Improving Ammunition Supply Chain Management with RFID Technology

Ping Yan, Wen-liang Yang, Bo Tan, and Bo-biao Yu

Abstract Military logistics is undergoing a fundamental transformation, which aims to more rapid deployment. As important part of military logistics, ammunition supply chain management is still in rather primitive state not long ago. This paper summarizes technological advantages and limitations of RFID, analyzes status of ammunition supply chain management and gives benefits and problems from RFID. RFID-based system design is made to improve ammunition supply chain management and achieve asset visibility. Finally, some concluding remarks are given.

Keywords Ammunition • RFID • SCM

1 Introduction

The military is undergoing a fundamental transformation. This transformation is driven by the need for rapid deployment and troop sustainment for the duration of that deployment (Hammons and Chisholm 2006). The methods and ability to provide the right type of ammunition at the right place and at the right time requires an enormous infrastructure. The ammunition supply chain is a logistics pipeline that starts at the factory or depot and ends at the foxhole or the end-user of the product. Improving the supply chain can contribute to a smooth flow of support to armed forces during peacetime and war (Hancock and Lee 1998).

Supply chain management (SCM) has caught a lot of attention recently both by academicians as well as practitioners (Helms and Inman 2006). Supply chain

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management (SCM) is a broadened management focus that considers the combined impact of all the companies involved in the production of goods and services, from suppliers to manufacturers to wholesalers to retailers to final consumers and beyond to disposal and recycling. The goal of SCM is to seamlessly link all of the activities responsible for bringing goods and services to the market and efficiently manage the flow from start to finish.

Previous errors in package handling, frivolous spending on legacy systems and dirty data that is used in decision making are all reasons that the military needs to adopt a more efficient ammunition supply chain management system. In the past, the focus has been more so on improving the distribution process and refining inventory models instead of technological components. However, it still lacks great efficiency. That being said, how can we improve supply chain management using technology? While it will never be perfect, utilizing advancements in technology, such as RFID can drastically improve the system (Angeles 2005). Systems that implement automated processes to collect, maintain, organize, and analyze information in real-time empower businesses to exponentially increase efficiency, resulting in increased profits.

A great number of military services are using RFID technology to improve the efficiency of their process. The US Army, launched the Radio Frequency In-Transit Visibility (RF-ITV) System, which uses RFID tags and satellites to trace the identity, status, and location of cargo from origin (depot or vendor) to destination. Data from these two technologies is combined, processed, and accessed via web-based maps and reports, and provides global, logistics support. In addition, the US Navy's combat casualty care unit has used RFID technology to track combat casualties in Iraq. RFID chip sewn into the wristbands of naval personnel helps to track and identify the wounded arriving for treatment at field hospitals in Iraq. Medical data stored in the RFID chips travels with wounded seamen, and data is read by RFID-enabled handheld devices to identify each patient. The RFID technology also allowed doctors to add, change or create new triage records on the chip.

By looking at the current problems and limitations facing ammunition supply chain management, this paper examines RFID's potential in the ammunition supply chain and provides solutions to some of these problems. This paper is constructed as follows. Section 2 analyzes status of ammunition SCM. Section 3 briefly summarizes the RFID technology and gives benefits and problems from RFID. Section 4 describes the solution to asset visibility in ammunition SCM. Finally, we give some concluding remarks.

2 Ammunition Supply Chain Management

Ammunition is defined as "ammunition of all types, bombs, explosives, mines, fuses, detonators, pyrotechnics, missiles, rockets, propellants, and other associated items" (Li 2004). The ammunition supply chain is designed to provide responsive ammunition support to deployed forces anywhere in the world. The

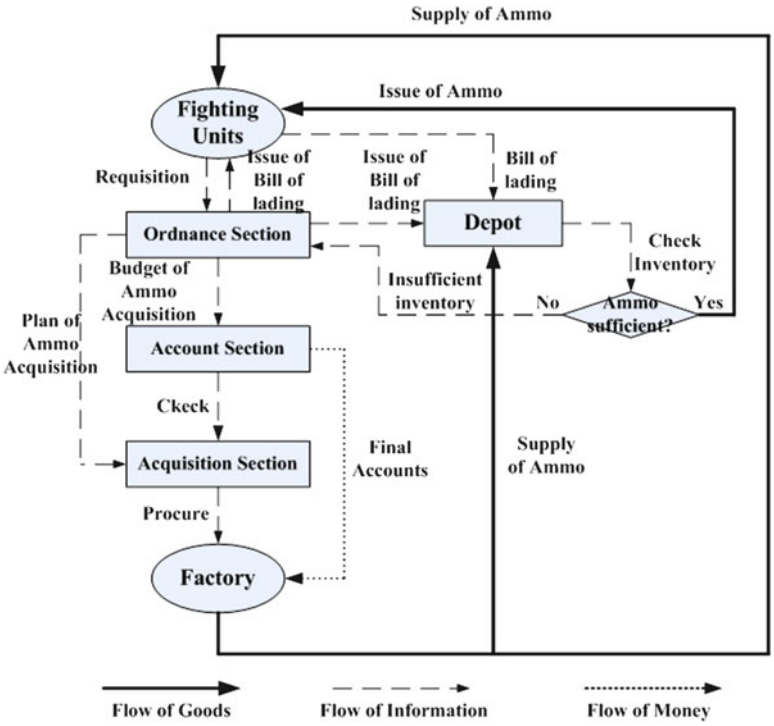

Fig. 1 Diagram of ammunition supply chain management

unique characteristics of ammunition can complicate the supply chain. Ammunition characteristics include size, weight, hazardous nature, storage and special handling requirements, accountability, and security issues.

Different agents, such as fighting units, depots, ordnance sections, account sections, acquisition sections, factories, packaging companies, transport companies, are weaved into this chain. The ammunition supply chain is a flow process, which may be described in terms of the subject of the flow, the resources that enable the flow and the communication that coordinates the flow (Zhao et al. 2011).

As shown in Fig. 1, the source of the total supply chain is the ammunition demand from fighting units. Having examined the requisition from fighting units, ordnance section will issue bill of lading to fighting units and specified depot. The depot need check its own inventory. If ammunition in stocks is sufficient the depot will issue the exact amount of ammunition to fighting units according to bill of lading. If inventory is insufficient, the depot will give ordnance section the recommendation of procuring ammunition. Ordnance section compiles the plan of ammunition acquisition and budget. Account section should check this budget and gives its opinion. According to acquisition plan and approved budget, acquisition section will issue order form to ammunition factory. The factory will supply the ammunition,

which can be transported either in containers or by break-bulk methods, to the depot or fighting units. Finally, account section will finish the final payments to supplier according to order form.

Ammunition SCM affects all aspects of ammunition support. Accounting, inventory control, and fighting ability of armed forces are all intimately linked to and dependent upon efficient management of the ammunition supply chain. Supply chains are systems with a flow of goods from supplier to end-user, made up of many facilities where communication and intensive coordination are a necessity. As with any system, one malfunctioning node can have major effects on all congruent and subsequent actions along the chain. This being said, supply chain management is perhaps the one area of business where creativity and flexibility are most necessary. Improved processes in ammunition supply chain can yield a plethora of cost cutting opportunities. Digital technologies are influencing ammunition supply chain management in very profound ways.

Inefficient supply chains can hinder businesses in a number of ways. Faulty distribution strategies can put the right product in the wrong place or the wrong amount of product in places where they are not needed. Inventory control has been one of the most visible problems facing supply chain management. Inventory management affects the way the military procures and stores ammunition. Efficient supply chain processes that abide by just-in-time inventory principles can greatly reduce their inventory holding costs.

It is pitiful that ammunition supply chain management of China's armed forces is still in rather primitive state not long ago (Xie and Li 2008). Ammunition were usually contained in unsealed wood packaging box, sealed metal packaging box, sealed plastic packaging box. And weight of individual package is less than 100 kg in order to be carried manually. Obviously, this kind of packaging can only provide simple protection and be consistent with ammunition support mode of carrying manually. There were several obvious disadvantages as followed in ammunition supply chain management:

- Almost each kind of ammunition has its unique packaging box. Even for the same kind of ammunition, the packaging box may vary according to different manufacturer and different manufacture date.
- Weight and size of different ammunition vary greatly. And depot lacks relevant facilities and carrier. It results in poor mechanization in ammunition supply process.
- Information exchanges between all kinds of business mainly rely on paper credence. The military can not keep track of inventory in real-time. And accuracy can not be ensured because of recording manually.

Recently, containers and trays started to be used in ammunition supply chain. And new equipments are also used in ammunition handling. It gives a chance for the military to improving the ammunition supply chain management. Information is power; therefore it follows that Information Technology is power. Nearly all business problems can be solved by proper manipulation and implementation of information. To overcome current inefficiency, further redesign of the supply chain

and leverage of new enabling IT is necessary. New technologies are always evolving tackle problems with the hopes of increasing productivity, lowering waste and increasing profit margins.

3 RFID Technology

3.1 What Is RFID?

RFID can be briefly described as one of the automatic identification methods using Radio Frequency (RF) technology to identify individual physical objects (Lahiri 2005).

RFID technology is composed of three parts: an identification tag, a reader and a computer. There are two primary types of RFID tags, active and passive, and each has advantages and disadvantages.

With Active RFID, extremely low-level RF signals can be received by the tag (since the reader/interrogator does not power the tag), and the tag (powered by its internal source) can generate high-level signals back to the reader/interrogator. Active RFID tags are continuously powered, which enables to be used when longer tag read distance is desired.

Passive RFID tags reflect energy from the reader/interrogator or receiver and temporarily store a small amount of energy from the reader/interrogator signal in order to generate the tag response. Passive RFID requires strong RF signals from the reader/interrogator, and the RF signal strength returned from the tag is constrained to very low levels by the limited energy.

Active tags are more expensive than passive tags because they send information using an internal battery source and store more data, while passive tags rely on the reader. Additionally, tags have a discrete memory capacity that varies from a small license plate to thousands of records. Data within a tag can provide any level of identification for an item during manufacture, in-transit, in storage, or in use.

3.2 Technological Advantages

There are many technological advantages of RFID that attract military facilities to implement RFID within their business processes. Advantages are as follows:

- Contactless: An RFID tag does not need physical contact to communicate with the reader.
- Writable data: RW RFID tags can be rewritten 10,000–100,000 times or more.
- Absence of line-of-sight: An RFID tag can be read from different angles without any requirement of line-of-sight visibility, and also through obstructing materials which are RF-lucent for the frequency used.

- Variety of read ranges: The reading distances of a RFID tag range from a few inches to more than 100 ft, depending on the type of tag and the RF used.
- Write data-capacity range: The data capacity of a RFID tag varies from a few bytes to virtually any amount of data depending on the type of tag and the physical dimensions and capabilities.
- Support for multiple tags reads: A RFID reader can automatically read several tags in its read zone in a short period of time.
- Rugged: RFID tags are able to function in harsh conditions to a fair extent. They are very durable and long-lasting.
- Perform smart tasks: In addition to its usual tasks, a RFID tag can perform specialized tasks such as measuring temperature and detecting motion.
- Read accuracy: The theoretical read accuracy is 100 % as written in the media; however, it differs from implementation to implementation.

3.3 Technological Limitations

Although, the technological limitations listed below should be considered before pushing RFID technology into military applications.

- Poor Performance with RF-opaque and RF-absorbent objects: If the object is packaged inside of an RF-opaque or RF-absorbent material such as metal or water, the RFID reader does not work well or completely fails in some cases.
- Impacted by environmental factors: The features of the operating environment are significant factors for read accuracy such as a large amount of metal or liquids.
- Limitations on actual tag reads: Within a specified time, there is a limit to how many tags can be read.
- Impacted by hardware interference: When the read zones of two or more readers overlap, their signals can interfere with each other resulting in duplicate or more tag reads. In addition, improper installation of a RFID system and the wrong orientation of tags can have negative affects on read accuracy.
- Limited penetrating power of RF energy: The capability of a RFID reader to read a tag from different angles, without any requirement of line-of-sight visibility or through RF-lucent obstructing materials, is limited to the power of RF energy.
- Immature technology: The variety of vendors manufacturing tags and readers that have different capabilities utilizing multiple frequencies without any globally agreed upon standards not only increases the innovations and advancements of RFID technology, but also increases the practical issues of implementation.

4 System Design of Ammunition Supply Chain Management Based on RFID

4.1 Feasibility of Applying RFID in Ammunition Supply Chain Management

Main content of ammunition information includes name of ammo, batch-year-factory information of ammo, name of important component, batch-year-factory information of important components, length-width-height of package, ammo amount in each box, total weight of each box. Maximal amount of characters is less than 600. Usually, these characters are printed on outer surface of package so that user can identify the ammunition by visual check manually. In order to identify automatically ammunition information, electronic product code, or EPC (Angeles 2005), can be used. EPC consists of an eight-bit header and three sets of data: EPC Manager (28 bits), object class (24 bits), and a serial number (36 bits). The header identifies the EPC version number. The EPC Manager identifies the manufacturer of the product in question. The object class refers to the exact type of product or stock-keeping unit. The serial number is the unique code that identifies the specific product item. The EPC itself will be embedded into the RFID tag in order to be transmitted. To successfully translate the tag, a tag reader must be used. The tag reader must be able to handle readings both fast and effectively, allowing for greater increase in speed through the supply chain.

Ammunition management software must be upgraded so that it can perform a number of major tasks supporting the network of readers, namely, data smoothing, reader coordination, data forwarding, data storage, and task management. The software must be efficient in that it can accurately read and record product information at high speeds and can remove duplicates in real time. In addition, the software must realize what information can be terminated at a certain point and what information must be forwarded up and down the supply chain. The resulting databases must be designed to store mass amounts of information as well as the ability to quickly retrieve information of a specific item. The user will take the EPC from the management software and quickly find the location of the detailed information of the product associated with the code.

Benefits from RFID technology are numerous for both the military and its suppliers. The incorporation of passive RFID tags into business processes enables automated data capture, resulting in efficient recording of materiel. The benefits to suppliers include:

- improved planning
- faster demand responses
- streamlined business processes
- improved efficiency in the recall of defective items
- increased ability to ensure that products remain stocked on military depot's shelves

The benefits for the military include:

- improved inventory management
- improved labor productivity
- elimination of duplicate orders
- replacement of manual procedures
- automated receipt and acceptance
- improved inventory and shipment visibility and management
- improved asset tracking

With benefits, however, come problems. Security is a major concern for RFID technology. Tags that are readable anywhere, anytime pose a risk to corporate and military security.

Accuracy of information is another concern. The US DoD ever identified suppliers using incorrect passive RFID tag ID headers when sending shipments to the US military. Suppliers must take care to ensure that they are using a tag header accepted by the military otherwise, the information is either lost or incorrectly added to the database.

Another problem is implementation. US DoD faces challenges achieving widespread RFID implementation because it is unable to demonstrate the return on investment to the military components that have primary responsibility for implementation.

The military have made some progress adopting RFID technology. These efforts include developing policy and guidance, establishing working groups and integrated process teams to share information and lessons learned both within and across the military components, providing funding to support implementation, and establishing pilot projects and initial implementation efforts at several locations.

4.2 System Design

Implementation RFID into ammunition supply chain can be summarized as followed (Tae Hwan Oh et al. 2012).

Step 1: Embed into every ammunition box an RFID tag that includes the EPC. Along with individual boxes, containers and trays can also be tagged with their own unique identifier. Type of tag may be different according to material of packaging box.

Step 2: The ammunition can be automatically and cost-effectively identified, counted, and tracked by implementing a reader's non-line of sight technology.

Step 3: When the ammunition leaves the manufacturer a RFID can send a beam of radio waves that activate the tags allowing them to be read by specific readers.

Step 4: Tags broadcast their EPCs to the reader, which rapidly switches them on and off in sequence, until all are read. The reader sends the EPC to a computer

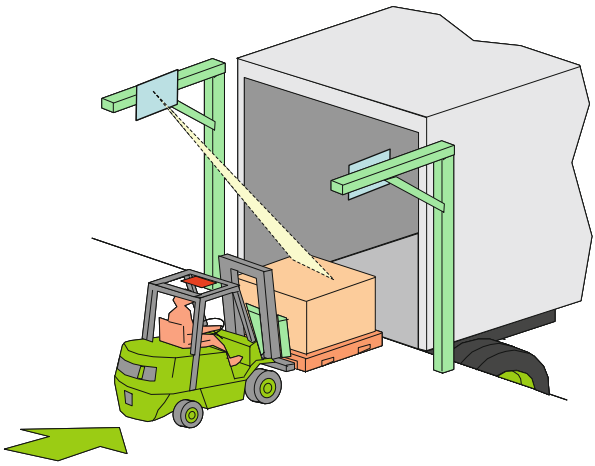

Fig. 2 RFID reader deployed at passage

running management software that sends the EPC to central database. Central database matches the EPC so that query result of comprehensive information about the ammunition is returned.

Step 5: The unloading dock contains a RFID reader that can read the items without opening packages to examine their contents and can be quickly routed to the appropriate truck.

Step 6: As the ammunition arrives at depots, a reader scans the items updating the inventory systems to include every item. This allows to stores to locate their entire inventory automatically and at low cost.

4.3 Achieving Asset Visibility

A combination of RFID technology and a well maintained ammunition supply chain management system can result in asset visibility system (Buckner 2002).

In-storage assets are those assets stored at retail supply, wholesale storage (both ashore and afloat), and disposal activities. They also include inventories held by maintenance activities to support repair operations and vendor-managed inventories that are part of vendor-military partnerships. This category of assets encompasses all classes of supply. In order to attain asset visibility in ammunition depot, RFID reader can be placed at gate or passage, as shown in Figs. 2 and 3. These readers can also be placed on carrier. Each packaging unit should be attached a RFID tag, which corresponds relevant ammunition information stored in central database of information center.

When ammunition are shipped to other places, corresponding RFID reader can identify and notify information center that which zone or which carrier the ammunition have been placed in. So information center can know how much

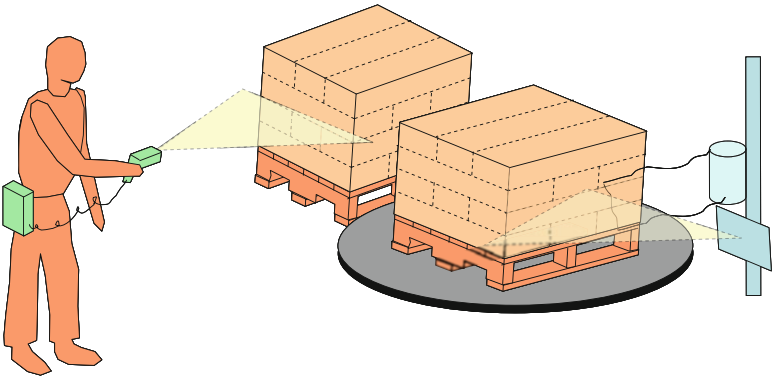

Fig. 3 RFID reader taken by storekeeper

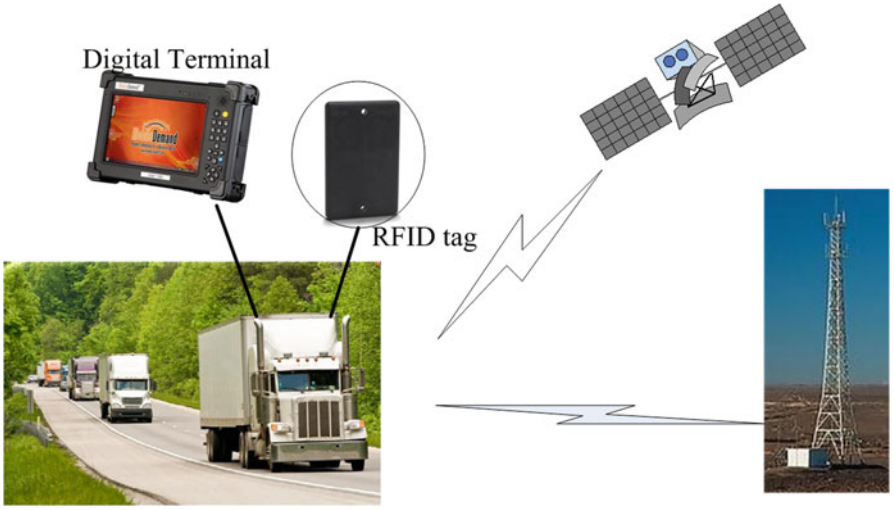

Fig. 4 Wireless or satellite transmitter on vehicles

ammunition received and how many ammunition issued in real time. Even turnover of ammunition in depot can be sensed.

In-transit assets are assets moving from origin to destination and thus are the objects of in-transit visibility. The military must be able to identify the contents of a shipment and monitor its movement throughout the logistics pipeline. The military also needs the ability to track item, unit, and personnel movements and to reconstitute and divert shipments. There are two methods to attain visibility in-transit. One is to place wireless or satellite transmitter on vehicles. Ammunition information will be transmitted to command or troop, as shown in Fig. 4. The advantage of this method is that authority can know information in transit. The disadvantage is its high cost.

Fig. 5 RFID reader deployed in theater

Another method is to place RFID reader on mobile telecommunication vehicles, which are deployed at specified zone or key route as shown in Fig. 5. When ammunition shipment gets across this zone, telecommunication vehicle will transmit relevant information to command or troop. The advantage of the second method is its lower cost. The disadvantage is that information in transit can only reached periodically.

It is expected that RFID will provide better inventory management and control. This can also translate into better released support for the troops in the battlefield. When the military is able to closely track these items operations will run more smoothly due to the fact of less variability and more reliable information of the localities of equipment and personal necessary for the war effort. Having the power to know where all supplies, and personnel are in a hazardous and fast paced environment allows planners to make good well informed decisions, which leads to a more powerful and responsive military.

5 Conclusion

Upon examining the problems associated with ammunition supply chain management and also identifying some of the solutions RFID technology can offer, it is clear that the integration of RFID technology into ammunition supply chain management will assure the synchronization of goods flow and information flow. It also helps to

improve asset tracking. While the technology is still relatively new and the initial investment associated with the transition to RFID based systems is substantial, it is clear that the benefits of RFID technology far outweigh the costs in the long run.

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