of monitoring.

- Demand of being informed timely about the goods conditions

It seems to be very welcomed if the end-users can track the goods in real-time by getting access to part of the logistics company’s ERP system. They are the people who care the most about the quality of the goods. If they find something unexpected happen, they can issue decisions whether to return the goods back directly or deal with some other approaches in time.

4.1.2 Customer demand analysis

The customer here indicates the companies that will potentially use the RFID monitoring system for tracking the goods in-transit or in warehouse in order to offer their customer a better service or to fulfill some certain rules stipulated by government or related organizations.
Market Research for RFID Real-time Cold-chain Monitoring System

- Demand of accurate and continuous condition monitoring
  Due to the regulations from the government or relative organization about the storage and delivery condition for a logistics company or manufactures are getting more and more rigorous, especially for the companies which involved in pharmaceutical area, some certain stricter standard or certification must be achieved to keep the companies qualified. For instance, to transport blood-product, the temperature along the whole way must be controlled at 4°C with ±0.5°C deviation. Thus to take a checkpoint inspection or to monitor with a truck level fixed sensor is far from enough. Meanwhile, as the requirements from their customers become more comprehensive, they have to put forward new plans in order to deliver better report to customers. Many companies in such field have already shifted their traditional monitoring approaches to some cutting-edge technology. This RFID tracking system is now the innovative one that more or less be adopted by some of the leading logistics companies already.

The company “World Courier” that is interviewed is now attempting to adopt RFID tracking system for some special shipments, but all they care about is the calibration of the system rather than the cost. Some of the goods they transport are way too valuable that the customers not really care about the freight they are charged. But they would expect to have an accurate and trustful record. Thus the monitoring system needs to be calibrated carefully before launch for real use. The precision should be at the scale of 0.2°C.

- Demand of smaller size of monitoring device
  Depends on the expectation from World Courier, the RFID tags are much thinner than the conventional data logger that they are using now. Sometimes, the package of the goods can be really small (with 10cm×10cm×10cm) it will encounter problems when insert the conventional logger inside the packages. But the RFID tags with a smaller size will facilitate this situation to great extent.

- Demand of acquiring data without manual violation
  Nowadays, for the companies that still using the traditional data logger for recording and monitoring, it’s inevitable for them to inspect the temperature by manually open the packages and take out the logger to read the data at the checkpoint. If the goods are very sensitive to temperature, this operation will be done under certain controlled ambient places. This may seem do nothing harmful to the goods, but for the logistics companies like World Courier, their inspection of temperature at certain checkpoints are relatively frequent, even it’s always operated promptly inside cooling rooms, still some potential risks have been involved for the degradation of the goods. By this means, it’s highly welcomed of the devices like RFID tags that enable the inspection conducted without manually opening the packages which will in that way reduce the violation to the goods to a great extent. By realizing this functionality, it’s also suggested that the power of the active radio frequency must be strong enough to pass through the liquid obstacle inside the gel-pack which will be wrapped around the
goods and RFID tags.

- Demand of getting real-time information from the goods in-transit

It always gets positive feedbacks when asking the companies about their opinion in getting real-time information about the goods in-transit, no matter they transport pharmaceuticals or foods.

4.2 Michael Porter’s Five Forces Analysis

This analysis is a framework for the industry analysis and business strategy development to identify the five forces that determine the competitive intensity and therefore attractiveness of a market. Attractiveness in this context refers to the overall industry profitability. An "unattractive" industry is one in which the combination of these five forces acts to drive down overall profitability. These five forces affect the company’s ability to serve its customers and make a profit. Among them, three forces refer to competition from external sources, and the remainder is internal threats.\[17\]

Under this framework, the attractiveness and the competitive environment of the existing market for RFID cold-chain real-time monitoring system is analyzed as follow:

4.2.1 The threat of substitute products- Medium

Admittedly, there are some other approaches for monitoring the cold-chain with similarity of this RFID system that can be considered as substitution. The mainstream solution is either the combination of GPS module, fixed position truck-mounted sensors and GPRS/CDMA transmitter for tracking the in-transit condition in real-time or placing several temperature loggers inside the goods and inspecting at checkpoint or downloaded the data for analysis after the shipment is concluded.

But when comparing with RFID system, the drawbacks of those conventional ones are quite obvious, majorly appear in the aspects that: the fixed sensors are not accurate enough to measure the real goods’ temperature, the data logger demand manual operations to read out the data and real-time information is not available.

- Customers’ propensity to substitute – Plus medium

In the real industry, the substitute methods have been used widely. The RFID tracking approach is just at the phase of “new adopter”, it so far hasn’t entered the mainstream market, which means it hasn’t crossed-over the chasm. Some of the pioneer customers mainly in pharmaceutical industry have stepped in this RFID technology, and some intend to step in by a small scale of adoption. That indicates a positive tendency of this innovative system. So far, even for the customers who have already adopted the RFID tracking system, they still used the conventional way to monitor goods with
cheaper value or more tolerable to environment.

- Relative price performance of substitutes- Medium
  The conventional method will do fulfill many customers’ requirements. Since the hardware and system cost is much cheaper than the RFID system, the price performance can be satisfying in general.

- Buyer switching costs- High
  So far, there is no company use only RFID to monitor their cold-chain. On the contrary, there are millions of companies involved more or less in different part of cold-chain logistics, but most of them just use the traditional way. The shift to RFID system will cost more than the normal system, but the extent relies on the scale of adoption as well as the customization of the system.

- Perceived level of product differentiation- High
  This RFID cold-chain monitoring system is considered to be very promising by experts. For the customers who use this system know so much about how this system serves differently from traditional ones. It undoubtedly can be defined with a high level of differentiation.

### 4.2.2 The threat of the entry of new competitors- High

Since it’s a promising application, many companies who used to manufacture traditional temp loggers or provide RFID solutions are now planning to launch their R&D in this RFID cold-chain tracking systems’ business.

- The existence of barriers to entry – Low
  From technical aspect, this system is not very hard to build up.

- Capital requirements –Medium
  The capital demand for build such system quite depends on the scale, as well as how the customer requires about the system. A small scale and independent use will not involve huge investment. But if the adoption scale is greater and demanding the system designed to be automatically compatible with company’s existing ERP system, the complexity and cost for maintenance and training for staff will demand more investment.

### 4.2.3 Current Intensity of Competitive Rivalry- High

There is a prevalent saying that where there is no competition, there is no market. Some competitors in this area have been identified, just to name a few: NEC Group ([www.nec.com](http://www.nec.com)), Sensor Logic ([www.sensorlogic.com](http://www.sensorlogic.com)), Sensitech ([www.sensitech.com](http://www.sensitech.com)), Savi ([www.savi.com](http://www.savi.com)), Syntax Commerce
Market Research for RFID Real-time Cold-chain Monitoring System

(www.syntaxcommerce.com), Sealed Air (www.sealedair.com), Secure RF (www.securerf.com), NXP Semiconductors (www.nxp.com), Intelleflex (www.intelleflex.com), Infratab (www.infratab.com), Identec Solutions (www.identecsolutions.com), Gentag (www.gentag.com)[1] and some Chinese companies such as ShangHai Super Ele & Tec (www.superrfid.net) etc.

● Threat of Numbers of players- High
So far, the target market is niche market with concentration on the customers dealing with high-value pharmaceuticals, relative products as well as some expensive flowers and foods. The market for this system is not yet mature, and relatively small, but there are quite many companies that have already launched their RFID monitoring service.

● Threat of similar solution from players- High
Some of those famous companies that are good at offering IT solutions have already released their service and comprehensive customized systems to the customers (as the NEC Group). The threat of similar solutions from them can be relatively high.

Just to make reference, here are some public parameters of the RFID monitoring system developed by ShangHai Super Ele & Tec: The on-chip memory inside the slave RFID tags is extendable to 256KB, the communication range between base station reader and active RFID tags is up to 80m, and meanwhile the range between tags and handset readers is around 30m, the low power chips in tag enable its lifespan to be around 5 years. The system is also designed to be high-throughput data acquiring, it enables around 200 slave tags transmitting data to the readers concurrently. The capacity of readers’ dynamic data reading speed is considerably high, they are able to get data from moving RFID tags with speed of 200km/h.[18]

● The market growth rates- Medium
When the technology becomes more mature with the durability and reliability of the tags getting improvement and the cost of unit of RFID tag with embedded sensor is reduced, this technology will cross the chasm and enter into the mainstream mass market that the growth rate will surge.

● Barriers for exit the market- Low
There is low barrier of withdrawing from the existing market.

4.2.4 The bargaining power of customers- Minus medium

The bargaining power is the ability of customers to put the firm under pressure, which also affects the customer's sensitivity to price changes.[16] So far, the initial market’s customer normally adopt such system to track their valuable goods, they would pay more attention on the reliability and accuracy of the system rather than the cost.
Market Research for RFID Real-time Cold-chain Monitoring System

- **Buyers’ volume - Minus medium**
  Due to the specialty of the active RFID tags, they can be reused for the period from 3-5 years, and the deploy density won’t be very high. So in this “new adopter” phases of such service, the buy’s volume won’t be very high in the first step.

- **Numbers of suppliers - Medium**
  Since there are already some existing competitors in the market, the number of suppliers of the similar service is considered to be medium.

- **Product Differentiation - Low**
  All the existing and potential competitors are competing to offer their customers with better service, but the main mechanism of the RFID and real-time tracking is probably the same. The improvement of operational details and the lower cost of services will distinguished the company from competitors. But both of them are not that easy to be realized.

- **Cost and complication of switching to an alternative product - Medium**
  Put the cost of shifting to alternatives aside, most of the customers require the RFID system can be integrated or compatible with their own ERP system, that the temperature or other status data can be automatically saved and categorized within their own database. This requires special customized system design oriented to different customers. Once a company adopts such system, it’s meaningless for them to shift to another supplier except a much lower price is offered.

- **Customers’ margins and the sensitivity of price - Plus medium**
  There is a referable hypothesis in year 2007 from Mike Nicometo who is the global information systems director of Cool Chain Group, a 3rd party logistics provider from Germany. He assumed that there is a cold chain company spending $3.6 million yearly on 200,000 vehicle-mounted non-RFID temperature monitors, would have to spend an additional $4.2 million to switch over to RFID tags. That's assuming a cost of only $15 per tag, and that each tag can be recycled 10 times. "It would be 26 monitors per truck rather than one," Nicometo says. "They're increasing their cost per load from $18 to $39."

  Even that the RFID tag developed by iPack center can be controlled at a cost around $ 6-7 which is significantly reduced comparing with the hypothesis in 2007. The customers are still always sensitive to the price.

- **Capability to produce the product by themselves - Low**
  The potential customers are concentrating their business scope in logistics or manufacture, they would rather purchase the service from professional IT solution providers than develop the system by themselves.
Knowledge about the production costs of the product for customer—Medium
Probably the customers will make some research about the existing suppliers and compare their price before real procurement. The knowledge about the production costs can be at a fairly medium level.

4.2.5 Bargaining power of suppliers—Minus medium

The major different components from other RFID solutions in this tracking system are the various kinds of sensors. The price for them can be varied quite much. There are numbers of suppliers in the sensor or RFID manufacturing business, which means the bargaining power from them won’t be very high.

![Figure 25. Michael Porter’s Five Forces Analysis](image-url)
5. Conclusion

The thesis contains many summaries from in-field interview with the people in cold-chain industry. The feedback and suggestions are reliable and meaningful. Here are some points extracted:

- From the opinion of the interviewed people, general idea about the market prospect of RFID cold-chain monitoring application can be perceived towards different cold-chain service fields. There are actually two main fields under research in the thesis, they are cold-chain for the pharmaceutical logistics and foods (include chain-restaurant, fruit and vegetable dealer etc.).

In the pharmaceutical field, the RFID tags are more benefits than the normal loggers, since they can record more accurate temp which is very essential for the staff to judge the quality of the goods. As it can be seen from the situation of the interviewed companies, there are 4 companies that dealing with pharmaceutical or clinical trials logistics, 2 of them has already adopted this RFID system for years, World Courier is now seeking to procure this system with high calibration and doesn’t care so much about the cost, the rest company Sinopharm shows high interests but just wondering the accuracy and cost of such system. From above, it’s shown that the pharmaceutical field is the most likely market at this “new adopter” phases even there are existing competitors.

In the foods field, the companies are still satisfied with their traditional devices. They do have the cooling-system in the warehouses that can be monitored remotely in real-time, but for transportation they think it will be enough to measure the temperature at a truck-level since there are no rigorous government rules and the customers feel satisfied with the report from loggers. The wholesalers normally don’t have their own trucks for delivery, all the transportation process will be handled by the 3rd party, the placement of data logger normally are depends on their customers’ demands. Most of these foods companies do not have on-going plans to shift to RFID system if the up-front cost is considered high. But situation can be changed, such like HAVI Logistics when serving for Beijing Olympics, the customer BOCOG demanded HAVI to use RFID tags for monitoring, and BOCOG are willingly to pay HAVI the extra cost, then HAVI adopted this system for temporary use and let a group of staff get trained on this. So in the foods business, the advanced level of devices they are adopting are mostly relies on customers’ requirements.

Meanwhile, recently it’s not very common in the food industry to monitor other parameters except temperature for the foods cold-chain. The First Expiring First Out (FEFO) inventory rotation order that depends on whether there is any temperature abuse of the goods is so far not been widely adopted. Most of the
Market Research for RFID Real-time Cold-chain Monitoring System

companies are using some elaborated dispatching algorithm or cross-docking logistics mechanism to shorten the inventory storage time. In most cases, the turnover time will be just 1-2days.

- For the pharmaceutical logistics companies, the most important issue is that this RFID system must be calibrated and tested carefully before launching into real use. The precision should realize in some certain level such as 0.5 °C or even 0.2 °C. The accuracy and reliability of the system is very essential for the customers.

- The background system can be developed as a simple separated system with independent database etc, but it’s more than welcome for the customers to buy one that is compatible with their existing management systems. The temperature data or other parameters that being monitored can be saved and retrieved from database by shipment number and comparison between different shipments can be conducted. (The traditional data logger methods generates PDF graphic that does not capable for any comparison or other operations of the data from database.)

- This active RFID + GPRS automatic tracking system so far has not approved by the Air Transport Association (IATA) for loading with the goods on the civil airlines. So in this situation, this tracking system is not available for transportation that carried out by airplane.

- For most of the fruits and vegetables wholesalers, the transportation process is conducted by the 3rd party logistics companies. They are now using data loggers with stamped envelope and expecting the receiver send them back, but the lost rate is quite high. If they shift to use this RFID system, some operation suggestion would be good to offer to them, in order to keep the RFID, master node devices and the recorded data safe.

Even though, there are already some giant companies occupied part of this market, it’s still considered to be a very encouraging field with the development of cold-chain standard, the relevant rules issued by the government as well as the higher expectation from the end-consumers.
References

Tracking goods with sensor-equipped RFID tags could revolutionize perishable-item transport by slashing spoilage-related costs.

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Mobile and Wide Area Deployable Sensor System for Networked Services


Market Research for RFID Real-time Cold-chain Monitoring System


## A. Information matrix of interviewed person

<table>
<thead>
<tr>
<th>No.</th>
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