RADIO FREQUENCY IDENTIFICATION QUEUING & GEO-LOCATION (RAQGEO):

A SPATIAL SOLUTION TO INVENTORY MANAGEMENT AT XYZ LOGISTICS, INC.

by

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DEDICATION

This research is dedicated to the advancement of scientific research for the GIS and RFID communities alike. I would also like to dedicate this to my family and friends to include my father, mother, sister, and brother-in-law, and friends David McCoy, Daniel Gonzalez, Breanna Marcum and others that were supportive of the hours I have devoted towards this research.

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LIST OF ABBREVIATIONS

ADA	Americans with Disabilities Act
API	Application Programming Interface
COP	Common Operating Picture
FOV	Field-of-View
FTP	Fleet Training Publication
GIS	Geographic Information Systems
GIST	Geographic Information Science and Technology
GLONASS	Global Navigation Satellite System
GPS	Global Positional System
IFF	Identification, Friend or Foe
IoT	Internet of Things
JEP	Joint Educational Project
JIT	Just-in-Time
LAN	Local-Area Network
M2M	Machine to Machine
MGAP	Mobile Grid Action Profile
NAVSTAR	Navigation Satellite Timing and Ranging System
NYK	Nippon Yusen Kaisha Logistics
PDA	Personal Digital Assistant
POA	Point-of-Action
PPE	Personal Protective Equipment
RAF	Royal Air Force

RAQGEO	Radio Frequency Identification & Queuing Geolocation
RFID	Radio Frequency Identification
ROI	Return on Investment
SSCI	Spatial Sciences Institute
UHF	Ultra High Frequency
US	United States of America
USC	University of Southern California
WAN	Wide-Area Network

ABSTRACT

New supply chain management methods using radio frequency identification (RFID) and global positioning system (GPS) technology are quickly being adopted by companies as various inventory management benefits are being realized. For example, companies such as Nippon Yusen Kaisha (NYK) Logistics use the technology coupled with geospatial support systems for distributors to quickly find and manage freight containers. Traditional supply chain management methods require pen-to-paper reporting, searching inventory on foot, and human data entry. Some companies that prioritize supply chain management have not adopted the new technology, because they may feel that their traditional methods save the company expenses.

This thesis serves as a pilot study that examines how information technology (IT) utilizing RFID and GPS technology can serve to increase workplace productivity, decrease human labor associated with inventorying, plus be used for spatial analysis by management. This pilot study represents the first attempt to couple RFID technology with Geographic Information Systems (GIS) in supply chain management efforts to analyze and locate mobile assets by exploring costs and benefits of implementation plus how the technology can be employed.

This pilot study identified a candidate to implement a new inventory management method as XYZ Logistics, Inc. XYZ Logistics, Inc. is a fictitious company but represents a factual corporation. The name has been changed to provide the company with anonymity and to not disclose confidential business information. XYZ Logistics, Inc., is a nation-wide company that specializes in providing space solutions for customers including portable offices, storage containers, and customizable buildings.

CHAPTER ONE: INTRODUCTION

In 2008 more things were connected to the Internet than people. By 2020, the number of devices connected to the internet is predicted to surpass 50 billion (Cisco 2014). These numbers are the reality of the Internet of Things (IoT), which is a vision that all objects will someday be interconnected (Cisco 2014). It is already being used through machine to machine (M2M) communication between devices through sensors and actuators to alert if a device needs upgrades or servicing. Radio Frequency Identification (RFID) technology is one of the contributing factors toward this vision. Early adopters of RFID technology are already relishing in business advantages. RFID technology is terrestrial or ground-based and consists of three main components: an antenna, transceiver, and transponder:

- The antenna and transceiver are handled via a RFID reading device that can interrogate, energize, and interpret data from the transponder.
- Transponders are represented as devices such as tags that identify an object they are attached to hence the name RFID tag.

RFID tags have been described as being similar to the magnetic strip on an ATM card (Technovelgy 2014). However, unlike an ATM card, it can be read remotely up to three or more feet depending on the type of tag (Technovelgy 2014). It has also been described as a “digital shadow” as it provides metadata information of the object it is bounded to over computer hardware and software (Ivantysynova et al. 2008).

The “digital shadow” has recently been recognized as a viable solution to eliminating wastes in supply chain management (SCM) through production, distribution, transportation, store, and retail processes. Each year United States retail industries combined lose about US$70 billion from current SCM practices (Liu et al. 2010). RFID technology provides readily available data to be used in SCM and can be collected by sensors, actuators, and reading devices.

This chapter introduces the fact that RFID tags have become increasingly popular, and organizations are also expanding their requirements to forge RFID, or terrestrial–based technology with satellite-based technology/Global Positioning Systems (GPS) to add spatial visibility to inventory management through two-dimensional map representations.

RFID and GPS technology used together is in its infant stages. It has never been applied in the context of a Geographic Information Systems (GIS) project for mobile assets. Companies are mostly using it as a means of quick identification, inventorying, and tracking inventory movement along a supply chain. However, it can provide other sources of information such as where products are located by attributes and proximity to specific features. The pilot study's technology and goals are explored in the following sections.

1.1 Pilot Study Goals

Investigating a problem spatially often leads to the discovery of patterns that can supplement the decision-making process and provide management with an "overall picture" or expanded detail. GIS has three unique strengths: spatial data management, interactive visualization, spatial analysis and decision making support (Work Site Alliance 2000). This study provides an in-depth cost-benefit analysis, advantages of spatial applications and RFID technology used together for mobile asset management.

Mobile assets are inventory items that can be repositioned in a yard, or moved to a customer site and back after a lease is complete. The study's results proved the ability to decrease costs attributed to human labor and increase efficiency in time involved in inventorying the company's assets. The results also introduced a new interactive visualization tool to quickly reference the location of units and recognize patterns within the storage yard using web-enabled GIS.

This study serves to replace traditional inventory methods in SCM to implement RFID and GPS technology along with a demonstration of its potential in GIS projects. SCM is defined as the oversight of goods and services as they move from a supplier to a customer (Zeidan 2009).

SCM concerns the "where" and "what" of inventory. These same terms are the essence of a GIS which can provide tools to analyze features by various attributes and spatial metrics. A GIS is defined as a "computer-based system to aid in the collection, maintenance, storage, analysis, output, and distribution of spatial data and information" (Bolstad 2008).

The use of a GIS will reduce time in finding an asset by specific qualities such as serial number or ADA-compliancy, and increase awareness of asset location in a storage yard. This is provided through a spatial workflow component of GPS coupled with RFID data ported through web – enabled GIS. It also provides a cost-benefit analysis seldom observed in RFID/GPS solutions and GIS.

XYZ Logistics, Inc. was selected for this pilot study. They lease and sell space and storage solutions including modular buildings, steel storage/conex containers, and customized storage spaces to a diverse market. XYZ Logistics, Inc. is a fictitious company but represents a factual corporation. The name has been changed to provide the company with anonymity and to not disclose confidential business information. Some of their customers includes federal and state government organizations such as military, law enforcement, school districts, as well as private companies including utilities and marketing organizations. XYZ Logistics has over 100 locations nationwide. Over the last three years, XYZ Logistics has adopted a business model of continued advancement in order to find solutions to reduce costs, and improve operational processes, such as tracking, locating, and preparing inventory.

In this research, the term logistics follows closely to Transfreight Inc.'s summarized definition: logistics is the control of movement, placement, planning, and execution of goods and services. XYZ Logistics' process of logistics consists of finding and moving units by forklift to their preparation bay, then deploying the unit to a customer's site after it has been prepared to specifications. To ensure logistical processes can operate accurately, most XYZ Logistics branches conduct a quarterly inventory for accountability of assets. Other branches are required to conduct monthly inventories.

Serial IO provided RFID and GPS equipment, cloud services, and consultation for the pilot study. They were selected because they were the first company willing to lease equipment for the pilot study. Serial IO was founded in 1992 and has been providing point-of-action (POA) solutions which is the use of mobile tools for tracking assets with sensors. They have a variety of customers nationwide providing mobile and cloud-based solutions over Wide-Area Network/Local-Area Networks (WAN/LAN) they develop to customer needs. They provide barcoding and RFID tag products and services customizable to a customer's needs such as security, asset tracking, or even attendee/employee time tracking through badges or wristbands. The RFID equipment included 25 GEN 2 UHF Passive RFID flex tags, and an Intermec IP30 UHF RFID reading device. The GPS device included a Trimble Juno T41XGR-TGA-00 which also served as a UHF RFID reading device. Cloud services included a free mobile application for a smartphone and the T41XGR-TGA-00, a Mobile Grid Action Profile (MGAP) service (specific to how the data is formatted and collected), Google map application programming interface (API) use and iScanList for uploading the data online to be retrieved. Consultation included discussion on customer requirements, pricing, and with Dave Boydston, the director of Serial IO and tracking solutions engineer expert. Dave Boydston also assisted in selecting placement of RFID tags for the pilot study, explained how it is currently used, and provided pricing for the cost-benefit analysis.

Separately, an Intermec IP30 UHF RFID reading device was also used and tested with a smartphone via BlueTooth technology. It was chosen because it is a relatively inexpensive UHF GEN 2 RFID tag reader and can be used with a smartphone. Additionally, every manager at XYZ Logistics has a smartphone provided by the company. The smartphone has two uses: one is to download Grid-in-Hand, a free mobile application that serves as a medium to capture RFID and GPS data, it also has a feature to upload the data to cloud services using either a cellular data plan or Wi-Fi. The second use is for commercial-grade GPS.

The Trimble T41XGR-TGA-00 proved to be a durable, all-in-one RFID/GPS device, that also would use the Grid-in-Hand application. The main difference is the device is professional grade, has more accuracy for GPS and its durability is more fitting for a XYZ Logistics storage yard. It’s increased amount of accuracy is not entirely necessary for the mobile offices, when a smartphone can provide similar results however there could be a scenario where configurable units are arranged to where their RFID tags may be within two meters and a distinct difference in their positions can be provided.

1.2 Purpose of the Thesis

The purpose of this work is to introduce a spatial workflow in the use and management of inventory fleets by utilizing Radio Frequency Queuing & Geo-Location (RAQGEO). This investigation will leverage GPS receivers with RFID reading capabilities, RFID tags, a Wide Area Network (WAN) for uploading, a geodatabase, and GIS services such as Google FusionTables, Serial IO's Google Map API.

The working hypothesis of this study is that a spatial workflow component will lead to increased efficiencies in time, reduced costs, a quicker inventory method, provide an updated COP in business environments requiring supply chain management similar to XYZ Logistics. The pilot study served as the first known exploration of GIS use in supply chain management in regards to mobile assets using item-level attributes such as serial numbers and other qualities to find and manage inventory. RAQGEO will be a significant enhancement to their culture of "Continuous Improvement."

To develop a basis of knowledge for this pilot study the following topics were explored: supply chain management, current JIT service solutions that companies sell such as Barcoding Incorporated and Serial IO, Ltd., RFID technology coupled with GPS capabilities, remote sensing using GPS data, Bluetooth technology between smartphones and RFID reading devices, and GIS functions. All data will be collected and exploited using RAQGEO. The primary datasets for this study are passive UHF RFID and GPS data that will be captured in a geodatabase. The RFID data provides unique identifier information along with product attributes. The data will then generate spatial information which can be viewed on a web-enabled map containing basic GIS functionality. The scientific community can gain further insight in how RFID technology coupled with GPS technology can improve inventory or fleet management and its beginning possibilities in GIS.

1.3 Thesis Organization

Following this section is a brief background and technical review of RFID and GPS technology as it pertains to SCM.

Chapter Two provides information on the construction of RFID tags, how it interacts with an RFID reader, the use of GPS along with RFID technology and backend database languages.

Chapter Three describes the methodology used throughout the pilot study to include the project model used to develop the schema, a description of the pilot study area, data collection, geodatabase design, and an overview of the middleware used to create products and spreadsheets.

Chapter Four covers a cost-benefit analysis comparing the traditional inventory management methods with RAQGEO. It leads to a discussion of disadvantages such as RFID security issues and collection concerns.

Chapter Five draws a conclusion from the research and applies the results to a method in which other companies can share similar results. A future works section follows that provides thoughts of how the technology can be expanded.

The research is followed by appendices that provides pilot study test observations of RFID tag readings, recommendations for RFID tag placements, RFID tag and device datasheets, and a look at the schedule used between parties related to the study.

CHAPTER TWO: RFID DEVELOPMENT & COMPOSITION

RFID technology today is known to track wide-ranging items, such as pets, livestock,, cargo, to name a few. The tracking involves tags, which are bound to an item (e.g., an individual, shipping container). Its demand is becoming higher as companies recognize its value in supply chain management, inventory or asset management and logistics. Companies such as Wal-Mart are realizing the benefits of RFID tags as their executives have calculated that out-of-stock occurrences have been diminished by as much as 1/3 with improved use of RFID technology (University of San Francisco 2014). Wal-Mart has also urged all of their suppliers to RFID tag all products (Millsap 2012). Some companies that work with logistics see the value of RFID technology for decreasing data processing times and easier tracking of assets, however, they also want to track a near-exact location of an asset. GPS technology must be used to identify this type of property and today it can be combined with RFID data. The technology is explored in the following sections.

2.1 A Brief History on RFID Collection

As described in the introduction RFID technology surfaced during World War II. It was first implemented in Britain’s Royal Air Force (RAF) to identify aircraft friend from foe. A 1947 Tele-Tech magazine article, “Identification, Friend or Foe - Radar’s Sixth Sense” by Louis Stuart has an in-depth description of the Identification, Friend or Foe (IFF) system that became a precursor to modern RADAR and RFID technology. IFF was installed on RAF aircraft for identification from ground control stations and later on ships at sea. The technology first used dipoles that would echo the same radio frequency transmission to the interrogating system that it received. It proved unsuccessful because it had irregular modulation producing radio frequency wavelengths of different power. By 1940, more sophisticated systems were designed called the Mark 1 and later the Mark 2. The dipoles were replaced with a receiver-transmitter. The technology was shared and adopted by US forces. It was coupled with radar stations and upon being energized by a return radar signal it would power on and send a pulse back to the object. The transponder on the aircraft would then send a reply back to a radar station (Stuart 1947). Radar stations with an IFF system had indicator screens that would show pips of objects being sensed (See Figure 1), with larger pips representing friendly aircraft or vessels (Stuart 1947).

The United States Naval History and Heritage Library's archive holds declassified documentation on Naval equipment, guides, and engineering manuals of its vessels to include RADAR. US Navy Fleet Training Publication (FTP) 217 the maximum coverage of the Mark II was about 75 miles and minimum of one mile. Atmospherics such as cloud coverage and reflective surroundings such as water could affect the signal. It could be used for aircraft to identify other aircraft, ground stations to identify aircraft or ships, and other mixes. It would create significant drag on aircraft as the Mark II was about 45 lbs. and would take up space inside the aircraft. It consisted of two parts: a transponder and a interrogator-responder. The transponder was carried on the vessel to be identified and the interrogator-responder was on a vessel or ground station. (US Navy FTP 217 1943).

Figure 1 shows how the signal is seen on a US SCR-602 radar range screen:

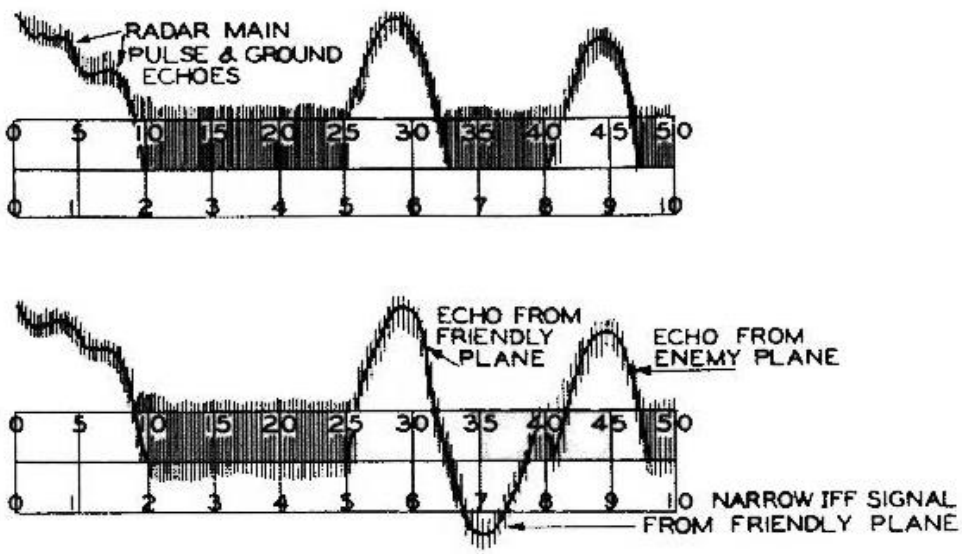


Figure 1: SCR-602 Radar Range Screen Reading, Source: VKDYM QSL.Net, 2014

In the oscillation of wavelengths the upward peak of the rising arches are called "crests" and downward sinking arches at the lowest point are "troughs." The deep and narrow trough displayed above represents the friendly aircraft. These same RADAR principals became the premise for today's RFID technology use in RAQGEO.

2.1.1 RFID Development

Through the 50's and 60's, the same IFF technology was further exploited and studied for a future in remote sensing capabilities. Stores created a single bit security tag as an anti-theft feature that was attached to merchandise. Readers would be placed near doors as they are today and would check to see if the tag was on or off (Roberti 2005).

In the 70's, the active RFID technology was patented by Mario Cardullo (Patent US3713148). During the same time period Charles Walton patented the first passive transponder which was used for opening doors based on radio signals. The US government was also testing the technology for tracking nuclear material transported by trucks to secured facilities. They used Los Alamos National Laboratory's services in its creation. A transponder would be located in the truck that would communicate with a receiver at secured facility gates (Roberti 2005).

The Agricultural Department needed a solution for tracking cows and pursued the help of the Los Alamos National Laboratory creating the first passive RFID tag. Over time the technology was further developed world-wide by various companies. IBM furthered the technology in the 90's and patented the first UHF RFID tags in which they used in pilot studies with Wal-Mart (Roberti 2005).

In 1999, the Uniform Code Council along with other companies funded an Auto-ID Center at the Massachusetts Institute of Technology where two professors studied the use of RFID tags in a supply chain at low costs. They commissioned RFID tags with only a serial number that could be used against an online database to lookup additional information for that serial number. This reduced the costs and enabled it to be attached to products for tracking purposes. As the Auto-ID Center gained more acceptance among the RFID community by 2003 its technology was licensed to the Uniform Code Council which in turn created EPCglobal. EPCglobal set international specifications for electronic identification (Roberti 2005).

Today RFID technology is being used for asset management and tracking the shipment of goods through entire supply chains. In the next section the composition of the technology will be explored.

2.2 RFID Tags & Readers

RFID technology requires three separate criteria: an antenna, a transponder, and a transceiver.

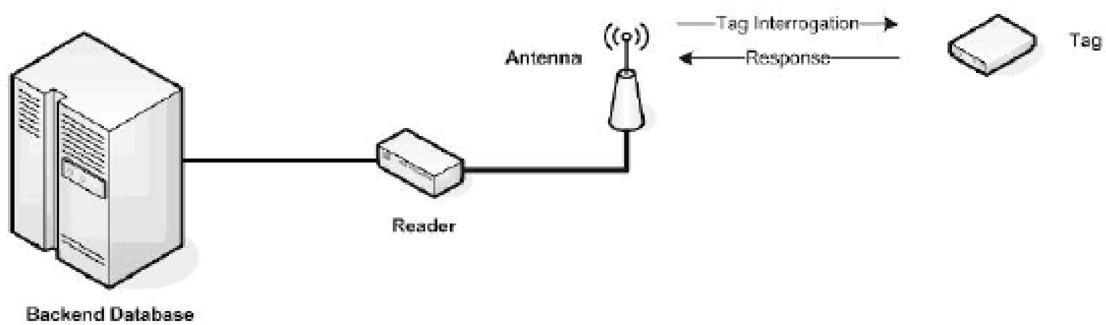


Figure 2: Basic RFID Reader & Tag Interaction Layout, Source: Lindstrom & Thornton 2005

Figure 2 displays the basic layout for RFID reader and tag interaction. A reader will interrogate a tag through an antenna and the tag will respond back to the antenna which the reader can then ingest into a backend database on the device or upload it to a network if it has internet access. Depending on the type of RFID tag there is different behavior when sending a response back to a reader.

There are three types of RFID tags- passive, semi-passive and active:

- Active tags use a battery to power their own microchip circuitry and transmission to a reader.
- Semi-passive tags use a battery for microchip circuitry but draw power from a reader.
- Passive tags have no battery and draw all of their power completely from a reader.

Just as the tags have specific principals for communication they also have different frequency ranges they operate on. Each frequency range is found to be used with different product and service types.

Table 1: Frequency Ranges for RFID Tags

Frequency Range	Description	Typical Applications
<135 KHz	Low Frequency, Inductive coupling	Access Control & Security Widgets identification through manufacturing processes, Ranch animal identification, OEM applications
13.56 MHz	High Frequency, Inducting coupling	Access Control, Library books, Laundry identification, OEM applications
868 to 870 MHz 902 to 928 MHz	Ultra High Frequencies (UHF), Backscatter coupling	Supply Chain Tracking
2.400 to 2.483 GHz	SHF, Backscatter coupling	Asset tracking, Highway toll tags, Vehicle tracking

Source: Data adapted from TutorialsWeb.com 2011

Table 1 shows that supply chain tracking/management favors the use of UHF tags. As RFID tags have become relatively expensive over time UHF tags have been favored over other tag types because they have been labeled as more “ubiquitous” as it can be placed along almost any type of surface anywhere and can be read. This is because of its radio wavelength propagation efficiency (ThingMagic 2014).

An active tag has a much farther read distance because of its use of a battery (RFID Journal 2014). A read distance is how far a signal can be broadcasted from a tag which is approximately one meter for the average ultra-high frequency (UHF) passive tag and several hundred meters for a UHF active tag (SkyRFID, Inc. 2014). RFID tags have been used largely by government agencies but today can be found implemented for logistics and shipping management.

2.2.1 RFID Tag & Reader Composition

The basic components to a passive RFID tag are an antenna, a microchip, and the substrate material it is connected to. The antenna is usually wrapped in a coil fashion and is used for receiving and sending out signals. The microchip contains unique identification information. The antenna usually is in a coil fashion so that it lengthens the signal as it is received to generate enough power to energize the microchip enough to get its information and send the signal back out to a reader. The phenomenon to generate power is called "near field." "The Near Field is a phenomenon that occurs in a radio transmission, where the magnetic portion of the electromagnetic field is strong enough to induce an electrical field in a coil" (Lindstrom & Thornton 2005). The activity happens as its namesake suggests, near the antenna. The distance depends on the radio signal's wavelength.

Figure 3: Passive RFID Tag, Source: Woodford 2007

Figure 3 displays the basic construct of a passive RFID tag. The silver portion is the antenna. The pink portion observed in the middle is the microchip and the substrate is adhesive sticky white paper that can be attached to a flat surface it was designed for. The difference for an active or semi-passive tag would be an addition of a small battery.

Intermec, now owned by Honeywell, today offers many RFID reading devices from handhelds, to vehicle mounts, fixed readers, printers and antennas. They were founded in 1966 working with barcode technology and later RFID. The 90's served as the period where they began working closely with IBM's RFID Division (which was later acquired by Unovo) to provide RFID solutions for tracking goods and shipments. In 1999, Intermec became the first company to create the first handheld RFID reader, which featured Windows and the ability to program tags (Grant 2005).

A RFID reader is actually a transceiver (a combination of a transmitter and receiver). The use of the word "reader" is inaccurate (Lindstrom & Thornton 2005). A RFID reading device will also interrogate a tag by transmitting a signal and then it will receive the information from it. The larger the RFID reader, the larger the chance the antenna will be separated from it.

RFID reader devices have a back-end API to connect to different types of Simple Query Language (SQL) databases including: MySQL, Oracle, PostgreSQL, SQL Server (RFIDvirus.org 2006).

Today, new supply chain management methods demand many fields of data to be collected. The next section introduces GPS theory as it relates to RFID technology.

2.2.2 GPS Receivers with RFID Capability

GPS was created in the 1960s and developed by the Department of Defense for military navigation (Parkinson 1994). It was first tested by the US Navy with only five satellites orbiting the Earth (MiTAC 2014). President Bill Clinton released a statement May 1, 2000 that after midnight that night selective availability, the intentional degradation of public GPS signals, would be lifted providing ten times the accuracy. The increase of positional accuracy has led to new uses of its technology. Today, there are approximately 30 satellites that make up NAVSTAR that orbit the earth at an altitude of 20,000 km (Institute of Physics 2014).

GPS is a satellite-based technology that requires communication between four or more satellites based in space for identifying a position— three for trilateration and one for error resolution. It uses a network of satellites that can be primarily either America’s Navigation Satellite Timing and Ranging System (NAVSTAR) GPS satellites or Russia’s Global Navigation Satellite System (GLONASS) GPS, but can also be a mix of a few other country's satellite data. They accomplish this either through smart tags with GPS integrated with the RFID tag or using GPS receivers with RFID-reading capability.

Figure 4 shows an illustration of trilateration. Trilateration is a technique used to calculate a location based on three satellites. GPS satellites broadcast geographic data and a time code. The intersecting point between three satellites provides a GPS receiver its own location. A fourth satellite provides small corrections to be applied for more accurate position data. The data can be further processed by ground control station for sub-centimeter accuracy.

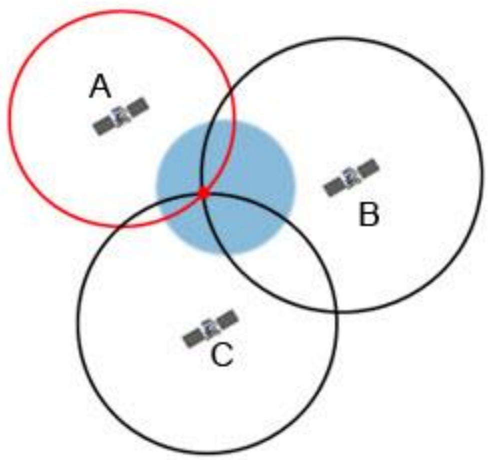


Figure 4: Trilateration of GPS Satellites, Source: Institute of Physics 2014

Off-the-shelf devices to read GPS signals are sold by companies such as Trimble, Motorola, Magellan, and Garmin sell GPS receivers.   It is known today that smartphones can also be used as GPS receivers when specific mobile applications are used. Several GPS receivers are built with RFID reading capabilities. Smartphones do not have built-in RFID reading capabilities but companies such as IDBLUE sell Bluetooth RFID stylus devices that can be used to read a tag and to draw or make selections on a smartphone screen.

As an RFID tag is read, it can pair collected data with a geographic location from a GPS receiver. Therefore, location data is based on the GPS receiver and not the RFID tag. The Trimble Juno T41XGR-TGA-00 and a Droid Bionic with an Intermec IP30 is used in this study. Software created specifically for the Trimble device for merging the data can be used. Serial IO developed an application that merges both the RFID and GPS data and makes it readily available to upload online called “Grid-in-Hand.” This is further explained in following sections.

RFID and GPS technology, used together, is not a completely new scientific concept. However, in terms of a GIS it is in its infant stages. Please review the following section for current yard management solutions.

2.3 Traditional Inventory Management & New Solutions

Inventory management is a subset of SCM. SCM requires inventory management by a service or retail operation to provide visibility on products or services that are needed to be ready for a customer. SCM has evolved since Henry Ford’s days of vertical supply chains, where all materials and processes were owned to create the final product for a customer (Christopher 2012). Today, many materials and processes are outsourced globally providing a need for tracking to help companies balance customer demand and inventory control. Because of the Auto-ID center’s study of RFID technology in supply chain management, it created a paradigm shift in SCM business models.

Major benefits in SCM for RFID includes the reduction of labor, improved inventory management, data collection, accuracy, and cost savings (Liu et al. 2010).

Traditional inventory methods require employees to know where their inventory is (usually done by observations) and takes them time to search for a product, or at XYZ Logistics, a unit. Many companies implement simple methods of organizing inventory in order to make processes more efficient such as pairing like items in a storage area for easier manageability.

One example of traditional inventory management is XYZ Logistics' use of a whiteboard map to display where units are located. Figure 5 depicts how XYZ Logistics currently tracks assets across their storage yard using magnets to represent units. Each magnet has a corresponding serial number written on it. Current disadvantages of this system is that it is cumbersome to maintain and is occasionally inaccurate. Human error can often lead to inconsistencies between the whiteboard map and where the fleet it truly located in the yard. During the study it was observed that the whiteboard, on occasion, could not be maintained on a daily basis when the designated employee was unavailable to maintain the map.

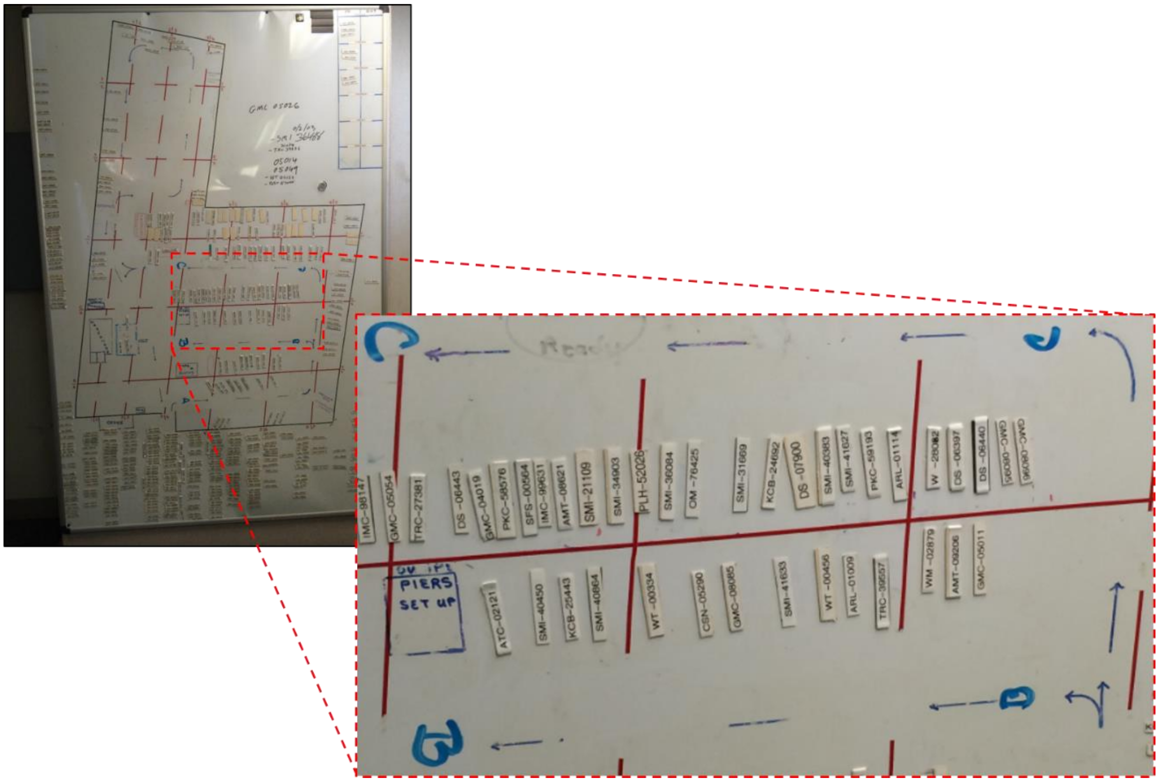


Figure 5: Whiteboard Map at Port of Long Beach Branch.

Similar to XYZ Logistics' whiteboard, units in the United States Army often use a similar type of representational layout called a Common Operating Picture (COP) which provides a spatial reference to identify the position of friendly troops, the enemy, key points of advantage, and assets to military leadership and analysts for strategic decisions (US Army ADP 3-0 2014). It is represented in either a paper or digital map format.

According to a separate branch in Oakland (actual location is also confidential), the branch manager stated the traditional inventory method takes approximately two days to complete and reconcile in a branch with a large inventory. Two employees search over approximately five acres at a branch with a printout. Some inventories are "blind," whereas serial numbers must be manually written and then cross-checked to an inventory report. Sometimes the placement of the serial numbers are not uniform and often require employees to search around a unit to locate other means of identification. The data is then used to confirm serial numbers identified as inventory in the company's database. A spatial workflow provides a solution to the inventory process without taking time from management or taking other employees from their primary tasks for excessive periods of time.

According to the director of Serial IO, Ltd., Dave Boydston, the traditional method is too cumbersome of a process that requires unnecessary human labor. The same results can be obtained using passive RFID tags and a Juno T41 GPS/RFID receiver, however with increased time efficiency, decreased labor expenses, and a more accurate and robust system.

2.3.1 Emerging RFID/GPS Tracking Solutions

RFID technology is being used in conjunction with GPS-technology to provide even more inventory control such as in the case for NYK Logistics. NYK Logistics manages the shipping and distribution of a variety of consumable products (i.e. computer software, clothes, food/beverages, and natural resources) with over 50,000 inbound ocean freight containers and 30,000 outbound trailers passing through Long Beach, California. They employ the technology to find an exact location of an asset within 10 feet. In 2003, this system replaced their old supply chain management system of people tracking containers and trailers manually over 70 acres (Maselli 2003).

RFID technology could yield labor savings of 36%. (Liu et al. 2010). Results of simulations have shown as much as 70% reduction in inventory costs (Liu et al. 2010). As organizations realize the savings of RFID technology they are beginning to implement the technology, many also seeking the ability to track asset locations. Companies such as Serial IO, Ltd., Leidos, Barcoding Inc., Zebra Technologies, AeroScout, and Wade Garcia & Associates are a few that are selling tracking services to customers as they have seen a demand in its technology.

The Davis-Monthan Air Force base currently uses Wi-Fi-based GPS/RFID smart tags (AeroScout tags) to manage over 4,400 aircraft across 2500 acres at a giant aircraft storage and maintenance area known as the “Boneyard” (Swedberg 2014). Wi-Fi is a trademarked expression by the Wi-Fi Alliance organization for specific network settings of the Institute of Electrical and Electronics Engineers (IEEE) 802.11xx standard. (Wi-Fi Alliance 2014). As of 2008, the 309th Aerospace Maintenance and Regeneration Group (AMRG) was planning to outfit over 1000 aircraft maintenance support equipment with

AeroScout tags. The Boneyard serves as a means to maintain decommissioned aircraft and sell parts to friendly foreign governments as necessary. The AeroScout tagging system allows them a means to quickly retrieve a given aircraft part over the entire lot. Figure 6 displays an overview of the Boneyard.

Figure 6: Screenshot of the Davis-Monthan Air Force Base, Arizona "Boneyard," Source: 2014 DigitalGlobe Image

The AeroScout tagging system uses a stand-alone mapping program called "MobileView." The AeroScout smart tag utilizes a Wi-Fi network and GPS technology. Smart tags have integrated GPS and use a battery source like an active RFID tag.

While this is an effective solution for the Air Force it may not be a viable solution for many companies, especially since companies are more concerned about Return on Investment (ROI). A warehouse study reported that only 15% of warehousing firms adopted RFID technology while only 44% did not consider adopting it at all because of concerns over ROI. (Liu et al. 2010). Components to the technology can be more expensive than returns would warrant leading to long pay back periods.

As an example, AeroScout would not respond to multiple requests for consultation. Additionally, there are no prices observed posted on any of their product webpages and after requesting a quote there was also no reply. However, another company, Wade Garcia & Associates, stated that GPS to track units costs approximately $10 for each unit per month. This would greatly increase a project's overhead cost. If the XYZ Logistics Branch at Port of Long Beach had approximately 200 units (in inventory), then this would increase their general administrative expenses to over $2,000 per month or $24,000 per year.

Serial IO can provide similar RFID/GPS solutions at a much less expensive rate through the elimination of GPS services for each unit by using a single GPS receiver with RFID-reading capabilities, and passive RFID tags. These type of solutions can provide an ROI in just under two years and provide unforeseen value in the future. This new method for inventory management offers reductions in costs, especially in terms of labor, increased time efficiency, and other value-added potential than traditional inventory methods.

CHAPTER THREE: PROJECT METHODOLOGY & COLLECTION

Chapter three describes the analytic methods and data sources used to complete this case study on a new, improved inventory management system using RFID, GPS, and GIS technology. The project consisted of a planning/requirements definition, implementation & adaption, and simulation study phases.

The planning/requirements definition phase involved discussions with branch managers on the traditional inventory method, assistance to conduct a traditional inventory alongside an employee taking many hours over two days. It also included research on various RFID/GPS solutions, how it could be adapted for fleet management, and finding a pilot study site. The implementation & adaption phase consisted of borrowing RFID/GPS tools and equipment, placement and collection of RFID tag data, and consultation with Serial IO on how to streamline the process. Finally, the simulation study phase consisted of a test run of the system from collection of all units in the storage yard through generating reports and cost–benefit analyses. A milestone was achieved before moving onto the next sections to include: secured a site, equipment, and definition for pilot study, the second milestone was the successful completion of a full-scale inventory using RAQGEO, and the final milestone was a cost-benefit analysis being completed.

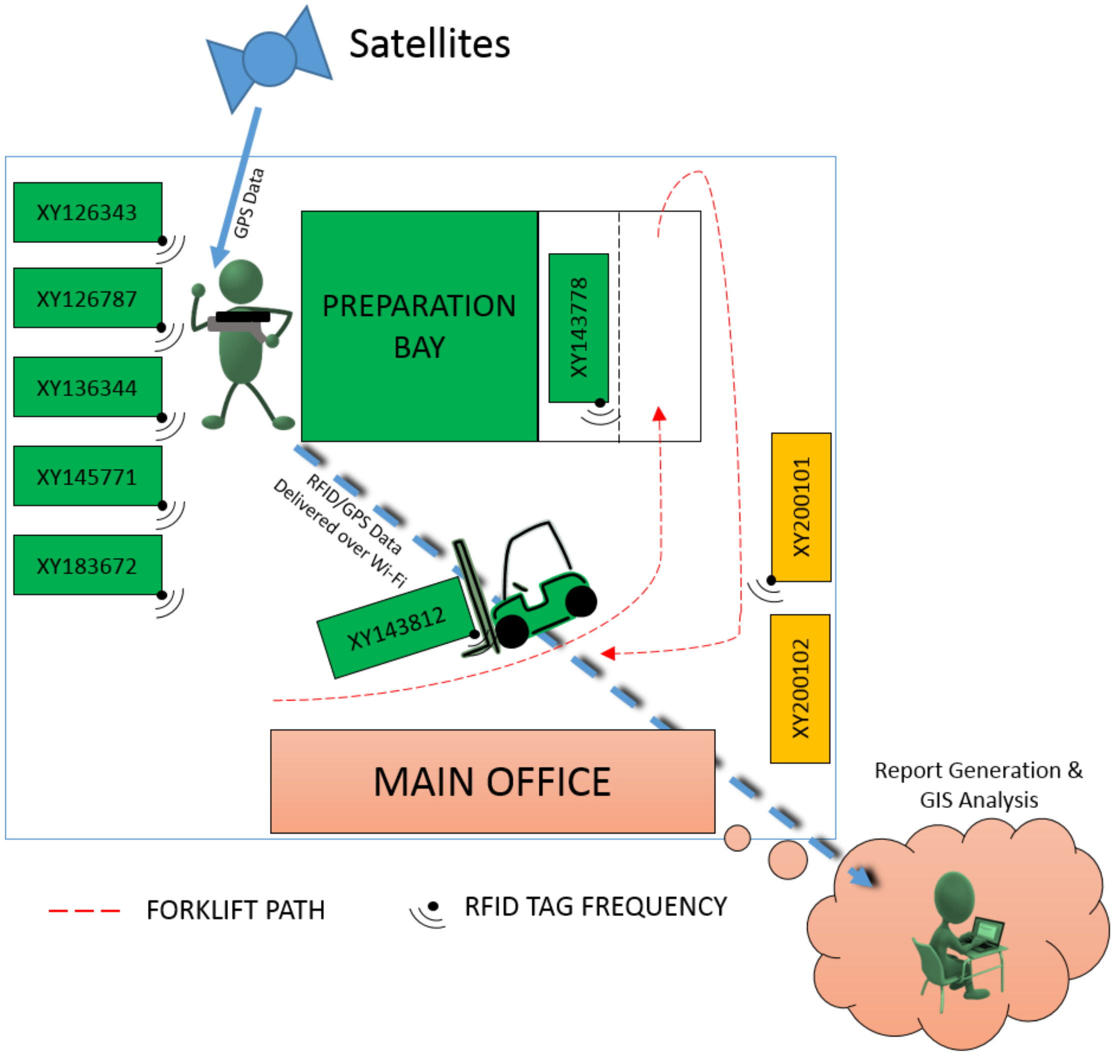


Figure 7: RAQGEO Collection Schema

Figure 7 illustrates the entire collection schema methodology of RAQGEO including an employee, an RFID reading device, RFID tags on containers, GPS collection from satellites, and the data transferred over Wi-Fi for report and map production by an employee or management. RAQGEO provides two-dimensional data across a storage yard in which can be used in a GIS.

The RFID tags were placed on the trailer hitch of most units, and for the steel containers and configurable units the tags were taped to the corners under serial numbers for demonstration purposes. The units on average are over two meters in width and there is approximately one meter between most of the units. Therefore, a commercial grade GPS or smartphone provides enough precision for this pilot study to differentiate between different units. The tags were collected from approximately one meter away by holding the Trimble T41 over the trailer hitch ball mount. With the Intermec IP30, the smartphone could be held separately over the trailer hitch ball mount as the IP30 was aimed at an RFID tag.

The chosen GIS mediums for this project were Serial IO's Google map API and Google Fusion Tables, however any GIS can be used with the data collected. Serial IO's map API can be adjusted to meet the needs of their customers. Google Fusion Tables is currently free and offers basic GIS tools such as "select by attribute" filters, like those found in ArcGIS Desktop 10.1 and more robust GIS software. Whereas GIS software can be very expensive and need training to understand and use, many web – enabled options are relatively inexpensive and easy to understand for new users.

3.1 Study Site- Port of Long Beach XYZ Logistics Branch Storage Yard

The Port of Long Beach XYZ Logistics Branch was the site chosen for the pilot study because it is considered one of the larger inventory level branches nation-wide. The branch had approximately 200 units in its inventory and over 1,000 units leased out to a variety of customers over surrounding city areas during the study. The actual study site is confidential, however the conditions and site was comparable to the Port of Long Beach.

Figure 8: Port of Long Beach XYZ Logistics Branch Overview, Source: 2014©Google Imagery/Map Data, Annotations by Bradley Griffiths 2014.

Figure 8 displays a representational layout of the study site from an overhead perspective. Outlined in green is the main office building. Outlined in black, to the right of the main office building is the preparation bay. Outlined in red around the outside of the fence surrounding XYZ Logistics is the entire branch. Most of its area is used for storage area for the units. The storage area served as the grounds for the pilot study.

The study was conducted over a period of two days – August 28th-29th, 2014. The first day was in the mid-90's Fahrenheit with little to no cloud coverage. There was cloud coverage the second day with a light rain in the morning. The humidity had increased and the temperature was in mid-to-high 80's Fahrenheit. There were no apparent differences with the equipment or environmental concerns during the study. See Appendix D for a breakdown of the study activities.

3.2 RAQGEO Data Flow Diagram

Figure 9 displays a data flow diagram for RAQGEO. RAQGEO begins with GPS and RFID data collected by GPS satellites and RFID UHF tags, then received by a RFID/GPS receiver (represented as an all-in-one device, however can be separate devices). The data received is then queued into the Grid-in-Hand mobile app, which then is uploaded over Wi-Fi to the iScanList Cloud service and saved in a geodatabase type format. The data then can either be converted to KML using PHP website scripting language which can be viewed in Google Map API. The Google Map API can then be analyzed for specific data and maps generated using spatial queries such as a "Select by

Attribute" type function. Separately, data can be downloaded as a .CSV file and used to generate inventory reports.

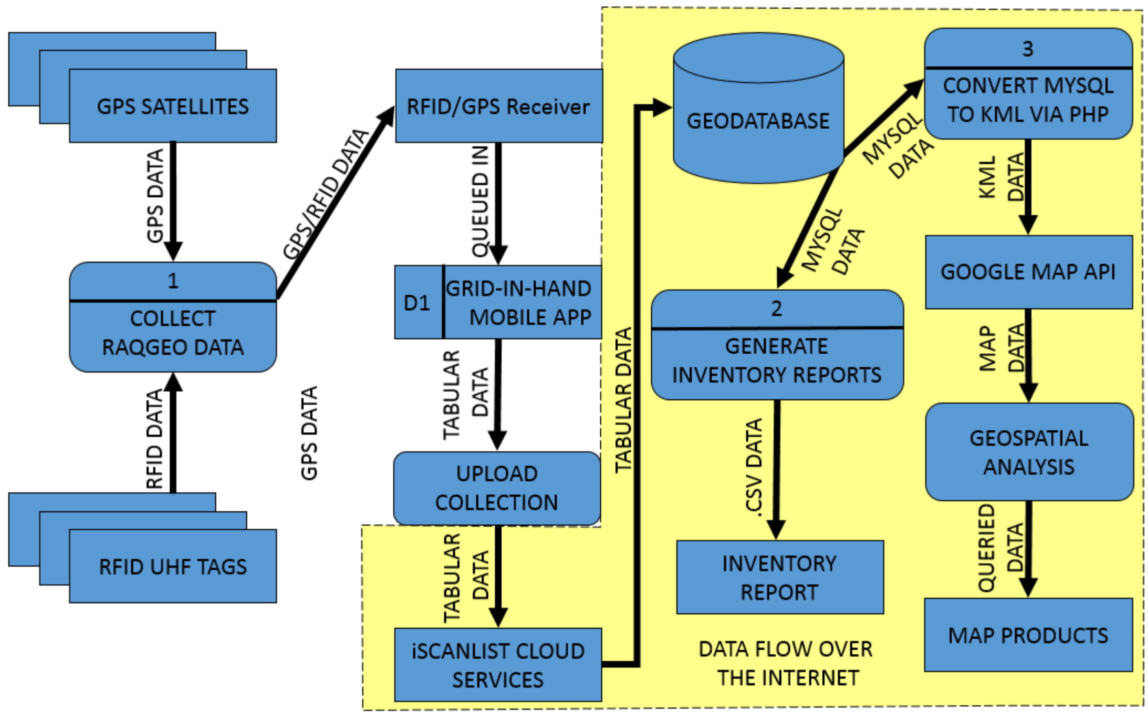


Figure 9: RAQGEO Data Flow Diagram (DFD)

3.3 RAQGEO Collection Schema

The United States Marines have used Serial IO's services to RFID tag main battle tanks and amphibious tractor equipment. The Dura 1500 tags with the standard adhesive foam have lasted through countless training exercises and are used for managing the equipment. A Dura 1500 tag is a proven tag to be used for asset management.

Two days of collection were made with various tags and equipment. The first day was 28th August, 2014 and consisted of an Intermec IP30 with Bluetooth technology coupled with a Droid Bionic with a 4.1.2 operating system, 10 one-inch flex tags and 15 two-inch flex tags. The Intermec IP30 has a read distance power of approximately one meter which is similar to the read distance of the RFID flex tags. The Droid Bionic viewed approximately 7 satellites all American NAVSTAR satellites with an accuracy of 10 feet according to a free downloadable app called “GPS Test” by Chartcross Ltd. The reads were collected in WGS 84 datum which is also used by Google Maps and Google Earth. Figure 10 shows a photo of the GPS Test application as seen from a user’s perspective.

Figure 10: GPS Test Application

The Grid-In-Hand mobile application was fired up and tags were setup both inside and on various units. The Droid Bionic sat on top of the Intermec IP30 and was a handheld unit. Once the trigger was pulled it was held until it would collect the data and location of each tag. The OMNI-ID flex tags used were non-commissioned and only contained the manufacturer's serial number. The mobile application would displayed a "unlicensed" error to communicate to a user that the tags were non-commissioned. A setting was applied to turn the unlicensed alert setting off. Figure 11 displays the Intermec IP30, Droid Bionic, and tape measure used on the first day of the study.

Figure 11: Equipment Used with Tags: From Left to Right- Droid Bionic with Otterbox case, Intermec IP30 RFID Reading Device, Tape Measure

The Grid-in-Hand mobile application has special settings that can be applied so that when a single tag of a specific ID is detected it cannot be collected more than once. Bluetooth technology was used to communicate between the IP30 and the Droid Bionic. Bluetooth operates at a spectrum between 2.4 GHz and 2.485 GHz and is used by cellphones mainly to communicate at a short distance of about one meter with other devices such as other cellphones or ear pieces (Bluetooth SIG, Inc. 2014). The Droid Bionic did not have cell service. Cell service is not required for GPS on the device, however to upload the collection to the server it must use Wi-Fi or cell service with internet capabilities. Another personal phone was tethered to offer a Wi-Fi network for the Droid Bionic to upload its data in spreadsheet form to the iScanList server.

Each type of unit at XYZ Logistics was tested. During the testing it was observed that any metal in the walls would not allow the RFID signal to pass through. Linoleum tiles, floors, and windows did not pose any obstruction to the signal. Aluminum along the trim of an aluminum door could sometimes provide a signal however it would be at different locations than right next to the tag i.e. toward the bottom of a door. See Appendix A for the different units and placements tested.

29 August 2014 was the second day of testing. Dave Boydston provided consultation services. He provided a Dura 1500 RFID tag, a ScanFob tag, and a Trimble Juno T41 XGR-TGA-00. Immediately it was noted that a Trimble Juno T41 XGR-TGA-00 was more durable and ergonomic than using a smartphone and the IP30 system. The IP30 and smartphone used two hands because the phone was not mounted, whereas the T41 could be used in one hand. The unit also has more durable construction including a gorilla glass screen, weatherproof material, and shock resistance. Additionally, the T41 has the ability to take pictures with an 8 mega pixel camera as grids are collected along with RFID data. It was able to connect to Wi-Fi by the use of a tethered phone to upload the collection. Data plans can be purchased for the devices; however, it was unnecessary.

Different placements of the Dura 1500 RFID tag were tested and the best recommendation was to place uniformly on all units, possibly next to where serial numbers are already displayed. Recommendations for are available in Appendix B.

3.4 Geodatabase Design

For purposes of this pilot study, a geodatabase is a database that has the ability to store and query data representing spatial information. The spatial data is provided through the GPS data and the type of geodatabase in the pilot study is MySQL, a database used for web applications using structured query language (SQL).

For testing purposes, three attributes were necessary: a unique identifier for each RFID tag, a timestamp, and a location. The unique identifier was provided by the RFID tag stock from OMNI-ID.

All RFID tags used for the study were noncommissioned which meant they were not programmed with specific ID numbers. The noncommissioned IDs consisted of a string of 24 characters. On the first test day with the IP30 and smartphone, the timestamp was based on the smartphone's time as the collected grid queued onto iScanList. On the second test day using the Trimble Juno T41, the timestamp was based solely on the device. The location data was provided by the smartphone on the first test day and by the Trimble Juno on the second day. The location data was collected in decimal degrees format "dd.dddddd," WGS84 datum, Mercator projection format. The data shows six decimal places which represents positional accuracy between 1.11 to .11 meters (Texas Commission on Environmental Quality 2013). The data did not have differential corrections applied to provide sub-centimeter accuracy, therefore the data could be two-five meters off based on the Trimble T41 collection and three to nine meters off on the Droid Bionic. However, all of the data will be collected in the same means and displaced approximately the same as it would with corrections. Figure 12 displays the basic collection attributes during the testing phase:

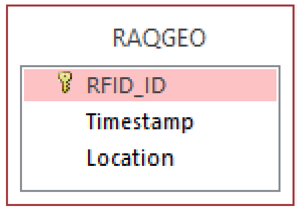


Figure 12: Basic RAQGEO Table

RAQGEO has the ability to be expanded out to include more attributes which would be necessary as RFID tags were purchased and placed on units. A specific action profile would need to be applied to the mobile application to allow for the ability to edit or add data to RFID tags. As shown in Figure 13 the following attributes were added: RFID Number, Serial Number (Serial_Num), Date/Time Stamp (Timestamp), Location, Unit Type, Ready Status (Ready_Status), ADA-Compliant Restrooms (ADA_Restroom), State Structure Codes (State_Code), Floor Composition (Floor_Comp), and the Number of Offices (Number_Offices). The data collected from the RFID/GPS readers collected only the Serial Number, Timestamp, and Location. ADA-Compliant Restrooms, State Structure Codes, Floor Composition, and the Number of Offices were simulated data added in Microsoft Excel 2010.

RAQGEO

Field Name	Data Type
RFID_ID	AutoNumber
Serial_Num	Short Text
Timestamp	Date/Time
Location	Number
Unit Type	Long Text
Ready_Status	Short Text
ADA_Restroom	Yes/No
State_Code	Short Text
Floor_Comp	Short Text
Number_Offices	Number

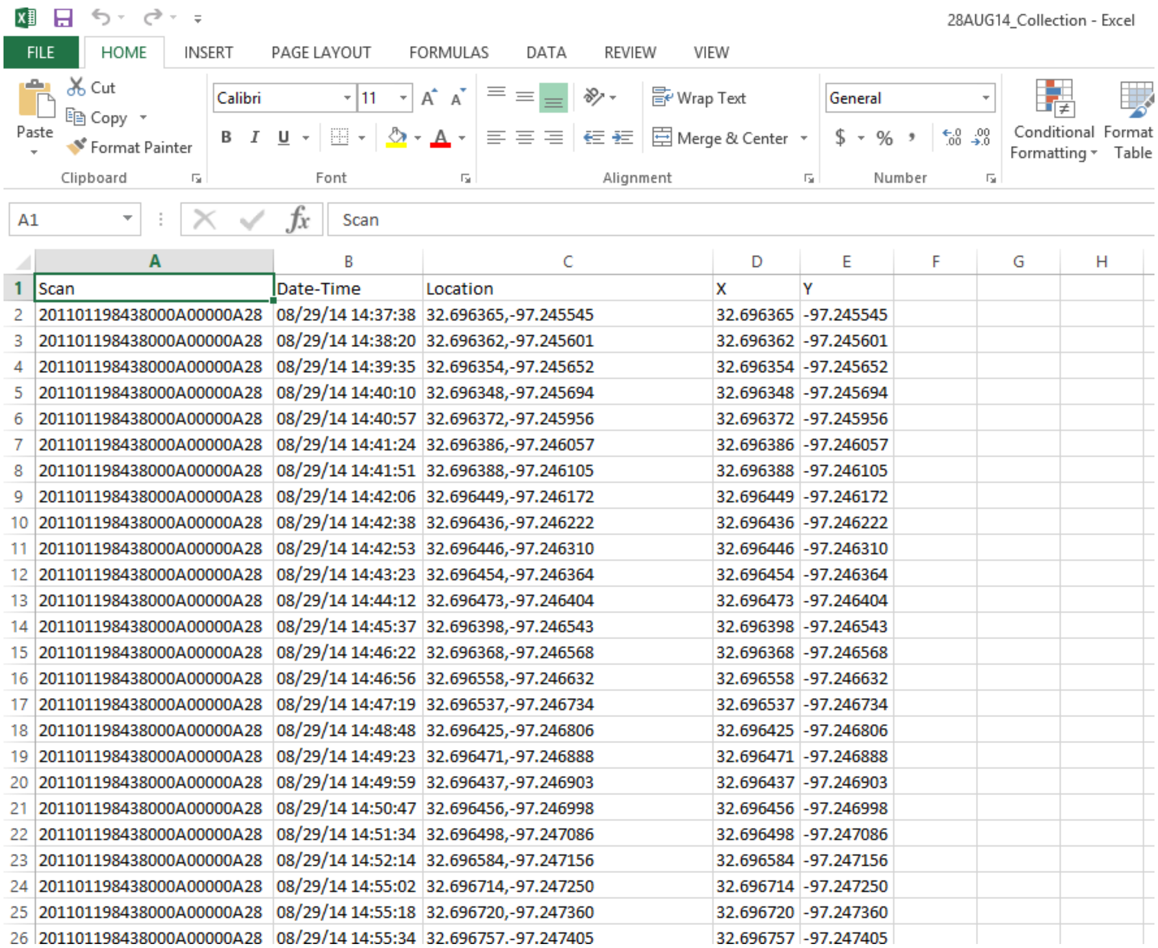
Figure 13: Ideal RAQGEO Attributes

3.4.1 iScanList & Grid-In-Hand Mobile Grid

Serial IO, LTD has a mobile application for both smartphones and Trimble or Motorola RFID/GPS reading devices called “Grid-In-Hand Mobile Grid.” The application can be operated without Internet or cellphone service until its data needs to be posted onto the iScanList server. This is accomplished over Wi-Fi or using device data plans; purchase of a device data plan is not recommended. Considering the business model of XYZ Logistics, it is recommended to wait until the Trimble device is within the branch’s Wi-Fi range, or tether a cellphone temporarily to provide the Trimble device a means of sending its data to the iScanList server. Service is not necessary during the RFID/GPS collection process and is needed only to upload to the iScanList server after the inventory is complete.

Figure 14: iScanList Collections

Figure 14 displays how each collection shows in the iScanList site. At the end of each collection there is a selection to "Upload Grid" and the collection is saved as a Comma Separated Values (.CSV) formatted table-structured text document. This gives it the ability to be quickly formatted into various other data types (including spreadsheets) to be used with different mapping or database software. Please see Figure 15 which demonstrates how the data appears:



	A	B	C	D	E
1	Scan	Date-Time	Location	X	Y
2	201101198438000A00000A28	08/29/14 14:37:38	32.696365,-97.245545	32.696365	-97.245545
3	201101198438000A00000A28	08/29/14 14:38:20	32.696362,-97.245601	32.696362	-97.245601
4	201101198438000A00000A28	08/29/14 14:39:35	32.696354,-97.245652	32.696354	-97.245652
5	201101198438000A00000A28	08/29/14 14:40:10	32.696348,-97.245694	32.696348	-97.245694
6	201101198438000A00000A28	08/29/14 14:40:57	32.696372,-97.245956	32.696372	-97.245956
7	201101198438000A00000A28	08/29/14 14:41:24	32.696386,-97.246057	32.696386	-97.246057
8	201101198438000A00000A28	08/29/14 14:41:51	32.696388,-97.246105	32.696388	-97.246105
9	201101198438000A00000A28	08/29/14 14:42:06	32.696449,-97.246172	32.696449	-97.246172
10	201101198438000A00000A28	08/29/14 14:42:38	32.696436,-97.246222	32.696436	-97.246222
11	201101198438000A00000A28	08/29/14 14:42:53	32.696446,-97.246310	32.696446	-97.246310
12	201101198438000A00000A28	08/29/14 14:43:23	32.696454,-97.246364	32.696454	-97.246364
13	201101198438000A00000A28	08/29/14 14:44:12	32.696473,-97.246404	32.696473	-97.246404
14	201101198438000A00000A28	08/29/14 14:45:37	32.696398,-97.246543	32.696398	-97.246543
15	201101198438000A00000A28	08/29/14 14:46:22	32.696368,-97.246568	32.696368	-97.246568
16	201101198438000A00000A28	08/29/14 14:46:56	32.696558,-97.246632	32.696558	-97.246632
17	201101198438000A00000A28	08/29/14 14:47:19	32.696537,-97.246734	32.696537	-97.246734
18	201101198438000A00000A28	08/29/14 14:48:48	32.696425,-97.246806	32.696425	-97.246806
19	201101198438000A00000A28	08/29/14 14:49:23	32.696471,-97.246888	32.696471	-97.246888
20	201101198438000A00000A28	08/29/14 14:49:59	32.696437,-97.246903	32.696437	-97.246903
21	201101198438000A00000A28	08/29/14 14:50:47	32.696456,-97.246998	32.696456	-97.246998
22	201101198438000A00000A28	08/29/14 14:51:34	32.696498,-97.247086	32.696498	-97.247086
23	201101198438000A00000A28	08/29/14 14:52:14	32.696584,-97.247156	32.696584	-97.247156
24	201101198438000A00000A28	08/29/14 14:55:02	32.696714,-97.247250	32.696714	-97.247250
25	201101198438000A00000A28	08/29/14 14:55:18	32.696720,-97.247360	32.696720	-97.247360
26	201101198438000A00000A28	08/29/14 14:55:34	32.696757,-97.247405	32.696757	-97.247405

Figure 15: 28 August Collection Data (.CSV Format) in Microsoft Excel 2013

Once the RFID tags are commissioned Column A would display the actual unit serial numbers. Column B is a date and time stamp. Column C is a mixture of latitude and longitude data within two meter accuracy. Columns D and E were user-added to split the latitude and longitude from Column C using a “MID” function in Microsoft Excel 2013.

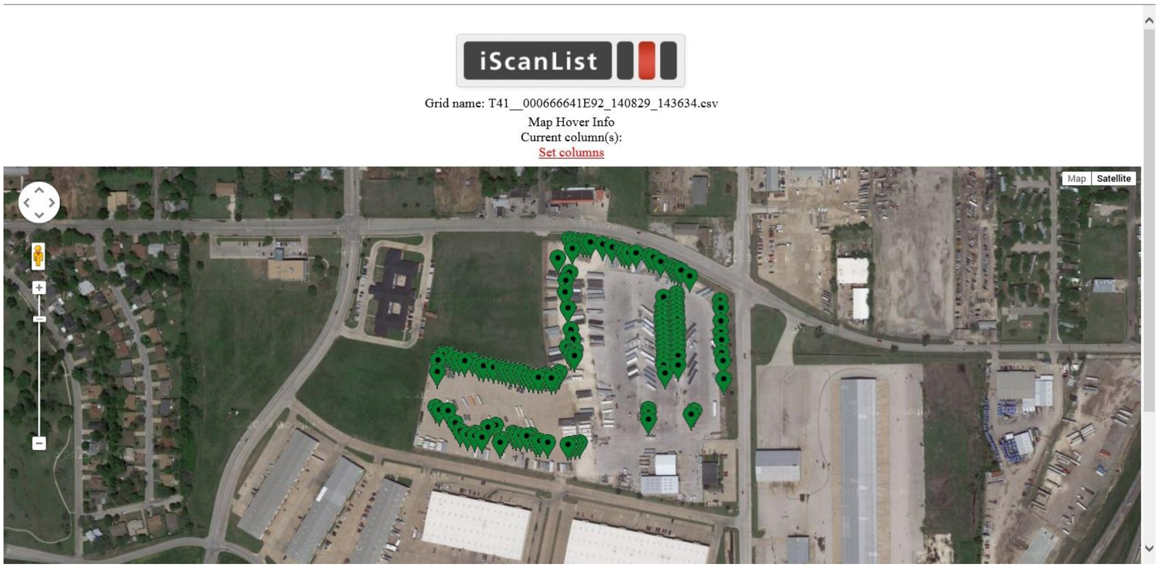


Figure 16: iScanList Map, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

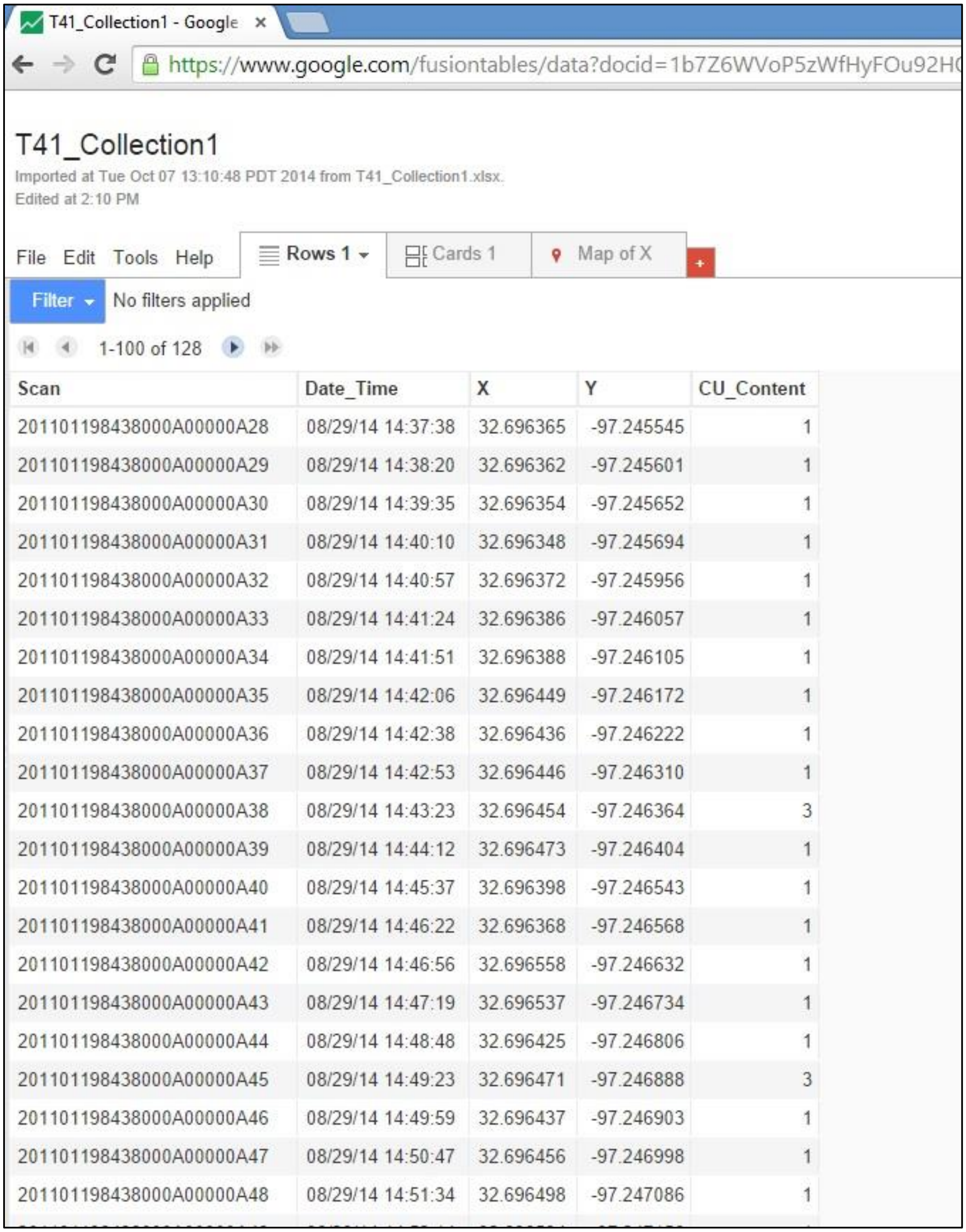
Figure 16 displays a map produced through iScanList that uses map API through Google maps. It also shows the placement of all the units collected during the second testing day. All the .CSV data is converted to a KML layer to be observed in the map, by the use of a geodatabase using MySQL and translated by PHP, a scripting language in iScanList. The .CSV data from the geodatabase is parsed and reinterpreted into KML using PHP scripts. A user can toggle through map types to view the area with satellite imagery. Since the data is collected in the same projection and datum as Google Maps and Earth it provides an accurate illustration of the placement of each unit in the shipping yard. Serial IO has shown that they can also create customer-specific applications and events on their site. For example, Serial IO can create a “Mouse Hover” event where as each of the pins is hovered over with the mouse pointer a balloon tip will display showing a picture of the unit plus its affiliated information. See Figure 17 for an example of the mouse hover event:

Figure 17: iScanList Mouse Hover Event, Source: 2014 Google, and data adapted by Bradley Griffiths & Serial IO.

3.4.2 Google Fusion Tables

Google Fusion Tables is a free online application that provides the ability to visualize spreadsheet data through a Google Map API interface similar to Serial IO’s tool. The key difference is that it can generate heat maps and values can be added to the data. First, the .CSV file needs to be downloaded from the iScanList site. Second, one must register or have a Google account they can access. After signing into one’s Google account they need to go to the Google FusionTables site accessible through this Uniform Resource Locator (URL): https://www.google.com/fusiontables/data?dsrcid=implicit.

The spreadsheet then needs to be uploaded and the data is then ready to work with. See the Figure 18 to see the uploaded spreadsheet in Google Fusion Tables.



Scan	Date_Time	X	Y	CU_Content
201101198438000A00000A28	08/29/14 14:37:38	32.696365	-97.245545	1
201101198438000A00000A29	08/29/14 14:38:20	32.696362	-97.245601	1
201101198438000A00000A30	08/29/14 14:39:35	32.696354	-97.245652	1
201101198438000A00000A31	08/29/14 14:40:10	32.696348	-97.245694	1
201101198438000A00000A32	08/29/14 14:40:57	32.696372	-97.245956	1
201101198438000A00000A33	08/29/14 14:41:24	32.696386	-97.246057	1
201101198438000A00000A34	08/29/14 14:41:51	32.696388	-97.246105	1
201101198438000A00000A35	08/29/14 14:42:06	32.696449	-97.246172	1
201101198438000A00000A36	08/29/14 14:42:38	32.696436	-97.246222	1
201101198438000A00000A37	08/29/14 14:42:53	32.696446	-97.246310	1
201101198438000A00000A38	08/29/14 14:43:23	32.696454	-97.246364	3
201101198438000A00000A39	08/29/14 14:44:12	32.696473	-97.246404	1
201101198438000A00000A40	08/29/14 14:45:37	32.696398	-97.246543	1
201101198438000A00000A41	08/29/14 14:46:22	32.696368	-97.246568	1
201101198438000A00000A42	08/29/14 14:46:56	32.696558	-97.246632	1
201101198438000A00000A43	08/29/14 14:47:19	32.696537	-97.246734	1
201101198438000A00000A44	08/29/14 14:48:48	32.696425	-97.246806	1
201101198438000A00000A45	08/29/14 14:49:23	32.696471	-97.246888	3
201101198438000A00000A46	08/29/14 14:49:59	32.696437	-97.246903	1
201101198438000A00000A47	08/29/14 14:50:47	32.696456	-97.246998	1
201101198438000A00000A48	08/29/14 14:51:34	32.696498	-97.247086	1

Figure 18: T41 Collection Data in Google Fusion Tables, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

Figure 18's data shows the RFID tag ID, a time stamp for the collection, an X, Y column representing Latitude and Longitude and then ADA Restrooms or "ADA-Compliant." The X, Y, and ADA-Compliant columns were all added to the spreadsheet via Excel 2013 before being imported. The X, Y columns were mixed in a single column by iScanList and then split into separate columns in Excel while the ADA-Compliant column was created for testing purposes but represent the average amount of ADA-Compliant buildings.

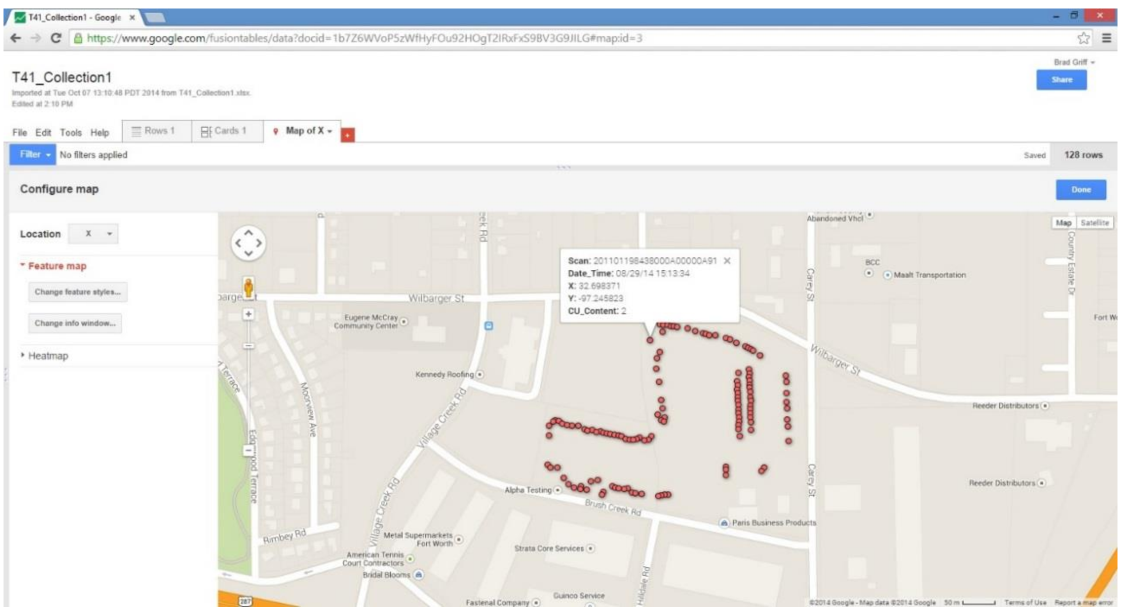


Figure 19: Google Fusion Table Feature Map, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

Figure 19 displays the data in a Google Map similar to Serial IO's map API through Google Fusion Tables. It uses the same toggle features between satellite imagery and a map with labels that is the same year and map data. The key difference is the ability to filter data. Figure 20 displays how a user wants to find a specific unit associated with the serial number "201101198438000A00000A30."

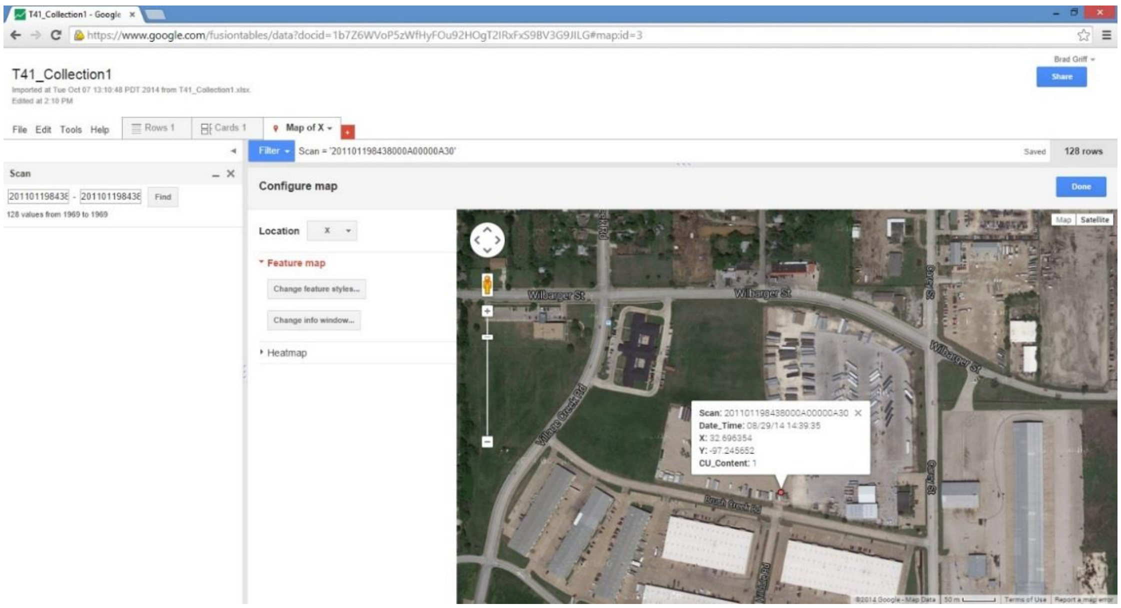


Figure 20: Google Fusion Table Map with Filter Applied, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

The filter tool can be used by management to quickly display where a unit falls within a yard. This is a cost-effective and efficient way to quickly find a unit's location based on its collected data. Management can use this as a COP to maintain awareness of where units exist in the yard. This solution eliminates the need for the whiteboard to be maintained and it will be accurate.

3.5 Attribute Focus

Some of XYZ Logistics assets include installed Americans with Disabilities Act (ADA)-compliant restrooms. Managers can immediately locate all units with ADA-compliant restrooms and provide the results to a sales representative that is requesting fleet availability of restroom units.

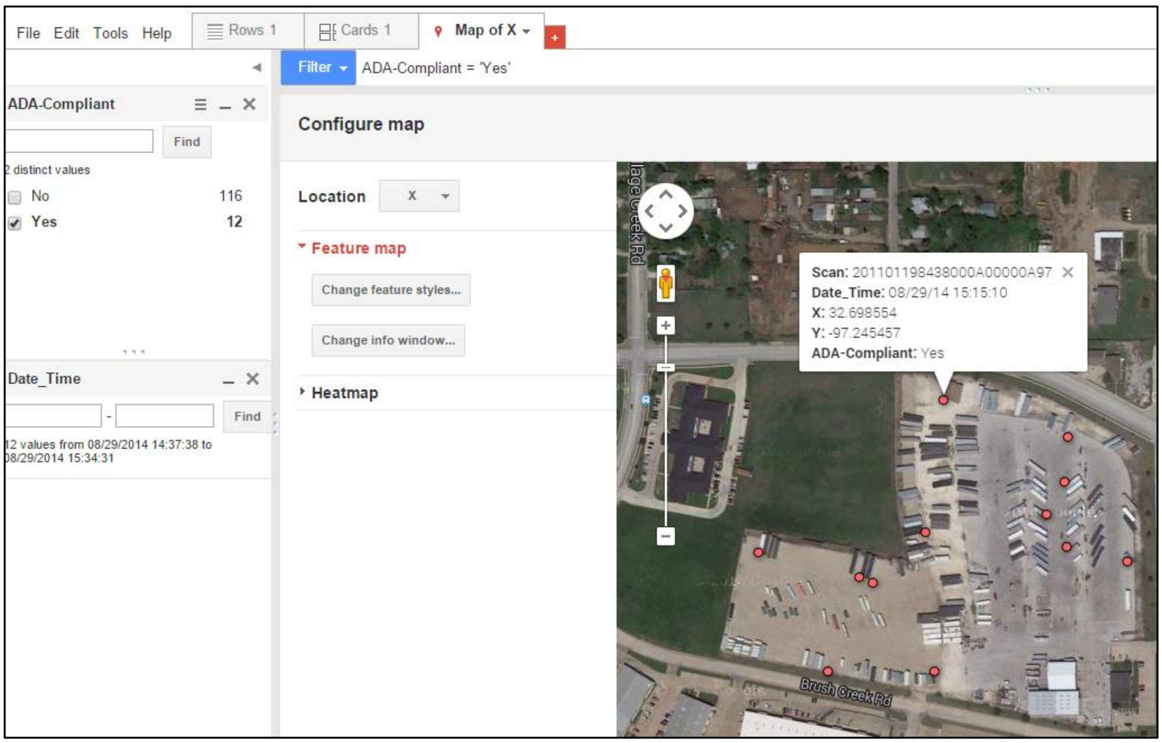


Figure 21: Google Fusion Table Map displaying ADA-Compliant unit locations, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

Figure 21 displays locations of all units that contain ADA-compliant restrooms. The filter applied is “ADA-Compliant= ‘Yes’.” A balloon tip can be shown once a user clicks onto one of the red dots (representing a unit) that will display the unit’s serial number. This is a valuable addition that the traditional whiteboard does not offer.

Additionally, it takes less time to provide the information, eliminates searching, and helps to dedicate more time to value-added tasks. The data would also provide unit serial numbers.

XYZ Logistics management may want to visualize locations of units that are not state-coded for Texas. State-coding is the structural integrity, occupancy ability, and building requirement licensing provided by each state. One example is that some states require a roof load to be able to hold 30 pounds per square foot whereas others are 20 pounds. If a branch in Oklahoma needs another unit quickly, the Port of Long Beach branch manager can search their fleet to quickly find a unit that already meet state code requirements for Oklahoma using GIS services.

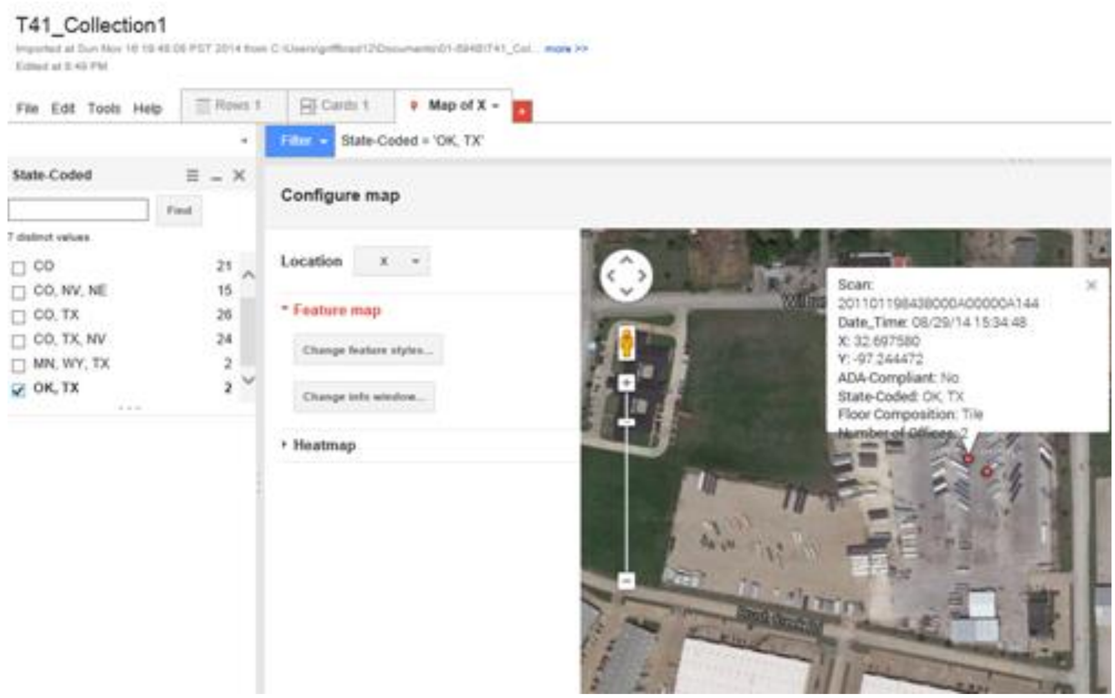


Figure 22: Google Fusion Table Map displaying OK State-Coded Units, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

As shown in Figure 22, there are two units that are state-coded for Oklahoma. A manager can direct forklift operators to the location to move the trailer and ready it for a shipment to Oklahoma. The manager can also see its other attributes in a balloon tip.

Additionally, if there is a customer request for a unit that has four offices and carpet, XYZ Logistics employees can quickly find a unit that matches this criteria using the GIS. Figure 23 shows these results.

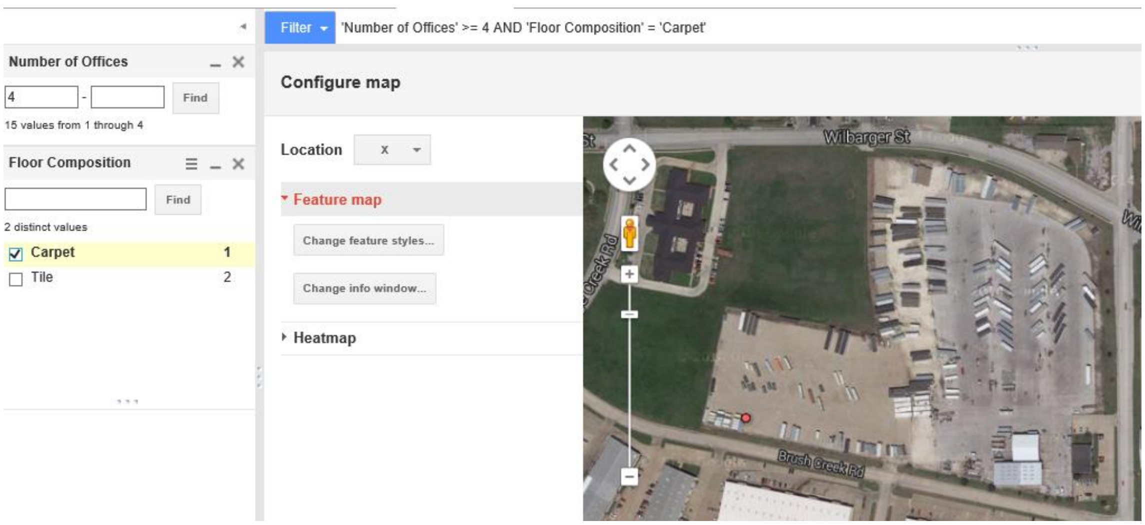


Figure 23: Google Fusion Table Map Displaying Units with Four Offices and Carpet Flooring, Source: 2014 Google & data adapted by Bradley Griffiths & Serial IO.

There are three units with four offices, however, only one has carpet already installed. A web-enabled GIS makes for quicker identification of a unit that contains these attributes versus the traditional method of employees checking all the units for one that meets this criteria or trying to use the whiteboard.

A GIS is an invaluable addition to inventory management within a SCM model. Using RFID/GPS data through RAQGEO provides many benefits far beyond the use of the traditional inventory method including the whiteboard.

CHAPTER FOUR: RESULTS

The following analysis provides an in-depth look at the added value that RAQGEO can add to XYZ Logistics and ends with a discussion of the advantages and disadvantages with the technology.

4.1 Traditional Method versus RAQGEO (Cost-Benefit Analysis)

Accountability of the units is a company requirement, therefore it is necessary labor. At XYZ Logistics, employees are taken from their primary tasks to perform the quarterly inventory, therefore it is important to note that employee positions are not eliminated with RAQGEO and the analysis is based on time in terms of labor allotted toward conducting the traditional inventory method versus RAQGEO. The metric used for XYZ Logistics is minutes saved. According to branch managers in Oakland and Port of Long Beach a traditional inventory currently takes approximately 3840 minutes (eight hours over two works days quarterly throughout the year). RAQGEO is assessed to take less than 240 minutes (one hour on one work day quarterly throughout the year) based on Day 2's study results.

Clearly, RAQGEO saves time, reduces costs, and provides increased productivity. Employees are pulled from their main duties such as preparing a unit or sales operations to conduct the inventory. The company is also discussing monthly or random inventories which will increase the time allocated to conducting an inventory on units however during the time of this study most branches were conducting inventories quarterly.

It is estimated that the labor alone for Oakland Branch's quarterly inventory is $3200 annually. This calculation is based upon an average salary found on Glassdoor of

$25 per hour over eight hours across two days over four quarters for two employees. This average salary provided is suggested as the average “fully loaded” (including benefits) package that includes a 401K retirement plan, comprehensive medical, and other costs associated with an employee. The RAQGEO inventory process is approximately $185.71 per year with $100 for employee salaries- based at $25 over one hour on one day, quarterly for a single employee to process. The $85.71 would cover the price to maintain cloud services with Serial IO distributed across multiple branches.

RAQGEO has several entry cost items which includes 5600 ABS – standard foam – custom commissioning OMNI-ID Dura 1500 Passive RFID tags which will have a combined cost of approximately $8640.00, a Trimble Juno T41XGR-TGA-00 at $3149, a one-day training course of $2500 for selected personnel, plus travel and expenses (lodging, gas, and per diem of about $200), and an action profile setup of $5,000. Additionally, there would be an annual cost for mobile and cloud services of $600 which Serial IO has cover three Trimble devices. For the purposes of this study, it will be assumed that cost will be divided by 7 for an area for possible future expansion to two additional devices. Figure 24 displays the branches and their respective areas in the United States. Each area has an average of seven branches.

The initial entry cost may be undesirable to a manager; however, by Year 2 the costs are already below the traditional inventory method, and there is an added value of sales staff being able to dedicate more time toward their primary tasks. See Table 2 below for a side-by-side comparison of the methods and a breakdown of the RAQGEO cost details.

The average lease term at some branches is 10 months for each unit. Each time a unit is returned for the first 10 months of the program will need an RFID tag. It is projected that an average of 30 units will return to each branch in the Mountain West Area in 2015. The Oakland Branch has approximately 54 units projected for 2015. A high number of 60 units is considered a high-volume scenario according to XYZ Logistics management Therefore, an average branch would need approximately 800 RFID tags the first year to use on all its assets.

1200 Dura 1500 tags were priced at $8640.00 which is $7.20 per tag. Each area has approximately seven branches and with approximately 200 units in inventory at each branch and 600 units leased, 800 RFID tags would be needed within the first year to cover units returning off of lease. 800 RFID tags * 7 branches is 5600. 5600 RFID tags*$7.20 per tag is $40320. $40320/7 branches is $5760 per branch in Year 1. Additionally, a Trimble T41XGR-TGA-00 is $3149.00 but can be shared between seven branches of a given area with a shared cost of $449.86. The one-day training course of $2700/7 branches is $385.71. The initial MGAP setup of $5000/7 branches is $714.29. The employee salary expense per branch would be approximately $100 over a year with quarterly inventories. The first year cost would be around $7409.86 per branch, however the following year it would be $185.71 which includes $100.00 for employee salary expenses, and $85.71 to maintain cloud services with Serial IO (which is $600 for three devices but is divided between seven branches).

Table 2: Traditional Inventory Method vs. RAQGEO Costs

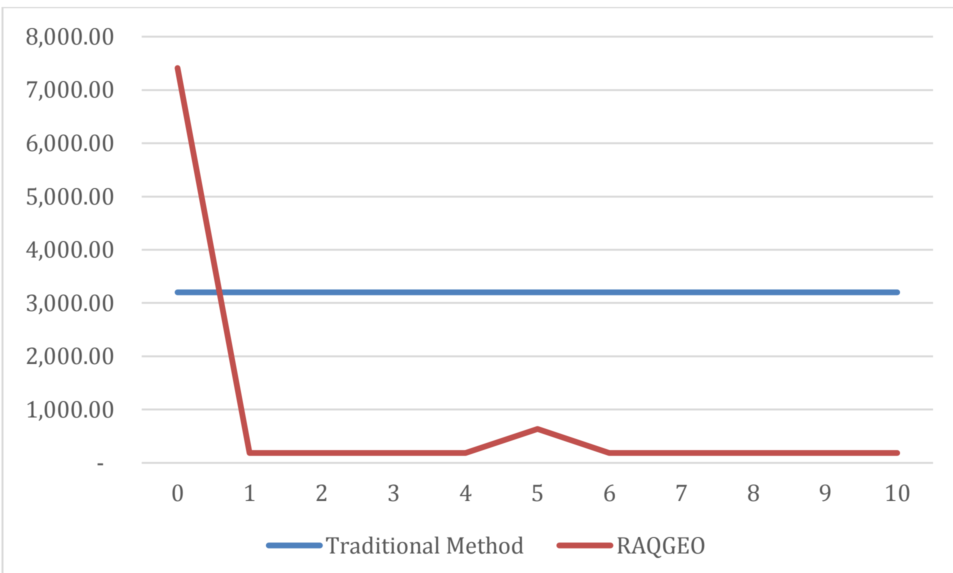
Year	Traditional Method	RAQGEO	RAQGEO Details
1	$3,200	$7,409.86	Entry Cost (Divided Among 7 Branches) +$100 for Employee Salary
2	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
3	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
4	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
5	3,200	635.57	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary+(Possible) T41 Replacement
6	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
7	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
8	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
9	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary
10	3,200	185.71	Annual Fee (Divided Among 7 Branches) + $100 for Employee Salary

**Values in US Dollars*

Table 2 shows the yearly costs associated with each system. The traditional method consists of a fixed cost of $3200 per year based on a quarterly inventory system. By the second year the cost is lower than the current method. In Year 5, there is a possible need to replace the T41. This is based on the extended warranty by Trimble. Trimble has a two-year standard warranty plus a two-year extended warranty on top of that with an additional purchase. Therefore, it is assumed that the warranty is made to match the expected lifetime of the device. After Year 10, it is assumed that the T41 will be replaced with newer technology that will likely be faster and cheaper. This is based off smartphone technology (since it is the primary platform for app development). The first smartphone was first sold August 16, 1994 by IBM for $899 on a two-year contract (Nick 2014). Just over ten years later, a Samsung Galaxy S5 smartphone with much more power and capabilities is sold for $199.99 at AT&T for a two-year contract (AT&T 2014). Therefore, this example alone suggests that costs associated with technology decreases over time and new technology will be introduced.

In addition to Table 2, Line Chart 1 illustrates the cost savings alone in adopting RAQGEO.

Chart 1: Line Chart Showing Cost Savings (Traditional Inventory Method vs. RAQGEO)



The Return on Initial Investment is made by the second year as observed in Table 3. By Year 3 the cost is completely covered and there is savings observed with less labor allocated toward inventorying the units.

Table 3: RAQGEO Savings

Year	Difference	Net Exchange	Savings
0	$ (4,209.86)	$ (4,209.86)	-
1	3,014.29	(1,195.57)	(3,014.29)
2	3,014.29	1,818.72	623.15
3	3,014.29	4,833.01	6,651.73
4	3,014.29	7,847.30	12,680.31
5	2,564.43	10,411.73	18,259.03
6	3,014.29	13,426.02	23,837.75
7	3,014.29	16,440.31	29,866.33
8	3,014.29	19,454.60	35,894.91
9	3,014.29	22,468.89	41,923.49
10	3,014.29	25,483.18	$ 47,952.07

**Values are in US Dollar.*

Table 3 reflects the savings in labor from the traditional inventory method versus RAQGEO. Each year the original cost of RAQGEO is subtracted by the year to year differences between each inventory method. For example, it is Year 1's net exchange plus the difference of the next year as calculated from Table 2.

A cost associated with RAQGEO that is unaccounted for in this cost-benefit analysis is the cost associated with the initial placement of the UHF RFID tags. However, the task of placing the tags can be covered while conducting the first inventory of RAQGEO because the time is assessed to take about the same amount of time as it would conducting a traditional inventory. Another issue is that XYZ Logistics employees may decide they want to customize iScanList cloud services more. For each new idea they can have Serial IO create a new MGAP which for a basic one costs $299.00 (Serial IO 2014). This is still easily covered within the savings.

Dave Boydston stated that the Dura 1500 RFID tags are expected to last beyond the life of a unit. The average unit has a lifespan of 20 years according to Port of Long Beach's manager.

According to the Oakland Branch manager, XYZ Logistics once had a training event where key personnel attended a training on operating forklifts, and since then have continued training personnel on forklift operation and have not needed retraining. It is assumed that XYZ Logistics will not need to be retrained in using the Serial IO equipment.

Note that if all XYZ Logistics branches conducted a monthly inventory that would drive the traditional method up to $12,800. $3,200*4 quarterly inventories each year.

4.1.1 Discounted Cash Flow

The savings found above does not reflect the time value of money. Table 4 shows a discounted cash flow illustrating that XYZ Logistics will value cost savings earlier in the project than later. A present value interest factor percentage must be used to represent a discounted value of RAQGEO. A present value interest is calculated from a company's total capital sources which may include short and long term debt and stocks. Then before tax calculations are required to arrive at a before tax weight. The sum of the before tax weight must be exceeded for a company for an investment to exceed debt and equity investors (Schmidt 2013). A present value interest of 6% was arbitrarily selected to provide an example of a discounted cash flow for this project and does not represent the actual number (which may possibly be a higher interest value).

Table 4: Discounted Cash Savings of RAQGEO

Values in US Dollars	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Costs	7,409.86	185.71	185.71	185.71	185.71	635.57	185.71	185.71	185.71	185.71	185.71	9716.82
Benefits	-	3,014.29	3,014.29	3,014.29	3,014.29	2,564.43	3,014.29	3,014.29	3,014.29	3,014.29	3,014.29	29693.04
Cash Savings	(7,409.86)	2,828.58	2,828.58	2,828.58	2,828.58	1,928.86	2,828.58	2,828.58	2,828.58	2,828.58	2,828.58	19976.22
Discount Factors	1.000	0.943	0.890	0.840	0.792	0.747	0.705	0.665	0.627	0.592	0.558	
Discounted Cash Savings	(7,409.86)	2,667.35	2,517.44	2,376.01	2,240.24	1,440.86	1,994.15	1,881.01	1,773.52	1,674.52	1,578.35	$12,733.57

**Values in US Dollars*

The costs represented in Table 4 are associated with RAQGEO's inventory method. The benefits observed is the difference between RAQGEO and the traditional inventory method for each year. Cash savings is the difference of the cost of the RAQGEO system investment (Costs) and the benefit of using the system through cash savings (Benefits). The discount factors are used from a present value interest factor table for six percent found in the publication *Contemporary Financial Management* by Moyer et al. 2014. The discounted cash savings is found by multiplying the cash savings by the discount factor and the total of $12,733.57 is only 47% of the total benefits after being discounted. The important factor is the discounted cash savings total still exceeds the cost of the RAQGEO inventory method by more than 31% calculated from the difference of the discounted cash savings and total costs divided by costs.

This table still reflects a quarterly inventory. If XYZ Logistics moved to a monthly inventory RAQGEOs benefits would be much more per year. Table 4 does not factor employee salary raises however the benefits would likely increase proportionately to costs because the benefits are calculated from the difference of the traditional inventory costs.

Table 4 is also displayed in Appendix E: Discounted Cash Savings of RAQGEO.

4.2 Benefits in Reducing Waste

After observing the side-by-side comparison it is conclusive that RAQGEO is a technology that will pay for itself over time plus provide a more ergonomic environment for employees.

One reduction that will be observed is less mistakes. According to Dave Boydston, RFID tags have a similar read accuracy as bar codes and may have one error in two million scans versus a typist that averages about one substitution made every 300 character entries on a keyboard. Similar studies reveal the same numbers, and one study also reveals that costs for the barcodes are recovered within the first year of implementation (Barcode Label Consultants, LLC 2010).

Additionally, the traditional inventory method takes roughly half a minute per unit. The process consists of reading over multiple pages of printouts, then searching for a serial number on a unit. Depending on the unit, it can be a lengthy process.

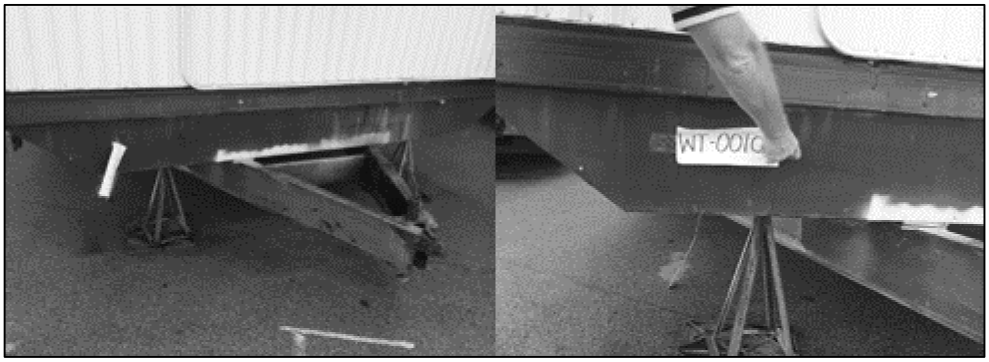


Figure 24: Side-by-Side of Serial Number Tag Falling/Showing.

As observed in Figure 25, this unit's serial number is a piece of close-off tape on the hitch. The paper was folded over and about to fall in the image to the left, and the image to the right shows the serial number being held up to be read. Most of the units do not have a uniform placement for serial numbers. This causes a waste of time and can cause further issues such as the identification of the units. See Figure 25 which shows another issue among many others:

Figure 25: Unit Serial Number Unknown.

On first glance Figure 26's unit displays a serial number that is either a 27 or possibly a 26. The only tool to help figure out that this was more likely 27 was a power supply box that had "T27" on its label possibly suggesting this is a 27. No unit serial number could be located (units are occasionally returned from customers with this issue). Dura 1500 UHF RFID tags have permanent adhesive and can also be bolted to a surface. The RFID tag is indiscrete, relatively flat, and a deliberate action would need to be taken to remove it.

The RFID tags could also be stamped with a unit serial number, eliminating the need to stencil serial numbers onto each trailer. Stenciling serial numbers onto a trailer is a task that takes time away from other preparation processes.

RAQGEO can have RFID tags uniformly placed on the outside of all the units. With the permanent adhesive it can easily stick and even be bolted to the trailer hitches of each unit or in uninterrupted sections along the configurable units and storage containers. During a practice collection from unit to unit it took approximately 8-15 seconds between each RFID collect with the entire yard being covered within one hour. That included the time it took to identify each unit's actual serial number, take pictures, and figure out how to traverse over a place that was unknown to an outside person. An employee that regularly uses the equipment and is trained on quickly collecting from unit to unit could average 5-10 seconds (walking time) between each unit plus a second of collection and have a spreadsheet with all the units and locations in the yard within half an hour. The next half hour could be used cross-referencing last reports for reconciliation.

As a note, some of these costs can be reduced; one method to exercise cost control could be established by sending all key leadership to one location to learn the RAQGEO system from the Serial IO consultant. Another exercise to reduce expense is to share tags between branches as needed. One additional expense for entry that is not reflected but may be important is the cost in labor as employees bolt or apply (with permanent adhesive) Dura 1500 RFID tags to each unit, however this process can easily be covered during the time the employees are conducting their last traditional-style inventory as it would be a quick process. As units came back from customers they could be outfitted with the tags or they could be installed on a site visitation, if deemed necessary. However, this method would increase expenses and is not recommended.

CHAPTER FIVE: DISCUSSION & CONCLUSION

This study investigated the utility of employing RFID technology with a spatial component in a company where supply chain management is critical. RAQGEO produces a spreadsheet that can be used to generate reports, heatmaps, and a COP for management among other products. The ability to eliminate non-value added movement through the yard has employees more focused on readying units and working with customers.

Figure 26: Military Vehicles with OMNI-ID 1500 RFID Tags, Source: OMNI-ID.

Figure 27 has yellow arrows pointing directly at OMNI-ID 1500 RFID tags. The RFID tags are fixed to each military vehicle with an adhesive foam and painted over to match the camouflage of each vehicle. These vehicles are highly mobile and are subject to training and use in deserted locations and rugged terrain. This tag is highly recommended for XYZ Logistics' operations.

5.1 Discussion

There are advantages and disadvantages of the RFID and GPS technology. Someone familiar with GPS technology would say there may be atmospherics that could affect the exact coordinates such as excessive amounts of metal, power lines, and possibly weather conditions. RFID collection is affected by metal and liquid. Today, OMNI-ID has developed RFID antenna technology that has better resistance to metals, however, if it is enveloped in metal or a liquid substance radio waves are not able to pass through these mediums. There are also other risks associated with the technology (see section below).

5.1.1 Disadvantages in Security

While testing RFID tags at XYZ Logistics it became clear that if someone else had an RFID reader they could also gather the information from the units. This poses a security risk as it is known that anything that emits a frequency is unsecure if left unencrypted.

Since RFID technology is based on radio waves, there is a potential for unintended listeners. Even the lowest powered RFID tags can have their signals intercepted at much farther distances than its usual read distance using various instruments. This security issue was demonstrated at the DecCon 13 security convention in Las Vegas, Nevada, in July 2005, as consultants collected RFID data over 69 feet away from a tag designed for a read distance of less than 10 feet (Lindstrom & Thornton 2005).

Websites such as hacknmod.com, Bishop Fox provide information on hacking RFID technology. YouTube videos provide step-by-step instructions of how to clone RFID technology with different equipment. RFID Security books that can be purchased online or at bookstores worldwide provide in-depth descriptions of how to hack the technology so a person can take preventive measures.

Rfidvirus.org provides in-depth instructions on how to write RFID viruses and worms. The site was created and is managed by the Vrije Universiteit VU Amsterdam University Faculty. They state that while they have hesitation by providing query lines of code online however they hope companies will benefit from it as they realize the threat is not theoretical (Vrije University 2006). A query is a statement used in database applications to call specific lines of data i.e. Select * where ID = 10 from Table. The asterisk stands for "all records," which is treated as rows of data. The word "table" is used in place of any named table where the data is stored and is similar to a spreadsheet.

They explain the process of creating an RFID virus is by affecting a database by having an RFID reader read a tag that is reverse engineered and query lines are applied to it. As the reader is used on other tags it begins to corrupt them. Additionally, the site also provides information on how to defend against RFID attacks.

One method is to conduct code reviews to find programming bugs in middleware software. Another is to use databases such as Oracle and MySQL that don't allow certain queries to be used. On the web-end PHP or Java website development languages can be used instead of HTML to provide more security (Vrije University 2006). XYZ Logistics has their yard fenced in which would help protect the unit's RFID tags from being bugged. The threat does exist however and as the technology increases there may be more risks. However, XYZ Logistics would have to determine if they would be a target and what, if any, value would the information be to an outsider. For example, an outsider would not benefit from knowing if a unit has ADA-compliant restrooms.

5.1.2 Disadvantages in Data Collection

GPS locations are based on the Trimble RFID/GPS reading device or a smartphone communicating with an Intermec IP30 not the RFID tag itself.

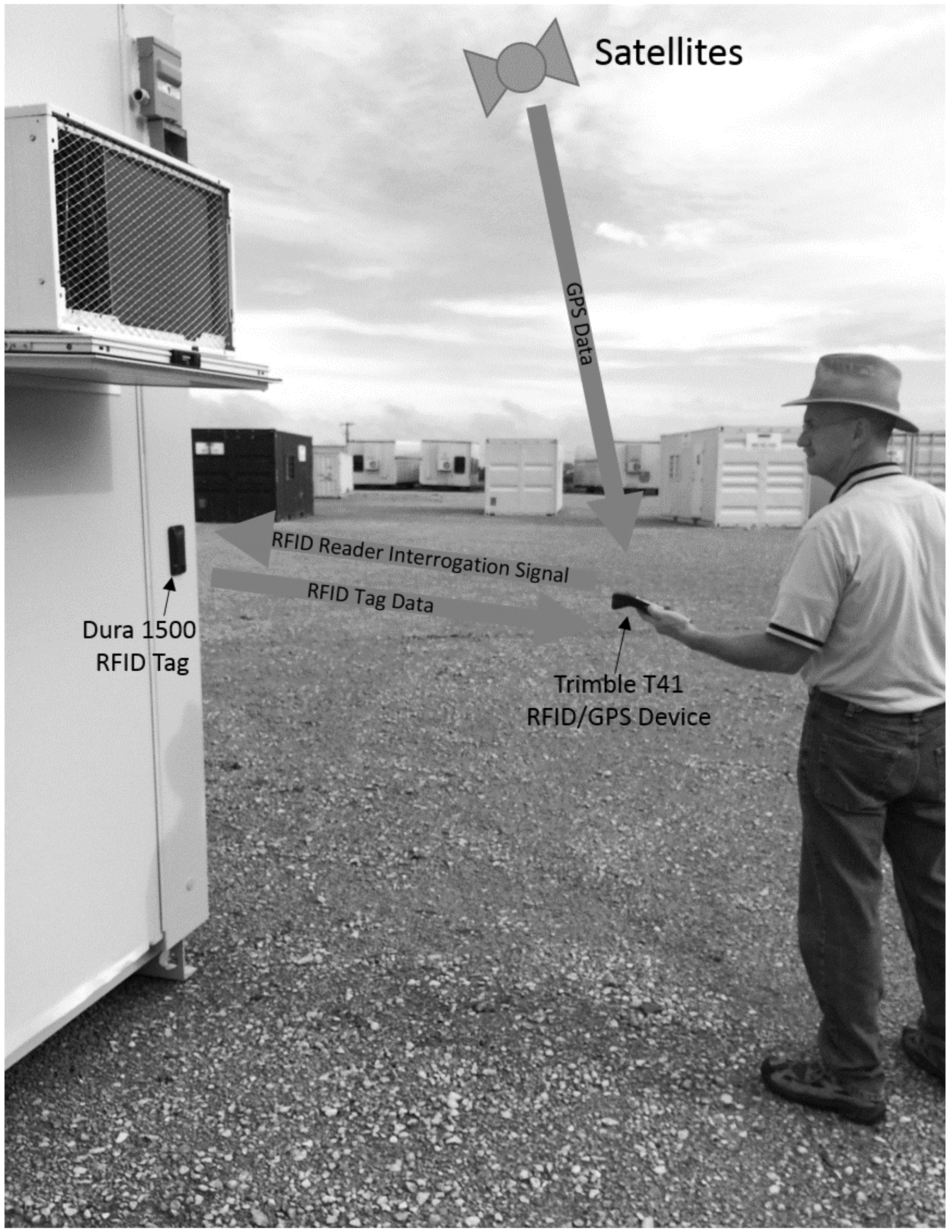


Figure 27: Diagram of RAQGEO Collection, Source & Annotations: Bradley Griffiths, 2014.

As shown in Figure 28 the GPS data is based on the position of the receiver, not the RFID tag. Therefore, an employee must stand where they would like the point to appear on the map API or in Google Fusion tables. The Trimble Juno T41 is going to be more accurate than the IP30 mixed with a smartphone. However, it still is affected by atmospherics such as powerlines, surrounding containers, and sky conditions according to Dave Boydston.

What if containers are stacked? Both container's tag data would be collected at the same time. The data is collected in two-dimensional form, however the Trimble T41 can also provide height if a customer required this information. Another solution is the T41 is able to take a picture as the RFID tag is collected. Therefore, management will be able to discern between two tags at a point.

The maps in Google Fusion tables or the API through iScanList both use the same imagery base from Google. Since the XYZ Logistics branches are usually near or in major cities the imagery is more current, however it will not accurately display what is there because units are constantly being moved. Instead it can be used as a reference point. In the future, XYZ Logistics potentially could invest for Serial IO to design a layer displaying the outlines of branches and use a basic map layer instead of imagery so it doesn't cause confusion. It is basic however it provides a cheap, effective way to see where units are within the yard.

One limitation for Google Fusion tables is the ability to only display 100,000 rows or 250MB of data (Google 2014). This will not pose an issue for XYZ Logistics because most branches have approximately 150-300 units while they have approximately another 800-1000 units that are on lease to customers. If management want to collect grids on units out at customer sites they can still view all units since it's under 100,000 rows. Plus the .CSV file of the collection data on 128 units in the shipping yard was only 13.8 kilobytes.

Another disadvantage is RFID tags cannot be placed inside most of the units. They must be mounted on the outside because even the thinnest of metals can block a radio signal. It was observed that aluminum could even pull a radio signal to a different position when a tag was placed along the inside of aluminum doors. Specific tags must be used that are weather and wear proof. The OMNI-ID Dura 1500 RFID tags fit the needs for XYZ Logistics. Recommendations for placement on the different types of units can be found in Appendix B.

Barcodes could have given a similar result; however, RFID technology offers the ability for further technology expansion and additional sensors to track movement. Other advantages RFID technology has over barcodes according to Liu et al. (2010):

- No need for line-of-sight readings
- Can hold more data than barcodes
- Can be password-protected
- Can be modified or have data added
- Effective even in harsh environments
- Can be read instantaneously by the same device

Barcodes are also cheaper; however, RAQGEO provides many more advantages to include the potential for growth such as an addition to sensors and web services. For instance, at a later point sensors can be installed in the yard to email management when a unit goes in and out of the preparation bays. Additionally, drivers can tag locations of units as they drop them off with a device such as an Intermec IP30 that can communicate via Bluetooth with a smartphone to send the data directly to a manager for safekeeping.

5.1.3 Advantages

RAQGEO has much potential beyond this initial study. For example, a T41 can be held in an employee's hand as they drive a golf cart around the yard and hold the trigger, instantly collecting the data and covering the entire yard within minutes. The opportunities in RFID and GPS data collection can provide much value-added to management especially for its use in GIS projects. It can help managers redesign the layout of their yards and provide a more ergonomic approach to tracking down specific units.

5.2 Conclusion

This study compared the traditional inventory methods in supply chain management to a new inventory method using RFID and GPS technology, and how GIS can be used from this data to provide even greater potential. The pilot study's results revealed that RAQGEO is a superior method of supply chain management for mobile units that continuously are moved across a storage yard and to/from customer sites. It is due to its demonstration of reduced costs, primarily in the form of labor, increased efficiency in time, and ability to quickly generate reports and identify locations of specific units throughout the yard. The cost-benefit analysis results showed that the savings in man hours and labor will easily cover the costs of the initial investment within the first three years. Again, the costs will not be as much for additional branches as key leaders can make site visits to train other branches eliminating consultation fees. The Dura 1500 RFID tags prove to be the most effective choice for XYZ Logistics and can even have a label added to them with a serial number for visual identification in a uniform position as well.

5.3 Future Research

RFID technology provides an abundance of future opportunities. As society moves toward the IoT concept, sensors and devices for tracking items will become more affordable and companies will invent new services for data capture. Companies that are early adopters of IoT type technology will have easier transitions and will see even further cost reductions as processes become automated.

In a meeting with an XYZ Logistics manager, a question was asked what if all the RFID tags are together in one bundle and collected at the same time. As demonstrated, all of the RFID tags were read by an RFID reading device at the same time and posted the same location for each row of data created. In theory, an RFID reading antenna with a far enough read distance can collect all of the RFID tags in the yard to instantly generate inventory reports within minutes. However, the location data would not be collected. To maintain the location data a solution would need to be developed that could provide communication between GPS technology and the RFID tags. One possible future solution would be exploring laser rangefinders such as the ones produced by Trimble. They can be pointed at an object to get its location data from afar. An investment of time and funds could possibly create a system with multiple laser rangefinders throughout a yard that collect RFID location and their ID through an automated collection algorithm throughout the storage yard. An automated collection algorithm could be a movement action.

Another possibility is using a small robot or drone to collect the RFID tag data by navigating along pre-programmed pathways. Figure 29 displays an RFID collecting robot in a study by an Intel Research team to test how a robot can be used to collect passive RFID tags.

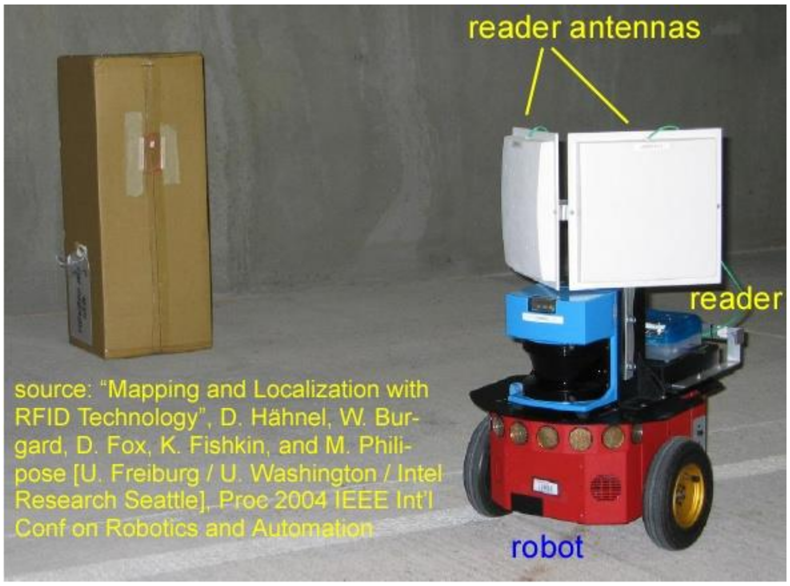


Figure 28: RFID Collecting Robot, Source: Philipose et al. 2003

Using IoT technology, a small robot or drone could potentially conduct inventories before management by using predictive analysis or being alerted by keywords from emails and other methods.

Smart tags offer a similar solution of providing both types of data without the need of an antenna or advanced system throughout a yard, however it is too expensive for most companies to use. Over time however the prices may drop presenting this as a more viable solution.

REFERENCES

114 Adams Communications. 2013. "Answers to General Bar Code Questions." Bar Code FAQ Answers. http://www.adams1.com/faq.html (accessed 9 October 2014).

AeroScout. 2009. "AeroScout T6 GPS Tag Datasheet." http://www.aeroscout.com/files/AeroScout%20T6%20GPS%20Tag%20Data%20Sheet.pdf (accessed 8 August 2014).

AeroScout Industrial. 2008. "AeroScout Wins Contract for New GPS and Wi-Fi Visibility Solution with 309th Aerospace Maintenance and Regeneration Group." http://www.aeroscout.com/amarg-081104/aeroscout-wins-contract-new-gps-and-wi-fi-visibility-solution-309th-aerospace-m (accessed 8 August 2014).

Barcode Label Consultants LLC. 2010. "Barcodes." Barcode Labels. http://barcodelabelconsultants.com/?p=22 (accessed 9 October 2014).

Bluetooth Technology. 2014. "A Look at the Basics of Bluetooth Technology." Bluetooth Technology Website. http://www.bluetooth.com/Pages/Basics.aspx (accessed 8 August 2014).

Bolstad, P. 2008. *GIS Fundamentals: A First Text on Geographic Information Systems.* AtlasBooks.

Chiu, M., Loffler, M., and Roberts, R. 2010. "The Internet of Things." McKinsey & Company. http://www.mckinsey.com/insights/high_tech_telecoms_internet/the_internet_of_things (accessed 24 October 2014).

Christopher, M. 2012. “Key Challenges of Supply Chain Management: an Urgent Message for Business.” http://www.som.cranfield.ac.uk/som/p17318/Think-Cranfield/2012/March-2012/Key-Challenges-of-Supply-Chain-Management-an-Urgent-Message-for-Business (accessed 9 October 2014).

Dooley, F. 2006. “Logistics, Inventory Control, and Supply Chain Management.” http://www.choicesmagazine.org/2005-4/supplychain/2005-4-14.htm (accessed 9 October 2014).

Environmental Protection Agency. 2011. "Kanban | Lean Manufacturing and the Environment | US EPA." EPA. http://www.epa.gov/lean/environment/methods/kanban.htm (accessed 8 August 2014).

Gaukler, G.M. 2005. RFID in supply chain management. Ph.D. diss., ProQuest, UMI Dissertations Publishing.

Glassdoor. 2014. XYZ Logistics Review [Company Confidential]. http://www.glassdoor.com/index.htm (accessed on 10 September 2014).

Grant, T. "Intermec Technologies Corporation." 2005. In *International directory of company histories,* 190-192. Detroit, MI, St. James Press, 2005.

Greg Goebel. "[2.0] Longwave Radar At War / Early American Radar Efforts." 2013. Vectors. http://www.vectorsite.net/ttwiz_02.html#m2 (accessed 8 August 2014).

Günther, O, Kletti, W., and Kubach, U. 2008. *RFID in manufacturing*. Berlin: Springer.

Google. "Keeping your account secure." 2014. Google Accounts Help. https://support.google.com/accounts/answer/46526 (accessed 8 August 2014).

Google Earth Help. 2014. "Google Earth Projection." https://support.google.com/earth/answer/148110?hl=en (accessed 8 August 2014).

Google Fusion Tables. 2014. "Google Maps JavaScript API v3." 2014. Fusion Tables Layer. https://developers.google.com/maps/documentation/javascript/fusiontableslayer (accessed 8 August 2014).

Impinj. 2014. "The Different Types of RFID Systems." Impinj Resources. http://www.impinj.com/resources/about-rfid/the-different-types-of-rfid-systems/ (accessed 8 August 2014).

Institute of Physics. 2014. "How Does GPS Work?" http://www.physics.org/article-questions.asp?id=55 (accessed 8 August 2014).

Lean Enterprise Institute. "Principles of Lean." 2009. What is Lean. http://www.lean.org/WhatsLean/Principles.cfm (accessed 7 March 2014).

Liu, L., Chen, Z., Yan. D., Lu, Y., and Wang, H. 2010. RFID in supply chain management. 2010 International Conference on E-Business and E-Government: 3279-3282.

Maselli, J. 2003. "Logistics Gets Cheaper by the Yard." http://www.rfidjournal.com/articles/view?617/ (accessed 14 November 2014).

MiTAC Intl.. "History of GPS." 2014. Mio Technology. http://www.mio.com/technology-history-of-gps.htm (accessed 8 August 2014).

Montana State University. "NAVSTAR Global Positioning System (GPS) Facts." 2014. NAVSTAR GPS Facts. http://www.montana.edu/gps/NAVSTAR.html (accessed 8 August 2014).

Moyer, C., McGuigan, J. Rao, R. 2014. *Contemporary Financial Management*. Cengage Learning. Canada. p. T-3.

NHHC. 1943. "IFF--Identification Sets- US Radar: Operational Characteristics of Radar Classified by Tactical Application [FTP 217]." The Navy Department Library. http://www.history.navy.mil/library/online/radar-13.htm (accessed 8 August 2014).

Nick, T. 2014. "Did You Know What Was The First Smartphone Ever?" PhoneArena. http://www.phonearena.com/news/Did-you-know-what-was-the-first-smartphone-ever_id58842. (accessed 8 August 2014).

NOAA. 2013. "Selective Availability." GPS.gov. http://www.gps.gov/systems/gps/modernization/sa/. (accessed 8 August 2014).

OMNI-ID. 2013. "OMNI-ID Dura 1500 Datasheet." http://www.omni-id.com/pdfs/Omni-ID_Dura_1500_datasheet.pdf (accessed 8 August 2014).

OMNI-ID GEN2. 2014. "Omni-ID Flex Tag - GEN2 UHF RFID Datasheet." Serial IO Products. https://serialio.com/products/rfid/rfid-tags/omni-id-flex-tag-gen2-uhf-rfid (accessed August 8, 2014).

Parkinson, B. 1994. GPS Eyewitness: The Early Years. GPS World, p. 42.

Philipose, M., Fishkin, K., Fox, D., Hahnel, D. 2003. "Mapping and Localization with RFID Technology." Intel Research. http://edge.rit.edu/content/P12015/public/Referenca%20Materials/RFID%20READER%20SKYTEK%20M9%20Module/Mapping%20and%20Localization%20with%20RFIDs.pdf. (accessed 01 November 2014).

Ramírez, J. 2012. Radio frequency identification (RFID) technology for academic, logistics and passenger transport applications. Ingeniería e Investigación. Vol. 32, No. 3., 2012, p. 58-65.

RFID Journal. 2014. "RFID Frequently Asked Question." http://www.rfidjournal.com/faq/show?68 (accessed 8 August 2014).

Schmidt, R. 2013. "What You Should Know About the Discount Rate." PropertyMetrics. http://www.propertymetrics.com/blog/2013/09/27/npv-discount-rate/. (accessed on 5 November 2014).

Serial IO. "About Serialio." 2014. Serialio.com. https://serialio.com/about-serialio (accessed 8 August 2014).

SkyRFID, Inc. 2014. "RFID Tag Maximum Read Distance." SkyRFID Website. http://skyrfid.com/RFID_Tag_Read_Ranges.php (accessed 8 August 2014).

Song, J., Haas, C., and Caldas, C. 2006. ”Tracking the Location of Materials on Construction Job Sites.” J. Constr. Eng. Manage., 132(9), 911–918.

Sony. "GLONASS." 2014. Developer World GLONASS. http://developer.sonymobile.com/knowledge-base/technologies/glonass/ (accessed 9 October 2014).

Swedberg, C. 2014. "Air Force Base Deploys Wi-Fi/GPS RFID System Across 2,500 Acres." RFID Journal. http://www.rfidjournal.com/articles/view?4441/2 (accessed 9 April 2014).

Serial IO. 2014. "Serialio.com." LinkedIn. https://www.linkedin.com/company/serialio-com (accessed 8 August 2014).

Stuart, L. E. 1947. "Identification, Friend or Foe- Radar's Sixth Sense." Tele-Tech Electronic Industries, January 1947, 60-67.

Technovelgy. 2014. "What is RFID?." Technovelgy.com. http://www.technovelgy.com/ct/technology-article.asp (accessed 8 August 2014).

Texas Commission on Environmental Quality. 2013. "Horizontal Accuracy Standards for TCEQ GIS Positional Data." https://www.tceq.texas.gov/gis/geocoord.html. (accessed 20 August 2014).

TransFreight Inc. 2009. "What is Logistics?." Logistics. http://www.transfreight.com/Lean_Logistics_Overview/What_Is_Logistics.aspx (accessed 1 March 2014).

Toyota. 2014. "Philosophy of complete elimination of waste." Just-in-Time. http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/just-in-time.html (accessed 1 March 2014).

TutorialsWeb. 2011. "RFID Frequencies." RFID: A Beginner's Guide. http://www.tutorialsweb.com/rfid/rfid-frequencies.htm (accessed 8 August 2014).

United States Army. 2014. "ADP 3-0 Unified Land Operations." Army Doctrine and Publications. Department of Defense.

University of San Francisco. 2014. "RFID Technology Boosts Walmart's Supply Chain Management." Supply Chain Management. http://www.usanfranonline.com/resources/supply-chain-management/rfid-technology-boosts-walmarts-supply-chain-management/#.VEmKTfnF_Uh (accessed 8 August 2014).

VK2DYM. 2014. "Radio Identification Systems- Identification, Friend or Foe I.F.F" VK2DYM's Radio and Radar Information Site. http://www.qsl.net/vk2dym/radio/iff.htm (accessed 8 August 2014).

Vrije Universiteit VU Amsterdam University. 2014. "How to Write an RFID Virus." RFID Viruses and Worms. http://www.rfidvirus.org/ (accessed 8 August 2014).

Wi-Fi Alliance. 2014. "Who We Are." Wi-Fi Alliance. http://www.wi-fi.org/who-we-are (accessed 8 August 2014).

Woodford, C. 2007. RFID tags. http://www.explainthatstuff.com/rfid.html (accessed 8 August 2014).

Work Site Alliance. 2000. “Chapter 5: GIS and Decision-Making.” Institute for Geospatial Research & Education- Eastern Michigan University. http://igre.emich.edu/wsatraining/TManual/chap.htm (accessed April 9, 2014).

Zeidan, H. 2009. “Supply Chain Management (SCM): The Inter-Organizational Network.” The Certified Accountant. 2nd Quarter 2009. Issue #38.

Zelbst, P., and Sower, V.E. 2012. RFID for the supply chain and operations professional. New York, N.Y.: Business Expert Press, 2012.

**XYZ Logistics is referenced however the actual company name is protected in confidentiality using the APA Publication Manual; 6th ed., § 1.11, p. 16; APA Ethics Code, Standard 4.07. The actual company was exposed to Serial IO and the thesis committee with an understanding that their name and association in the study is confidential.*

APPENDICES

APPENDIX A: OMNI-ID FLEX RFID TAG TESTING

**All photos were taken from an iPhone 5s by Bradley Griffiths. RFID tags were placed along different types of material and units.*

Test One: RFID tag was sat on the trailer hitch.

Result: Easily detectable by IP30 RFID reading device.

Test Two: RFID tag was sat on the West window on outside (not shown in picture)

Result: Easily detectable by IP30 RFID reading device.

Test Three: RFID tag was sat inside defect along sheet metal.

Result: The RFID tag was undetectable unless the IP30 RFID reading device was held along the open defect portion of the sheet metal.

Test Four: RFID tag was sat on outside trim of unit.

Result: Easily detectable by IP30 RFID reading device.

Test Five: RFID tag was placed inside unit with door closed.

Result: IP30 could not read through aluminum door. However, if the IP30 was held underneath the unit it could read through the floor boards and linoleum.

Test Six: RFID tag was placed inside plastic sleeve on inside of conex door.

Result: Once the door was closed the IP30 could not read through metal.

Test Seven: RFID tag was taped to wall inside a configurable unit.

Result: The IP30 could not read the tag directly through the wall, however it could pick up a signal along the trim of the door through the aluminum. Conclusively, this is not reliable to have a tag inside these type of containers.

APPENDIX B: RECOMMENDED RFID TAG PLACEMENT

**These recommendations are for the OMNI-ID Dura 1500 RFID tags that are ideal for XYZ Logistics' operations. All photos were taken from an iPhone 5s by Bradley Griffiths and Dave Boydston helped provide expert advice on where the RFID tags should be placed.*

<u>Configurable Unit</u>

Description of Placement: The RFID tag can be placed on a section that does not change. The configurable unit has walls that can be interchanged with walls of different arrangements such as multiple windows.

Single-Wide Trailer

Description of Placement: The tag can be placed next to where a serial number is supposed to be displayed or possibly along the trailer hitch section.

<u>Steel Container/Conex</u>

Description of Placement: The tag can be placed just below the serial number on the outside of the container.

<u>Section Modular Building</u>

Recommendation of Placement: The tag is displayed here right above the serial number.

APPENDIX C: RFID PRODUCT DATASHEETS

OMNI-ID Dura 1500 RFID Tag

Omni-ID®
Building Intelligent Supply Chains

Visit www.omni-id.com to learn more about the complete line of Omni-ID RFID products.

Omni-ID® Dura 1500

Omni-ID Dura 1500 is the most durable and long range tag product offering long read ranges across all geographies. Designed with heavy industry in mind, the Omni-ID Dura 1500 features extreme impact resistance and high temperature ratings, enabling it to be deployed in outdoor heavy industry environments anywhere in the world.

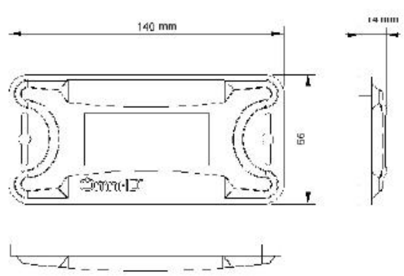
Building Intelligent Supply Chains

With an excellent read range across all geographic regions and a durable, high heat resistant encasement, the Dura 1500 is best suited to outdoor applications, including:

- Container tracking for yard management.
- Cargo tracking.
- Defense asset management.

Physical Specifications

Encasement	ABS or Polycarbonate
Size (mm) (tolerance)	140 x 66 x 14.0 (+/−1.0)
Size (in) (tolerance)	5.51 x 2.6 x 0.55 (+/−0.04)
Weight (g)	79.0 (ABS) 82.0 (PC)



Dimensions stated in mm

RF Specifications

Protocol	EPC Class 1 Gen2
Frequency Range (MHz)	860–960 (global)
Read Range (Fixed reader)[1]	Up to 15.0 (global)
Read Range (Handheld reader)[1]	Up to 7.5 (global)
Material Compatibility	Optimized for metal
IC Type (chip)	Alien H3
Memory [2]	EPC - 96bits User - 512bits TID - 64bits

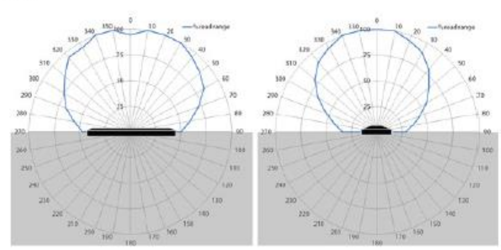
1. Quoted performance achieved using standard testing methodology. Read range will vary with reader hardware and output power.

2. EPC and User memory are reprogrammable, TID is locked at point of manufacture.

Radiation Patterns

Large Metal

Sheet



Source: http://www.omni-id.com/pdfs/Omni-ID_Dura_1500_datasheet.pdf

OMNI-ID Flex RFID Tag

Omni-ID®

Identify with innovation

Visit www.omni-id.com to learn more about the complete line of Omni-ID RFID products.

Omni-ID Flex®

Omni-ID Flex is a medium range tag with outstanding performance-to-size ratio. The Flex provides high-performance RFID tag identification in metallic or non-metallic environments with a low profile and a read range of over 16 feet.

Omni-ID Flex comes standard with a printed label finish. It is also available in a low-profile ruggedized rigid case for applications with harsh environmental requirements.

Product Specifications

	Flex Label	Flex Rigid Case
Read Range (m)[1]	Up to 5.0 (US) Up to 3.5 (EU)	Up to 5.0 (US) Up to 5.0 (EU) Up to 4.0 (JPN)
On Metal or Balanced	Balanced	Balanced
Size (mm) (tolerance)	77 x 15 x 2.8	100 x 21 x 7.2 (+/- 1.0 mm)
Size (in) (tolerance)	3 x 0.6 x 0.11	3.9 x 0.8 x 0.28 (+/- 0.04 in)
Weight (g)	2.9	11.6
Encasement	Synthetic Label	Rigid case (ABS)
Frequency Range (MHz)	902–928 (US) 866–868 (EU)	902–928 (US) 866–868 (EU) 952–954 (JPN)
IC Type (chip)	Alien Higgs 3	Alien Higgs 3
User Memory (bits)	512	512
Operating Temperature (C)	+5 to +40 °C	−20 to +55 °C
IP Rating	IP54	IP68
Shock and Vibration[2]	MIL STD 810-F BS EN 60068-2	MIL STD 810-F BS EN 60068-2
Attachment	Film adhesive (std.) Foam adhesive (opt.)	Manual (std.) Film adhesive (opt.) Foam adhesive (opt.)
Order Number	013-EU , 013-US :507 (std. foam), :508 (premium foam)	022-EU , 022-US , 022-JPN :502 (film), :507 (std. foam), :508 (premium foam)

1. Quoted performance achieved using standard Omni-ID test methodology, details available upon request.
2. Product designed to meet MIL STD 810-F and BS EN 60068-2. Please contact Omni-ID for further details.

All Products are RoHS Compliant

Omni-ID DS_Flex111810

Source: https://serialio.com/sites/default/files/pdf/Omni-ID_Mid-Range_RFID_Tag_Flex_DS.pdf

Trimble Juno T41XGR RFID/GPS Receiver

The flexible, fully-rugged Juno T41 is available in a wide variety of configurations. Build the handheld computer you need: Android or Microsoft Windows operating systems, Barcode Imager, Ultra-High Frequency RFID, Smartphone or GPS collector (or combinations). Every Juno T41 is a reliable small workhorse computer designed to last for years in any environment.

KEY FEATURES & MODELS

Juno T41 C, X, M: Basic Model with Smartphone option

Fully Rugged design with IP65 or IP68; Mil-ST-810G

Choice of Operating Systems: Windows Embedded Handheld (WEHH) 6.5 or Android 4.1 "JellyBean"

Processor: 800 MHz or 1GHz TI OMAP 3

RAM: 512 MB

Multi-touch User Interface with capacitive stylus compatibility

8 MP camera with dual LED flash and geo-tagging/ Audio/Video

2-4 Meter integrated GPS receiver w/SBAS

Bluetooth and Wi-Fi 802.11 b/g/n; CCX certified

4.3" WVGA Sunlight-readable Corning® Gorilla® Glass Display

Accelerometer and Electronic Compass

Full-Day Battery Life

Raw GPS Data Available for post-processing to enable sub-meter performance

3.75G cellular data, text & voice optional

Camera Barcode Scanning Application

Software Development Kit to customize workflow

Juno T41 R: Ultra-High Frequency RFID

Rapid-Read, high-accuracy performance on multiple tags with multiple orientations, even in crowded conditions

Read-Range: 3.5+ (12'+) Meters for $5\ cm^2$ (2") UHF tags in unobstructed space

Integrated antenna with the ability to transmit up to +30 dBm (1 Watt) power for demanding applications

Configurable performance settings and use-case parameters in the pre-loaded Trimble SearchLight application

Supports EPCglobal Gen 2 (ISO 18000-6C) protocol

Automatically configured and ready for use around the world:

- FCC Certified (North America): 902-928 MHz bands
- ETSI Certified (EU): 865.6-867.6 MHz bands
- ACMA Certified (AU/NZ): 920-926 MHz bands

Easy-to Use Software Development Kit (SDK) and Application Programming Interfaces (APIs) to customize all settings including read range, power consumption and other features

Juno T41 G: Real-Time Enhanced GPS: Accuracy 1-2 Meters in Real Time[1]

Juno T41 S: 1D/2D Barcode Imager

White light illumination and red LED-based aimer for ease of use

High-motion tolerance for quick scanning responsiveness

Omni-directional reading capabilities for real world use conditions

Rapid Scanning Capability for high read rates no matter the angle or orientation

Access to other valuable tools such as:

- Multicode reading
- Data editing
- Image capture
- Illumination, aiming, presentation modes

Reliable Performance in Reduced Signal Environments

Real-time GPS accuracy of 1-2 meters[2] with SBAS

Dramatic performance improvement with GPS Accuracy Algorithm Enabled[5]

Small, portable & ergonomic form-factor

Note: X models contain C functionality and options
Note: S and G models contain C and/or X functionality and options

Trimble.

ULTRA-HIGH FREQUENCY SUPPORT: THE "R" CONFIGURATION

The Juno T41 R integrates the Trimble ThingMagic Mercury6e-Micro (M6e-Micro) RFID reader into its small, compact form factor. Using EPCglobal Gen 2 RFID technology, the T41 R rapidly reads tags at different frequencies almost simultaneously, for accurate reads in real world conditions.

The Juno T41R can read a single square 5 cm^2 (2 square inch) UHF RFID tag more than 3.5 meters (11+ feet) away from the unit in unobstructed space. In more challenging environments with higher

Source:
http://sdgsystems.com/download/Marketing/Datasheets/Trimble/Juno%20T41/Juno T41_Datasheet_2014_LowRes.pdf

APPENDIX D: PILOT STUDY SCHEDULE

RAQGEO PILOT STUDY AGENDA

THURSDAY, AUGUST 28, 2014	
8:00 am to 10:00 am	Introductions & PowerPoint Overview
10:00 am to 12:00 pm	Safety Orientation/Organization Requirements
12:00 pm to 1:00 pm	Lunch
1:00 pm to 5:00 pm	RFID Tag Placement and Practice (By Students)

FRIDAY, AUGUST 29, 2014	
8:00 am to 10:00 am	Meeting with Serial IO Consultant for (Students & Consultant)
10:00 am to 12:00 pm	Test RAQGEO System & Spreadsheet Data
12:00 pm to 1:00 pm	Lunch
1:00 pm to 3:00 pm	Database Implementation and Requirement Refinement
3:00 pm to 4:00 pm	Q&A with Consultant for Pilot Study
4:00 pm to 5:00 pm	Discuss with Consultant on Phase II Goals and Necessary Equipment

Notes:

All green, underlined text are periods of time where students and consultant will be out in the yard working with equipment.

*Friday morning the consultant's main role will be working with the students directly for the system network scheme and testing.

*Friday afternoon the consultant will be a part of a discussion at the end of the day to review the pilot study results

APPENDIX E: DISCOUNTED CASH SAVINGS OF RAQGEO

Values in US Dollars	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Costs	7,409.86	185.71	185.71	185.71	185.71	635.57	185.71	185.71	185.71	185.71	185.71	9716.82
Benefits	-	3,014.29	3,014.29	3,014.29	3,014.29	2,564.43	3,014.29	3,014.29	3,014.29	3,014.29	3,014.29	29693.04
Cash Savings	(7,409.86)	2,828.58	2,828.58	2,828.58	2,828.58	1,928.86	2,828.58	2,828.58	2,828.58	2,828.58	2,828.58	19976.22
Discount Factors	1.000	0.943	0.890	0.840	0.792	0.747	0.705	0.665	0.627	0.592	0.558	
Discounted Cash Savings	(7,409.86)	2,667.35	2,517.44	2,376.01	2,240.24	1,440.86	1,994.15	1,881.01	1,773.52	1,674.52	1,578.35	$12,733.57