The “Smart” Fire Department

Increasing public safety with RFID technology

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Summary

This study was performed with two main goals in mind. The first was to research the possibilities of building a fire engine adaptation of the "Smart" Toolbox by Flörkemeier, Lampe & Schoch 2003. The second goal was to research the financial possibilities of implementing the RFID asset management system for the Rotterdam-Rijnmond Fire Department (RBRR).

The goals of this research were formulated after having done some research after an asset management problem was presented to me by a colleague of mine at the fire department of Rotterdam-Rijnmond. The problem presented to me is that the Fire Department is losing costly and critical equipment especially at major emergency incidents. When multiple fire stations work together, all the equipment and gear get mixed up and when leaving the emergency scene the wrong equipment and gear is returned to the fire station. This could lead to more equipment purchases, higher material and inventory costs and more important, fire engines not being fully equipped with the mandatory equipment which enhances the risk of losing lives that could have been saved.

Having done some research on RFID technology in the past, this seemed as a perfect research for my master thesis at the Erasmus University Rotterdam. This thesis starts off by giving some background information on the origin of the research and some theoretical information on the researched literature. It provides information on the RFID technology and the organization that it will be implemented in. Then it goes in detail on the asset management processes within the organization followed by the proposed asset management solution and ends with the financial calculations of the proposed investment.

The proposed RFID asset management solution implies that by attaching RFID tags to all equipment, gear and fire resistant garment and installing RFID readers at the designated locations on the fire engines and in the fire stations; asset management of all portable assets can be improved. This RFID implementation could yield a lot of efficiency gains due to automation of certain manual labor and also mitigation or even elimination of certain risks.

The RFID implementation enables automatic tracking and tracing of these assets at all times and also the ability of programming assets to trigger certain actions automatically. By automatically triggering preprogrammed events, lots of manual labor could be reduced or even eliminated within the described asset management processes. From a user's point of view it may seem that the smart assets manage themselves. This ability is the "Smart" feature of the RFID solution, which is referred to in the title of this research. The solution in mind will result is having "Smart" Fire Engines and "Smart" Fire Stations, therefore the research title: The "Smart" Fire Department.

The findings of this study strongly suggest that it would be wise to first experiment with the "Smart" fire engine concept and if it indeed can deliver on the theoretical benefits researched, it could be a serious quality improvement investment option for the fire department. The benefits would first of all mean a higher safety level for the public and the firemen, as the firemen will always be properly equipped with the right tools at an emergency scene plus due to the asset management efficiency gains the firemen can spend more time on preparing for emergencies. These efficiency gains will also result into lower personnel costs as less man-hours are needed for asset management processes at the fire stations.

Acknowledgements

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- Stuart Benjamin, Director at Accordus UK Ltd. (Henfield, United Kingdom)
- Gregory Stewart, Managing Member, Orbiter LLC. (Washington, USA)

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1 Introduction

After attending a seminar on Radio Frequency Identification (RFID) in 2008, I really got interested in the RFID technology and I got the idea of incorporating this technology in the line of work of the Fire Department, as I have been working for almost two years for the mother organization of the Fire Department in Rotterdam, Veiligheidsregio Rotterdam-Rijnmond (VRR). The main reasons for wanting to incorporate the use RFID in the line of work of the fire department are that I truly believe in the potentials of RFID technology, I have access to most of the needed information of the fire department, I have sponsorship from within the organization and above all I get the chance to contribute to the improvement of public safety.

In order to come up with a research topic for my master thesis involving the fire department I started conducting some exploratory interviews with people within the VRR organization. The definite research topic came from an interview I had with the head of the IT department of the VRR. I was telling him about the seminar on RFID technology I had just attended on which he then told me of an RFID solution they wanted to research a few years ago for a certain problem the fire department has. After performing some research on the combination of the topics RFID and the Fire Department I really started to believe that this could be a solution for that specific problem the head of the IT department was telling me about.

1.1 Main Problem

The main problem drawn from the conducted interview with the head of the IT department of the VRR is that the Fire Department is losing costly and critical equipment especially at major emergency incidents. When multiple fire stations work together, all the equipment and gear get mixed up and when leaving the emergency scene the wrong equipment and gear is returned to the fire station. This could lead to more equipment purchases, higher material and inventory costs and more important, fire engines not being fully equipped with the mandatory equipment which enhances the risk of losing lives that could have been saved.

Background information on the problem:

A fire department usually contains one or more fire stations within its boundaries; each fire station provides fire protection within a certain jurisdiction. Each fire station has its own vehicles and each vehicle should carry a mandatory set of tools and equipment according to the regulation standards.

The problem starts when there's an escalated emergency incident and multiple fire stations and/or fire departments have to work together. During these hectic rescue missions all equipments are set aside unsorted after being used and by the time that they are finished each crew takes what they know or think are theirs and leave the emergency scene. The problem with this is that all equipments are most of the time standard regulation equipment and therefore easily to be mistaken to be yours which can result into under-equipped fire engines when leaving the emergency scene. Under-equipped fire engines that need to go directly to a following incident might not be able to perform their tasks properly which can result into unnecessary loss of life and property.

1.2 Solution in Mind

The solution to the problem I have in mind is an RFID system for asset/equipment management and tracking for the fire department which applies the "Smart Box" concept by Flörkemeier, Lampe & Schoch (2003) to create a "Smart Fire Truck". By tagging all equipment, an RFID system may be implemented for managing equipment information such as their location, inspection and maintenance details in a more secure and efficient manner. The "Smart Box" is a self operating RFID system that may be implemented on a fire truck to check if all mandatory equipment is in place when leaving the fire station or emergency scene, this system will be able to report directly to the mobile data terminal located in the front cabin of the truck.

I believe by implementing an RFID asset tracking and management system we will not only be able to mitigate the public and personnel safety and asset costs problem, but also improve overall efficiency at emergency scenes and at the fire stations. The how and to what extent it is technically and financially possible will be researched and documented in this thesis.

The lists below give an overview of the possible advantages and threats for the RFID solution in mind. The advantages and the threats listed below will be analyzed during this research and where possible be made tangible.

Possible Advantages[1]:

- The right assets are assembled on the fire engine before it leaves the station – and that those assets are fit for purpose, i.e. regular maintenance is up to date and all repairs have been completed. Benefits:
    - Saves time and costs in manually managing the inventory.
    - Ensures proper preparedness for emergencies.
    - Increases public and personnel safety.
- All deployed assets are recovered to the right fire engine after the incident. Benefits:
    - Saves time finding the deployed assets, using real-time location tracking.
    - Saves time and costs in not having to swap assets with other fire departments after the event.
    - Lowers tool & equipment expenses.

- Because of the automatic asset recognition and maintenance information upkeep, less man-hour is needed for asset management tasks. Benefit:
    - Lower personnel costs.
    - A more efficient Fire Department.
    - An operationally better fire department is created; more time can be spent on core business activities of the fire department.
- The locations of deployed assets are constantly monitored and that unexpected movements can be responded to in case of theft. Benefits:
    - Tagged assets can be quickly located for recovery to the host fire engine or for redeployment elsewhere at the incident site.
    - Potential theft (of expensive and life-saving equipment) can be intercepted.

[1] Some of the advantages mentioned are paraphrased from an e-mail conversation conducted in February 2009 with Mr. Stuart Benjamin, Director at Accordus UK Ltd. (Henfield, United Kingdom).

Possible Threats:

- Initially a high financial investment.
- Implementation resistance: Firefighters are known to distrust new technology.
- Huge cultural change is needed when business processes are changed in traditional professions.

1.3 Research question

The main research question for this research is:

> *Will an RFID asset tracking & management system be a technically viable solution and financially sound investment for mitigating the main research problem?*

Two sub-questions have been formulated to help answering the main research question. The following two sub-questions will be answered at the end of the research in order to provide an answer to the main research question.

- Is the use of RFID technology technically possible and logical for asset tracking and management of fire department equipment and tools?
- Are the increase of public safety and the decrease of asset management costs worth the investment in an asset management RFID system for the Fire Department?

1.4 Theoretical background

The use of any form of RFID technology by the fire department is not a common thing, at least not in the Netherlands. In this section of the thesis I will give a short overview of the information found on the use of RFID technology by fire departments around the world. After that I will analyze and discuss the information found on the use of RFID technology for asset management followed by information on the "Smart Box" concept. At the end I will look in to the research done on public safety costs quantification which will be used for the cost-benefit analysis in the investment consideration process, but first I will provide some information on the approach used for gathering all the information.

Note: Some of the sentences or fragments used in the article summaries are (partially) quoted from the original article.

1.4.1 Literature Search Approach

The information used in this literature review is gathered through various channels. The information search started with contacting possible people that may have information on RFID developments within the organization itself and searching the digital information network of the organization for RFID related information. Unfortunately this step did not deliver much information as the RFID technology is a fairly unknown technology for fire departments in general. The second information source approached also failed for the same reason as the first source, the Erasmus University's library catalogue was used for searching for information on fire fighting in combination with RFID. The third approach was more successful, this was when I started searching for information directly related to my research with the "Google Scholar"

(http://scholar.google.com/) and "Scirus Scientific Research Tool" (http://www.scirus.com/) search engines. These search engines were found through the Erasmus University's library databank. Finally after finding some relevant and usable information the choice was made to contact a few people or organizations involved with the research papers found for when needed more detailed information.
The reason for starting to look for information close to home (VRR) and then working my way out is because I think that if the information is already available within the organization the more specific it will be for the problem. But due to the newness of the technologies being used in the envisioned solution for the main problem of the research, general sources on the World Wide Web had to be used.
The most used keywords when searching were a combination of the following words: RFID, fire, department, firefighter, fireman, asset, inventory, tools, smart, box, toolbox, equipment, gear, management and tracking. For the quantification of public safety: marginal cost saved life, cost of death prevention, monetary value of life, social cost–benefit analysis, human capital, willingness to pay (WTP) and economic value of life.

1.4.2 RFID & The Fire Department

The information I found on RFID technology being used by fire departments around the world extends from a laundry information registering system in Germany to a patient tracking system for mass casualty incidents in the United States of America. The findings will be split up into three groups and listed below. The first group of findings contain RFID implementations that are less relevant to the research and therefore will not be discussed in detail. The second group of items found are either directly relevant for the research and the third are spin-off implementations that can be incorporated in the ultimate implementation, the second and the third group will therefore be thoroughly analyzed in this segment.

A. Less relevant to the research

A1. Patient Tracking System, The Seattle and Anaheim Fire Department (USA) and Kasuga-Ohnojo Nakagawa Fire department (Japan)

A2. RFID communication systems (Australia and USA)

B. Highly relevant to the research

B1. Monitor equipment and supplies (2009), The Anaheim Fire Department (USA)

B2. Equipment detection (Florida and California, USA)

C. Possible spin-offs

C1. Protective gear laundry system, The Krefeld Fire Department (Germany)

C2. Real-Time Firefighter Movement Tracking System, The Anaheim, Chicago Fire Department and the NIST Maryland (USA)

A. Less relevant to the research

A1. Patient Tracking System

INTERMEC TECHNOLOGIES CORPORATION (2007) a technology solutions provider published a case study of a mass casualty drill done by the Seattle Fire Department to demonstrate their patient tracking system. This system is to be used track patients at mass casualty incidents. The innovation in this case study is that instead of using regular triage paper tags on which the first responders' triage officer (firefighters, medics) will write the patient's triage number with pens and markers, they now attach an RFID tag to the patient. The advantage that this brings is that the patient can be tracked from

the moment he/she leaves the scene onto the arrival at the area hospital. This means that the location and the gathered information of a patient are at all times available and a lot of time is saved because there's a lot less manual labor necessary in order to do this. When the patient arrives at the hospital he/she can be treated directly without contact from the medics with the first responders at the incident scene.

- Other than the confirmation that it is possible to use RFID technology in crisis environments, which is a positive note for the research, this case study is not that relevant to the research.

INOUE, SONODA & YASUURA (2006) conducted experiments with a triage system using RFID where the triage tags were used to classify and transport the injured effectively and secondly to obtain and publish state and scale of the mass emergency incident. By embedding an RFID tag onto a triage tag the following advantages were made in comparison to the regular paper triage tags: Unique numbers for all patients, storage for communication data if no wireless communication is available and fast information retrieval of the injured person when needed for treatment. From the experiments, the RFID triage system proved to be effective in mass casualty incidents of about 100 injured people.

- One thing that I was curious about was if this system will also be effective in minor casualty incidents due to for example the limitation of information storage space. When the crisis level is not that high more information can be communicated with the regular communication devices and the medics can be more effective when treating the injured. The patients-to-medics ratio limit for effective usage of an RFID triage system should still be researched in order to make the decision on implementing such a system.
  As the previous article, this article isn't that relevant to the research.

A2. RFID communication systems

TELEPATHX (2006), an Australian based developer of intelligent reactive (WSN) wireless sensing network infrastructure technology, has an article of an RFID based fire alert system, on an RFID weblog website. In this article they promote their RFID based fire alert system, Firesight. The RFID component of this system provides the communication to the base station and this system alerts the fire department of a fire and its location.

- Although this article doesn't directly contribute to the essence of the research, I do take two things from the article that I can use for the research. The first piece information is that RFID-tags are able to endure and function in high temperature conditions. The second thing is a positive note for the RFID implementation I am researching which is derived from the fact that even though firefighters generally are very resistant to new technology, some fire departments are using this alert system.

JORGENSEN & SCHIPPER (2008) have performed a research on a NASA owned RFID system that establishes information lifelines between firefighters in a burning building and a fire chief at a control station near but outside the building. This system would enable identification of trails that firefighters and others that could follow to escape from the building. By dropping RFID sensor tags in a burning building, the tags would serve as waypoint marks that would be picked up by the RFID readers carried by the firefighters. These signals can be used by the firefighters themselves to help them find their way out and by the fire chief outside to plan the escape routes.

- No additional conclusions that are relevant to the research could be drawn from this article other than two previously made ones, which are:

1. The ability to endure high temperatures and function properly in these types of conditions.
2. The fact that firefighters have participated in this research, which shows that fire departments might consider implementing new technology even though they're generally resistant to new technology.

B. Highly relevant to the research

B1. Monitor equipment and supplies

BACHELDOR (2008) recently published an informational article on a multipronged RFID system which is currently in the planning phase and is being developed by the Anaheim Fire Department alongside an RFID solutions development company called Verdasee Solutions. The article states that the RFID technology will help the California organization monitor the location and status of not only firefighters, equipment and supplies but also disaster victims.

Not all three areas of RFID implementations in this article are completely relevant to the research. Disaster victims' location and status monitoring RFID systems have been discussed in section A and firefighter location tracking will be discussed in section C.

The additional information this article provides on the triage tag system is more detailed information on the amount of fire stations taking part is this implementation, the exact type of tags and readers being used, the solutions partner and equipment supplier.

The information given on the real-time firefighter tracking solution contained information on the type of tags and readers that will be used and that they are hoping to deploy this the following year. The interesting information this article provides on firefighter tracking solution that others have not is that fireproof Wi-Fi nodes (size of a child's lunchbox) will be placed in the burning building and used for data transmission between the firefighting officials' computer and the handheld readers firemen carry when searching for their tag-wearing colleagues.

The RFID implementation we are really interested in, in this article, is the equipment and supplies location and status monitoring RFID system which is scheduled for 2009. This element will not only be used for location tracking, status monitoring, keeping service dates and maintenance schedules but also for the automatic weekly restocking of the equipment and supplies warehouse.

- The article unfortunately doesn't really go into detail for this element of the system, but it does provide the reassurance that the problem for which we are performing this research is a known one and we are not the only ones thinking that RFID technology might be an answer to this problem.

B2. Equipment detection

NAMM & CAIN (2005) have filed a patent for a method and apparatus for locating a fire hose by integrating one or more RFID tags into it. By wearing a portable tag reader (interrogator) a firefighter is able to find the closest fire hose in a building in an emergency situation. By applying the RFID tags to firefighters' own fire hoses, the firefighters are able to use the RFID signals to find an exit in a burning building when their vision is impaired.

This patent application publication provides detailed information on how and where to integrate RFID tags into fire hoses and what apparatus should be used to read them. The method for applying RFID tags onto fire hoses comes down to using the several inner layers of coating a fire hose has to attach the tags. To be more precise a fire hose is built from a sealed inner layer (rubber) with one or more outer

layers of woven material (woven polyester) and the RFID tags are preferably laid between the outer woven layers.

- The reason for including this paper into the highly relevant section is because this exact issue with tagging fire hoses was one of the contra issues that were discussed in the conversation/interview I had with the head of the IT department of the VRR upon deciding to research the asset management and tracking problem. Therefore this patent application publication provides is a total solution for one of the issues I encountered when discussing the possible RFID solution. This patent application publication also serves as an eye-opener for other RFID tagging issues I may encounter during this research; it broadens your possible solutions for tagging issues.

NICHOLSON & MONAHAN (2001) have invented and filled a patent for a high temperature RFID tag to reduce or eliminate the disadvantages and shortcomings the prior RFID tags had when exposed to extreme heat. The "survival temperature", the temperature at which a tag can be exposed to without affecting its performance upon returning to an operating temperature, of the tag ranges approximately from -40^{o} C. up to 300^{o} C. while the "operating temperature", the temperature at which a tag can perform its intended functions, is approximately between -18^{o} C. and 135^{o} C. The innovation for this RFID tag is its housing, the housing consists of a base and a top which form a chamber the tag. The materials used for the housing are thermally resistant and include an integrated circuit.

- The main reason I included this patent application publication in this section of the literature review is because the solution I will be researching includes tagging firefighters' equipment, therefore the ability of an RFID tag to endure and perform in extreme hot conditions is a must.
  Although the maximum "survival temperature", of 300^{o} C. for this RFID tag, is not enough to withstand direct fire but it at least proves that thermal resistant RFID tags do exist and the way of integrating the tag onto the equipment makes sure that the maximum resistance temperature of the tag will match the equipments'.

C. Possible spin-offs

C1. Protective gear laundry system

BROOKS AUTOMATIONS (2008) have published a case study of their RFID solution for improving tracking and managing of the firefighters' protective clothing. This solution was created for the Krefeld Fire Department in Germany; their goal was to ensure all of the garments were in good working order and to determine if any replacement materials were needed.

The core of the problem is that regular washing and disinfecting of the clothing is crucially needed and required by law, but on the other hand; with each laundry/disinfecting action the gear sustains a certain degree of damage. Therefore each item can withstand a certain number of cleaning treatments before it must be discarded and replaced.

The solution Brooks automations had created was to insert an RFID tag into each fire resistant garment which is designed specifically for the laundry application that registers every treatment the protective gear receives. Because of the unique identification number each garment has makes it nearly impossible to confuse of lose laundry items. With this solution the Krefeld Fire Department first increases safety and secondly manages and maintains the necessary replacement of materials and the associated costs such as manual inventory checks, non-automated administrative tasks, etc, etc.

- This article is placed under "possible spin-offs" because it is a really interesting addition to the already envisioned solution to the main problem of the research. In the possible solution every piece

of equipment or gear is being tagged anyways and if the Rotterdam Fire Department does not already have a solution for the problem being mentioned in this case study, the Brooks Automations' solution could as well be implemented in Rotterdam at a later stage.

C2. Real-Time Firefighter Movement Tracking System

SWEDBERG (2006) wrote an article for the 'RFID Journal' website to inform the readers on the experiments being done with the RFID location pinpointing system for firefighters inside of burning buildings by the Chicago Fire Department. This system was called to life as a response to the shortcomings the two-way radios that are currently used by firefighters, they require firefighters to themselves provide status reports on their locations. Researchers At the University of California., Berkeley, together with an organization named CITRIS have developed a system that provides firefighters and command chiefs details about rescue workers' positions inside a building called 'Fire Information and Rescue Equipment' (FIRE). This system consists of two elements. The first being a wireless network with sensors that register and report changes in the environment to firefighters which can be installed in smoke detectors and door jams in commercial buildings. The second element in this system is the tags attached to the air tanks worn by firefighters who are read by the sensors to send out information on a firefighters' location when inside a building. Knowing the location of the firefighters helps commanders make tactical decisions, such as when to have firefighters evacuate. When this system will be implemented is still unknown, in the meantime they will continue to test the technology to obtain proof the FIRE system works effectively.

- The reason why this article has incorporated in this section is because I really believe in the ability of this tracking solution creating a safer work environment for firefighters. The best part of this system is the fact that after the solution for the main problem I am researching has been implemented, the adoption of the 'FIRE' system would be relatively less costly. The only element needed for the system to work will be the sensors installed inside the commercial buildings, because every piece of equipment worn and carried by firefighters will be supplied with an RFID tag which makes it a great addition for the future.

1.4.3 RFID for Asset Tracking & Management

A. Asset Tracking & Management system for construction tools

GOODRUM, McLAREN & DURFEE (2005) have done a research on possible RFID systems for the development of a tool tracking prototype for the construction industry and in this paper they present the results. The reason for this research is that tool availability is a critical factor in the productivity of construction crews and the way construction companies are solving this problem is by overstocking construction jobsites with the required hand tools. By developing a tool tracking and inventory system which is also capable of storing operation and maintenance data they're trying to make a big step in improving efficiency at construction jobsites.

The RFID solution presented in this research paper is the use of a large stationed toolbox equipped with tag-readers for picking up the RFID signals the tools, which have active RFID-tags incorporated into them, are transmitting. The reason for using stationed readers is because these readers have more reading range then hand-held readers. The tagging of the tools is done within the tools themselves, therefore the tags are protected by the tool casing and the way the tools are operated won't have to be altered. The usage of active tags instead of passive ones is because they can be read from further away due to the fact that they send out the signals themselves and active tags are more capable of transmitting

RFID signals in environments with a lot of metal objects and low temperatures. Although the use of active tags have the disadvantage of having to replace their batteries after time, the tags used have batteries with a lifespan of 5 years which is equal to the lifespan of the tools themselves and therefore not relevant in this RFID solution.
The implementation limitations for this research were:

A. The economics (the active tags used cost a lot)
B. The lack of technology standardization (Due to not having an RFID standard for this field, there are only a few manufacturers which means they can determine the market prices themselves and secondly the lack of standards does not help promote tool manufacturers to incorporate the tags within the tools.)
C. The lack of directional and range data (active RFID tags do not provide directional or range data from the reader to the tag)

Although this solution has its limitations, RFID technology has significant potential to improve tool inventory and allocation on a construction jobsite.

- For the research on asset tracking and management of fire department tools this research has a lot of relevance due to the fact that a construction site has a lot in common with an emergency scene (tools scattered on a field / terrain full of obstacles, debris / dirt and people).
  Important information to take away from this research is the information on the type of RFID tags and readers and the way of tagging the tools, especially the motives behind the decisions made.
  The limitations are also relevant to keep in mind although the first limitation, the economics, is one to be discarded due to the fact that since 2005 the tag prices have gone down drastically and the special equipment used by the fire department have on average a higher cost than regular construction tools therefore the need to safeguard these assets is much higher.

SCHNEIDER (2003) wrote an article on the use of RFID technology and its applications in the commercial construction industry. Basically there is nothing new on tools and equipment management compared to the first article in this section. What makes this article worth mentioning is that in addition to the technical information that was also mentioned in the first article, the writer also includes financial data gathered from financial researches. The following financial data comes from a Tool Watch market research conducted in 1998: A contracting company with 30 employees spends annually $30,000 on tools without a tracking system and similar companies with a tool tracking system had an average of 40% less expenditures on tools.

- Apart from the same technical information on and limitations of RFID for tool tracking on construction sites as the first article in this section, this article provided some financial information in the results of an RFID tool tracking implementation. This article says that an average of 40% on tool expenditures can be saved.

B. The "Smart Box" Toolbox Concept

B1. Smart Toolbox and Smart Tool Inventory RFID solution

LAMPE & STRASSNER (2005) have written a paper to show that RFID technology has a high potential to improve moveable asset management. The reason for this is because in this and age moveable asset management is still not appropriately supported by existing IT-systems. Information on location, status and usage of individual pieces of equipment cannot be managed by the majority of asset management systems.

Figure 1: Smart Toolbox application

With the proposed RFID asset management solution proposed in this paper assets become able to manage themselves, which eliminates many manually done tasks like locating the assets, tracking their usage or inspecting for maintenance. This leads to reduced costs since less human intervention is needed, human errors are eliminated and manual data gathering is avoided.

The writer states that a good asset management systems should be able to:

- Manage assets individually,
- Allow to locate the right assets,
- Provide information about current physical status (quality) of an asset, and
- Keep an information history of an asset.

The example used in the article to demonstrate the potentials of the RFID solution is a smart toolbox and a smart tool inventory application for an aircraft maintenance company.

Toolbox example

Each mechanic is assigned a specific toolbox for which they are personally liable for the tools, damages caused by the tools and tools lost are to be billed to the responsible mechanic. Therefore intensive manual checking is needed. For this reason they are equipped with a Smart Toolbox that is constantly checking if its tools are placed back into to the toolbox and it also reports the placement of tools that do not belong to the toolbox. For the Smart Toolbox to work; RFID tags are attached to all tools and the boxes are equipped with readers and antennas. In addition to monitoring its content, the Smart Toolbox also registers the user of the toolbox by reading the mechanics' tagged badge, and registers the usage of the tools by the timing the absence of the tools. Challenges that a real world implementation of this Smart Toolbox faces are: (a) Most tools are made out of metal, which require specialized RFID hardware (e.g. low frequency systems or ferrite core tags); (b) The toolbox itself is made out of metal, solved by placing antennas in each drawer; (c) Some of the tools have small size, which makes it more challenging to attach the tags.

The Smart Tool Inventory example

The implementation consists of an RFID client application that handles the identification of the tools and mechanics (users) and manages the checkout and return process. No explicit user interaction

with the system is needed by the service operator since the status of the toolboxes trigger all processes. This system faces the following challenges: (a) most tools are made out of metal, which is solved by using specialized RFID hardware; (b) RFID tags need to be attached to the tools.
As for both the Smart Toolbox and the Smart Toolbox Application solution: The tagging of the tools should be done during the manufacturing process of the tools.

- This paper is really helpful when it comes to the RFID asset management solution I have in mind for the main problem of the research. The issues the mechanics face in the example are in many ways similar to the same issues the firemen face with their tools at an emergency scene. Therefore I intend to create a Smart Fire Truck as a solution for the main problem.
  The Smart Toolbox and inventory application solution and its challenges will be taken into consideration for the solution for the fire department.

B2. Smart Box Application Model

LAMPE & FLÖRKEMEIER (2004) have created a model and framework to facilitate the implementation of Smart Box applications. This paper proposes the usage of a software framework for the development of applications or appliances, based on the "Smart Box" application model. This class of computing applications can be described as automatic content monitoring applications using Auto-ID technologies such as RFID. The Smart Box application model is based on the concepts of location and object to represent a kind of a box and the items and persons that are related to the box. The framework uses RFID technology to bridge the physical and virtual world and sense the contents of a box.
The following applications, demonstrators and application ideas, were analyzed to better understand the Smart Box application domain:

- Magic Wardrobe: Knows about clothes placed inside and suggest clothes that fit together the best based on entries in the personal calendar (e.g. business meetings).
- Smart Shelf: Products on a shelf are monitored to enhance replenishment and identify misplaced products.
- Smart Surgical Kit: The usage of bandages and swabs during a surgical operation is monitored and the usage status is displayed to avoid leaving any operation tools in the patient.
- Smart Fridge: Keeps track of its content, suggests recipes based on content and warns if goods reach expiry date or contain any allergic ingredient.
- Smart Toolbox: Monitors the tools in a toolbox and the mechanic. Displays the content of the toolbox and tool usages and warns if tools are missing or placed in the wrong toolbox.

The application settings for these Smart Box applications are clearly defined. All objects are either in some kind of a box or are outside the box. If they are inside, they are detected by the system and actions associated with certain system states are triggered. If they are outside, they are not detected and some assumptions are made. It is obvious that the absence of items can also trigger actions. Every action is predefined and these are triggered by the different states the box is in when the Box compares its current contents or sensor readings. The states of the boxes are determined by the completeness and correctness of the items that are supposed to be in the box or physical property of an item such as if the usage level of a tool is in the accepted usage range.
The developed Smart Box Software framework core consists of the following major components:

- The Auto-ID and sensor infrastructure makes the connection to the real world and automatically senses physical properties and identifies persons and things at certain locations.

- The transformation and interpretation component that interprets, transforms and corrects the data from the Auto-ID infrastructure according to deterministic or probabilistic rules in order to reduce errors and uncertainties. It also maps the resulting data into the model.
- The model itself.
- The application logic provides the model with the conditions and states the application is interested in. The application is notified by the model about state changes and triggers the preferred action.

The adequateness of the framework was demonstrated by implementing the applications of a "smart" medicine shelf. However to find the right balance between a too simple or complex model, more Smart Box applications have to be implemented using the proposed model.

- The information this paper provides will be, as the information provided in the previous paper, very helpful for the process of creating a possible RFID Smart Box solution for our main problem. For our research problem we will especially be looking at the last mentioned implementation in the list of examples, the Smart Toolbox, as this one is the most similar to the potential solution for our research problem. Also it is really good to have seen the other examples; they are quite helpful for broadening the ideas for the potential solution of the research problem.

  Other than the possibilities seen in this paper, the proposed Smart Box application framework elaborated in this paper is definitely going to be used for the process and software redesign. The framework seem logically built, therefore they will definitely be used.

1.4.4 Quantification of Public safety

In the attempt of finding a way to be able to quantify the public safety benefit that RFID solution might bring, several possible theories were found. The most used approaches for allocating monetary value human lives found were the human capital (HK) and the willingness to pay (WTP) theory. Because of each theory having its own fair share of criticism I have chosen to discuss a theory which combines the two and there for be a more middle of the road solution that incorporates the essence of both theories.

Economic Value of Life

LANDEFELD AND SESKIN (1982) have written a paper on linking the theory of the economic value of life to practice.

In the past the human capital (HK) estimates have been routinely used for calculating the economic value of life in order to perform cost-benefit analysis of health programs. Recently economists have been saying that the economic value of life to be used in cost-benefit analysis is better calculated individually based on the willingness to pay (WTP) for small changes in their probability of survival. After reviewing the major approaches to valuing risks to life, this paper concludes that the HK and the WTP theory are best to be combined for achieving a clear, consistent and objective value for use in cost-benefit analyses of policies affecting risks to life.

In the standard HK approach it is assumed that the value to society of an individual's life is measured by future production potential, usually calculated as the present discounted value of expected labour earnings. The net loss to society is the difference between earnings and maintenance (consumption) expenditures. Even though it might seem pretty logical, the standard HK approach has some flaws like estimations of zero value for persons without labour income such as retired individuals with only

investment or pension income. The standard HK approach also ignores issues like aversion to risk or loss of leisure which itself has value for the individual and perhaps for others as well. Despite the conceptual problems associated with the HK approach, the technique is still widely used mostly because the necessary data are not difficult to obtain and after all it does project numerical estimates on life expectancy, labour force participation and projected earnings.

Because of inadequacies associated with the HK approach, some economists say that the same valuation of loss of life in safety decisions should be used for valuing life in cost-benefit analysis. The relevant question for calculating this value is; What are individuals "willing to pay" (or accept as compensation) for a change that will affect loss of life? The issue is not the value of an identified individual's life; rather, it is the value of a reduction in the probability of death for a given population. In other words, it is the aggregate value a population at risk places on programs that save "statistical" lives or the sum of the amounts individuals are willing to pay ex-ante to "buy" small reductions in the probability of their death. A survey approach is used to retrieve the value of life in the WTP method but what researchers have found is that people are willing to pay different amounts for the reduction of risks depending on the type of risk. The estimated value for a saved life rises drastically when the risk is having a heart attack, dying from cancer or when concerning safety in airline travel. Another problem with this method is that people act differently when asked how much they are willing to pay and when asking them to actually pay that amount of money.

The proposed solution for this research is an adjusted WTP/HK approach which embodies characteristics of both the standard HK method and the revealed-preference WTP method. As with the standard HK approach, it includes only economic losses associated with death which means, the resulting estimates can be considered a lower bound for the value per statistical life. As with the revealed-preference WTP method, it is based on WTP for small changes in risk of death from the perspective of the individual rather than from that of society. The adjusted WTP/HK approach resolves some of the problems associated with the other two procedures. For example, because of the link with WTP, the adjusted estimates provide the welfare basis missing from the standard HK approach. At the same time, the choice of an appropriate discount rate to apply to future forgone income is made easier since the adjusted estimates are based on an individual rate of return rather than the more uncertain social rate of return. Finally, while the adjusted method does not include all the intangible factors that, in theory, would be included in revealed-preference WTP estimates it does provide policymakers with a consistent, objective, and understandable procedure for placing an economic value on HK assets (lives) if one is willing to treat them equally with financial assets.
The value of life estimations for the adjusted WTP/HK method can vary per individual depending on the age and gender group the person is in. For example, for males aged 40 to 44, the adjusted WTP/HK estimate is approximately $660,193, almost four times as great as the standard HK estimate.

- Even though the allocation of monetary value to human lives is considered morally incorrect and is never openly discussed I will have to incorporate the value of the possible extra saved lives in the cost-benefit analysis to properly evaluate the RFID solution I am researching.
  The main reason why I have chosen to include this paper in the literature review is because the researchers that have written this article have created an approach for calculating the monetary value of life that is derived from the two most used approaches I came across during my search for life valuation method. Another reason for choosing this method is because the theory behind

it and the mathematical application of the adjusted WTP/HK are thoroughly and clearly explained in the article.

The value for a saved life that will be applied in the cost-benefit analysis of the research will be an average value drawn up from a table with the calculated values displayed by gender and age category. The theory behind the adjusted WTP/HK method was clearly and well structured presented in the article and therefore I found to be adequate enough to be applied in this manner.

The reason why the valuation of saved lives will not be dealt with more care is because first of all, it is not part of the core research. Secondly, you know beforehand that whichever valuation technique you choose to use, you will always have some people that will disagree with the approach and it will take a complete new research to maybe give a better funded monetary value to a human life.

1.5 Methodology

In order to be able to do the research on RFID technology for the fire department I had to start by performing a literature review to gain information on what has been said about and done with this technology in combination with this field of work. Because of the newness and therefore lack of information that is documented on this specific research topic a broader field en desk research will be needed.

To gain more knowledge on RFID technology in general, the internet will be a good enough source of information because I've previously performed a research on a supply chain management RFID solution for a food retailing company. For more detailed information on RFID asset tracking and management solutions the internet and people from the field such as vendors or developers will be approached and interviewed. For detailed information on the gear and equipment, operational and administrative processes and other Fire Department issues, interviews and questionnaires are to be used on fire department personnel.

Methods:

- ***Analysis, Synthesis & Conceptual Model***

  The information gathered by applying this method will serve as the groundwork for performing the questionnaires and interviews and the research as a whole.

  Analysis: The main research problem is to be analyzed to present it in a simplistic and clear way. The information needed will be gathered by field and desk research. The terminologies used within the main research fields, fire fighting and RFID technology, will be clarified for future use after the main reasons for performing the research are clear. The outcome of this analysis method will be a main research question which is formed by simpler sub-questions and clear and usable terminologies.

  Synthesis: A shared understanding is created from the diverse information sources used for gathering information on a fairly new and un-researched use of the RFID technology.

  Conceptual Model: This is a model that will be built to give a schematic overview of the exact acts / processes and relations where the main problems take place when being carried out by the fire department.

- ***Literature Review***
  A literature review will be performed to get more information on asset tracking and management RFID implementations for the fire department.
  Because of the newness of this technology plus the specific field for which we want to use it, more general topics will have to be researched. The broader scientific literature topics to be reviewed are: RFID asset tracking and management, Tool tracking (construction industry), RFID implementations for the fire department in general and fire department equipment and/or gear tracking and management without the use of RFID technology.
  The sources to be used for gaining information on these topics are: the university library, internet (scientific) search engines, scientific papers publishers and personal contact with researchers and vendors found on the internet.

- ***Questionnaires***
  A questionnaire will be used for gathering information from several groups of people within the operational side of the fire department. This quantitative questionnaire will be for gathering information on the risks and impact of the loss of equipment and therefore not being properly equipped for some incidents. These questionnaires will be handed to approximately 27 fire marshals from 9 different fire stations. District leaders and ex-firefighters will also be approached to fill out the questionnaire.

- ***Quantitative Methods (Statistics)***
  Skills acquired during the course "Methods and Techniques, FEW7360" will be used for setting up the questionnaire that will be used for the quantitative research on the risks and impacts of losing equipment at emergency scenes and not being properly equipped when they roll out to an emergency scene. After the questionnaires have been filled, these skills are used to actually interpret, analyze and present the results properly.

- ***Interviews***
  Open interviews will be conducted for gathering information from several groups of people on different topics such as:
  - General information on fire department's assets - Front and back office personnel;
  - The asset tracking and management process - Front and back office personnel;
  - RFID implementations for asset tracking and management - Vendors and Researchers;
  - The consideration of preventive investments - Prevention department personnel;
  - Equipment loss at the scene and its impact - Incident analysis team and District Commander.

- ***Economical/Investment analysis***
  The economics accompanying the RFID solution will also have to be calculated, analyzed and presented in the proper way in order to able to give good and structured advice on the investment. Calculations such as cost-benefit and return on investments (ROI) calculations of the RFID implementation will be performed. The skills needed for this were acquired from the several economics courses.

- ***Process analysis and documentation***
  Process analysis diagrams like activity diagrams and dataflow diagrams will be used for modeling the present asset management processes and for remodeling these processes when the RFID solution is

implemented. The process analysis skills have been acquired from the third year course "Business Process Modeling, FEW0473".

- ***Software architectures***
  Knowledge obtained from courses like "Advanced Software Architectures, FEB33008" and the several programming courses, from the bachelor phase of the Informatics & Economics study at the University, will be used to for analyzing the current applications and for estimating the adaptations needed when implementing the RFID solution.
  The current applications are to be analyzed in order to give a proper indication of the technical adaptations needed to make the RFID solution work on the current systems. A rough estimation of the analysis and implementation costs accompanying the application changes will also be calculated and presented in the financial section of the research.

1.6 Research Setup

An overview of the items that will be elaborated in this thesis will be given in this section.

Research introduction:
To start-up the research I will start by giving some general information on the RFID technology, the "Smart Box" concept and in what ways it is or has been used by the fire department in general. In the second introductory chapter, I will give some general information on the "Veiligheidsregio Rotterdam-Rijnmond" organization, its relationship to the Rotterdam Fire Department and zoom into the Rotterdam Fire Department organization.

Research core:
The core of the research will start by presenting all basic information on the fire departments' assets and depending on the type of equipment and its dimensions or material, the things to take into account when applying RFID tags or receivers will be listed per item. Information on the way that these assets are currently being managed is also given. The reason why this is done at the beginning of the research is to get acquainted early enough with the subject terminology and in this way make it easier to be able to discuss the problem and possible solutions.
After the assets and terms being dealt with in this research have been clarified we will look into how they are utilized and managed. All processes on which the RFID solution might have a direct impact on will be schematically modeled to identify and better understand the bottlenecks in the daily operations and the asset management processes. The risks involved with these processes will be indentified, analyzed and valued. This way their impact will also be made tangible.
The fifth chapter of the research will be used to present several possible RFID solutions for the problems encountered in the previous chapter. The proposed solutions will be researched and evaluated to make it possible to choose the best alternative that will be depicted in detail in the following chapter. The advised implementation will be presented in detail in this chapter, including the hardware, software and business process alterations.
The financial calculations for the chosen RFID implementation described in the fifth chapter will be presented in the sixth chapter. The monetary quantification of the total investment and its benefits will be

analyzed by performing some standard investment analysis computations to be able to give proper advice on whether to invest in this RFID technology solution or not.

Research conclusion:

At the end of the research we will provide the answers to the main research questions, give our advice on the implementation of the proposed RFID asset management & tracking solution, followed by the general research conclusion and future research recommendations.

2 Radio Frequency Identification

This chapter provides some general information on the Radio Frequency Identification (RFID) technology for two main reasons. One is to educate the reader that is not familiar with the technology sufficiently enough to be able to understand the research. The second reason is to create a shared understanding when certain terminologies are used.

2.1 RFID Basic Information

"Radio frequency identification, or RFID, is a generic term for technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a serial number that identifies a person or object, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers that can make use of it" Radio-frequency identification (RFID Journal 2008).

RFID History

Léon Theremin invented in 1946 a tool to transmit radio waves with audio information. This was a passive form of RFID. A similar technology was invented in 1939. The British discovered an IFF (Identification Friend or Foe) transponder, which was used by the allies in World War II to identify airplanes. Transponders are still used by military and aircraft to this day. Another early discovery of RFID is the landmark in 1948 by Harry Stockman, called "Communication by Means of Reflected Power".

The patent of modern RFID is on the name of Mario Cardullo: a passive radio transponder with memory. It was demonstrated in 1971 to the New York Port Authority and other potential users. It uses a transponder with 16 bit memory. Since 1990 has RFID technology been used for numerous purposes such as for transportation (automotive vehicle identification, automatic toll system, electronic license plate, electronic manifest, vehicle routing, vehicle performance monitoring), banking (electronic check book, electronic credit card), security (personnel identification, automatic gates, surveillance) and medical (identification, patient history). The following figure gives an overview of the evolution of RFID technology.

The Decades of RFID

Decade	Event
1940–1950	Radar refined and used, major World War II development effort. RFID invented in 1948.
1950–1960	Early explorations of RFID technology, laboratory experiments.
1960–1970	Development of the theory of RFID. Start of applications field trials.
1970–1980	Explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980–1990	Commercial applications of RFID enter mainstream.
1990–2000	Emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.
2000–	RFID explosion continues

Figure 2: The RFID evolution (Landt 2005)

RFID Components

An RFID system consists of three major components which are the RFID tag, the reader and the middleware. The information in this section has been cited and/or paraphrased from the article: *What Every Internal Auditor Should Know About RFID*, Knowledgeleader, June 2006.

Tags

Tags are the heart of an RFID system, because they store the information that describes the object being tracked. Specific object information is stored in the memory of tags and is accessed via the radio signal of RFID readers.

Data is transferred between a tag and a reader via low-power radio waves, which are tuned to the same frequency. To obtain information from a tag, a transceiver must send a signal to the RFID tag, causing the tag to transmit its information to the transceiver. The transceiver then reads the signal, converts it to a digital format, and transmits it to a designated application such as an inventory management system.

Figure 3: Two different forms of an RFID Tag

Tags may be active or passive and read-only, write-once, or read-write. Below is a description of each:

- ***Active tags*** have a battery, which runs the microchip's circuitry and enables the tags to send a stronger signal to the reader, and have a read range of approximately 30 meters.
- ***Passive tags*** have no battery. Instead, they draw power from a reader, which sends electromagnetic waves that induce a current in the tag's antenna and powers the microchip's circuits. The chip then modulates the waves the tag sends back to the reader. Passive tags have a read range of approximately 9 meters.
- ***Read-only tags*** contain data, such as a serialized tracking numbers, which are pre-written onto them by the tag manufacturer or distributor. Read-only tags are generally the least expensive, because they cannot have any additional information included as they move throughout the supply chain. Any updates to that information have to be maintained in the application software that tracks the stock unit's movement and activity.
- ***Write-once tags*** enable a user to write data to the tag one time during production or distribution. This information can be a serial number or other data, such as a lot or batch number.
- ***Full read-write tags*** allow new data to be written to the tag as needed and written over the original data.

Readers and Antennas

RFID readers are devices that convert radio waves from RFID tags into a form that can be passed to middleware software. An RFID tag reader uses antennas to communicate with the RFID chip. Reader requirements vary depending on the type of task and application, and almost all applications will require multiple forms of readers to make a successful system.

There are a variety of different reading systems and technologies. These include:

- ***Handheld readers*** that act like a handheld bar code scanner.
- ***RFID readers*** embedded into mobile data collection devices.
- ***Fixed readers***, which are mounted to read tags automatically as items pass by or near them.

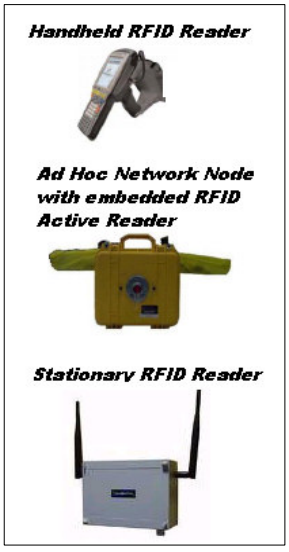

Figure 4: RFID Readers

Middleware

Both middleware and software applications are required in an RFID environment. A major issue for companies seeking to implement an RFID solution is the lack of sufficient middleware to link RFID systems and enterprise applications. Middleware software or applications are needed to manage the flow of data from readers and send the data to back-end management systems.

RFID middleware assist with the following:

- Retrieving data from readers.
- Filtering data feeds to application software.
- Generating inventory movement notifications.
- Monitoring tag and reader network performance.
- Capturing history.

Analyzing tag-read events for application tuning and optimization.

2.2 RFID use

RFID systems can be used anywhere that a unique identification system is needed, from clothing tags to pet tags to food.

General

Here are a few examples of common usage of RFID technology:

- ***Hospitals***

  RFID systems are being used in some hospitals to track a patient's location, and to provide real-time tracking of the location of doctors and nurses in the hospital. In addition, the system can be used to track the whereabouts of expensive and critical equipment, and even to control access to drugs, pediatrics, and other areas of the hospital that are considered "restricted access" areas.

- ***Businesses***
  Businesses use (credit-card shaped) RFID tags for granting access to buildings, specific areas and applications.
- ***Retailers***
  Retailers attach anti-theft hard plastic tags to their merchandise for theft detection in their stores and for real-time inventory monitoring and tracking.
- ***Container Ports***
  Container Ports use heavy-duty transponders to track shipping containers.
- ***Veterinarians***
  Veterinarians use (rice-sized) animal tracking RFID tags to identify and track animals. These tags are inserted beneath the skin. These tags can contain information on the animals and their owners.
- ***Pharmaceutical companies***
  Pharmaceutical companies have embedded RFID chips in drug containers to track and avert the theft of highly controlled drugs.
- ***Airlines***
  Airlines use RFID tags to track passenger bags in order to reduce the number of lost bags and make it easier to route bags if customers change their flight plans.

Fire Department

The information I have found on RFID technology being used by fire departments around the world extends from a laundry information registering system to a patient tracking system for mass casualty incidents. Most of these RFID solutions have not even moved from the experimental stage to really been implemented and used. Here are a couple of examples of fire department RFID implementations:

- ***Patient Tracking System***
  This system is used to track patients at mass casualty incidents. The innovation is that instead of using regular triage paper tags on which the first responders' triage officer (firefighters, medics) will write the patient's triage number with pens and markers, they now attach an RFID tag to the patient. The advantage that this brings is that the patient can be automatically tracked from the moment he/she leaves the scene onto the arrival at the area hospital.
- ***RFID based fire alert system***
  There is an RFID based fire alert system called Firesight. The RFID component of this system provides the communication to the base station and this system alerts the fire department of a fire and its location.
- ***Protective gear laundry system***
  This systems goal is to ensure all of the garments are in good working order and to determine if any replacement materials are needed. Each fire resistant garment can withstand a certain number of cleaning treatments after that it must be discarded and replaced. The laundry application registers every treatment the protective gear receives by attaching an RFID tag to each fire resistant garment.
- ***Real-Time Firefighter Movement Tracking System***
  This system consists of two elements. The first being a wireless network with sensors that register and report changes in the environment to firefighters which can be installed in smoke detectors and door jams in commercial buildings. The second element in this system is the tags attached to the air tanks worn by firefighters who are read by the sensors to send out information on a

firefighters' location when inside a building. Knowing the location of the firefighters helps commanders make tactical decisions, such as when to have firefighters evacuate.

2.3 The "Smart" Toolbox Concept

"The Smart Toolbox automatically monitors the content of the toolbox using RFID technology, i.e. RFID tags are attached to all tools and the boxes are equipped with RFID readers and antennas. The smart toolbox checks whether the state corresponds with the desired configuration. The desired configuration of the toolbox is reached if two conditions are fulfilled: (a) The toolbox is complete, i.e. there are no empty spaces in the toolbox, and (b) if the content is correct, i.e. all the tools present in the toolbox actually belong to the toolbox. The state of the toolbox is visualized in two ways corresponding to the two conditions: (a) Missing tools are shown by empty spaces, and (b) tools that belong to a different toolbox are highlighted with a special indicator." Lampe & Flörkemeier 2004.

2.4 RFID Advantages & Disadvantages

Some general RFID advantages and disadvantages are:

Advantages

- Unique code, every single object is always and everywhere traceable;
- No physical contact needed, the reader can read the chips from a particular distance;
- Don't have to be in sight, the reader can trace chips through products;
- Hundreds of codes can be read in seconds;
- Bigger reading distances are possible (compared to barcode);
- Falsification of RFID-tags is more complex then barcode-falsification;
- Falsification is difficult because of the unique code, imitations are easily traceable because of the EPC[2] registration code;
- RFID-tags don't get unreadable very fast (barcode can, by dirt and folded barcode etc.).

Disadvantages

- Privacy and security issues can play a role;
- Read and write possibilities make it possible for fraudulent practices;
- Because of the great reach of the tags, collision is possible. This means that unintended RFID-tags can be read, which can disturb data processing;
- A lot of information systems are not prepared to process all the data. (Special middleware en edge ware will be developed for these problems.) Radio-frequency identification (Anon 2008)

[2] Electronic Product Code (EPC): Each RFID-tag has a unique and standardized identification number, managed by the EPCglobal Consortium.

2.5 Conclusion

The information presented in this chapter is to give the reader some general information about the RFID technology and more importantly the "Smart" Toolbox concept which is the core idea for this research.
The basics are:

- **What it is:** A contactless way of communication for objects by using radio waves.
- **How it works:** Transponders (tags) send out signals which are picked up by a reader which is then transformed by middleware into usable information.
- **Why it is used:** This technique is used for contactless object identification.

On completion of this chapter the reader should be able to understand the used RFID terminology and the way the technology is applied in this thesis.

3 VRR Organization Description

Now that the main technology, RFID, being researched has been explained to the reader we will continue by describing the field that this technology will be implemented in.
This chapter is used for providing some background information to help the reader better understand the terminologies used in this research documentation. In this chapter the "Safety Region Rotterdam-Rijnmond" organization and the for this research it's most important sub-organization "The Rotterdam-Rijnmond Fire Department" will be described In this chapter we will also provide the reader with general information on the fire fighting profession in general and how it is organized in the Rotterdam-Rijnmond area.
The mission and vision of the organization will be made clear in order to provide a better understanding of the organization and its sub-departments, especially the fire department.

3.1 The Safety Region Rotterdam-Rijnmond

The official name of the organization that is being used as the test subject for the RFID solution that is being researched for this thesis is the "Veiligheidsregio Rotterdam-Rijnmond", in short VRR. The English translation of the company name is "The Safety Region Rotterdam-Rijnmond".
The VRR is the parent organization of the Fire Department, the Emergency Medical Service and the Public Safety Answering Point for the Police Department for the Rotterdam-Rijnmond area in the Netherlands.

Figure 5: Official VRR logo

VRR Background
Safety regions are formed by the government to ensure that emergency services cooperate intensively and provide professional aid and protection against possible risks and threats. There are currently 25 safety regions in the Netherlands of which the VRR is one of them.
The VRR was formed after the Dutch government, by means of the Government Issue on safety regions and the bill on crisis control of 2004-2007, gave notice to the importance of setting up safety regions. The VRR was formed by 20 municipalities in the Rijnmond region in the Netherlands.
Municipalities in the Rijnmond region have already been working together for a long period of time. The set up of the VRR has only made the cooperation between the municipalities official. It means shorter communication lines, direct harmonization, clear powers and therefore an improvement of the safety assistance to the citizens. You could say: "The safety region is the beating heart of the calamities and crisis control!"

The VRR consists of four executive boards which occupy themselves with the core functions of the organization. These executive boards are the Risk and Crisis management service (SRC), the Emergency Medical Service Rotterdam-Rijnmond & the Medical Assistance Team at accidents and calamities (A&G), the Public Safety Answering Point for the Police Department (GMK) and the Regional Fire Department Rotterdam-Rijnmond (RBRR). Along with the four core organizations, the VRR narrowly cooperates with

other municipalities in the region, the Rotterdam-Rijnmond Police Department, The Port of Rotterdam Authority, Environmental Protection Agency (DCMR), the Public Prosecution Service and the Regional Water Boards. The organization chart is displayed in the figure below.

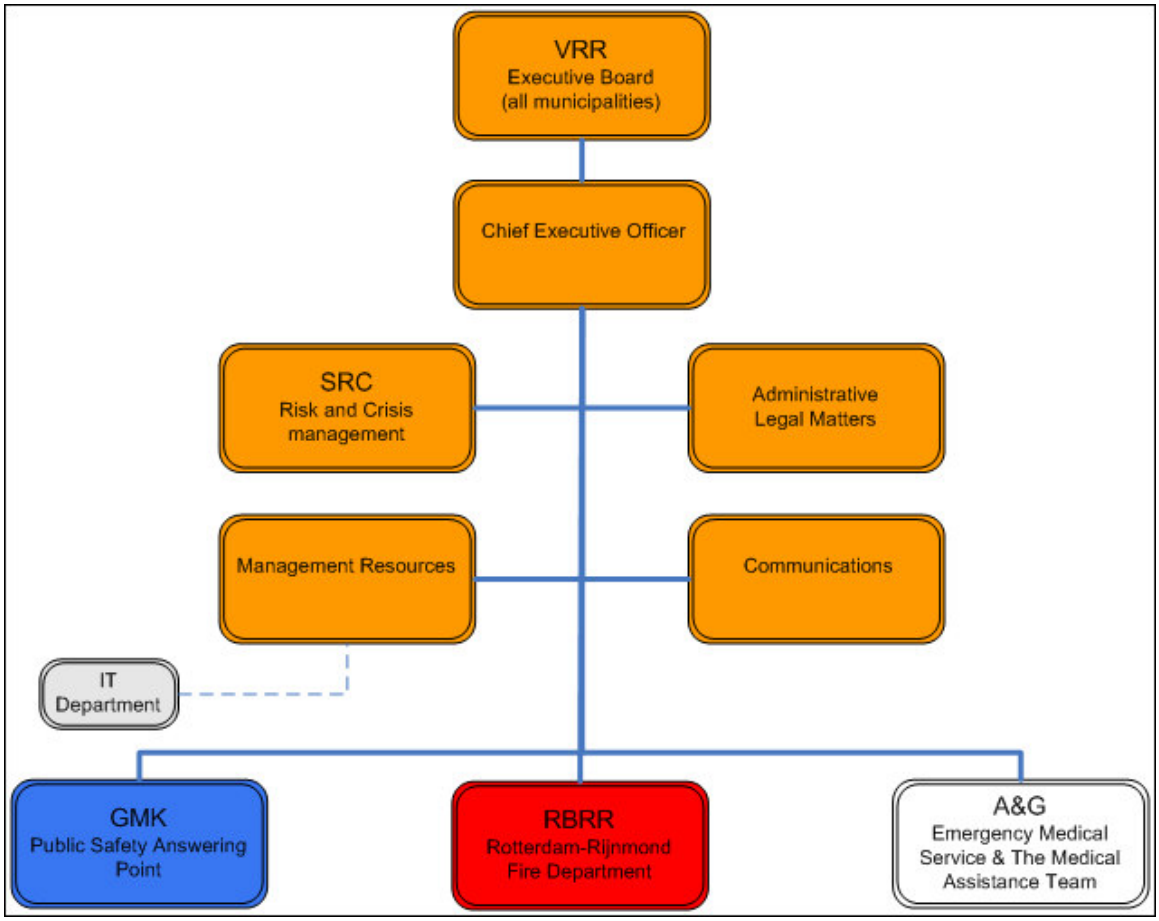

Figure 6: VRR Organization Chart

The other departments seen in the organization chart above have an aiding role to the core business departments and because of the technical nature of the research I will explicitly point out the IT department of the VRR. Together with sub-departments such as Human Relations and Finance & Control, the IT department is a sub-department of the Management Resources department which consists of a total of 6 sub-departments. The IT department is in charge of the network infrastructure, the computer hardware and the tech support for the whole organization.

At present the VRR employs approximately 2000 people of whom the Rotterdam-Rijnmond Fire Department, the Public Safety Answering Point and the Emergency Medical Service take up for almost 90% of the total number of employees. The remaining employees occupy managing and assisting roles to the different core departments of the VRR.

VRR Goal

The main task of the VRR is to connect a large number of partners in security and facilitating the cooperation within those partners with the aim of providing a safer region.

Its main goal is to provide a safer Rijnmond region with the following objectives:

- Prevent, limit and fight fire and provide fire safety;
- Saving people and animals;
- Organizing transportation of patients and victims of accidents;
- Preparing and providing suitable, organized and coordinated medical assistance at accidents and calamities.

Recent Developments VRR

In this segment we will provide information on some of the recent developments within the VRR. These 4 items have been handpicked from the VRR annual report for year 2008.

- ***Completely regionalized fire department***

  The Rotterdam-Rijnmond region reached a completely unified fire department organization in the year 2008. All thirteen municipalities have joined forces to form one regional fire department since the 3rd of April 2008.

  The joined forces will contribute to a higher public safety and lower operating costs due to centralized management, acquisitions and overhead costs.

- ***Fire Investigation Unit***

  The Police Department was the only one performing fire investigations before the VRR Fire Investigation Unit was set-up. The only purpose for performing fire investigations the police department had were to identify arson, the fire department on the other hand will not only be able to judge their performance at an incident with fire investigation, but also the effectiveness of a prevention measure.

  On average there are 13.000 fire incidents a year of which 460 are eligible for investigation. The community safety project has chosen to make fires in residential buildings and houses eligible for fire investigation.

- ***Mobile Data Terminals***

  The VRR decided at the end of 2008 to invest in mobile data terminals (MDT's) for some of their fire engines after successfully experimenting for half a year with two MDT's.

  This device uses two displays, one in the front cabin and one for the back. A lot of information is made available through this device such as: route navigation, fire hydrant locations and critical geographical & hazardous materials information for the incident surroundings.

Figure 7: CityGIS Navigator MDT

- **Flood Management Taskforce**

  At the start of 2008 the VRR formed a taskforce for managing floods called TMO. The crisis management departments, in cooperation with the water boards and the Rotterdam-Rijnmond area municipalities, have been subsidized for conducting 6 projects regarding floods management.
  This unit accesses the risks of having high water levels and designs and trains for emergency procedures. They are also in charge of informing and preparing the public for when disaster strikes.

3.2 Regional Fire Department Rotterdam-Rijnmond

Because of the fact that the RFID solution being researched for this thesis will specifically be for the Regional Fire Department Rotterdam-Rijnmond, a sub-organization of the VRR, we will start by an overview of the firefighting profession in general then followed by the Rotterdam fire department organization.

3.2.1 General Fire Department Information

Fire fighting in the Netherlands is a task of the municipality. Nearly each municipality has thus its own Fire Department (FD). One larger than the other: that depends of the scope of the municipality.
The FD is mostly known for extinguishing fires, but the FD has for example a coordinating role at calamity suppression and crisis control. Aside from these the FD also give recommendations concerning the prevention of fire risked situations. Along with other safety organizations the FD is in charge of public safety.

Figure 8: Official Fire Department emblem in the Netherlands

There are primarily two types of firefighters in the Netherlands, the *Career* (full-time) and *Volunteer firefighters*. Approximately 80% of all firefighters in the Netherlands are volunteer firefighters. Career fire fighters are full-time firefighters, working organized shifts, usually based in a centrally located fire station. The volunteer firefighters are part-time or on-call firefighters who may have other occupations when not engaged in occasional firefighting. They are compensated as employees during the time they are responding to or attending an emergency scene, and possibly even for training drills.

Fire Department Tasks

The most well-known task of the FD is extinguishing fires. The FD does however much more; they are in every possible way active in the field of fire safety and calamity suppression. From executing fire safety regulation controls to providing information on fire safety.
The FD tries to prevent incidents, but if anything goes wrong you can count on them. The FD activities can be split up into 5 major tasks chain which are:

1. Pre-Action
2. Prevention
3. Preparation
4. Repression
5. Restoration

Pre-Action

The first step in the 5 tasks chain is the prevention of risky situations. The FD provides valuable recommendations in the earliest planning stage of large projects. Think for example of the construction of a new residential area or a railway. Security impacts are analyzed in order to make the right choices during the earliest planning phases. What is for example a safe location for the construction of a depot for dangerous substances? And what is not? It is not about detailed regulations at the pre-action department, but about incorporating safety in the decision-making process.

Prevention

At the prevention department it's about clearly defined safety measures in order to improve safety. How can fires be prevented or at least the risk on fires can be decreased as much as possible? And how can fire accidents be prevented or be limited? Important tools for accomplishing these tasks are the construction regulations and fire safety regulations which apply in the Netherlands. Think of the use of inflammable materials, escape trails, fire extinguishers, fire detectors and clearly indicated fire exits. The prevention department check if the prescribed rules are kept and provide recommendations on usage permits for safety threatening materials.

Preparation

Preparation stands for 'to be prepared for'. To be able to act rapidly and provide proper aid when called upon, fire rescuers must be well trained and also the materials are to be ready-for-use. The setting-up of calamity suppression plans and the provision of the proper exercises is also a part of this phase. Aside from these tasks the preparation department also carries out the task of informing the public on preparation measures when this is needed.

Repression

Providing aid to people and animals fit the job description of the repression department. This is the most visible part of the FD. Think about extinguishing fires, rescue dives or cutting open a car in order to release a trapped person.

Repression tasks are for example:

- Extinguishing fires / prevention of fire escalations;
- Rescue diving;
- The measuring and clearing of contaminated areas;
- Aid at storms and floods (drain cellars, clear fallen trees);
- Trace gas leaks;
- Rescue animals in need;
- Treat patients;
- Several clean-up tasks such as hosing down the pavement after accident have taken place.

Restoration

The first four activities aim directly at our target groups. This last one does that indirectly. This activity is about getting fully prepared for the next call as soon as possible after an incident. Therefore restoration includes everything what is necessary to return to the normal (daily) situation as soon as possible. For example cleaning up the used equipment and ensure that the vehicles are 'ready for action'.

Also after returning to the fire station every rescue mission is evaluated with the aim of learning from it for a next rescue mission. Firemen encounter all kinds of situations during a rescue mission and sometimes also get to see dreadful things. For this reason firemen can count on psychological aid to come to terms with shocking experiences in a good manner.
Restoration for fire victims is provided by a the 'Salvage' foundation, a service organization for the Dutch fire insurance companies.

Fire Department Assets

Because of the nature of the research we will focus on the assets used by the repression division. The fire department has four main types of assets for repression, *the fire apparatuses*, *protective gear*, *equipment & tools and First Aid & Electronics*. In this section we will give a compact overview of their assets with a few examples, in the following chapter we will go in detail on these assets and how they are managed. The reason for this is because this research focuses on the management of these assets and therefore the information will be too much and too important to be presented within another chapter.

1. Fire Apparatus *(Dutch vehicle code)*
    - Fire extinguishing vehicles
        - Fire Truck: Fire Engine (TS)
        - Foam Fire Engine (SB)
        - Fire Extinguishing Boat
    - Support vehicles
        - Technical rescue vehicle (HV)
        - Turntable Ladder (AL & HW)
        - Various types of trailers (pump, relief, water, meals etc.)
        - Rescue Boat (BRV)
        - Water rescue vehicle (WO)
        - Airport Crash Tender (CT)
2. Equipment and Gear
    - Fire Fighting Gear (Harnesses, helmets, gloves, etc.)
    - Regular Equipment & Tools (Chainsaws, axes, hammer, etc.)
    - Firefighting Equipment & Tools (Fire extinguishers, fire hoses, etc.)
    - Electronics (Lights, generators, radios, etc.)
    - First Aid & Personal Care (First Aid Kits, AED's, breathing equipment, etc.)
3. Fire Resistant Garment (Coat & Pant)

3.2.2 RBRR organization

The fire department has been locally organized since the old days. But nowadays in order to be able to cope adequately with the increase of risks and the increase of their complexity, the government decided in 2006 to start with the process of organizing fire departments regionally.
The formation of the Regional Fire Department Rotterdam-Rijnmond is now in full swing its official name is the "Regionale Brandweer Rotterdam-Rijnmond" (RBRR). The new regional organization is more efficient and effective in providing safety without the local fire departments having to lose there true

identity. The fire departments in the Rotterdam-Rijnmond region are part of the Rotterdam-Rijnmond Safety Region.

The Rotterdam fire department is lead by the commissioner of the Rotterdam-Rijnmond area. The organization consists of four staff departments and seven fire department districts. The organization structure for the RBRR is displayed in the following organization chart.
In the remaining paragraphs of this chapter we will provide more information on the several departments given in the organization chart.

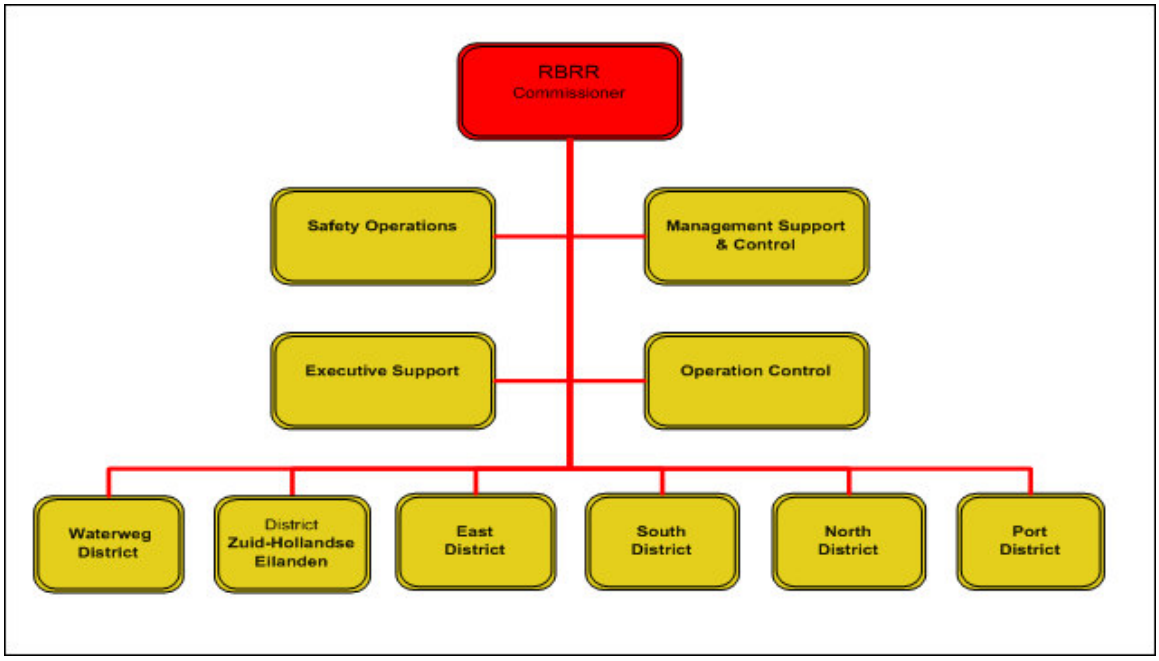

Figure 9: RBRR Organization Structure

RBRR Sub-Departments

The RBRR sub-department can be devided into two group, the staff departments and the fire department districts.

Staff Departments

1. *Management Support & Control*

   Management Support & Control is one of the four staff departments of the RBRR. The department consists of five officers, an executive secretary, an account manager, a management assistant, a financial controller and a HR coordinator.

2. *Safety & Operations*

   Pre-Action, Prevention and Preparation are the tasks that this department focuses on. Safety Operations is divided into two operational teams: the Fire Safety team and the Preparation team.

   The Fire Safety team

   The Fire Safety Team deals with fire safety issues in the broadest sense of the word. The team has in fact two groups of clients. In the first place, the management team of the VRR is provided with advice on policy, such as on the work processes within the fire division. The second group are the

RBRR districts. Together with the seven Divisional Officer the fire safety team strives to maximize uniformity in work processes and procedures in the region. Their main tasks are:

- Prevention: Focusses on fire prevention matters;
- Monitoring, Verification and Compliance (TCH): To determine whether the rules and regulations are complied with;
- Fire Research: Focuses on the investigation of fire development and fire causes;
- Community Safety: Risk identification and analysis in order to provide public safety;
- Fire Safety Engineering: Focuses on advising on extraordinary fire safety issues and special projects for which no standard laws and regulations yet exist.

The Preparation team

The Preparation team makes policy and advices on the following areas:

- Fire suppression operations;
- Personnel fire care;
- Operational equipment and material demands;
- Planning and procedures;
- Providing operational information and information management.

3. *Executive Support*

The Executive Support (EXO) department is the link between the Safety Operations Department and the RBRR Districts. The department consists of two teams: Training & Practice and Advice & Support. Their main tasks are:

- Personnel recruitment and selection;
- Keeping up operational knowledge and skills;
- Keeping the operational stand-by fire fighting functions prepared;
- Formulating technical requirements for materials and equipment;
- Coordinating operational logistics;
- Facilitating practice time for the fire fighter.

4. Operation Control

The main task of operational control (OC) is doing research on the fire suppression operations with the aim at getting policy and practice aligned. In each research the rules, guidelines and standards are compared to the operations in practice. A study may suggest that the prescribed frameworks are not met, but it can also show that the frameworks do not fit in practice. OC makes sure that policy and practice are aligned.

OC has an examining function and retains itself to writing a research report with recommendations. It is then up to management, other staff-departments and other policy makers to rewrite the policies and frameworks if necessary.

RBRR Districts

1. *Waterweg District*

   The fire brigade of Waterweg District is responsible for the fire suppression operations in the north-western part of the region. This district watches over the safety of more than 182,000 residents of the municipalities Schiedam, Vlaardingen, Maassluis and Hoek van Holland. The area that they are responsible for is greater than 5500 hectares.

   The members of the Waterweg brigade do their work out of 4 fire stations, across the 4 counties.

2. *The Zuid-Hollandse Eilanden District*

   The Zuid-Hollandse Eilanden District is a migration of the Voorne-Putten District and the Goeree-Overflakkee District.

   The Voorne-Putten District consists of 5 fire rescue teams and the district watches over the safety of more than 155,000 residents of the municipalities Bernisse, Brielle, Hellevoetsluis, Spijkenisse and Westvoorne. The area that they are responsible for is greater than 19,000 hectares.

   The members of the Voorne-Putten brigade do their work out of 5 fire stations, across the 5 municipalities.

   The Goeree-Overflakkee district consists of 4 brigades and watches over the safety of more than 47,000 residents of the municipalities Dirksland, Goedereede, Middelharnis and Oostflakkée. The area that they are responsible for is greater than 26,000 hectares.

   The members of the Goeree-Overflakkee brigade do their work out of 13 fire stations spread across the 4 municipalities.

3. *East District*

   The Rijnmond East District consists of 4 fire brigades and ensure the safety of more than 250,000 residents and employees of the municipalities of Capelle aan den IJssel, Krimpen aan den IJssel and the Rotterdam boroughs Kralingen-Crooswijk and Prins Alexander. The area that they are responsible for is greater than 22,000 hectares.

   The members of the eastern district brigade do their work out of 4 fire stations, across 3 counties.

4. *South District*

   The southern district of the Rijnmond area is a merger of five fire departments: Albrandswaard, Barendrecht & Ridderkerk, Rotterdam South District and the Inter-Municipal fire department of Rotterdam South.

   The southern district is responsible for the fire suppression operations of the municipalities Albrandswaard, Barendrecht and Ridderkerk and boroughs Charlois, Feyenoord, IJsselmonde and Waalhavengebied. Approximately 330,000 inhabitants live in the southern district area.

   The members of the southern district brigade do their work out of 7 fire stations spread across the 4 municipalities.

5. *North District*

   The fire department for this district is responsible for the fire suppression operations in the northern part of the Rotterdam Rijnmond area. The district watches over the municipalities of Rotterdam and Lansingerland (municipalities Berkel & Rodenrijs, Bleiswijk and Bergschenhoek) and the Rotterdam boroughs Delfshaven, Hillegersberg-Schiebroek, Noord and Overschie. The northern fire brigade ensure the safety of more than 272,500 residents and hundreds of companies.

The northern district consists of six fire stations. The municipality Lansingerland consist of three fire stations and the Rotterdam section of the brigade work out of four fire stations. All Rotterdam North fire stations are occupied 24 hours a day. In addition, the Frobenstraat fire station has a volunteers operated vehicle.

6. *Port District*

The Port fire brigade monitors the safety of a large part of the Rotterdam port and industrial area, in addition to this they also watch over the residential areas Rozenburg, Hoogvliet, Pernis and the surrounding recreational areas.

The Port District does not have its own fire fighting units. The preparation for the actual fire suppression operations including the repression task, is taken care of by the 'Gezamenlijke' Fire department (GB) since 1998. The members of the port district brigade do their work out of 7 fire stations.

The table below provides an overview of the allocation of the tasks within the RBRR staff departments and districts discussed in this paragraph.

Task	**Central (C) / Local (L)**	**Department**
1. Pre-Action	C	Safety & Operations
2. Prevention	C / L	Safety & Operations / RBRR Districts
3. Preparation	C / L	Executive Support / RBRR Districts
4. Repression	L	RBRR Districts (except for the Port District)
5. Restoration	L	RBRR Districts (except for the Port District)

Table 1: RBRR tasks allocation

3.3 Conclusion

The purpose of this chapter was to provide the reader with a global indication of the fire department organization in the Rotterdam-Rijnmond area in order to be able to understand specific terms used in the remaining of the research. In addition to the organization information this chapter was also to educate the reader on the fire fighting profession, especially the different tasks they carry out. The general public most of the time think that firefighters only put out fires because the repression tasks are indeed the most visible ones, but there are many more important tasks that meet the eye. As the repression side of the fire department will be the most important part for this research, we will analyze the repression assets and their management processes in detail in the following chapter.

4 Asset Management

Having given an idea of the fire department organization and the main technology being focused on in this research in the previous chapters, this chapter will be used for going into detail on the fire department assets and problem at hand. Because of the nature of the research we will only focus on the assets used by the repression division. What they are, how they are managed and what the issues & risks are concerning asset management. The defined asset management processes will be analyzed at the end of this chapter in order to identify if there are business needs to research the RFID asset management solution in mind, or will this research only be performed for scientific purposes.
The information on the assets and the way their managed was gathered by conducting interviews with the materials management departments across two fire department districts within the Rotterdam-Rijnmond fire department (RBRR). The details of the materials lists and the conducted interviews can be found in appendix 1 and 2.

4.1 General Asset Information

The assets that are especially used by the repression department can be divided into three groups of assets, *fire engines*, *equipment & gear* and *fire resistant garment*. Off course there are more assets present at a fire station which is used by the repression department, but for this research we will be focusing on the assets that leave the station when the fire department is needed. These assets are to be tagged in order to make the RFID solution in mind (§1.2) work. The fire resistant garment have been added to the "to be tagged" list for their relation to one of the most interesting spin-off RFID automation solutions for the fire department (§1.4.2) which can be easily be implemented with the main RFID solution.
The list below gives an overview of the RBRR assets used by the repression department which are of importance to the RFID asset management solution in mind. In the remainder of this section we will go more in detail on these assets.

1. Fire Apparatus
    - Fire extinguishing vehicles
    - Support vehicles
    - Specialist vehicles
2. Equipment and Gear
    - Fire Fighting Gear
    - Regular Equipment & Tools
    - Firefighting Equipment & Tools
    - Electronics
    - First Aid & Personal Care
3. Fire Resistant Garment (Coat & Pant)

Fire Apparatus
The RBRR has two main types of fire engines which are the *fire extinguishing vehicles* and the *support vehicles*. Almost a total of 150 repressive service vehicles spread across 6 fire department districts. Other

than these vehicles the RBRR also has a lot regular vehicles for the officers in charge of the total coordination at major incidents. Because of the specific research topic these vehicles are left out. The vehicles (fire engines) are defined as a certain type of vehicle (based on certain standard specifications), not by manufacturer and model and their acquisition is done by a European procurement process.
The main fire engine (TS) will be dealt with in a more detailed manor in this section; the other types of vehicles will only be named. The fire engine will be used as an example when analyzing the assets on this vehicle and later on it will be used as an example for the RFID solution in mind for the main problem for this research.

Fire extinguishing vehicles

- *Fire Engine (Dutch: Tankautospuit TS)*

The fire engine is the common vehicle of the fire department. It is a multi-purpose vehicle used for transporting the fire fighters and the equipment for a wide range of fire-fighting and rescue tasks. It carries a large variety of equipment, apparatus and tools, in the following paragraph we will take a more detailed look at the equipment carried by this vehicle. The equipments are stored across 15 standard compartments; each fire engine must be furnished exactly the same.

Figure 10: Fire Engine

Because of the wide range of tasks for which this vehicle can be used for, every fire station of the RBRR is occupied with at least one and the larger stations up to three. These fire engines have a technical average lifecycle of 12 years and are valued at approximately € 225.000 and at € 305.000 including all equipment on board. As for the economical lifecycle it is wise to relocate a fire engine to a less busy area after 4 years of service.

- *Foam Fire Engine (Dutch: Schuimblusvoertuig SB)*

Support vehicles

- *Technical rescue vehicle (Dutch: Hulpverleningsvoertuig HV)*
- *Turntable Ladder (Dutch: Autoladder AL & Hoogwerker HW)*
- *Various types of trailers (Dutch: Haakarm HA)*
- *Rescue Boat (Dutch: Brandweervaartuig BRV)*
- *Water rescue vehicle (Dutch: Waterongevallen voertuig WO)*
- *Airport Crash Tender (CT)*

The vehicles' allocation within the RBRR is displayed in the table below (table 2).

District name	TS	SB	HV	AL	HW	HA	BRV	WO	CT	Total
Waterweg	9	0	3	3	2	4	0	2	0	**23**
Rijnmond-Noord	14	1	2	3	0	3	4	0	4	**31**
Rijnmond-Oost	9	0	2	2	0	4	1	1	0	**19**
Rijnmond-Zuid	14	1	2	2	1	4	1	1	0	**26**
Zuid-Hollandse Eilanden	24	0	6	0	1	2	1	4	0	**38**
Total	**70**	**2**	**15**	**10**	**4**	**17**	**7**	**8**	**4**	**137**

Table 2: RBRR vehicle allocation

Equipment and Gear

Due to the nature of this research we will only look into the firefighting equipment and gear used by the repressive unit. Each one of the vehicles mentioned in the previous section has a mandatory set of equipment and gear that always has to be present and ready for use at all times in case of an emergency.

The prescribed set of equipment and supplies for fire engines in the Netherlands is put together by the Ministry of Internal Affairs, as for the vehicles only the equipment types and minimal requirements are defined, not the exact brand and model.

From the equipment and supplies list mentioned above, at least 95% of the items are carried by the fire engines of the RBRR. The reason for this is because of the diverse infrastructure across the Rotterdam-Rijnmond area. For example a vehicle allocated to the city centre of Rotterdam does not need to equip tools for fighting forest fires but instead it does need special equipment for fighting fires in tall buildings. Therefore each fire department district of the RBRR is allowed to customize its equipment and gear list for its units. The RFID solution being researched is aimed at managing the assets being used at an emergency scene.

Except for the equipment and gear loaded onto the vehicles, a short supply of the items regularly replaced is kept at every fire station. All other items are either acquired through the main assets depot at the main district fire station or ordered direct from the supplier. For the specific firefighting equipment and gear there are a few suppliers from which items can be acquired though asset purchase agreements and the non-specific pieces of equipment can be bought from regular (hardware) stores. The asset costs vary widely from € 20.000 for the hydraulic cutting apparatus and € 5.000 for the water pump to the least expensive stuff like € 0,10 for a pair of medical latex gloves.

For the future the aim of the materials management departments across the RBRR districts is to form a central acquisition organization in order to cut costs by bundling the purchases and create uniformity in the equipments used. This central purchasing organization will then also keep a central equipment warehouse in order to lower the warehousing costs.

In order to give an impression of the equipment and gear being used by the repressive unit of the RBRR we have analyzed a printed copy of the checklist used for the vehicle completeness check performed daily for the Fire Engine (TS), the most popular fire fighting vehicle.

Figure 11: Fire Engine Equipment & Gear

Because of the large amount of items listed for this vehicle (almost 500), we have chosen to categorize these items into five main categories, *Fire fighting gear*, *regular equipment & tools*, *firefighting equipment & tools*, *electronics* and *first aid and personal care*.

The lifecycle the equipment varies heavily from 12 years for some fire hoses to 1 year for certain breathing apparatuses. Usually all equipment is replaced when the fire engine itself gets replaced.

The item sub-categories plus the amounts are displayed in the following table (Table 3). An example of a complete checklist for a Fire Engine can be found in appendix 1.

Nr	Main Category	Sub Category	Amt.
1	Fire Fighting Gear	Packs, Radio Harnesses & Fire Shelters	2
		Hot Shield, Fire Helmets, Boots, Goggles and Gloves	82
		Hydration & Cleaners	2
		Oxygen Tanks and Masks	3
		Chemical Protective Gear	14
		Other	11
2	Regular Equipment & Tools	Fire Axes, Shovels and Hoes	11
		Hydraulic cutting tool, Chainsaw and other cutting tools	13
		Maps, Charts, Paper and other writing or marking tools	19
		Ladders and other climbing tools	10
		Misc. Tools (including hand tools)	40
		Tool accessories	20
		Other	64
3	Firefighting Equipment & Tools	Fire Hose, Nozzles, Couplings, Valves and Reels	73
		Portable Tanks, Pumps & Sprinklers (including Foam)	5
		Foam and Foam Nozzles (weg)	2
		Firefighting guides and charts	4
		Other	18
4	Electronics	Lights, Batteries, Generators and Headlamps	16
		Radios, GPS and Personal Rescue Equipment	14
		Accessories	8
5	First Aid & Personal Care	First Aid & Skin Products	1
		Breathing & Respiratory Equipment	17
		Other	5
		Total	**454**

Table 3: Fire Engine Equipment & Gear

The main reason for analyzing the equipment and gear at item level is primarily to see if and how each item can be tagged with an RFID transponder as each item already posses a unique identification number. This issue will be dealt with in the next chapter when we present the possible RFID solution for the fire department asset management problems.

Fire Resistant Garment

The fire resistant garment to be taken into consideration for this research consists of two pieces, the coat and the pants.

The reason for only adding these two garments to the "to be tagged list" is as mentioned earlier for its relation to one of the most interesting spin-off RFID automation solutions for the fire department that we stumbled upon during the literature study for this research (§1.4.2). This solution can be easily be implemented with the main RFID solution. The solution found was an RFID laundry management system for firefighters' protective clothing.

The problem is that thorough cleaning treatment of the protective

Figure 12: Fire Resistant Pants & Coats

clothes is crucial, but with each laundry/disinfecting action the gear sustains a certain degree of damage. Therefore, each item can only withstand a certain number of cleaning treatments before it must be discarded and replaced. By attaching RFID transponders to each piece of clothing, each item's number of cleaning treatments can be monitored and therefore correctly be dealt with.

4.2 Asset Management Processes

Each fire department district in the Rotterdam-Rijnmond area has one materials management team and all asset management processes are designed and monitored by this group. They are responsible for managing the whole lifecycle of each asset, from identifying the need for an asset to its disposal. The daily asset management processes are carried out by the local firefighting unit on duty at the fire station and certain specialized tasks are carried out by external parties.

The asset information on every item's lifecycle is kept and managed with the computerized asset management system named "Prebear: Materieel" by the company "AVD-ICT". "Prebear" is an ERP-system which consists of 8 different modules for managing all the needs of a firefighting organization, the RBRR only uses the material management module called "Materieel". Information such as the item's registration number, location, maintenance date, inspections date, monetary value, supplier, and usage status of vehicles and equipment are registered in this stand-alone system. Other business needs such as the purchasing of the vehicles and equipment are registered in the financial management system called "SmartStream" by "Infor, Inc.".

In this paragraph we will elaborate some of the different asset management processes that are most likely to benefit from implementing the RFID solution in mind described in §1.2.

The asset management processes that will be analyzed before the implementation of the RFID solution in mind (§1.2) in order to be able to research the possible benefits are:

A. Fire Engine replenishment (at emergency scene)
B. Vehicle completeness check
C. Periodical maintenance & quality inspections
D. Fire resistant garment laundry

Note: The information used for describing & analyzing the processes mentioned above were gathered by interviewing the materials management managers for the South and North RBRR districts.

A. Fire Engine replenishment process (at emergency scene)

This process is where the main problem being researched for this thesis is located. The main RFID solution was initiated to remediate the problems found in this process. All other processes analyzed in this research are offspring RFID solutions to the solution in mind for remediating the main problem of this research.

This process starts when a firefighting unit is finished at an emergency scene and needs to gather all their assets deployed during the rescue mission in order to replenish their vehicle. It is crucial that this process is carried out carefully because errors during this process could lead to fire engines being deployed without being fully equipped with the mandatory equipment which enhances the risk of losing lives that could have been saved.

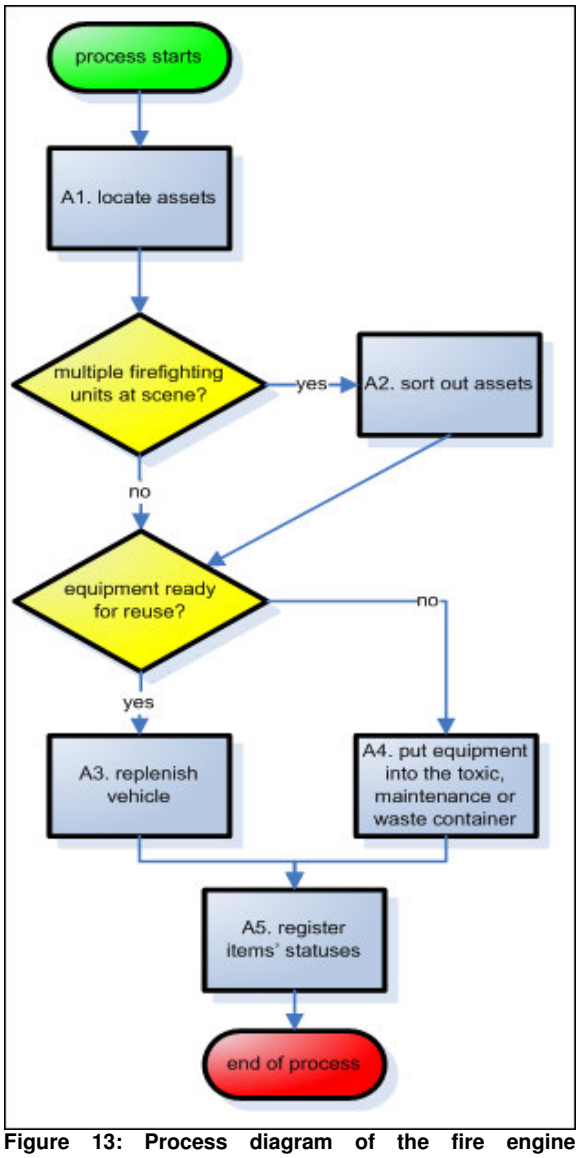

Figure 13: Process diagram of the fire engine replenishment process (at emergency scene)

Step	Description
A1. Locate Assets	When a fire engine is finished at an emergency scene its crew has to locate all equipment used at the scene.
A2. Sort out assets	When more than one fire engine has been active at an emergency scene all equipment located will have to be allocated to its fire engine, by analyzing the items' unique identification number.
A3. Replenish vehicle	All equipment located and/or allocated to its fire engine will have to be put back in its proper location in the fire engine.
A4. Put equipment into the toxic, maintenance or waste container	Every piece of equipment that isn't ready for use needs to be put into a toxic cleaning or "to be maintained" or waste container carried by the support vehicle at the emergency scene.
A5. Register items' statuses	Every item which is not returned to the fire engine needs to be marked on the equipment list.

Table 4: Steps description process A: Fire Engine replenishment process (at emergency scene)

B. Vehicle completeness check process

This process is completely carried out once a week. Not every compartment is fully checked daily, only the main items of this check process are carried out on a daily basis at the start of a new firefighting unit shift or at return from a major incident. Each unit is responsible for having a fully equipped stand-by vehicle at all times. The unit commander assigns a crew to perform this process.

The reason why we foresee this process to benefit from the RFID implementation is because there are many time-consuming manual tasks to be carried out which can be automated.

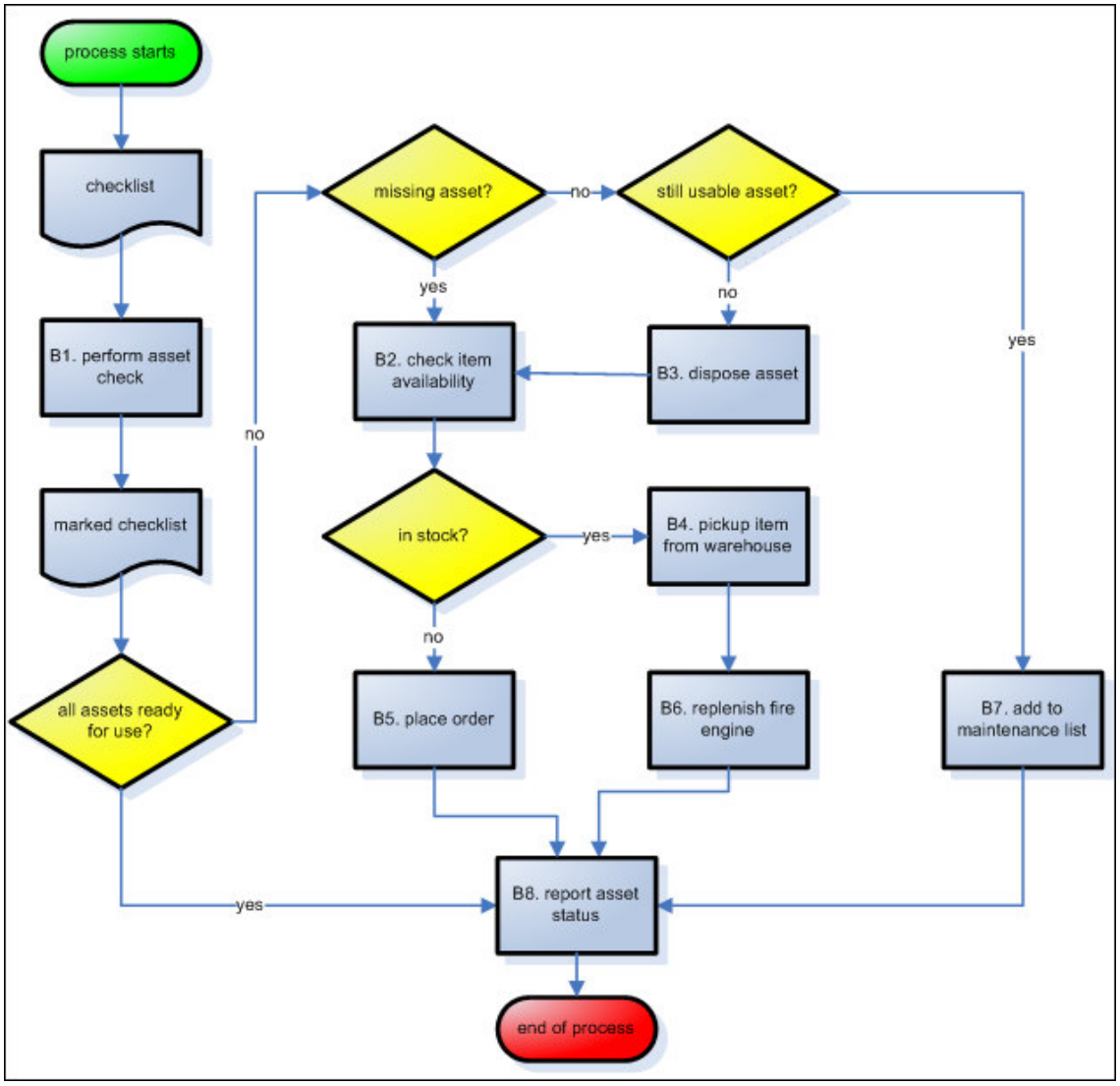

Figure 14: Process diagram of the daily asset availability check process

Note: The textual explanation of the process presented in Figure 14 can be found on the following page in Table 5.

Step	Description
B1. Perform asset check	At the beginning of a new shift a routine check with a checklist has to be performed in order to make sure to have a fully operational fire engine.
B2. Check item availability	Check in the asset management system if the missing item is in stock at the fire station or within the fire district.
B3. Dispose asset	Dispose of unrepairable piece of equipment, this step is carried out when unrepairable items are found during check-up.
B4. Pick-up item from warehouse	When a needed piece of equipment is in stock, the item is picked up at the local or the districts' warehouse.
B5. Place order	When a needed piece of equipment is not in stock, an order for this item needs to be placed at its supplier.
B6. Replenish fire engine	Replenish fire engine with the new or temporary replacement equipment when item is missing, unusable or up for maintenance.
B7. Add to maintenance list	Register an unusable but repairable item to the maintenance list, when found during check-up.
B8. Update asset(s) status(us)	Update an asset's status in the asset management system. (missing, unrepairable, up for maintenance, in use)

Table 5: Steps description process B: Vehicle completeness check process

C. Periodical maintenance & quality inspections

This process is triggered by the asset management information system each time asset needs maintenance or needs to be re-inspected. Depending on the type of maintenance or inspection the process is carried out by a licensed employee or an external party.

For instance daily vehicle or machinery maintenance tasks are performed by the firefighting unit on call, but the yearly vehicle or asset check-ups are done by the product dealer or certified maintenance or inspections company.

As for the previous process the reason why we foresee this process to benefit from the RFID implementation is because there are many time-consuming manual tasks to be carried out which can be automated.

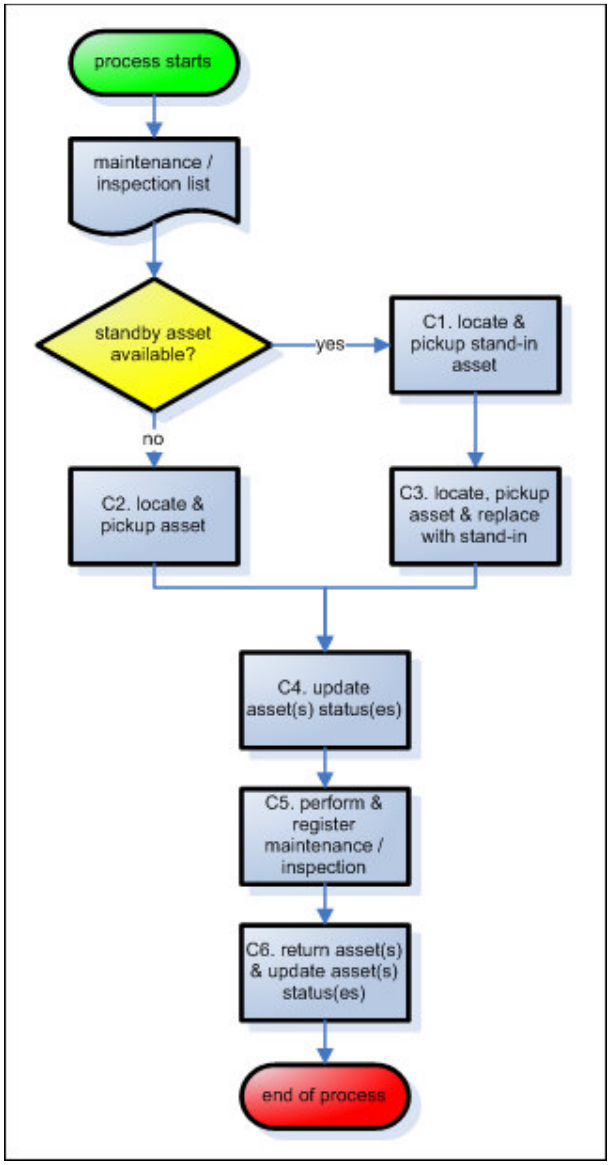

Figure 15: Process diagram of the periodical maintenance & quality inspections process

Step	Description
C1. Locate & pickup stand-in asset	Stand-in equipments for the equipments on the maintenance and/or inspections list need to be located in the fire station and taken to the fire engine.
C2. Locate & pickup asset	Equipments in use on the maintenance and/or inspections list need to be taken from the fire engine to the maintenance or inspections area.
C3. Locate, pickup asset & replace with stand-in	The equipment to be maintained and/or inspected needs to be pickup and replaced with the stand-in equipment gathered in the first process. The picked up item needs to be taken from the fire engine to the maintenance or inspections area.
C4. Update asset(s) status(us)	The items status(es) need to be updated in the asset management systems. (in maintenance, inspection or in use)
C5. Perform & register maintenance / inspection	Maintenance and/or inspection needs to be performed. The maintenance and/or inspection details are registered in the asset management system.
C6. Return asset(s) & update asset(s) status(us)	Assets are returned to their initial locations and their statuses are updated.

Table 6: Steps description process C: Periodical maintenance & quality inspections

D. Fire resistant garment laundry

The main reason for including this process in this research is because it is an easy process to automate together with the main RFID solution being researched. The idea for automating this process comes from an article we came across when performing the literature study upon starting with this research. RFID technology is used in this article for registering laundry treatments given to fire resistant garment used by the fire department because each piece of garment can only sustain a number of treatments and still guaranty the minimum regulative protection.

The actual laundering of the garments process is carried out by an external party who is specialized in this field but the management of the fire resistant garment is a time consuming labor intensive tasks that can easily be automated when the RFID technology is implemented at a fire station.

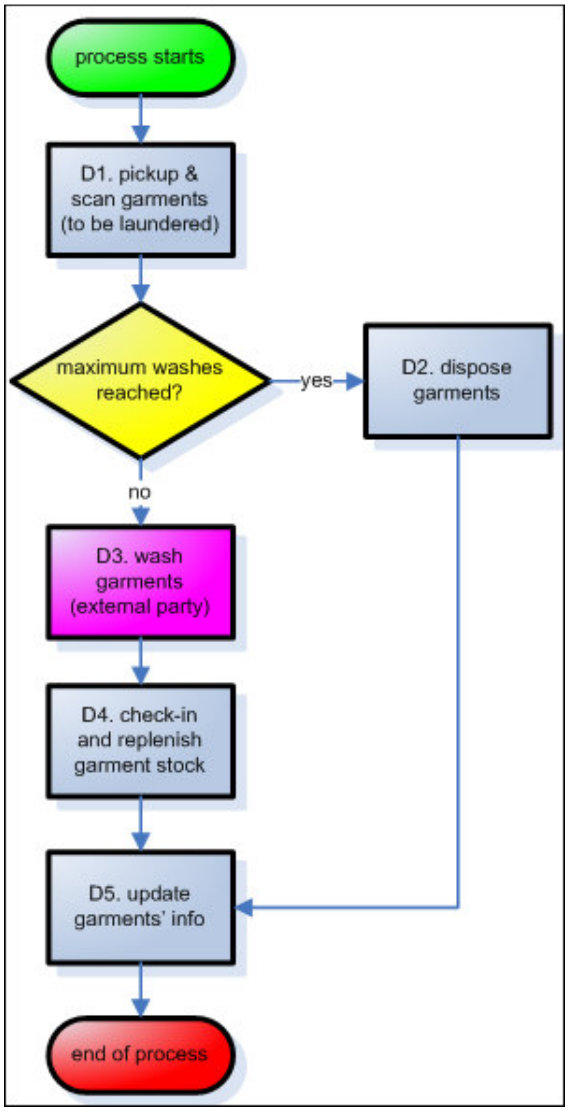

Figure 16: Process diagram of fire resistant garment laundry process

Step	Description
D1. Pickup & scan garments (to be laundered)	Pickup items to be laundered and check them out.
D2. Dispose garments	Dispose of items which their maximum washes have been reached.
D3. Wash garments (external party)	The items to be washed are picked up and returned after they have been washed.
D4. Check-in and replenish garment stock	The washed items are checked-in and stored.
D5. Update garments' info	The garments' details and statuses are updated in the asset management system.

Table 7: Steps description process D: Fire resistant garment laundry

4.3 Asset Management Process Risk Analysis

This section of chapter four provides an analysis of the processes given in the previous paragraph (§4.2). By analyzing these processes we can identify the threats and the inefficiencies. These threats and inefficiencies will later on be quantified where possible in order to be able to evaluate the RFID asset management solution in mind for the main problem for this research.

4.3.1 Threats & Inefficiencies Identification

The threats and inefficiencies presented in the following table (table 8) have been identified, with the changes that the RFID implementation will bring to these processes in mind, based on own insight and revised by the materials manager from the south district of the RBRR.
The risk impact and the results for the threats are presented in the 2nd table in this segment (table 9).

Step	Threat	Inefficiency
Process A: Fire Engine replenishment process (at emergency scene)		
A1. Locate Assets	T1. Items cannot be found at the emergency scene.	I1: Locating items at an emergency scene after incident is hard. Especially in dark, flooded, smoked-out and full of debris environments.
	T2. Fail to identify missing items and therefore these items are left behind at an emergency scene.	I2: A fire engine should be fully operational as quick as possible and there is not always time to perform a complete check before leaving an emergency scene.
A2. Sort out assets	T3. Items get taken by the wrong fire engine.	I3: Sorting items manually in unfit environments takes a lot of time and is highly sensitive to errors.
A3. Replenish vehicle	T4. Items are misplaced.	I4. No time to mark the items for revision.
	T5. Broken items are put back onboard.	
A4. Put equipment into the toxic[3], maintenance or waste container.	T6. Toxic items are put onboard before cleaning.	
A5. Register	T7. Missing items not marked.	

[3] A toxic / hazardous materials treatment / cleaning support vehicle (trailer) is also deployed at an emergency scene when needed.

	T8. Wrong findings or annotations because of human errors.	I5: Manual checks and registration of findings take a lot of time.
B. Vehicle completeness check process		
B1. Perform asset check	T8 (see T8)	I5 (see I5)
	T9. The person performing the check can forget to check some items.	I5 (see I5)
	T10. Checklists can get lost in the document flow before the annotations are processed in the asset management system.	
B2. Check item availability		I6. Manual checking in the system can be automated.
B3. Dispose asset	T11. A wrong item can be disposed of due to registration errors.	
B4. Pick-up item from warehouse	T12. Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	I7. Locating an item manually can take a long time if the item location is incorrect or not available in the asset management system.
B5. Place order	T13. Wrong orders can be placed due to wrong annotations on the checklists.	I6 (see I6)
	T14. Orders can be delivered too late, which can result in an incomplete Fire Engine in case of emergency.	
B6. Replenish fire engine	T6 (see T6)	
B7. Add to maintenance list		I6 (see I6)
B8. Update asset(s) status(us)	T15. Human errors when updating asset management system.	
C. Periodical maintenance & quality inspections		
C1. Locate & pickup stand-in asset	T12 (see T12)	I7 (see I7)
C2. Locate & pickup asset		
C3. Locate, pickup asset & replace with stand-in		
C4. Update asset(s) status(us)	T15 (see T15)	I5 (see I5)

C5. Perform & register maintenance / inspection		I5 (see I5)
C6. Return asset(s) & update asset(s) status(us)	T15 (see T15)	I5 (see I5)
D. Fire resistant garment laundry		
D1. Pickup & scan garments (to be laundered)	T16. A piece of garment can be overlooked and not be scanned.	I8. Manual scanning of each piece of garment is time consuming and can be automated.
D2. Dispose garments	T11 (see T11)	
D3. Wash garments (external party)		
D4. Check-in and replenish garment stock	T16 (see T16)	I8 (see I8)
D5. Update garments' info	T15 (see T15)	I5 (see I5)

Table 8: Threats & Inefficiencies per asset management process

The threats identified in the table above have impact on several risks, the division of the threats across the risks and the risks impact can be found in Table 9.

Risks	Impact	Threats
A. Not being completely equipped for an emergency call, which increases the chance for fatalities.	Decrease of public and/or personnel safety.	T1, T2, T3, T7, T8, T9, T10, T12, T14, T15
B. Unsafe equipment or fire resistant garment can be used, which can put fire fighters' lives in danger.		T4, T5, T6, T8, T9, T10, T11, T15, T16
C. Higher purchasing costs.	No room in financial budget for other needed purchases.	T1, T2, T3, T8, T11, T13, T15, T16

Table 9: Risks Impact (to be used in the impact analysis in the following chapter)

4.3.2 Threats & Inefficiencies Analysis

The likelihood of occurrence of the threats and also the quantification of the inefficiencies were determined by conducting surveys with fire fighters. An example of each of the surveys (questionnaires) used for this analysis and an overview of the results can be found in appendix 3.

The summary of these surveys are given below in tables 10 and 11.

Risks Analysis Survey

The risks analysis survey was performed in order to find out the likelihood of occurrence of the threats identified in the previous paragraph. With the results we will perform a comparison with the situation after the proposed RFID solution has been implemented.

Based on the *non-probability sampling method*, *convenience sampling*[4], we opted to conduct the survey with the fire engine commanders from two of the three main districts of the RBRR.

The threats likelihood of occurrence questionnaire was distributed to 30 firemen across two districts of the RBRR, East and South. From these 30 firemen we got 5 responses in return.

Survey 2: Threats likelihood of occurrence		Mode	Mode Description	Freq.
A1	Items cannot be found at the emergency scene.	B	Few times a Year	4/5
A2	Items missing on a fire engine are overlooked and left back.	B	Few times a Year	4/5
A3	Items get taken by the wrong fire engine.	B	Few times a Year	4/5
A4	Items are misplaced.	B	Few times a Year	2/5
A5	Missing items not marked.	B	Few times a Year	3/5
A6	Wrong findings or annotations because of human errors.	A	Never	3/5
B7	Missing items not marked.	B	Few times a Year	3/5
B8	Checklists can get lost in the document flow before the annotations are processed in the asset management system.	A	Never	4/5
B9	Wrong findings or annotations because of human errors.	A	Never	4/5
B10	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	B	Few times a Year	3/4
B11	Wrong findings or annotations because of human errors.	A	Never	3/5
B12	Orders can be delivered too late, which can result in an incomplete Fire Engine in case of emergency.	B	Few times a Year	5/5
B13	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	B	Few times a Year	2/4
C14	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	B	Few times a Year	3/5
C15	Human errors when updating asset management system.	B	Few times a Year	3/5
D16	A piece of garment can be overlooked and not be scanned.	A/B	Never /Few times a Year	2/5
D17	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	A/C	Never /Few times a Month	2/5

Table 10: Statistical Analysis - Survey 2: Threats likelihood of occurrence

Result Conclusion Survey 2 (Threats likelihood of occurrence)

Aside for the low response rate there are several more reasons that lead to the conclusion that the survey results may be biased.

The materials managers gave at the start of the research an impression that the likelihood of occurrence for these threats are higher than the results given by the firemen. The most likely explanation is the fact that the management has an overview of the whole district, they see the bundled orders daily and the firemen only see their own orders. On top of this, a firemen only works 3 times a week, he/she doesn't see what happens

[4] "With a convenience sample the selection cost is minimal, simply because the sample is selected on the basis of just that, convenience." FERBER (1977)

on the other days at their fire station. Another possible explanation for this can be that the firemen don't want to look bad by admitting that they don't handle their equipment securely.
The results in Table 10 indicate that there are definitely some needs to research the RFID asset management solution in mind, but as the identified threats do not occur that often we can conclude that the urgency is low.
This conclusion does not support the impression given by the management of the materials management department. Therefore in order to get a better overview of the likelihood of occurrence of these threats, the materials managers will have to start registering the reason for ordering each item in the future.

Inefficiencies Analysis Survey

The inefficiencies analysis survey was performed in order to find out the duration of the defined processes identified in paragraph 4.2. With the results we will perform a comparison with the situation after the proposed RFID solution has been implemented.
Based on *convenience sampling method*[4] we opted to conduct the survey with the fire engine commanders from two of the three main districts of the RBRR.
The process duration survey had a response of only 8 people out of the 30 which had been asked. In the table below computations of statistical measurements are presented. The dataset can be found in Appendix 3: Threat Likelihood & Process Duration Surveys.

Survey 1: Process Duration		Mean	Med.	Std. Dev.	Min	Max	Range	Ratio[5]
A1	Locate Assets	3.86	3	2.04	2	6	4	1.0
A2	Sort out assets	7.14	8	3.18	3	10	7	1.1
A3	Replenish vehicle	4.57	4	2.23	2	8	6	1.4
A5	Register items' statuses	2.29	2	1.70	1	6	5	1.0
	Totals (minutes)	**17.86**		**5.81**	**10**	**26**	**16**	
B1	Perform asset check	37.86	30	24.47	20	90	70	1.4
B2	Check item availability	7.00	7	3.00	3	10	7	1.2
B5	Place order	4.00	4	1.00	2	5	3	1.3
B6	Replenish fire engine	10.00	10	4.69	5	15	10	1.1
B8	Update asset(s) status(us)	7.57	8	2.51	5	10	5	1.0
	Totals (minutes)	**66.43**		**25.57**	**37**	**115**	**78**	
C1	Locate & pickup stand-in asset	15.29	15	9.52	2	30	28	1.5
C3	Locate, pickup asset & replace with stand-in	11.43	10	2.44	10	15	5	1.3
C5	Perform & register maintenance / inspection	8.29	5	5.22	2	15	13	1.4
C6	Return asset(s) & update asset(s) status(us)	12.14	10	9.51	5	30	25	1.3
	Totals (minutes)	**47.14**		**10.95**	**30**	**60**	**30**	
D1a	Pickup garments (to be laundered)	7.86	10	2.67	5	10	5	0.9
D1b	Scan garments (to be laundered)	3.71	4	1.38	2	5	3	1.4
D4	Check-in and replenish garment stock	7.71	9	3.09	2	10	8	1.3
D5	Update garments' info	8.57	10	1.99	5	10	5	1.1
	Totals (minutes)	**27.86**		**4.53**	**14**	**35**	**21**	

Table 11: Statistical Analysis - Survey 1: Process Duration

[5] Ratio is calculated by dividing the Range by 2* the Standard Deviation.

Result Conclusion Survey 1 (Process Duration)

Although the response level is not that high we can conclude that the responses are valid due to the fact the Ratio of the responses are always rounded 1(the response range is always double the value of the standard deviation).

In other words the responses lie in an acceptable range therefore likely to be a valid representation of the reality. This makes the information gained by conducting this survey very useful for the next chapter, where we will try to calculate the measurable gains of the RFID implementation.

4.4 Conclusion

In this chapter we have focused on the asset management processes of the repression division of the RBRR. Explained how they are carried out, identified the threats that they pose & analyzed the risks and identified the process durations by performing surveys with the operational staff of the Rotterdam Rijnmond fire department.

Based on the *Result Conclusion Survey 2 (Threats likelihood of occurrence)* we could conclude that there is a low urgency to research the RFID asset management solution in mind, as the identified threats almost never occur according to the operational staff of the RBRR (unlike the initial information given by the materials management departments' managers).

Even though we think the survey results may be biased, there is a chance that the conclusion might still be right. In that case we can still carry on the research as intended, but perhaps only for scientific purposes and just improving overall safety.

5 RFID Asset Management Solution

Having analyzed the asset management processes and evaluating the threats and inefficiencies in the previous chapter it is now time to look into the RFID asset management solution presented earlier in §1.2. In this chapter we elaborate the changes that the RFID solution in mind will bring and analyze the technical feasibility, the possible benefits of this proposal and the technical details of the proposed implementation solution. The financial investment analysis accompanying this proposal will follow in the upcoming chapter.

Solution in short

By attaching RFID tags to all equipment, gear and fire resistant garment and installing RFID readers at the designated locations on the fire engines and in the fire stations; asset management of all portable assets can be improved. This RFID implementation could yield a lot of efficiency gains due to automation of certain manual labor and also mitigation or even elimination of certain threats.

The RFID implementation enables automatic tracking and tracing of these assets at all times and also the ability of assets triggering certain actions automatically. By automatically triggering preprogrammed events, lots of manual labor could be reduced or even eliminated within the described asset management processes. From a user's point of view the smart assets seem to manage themselves. This ability is the "Smart" feature of the RFID solution, which is referred to in the title of this research. The solution in mind will result is having "Smart" Fire Engines and "Smart" Fire Stations, therefore the research title: The "Smart" Fire Department.

5.1 RFID Solution Details

The implementation of the RFID asset management solution can be split up in three parts corresponding to the three RFID components described in §2.1; the tag, the reader and the middleware plus the operational changes for the end-users. In this paragraph we will elaborate the changes needed in the four areas in order to make the RFID solution possible. Along with the changes description we will give provide the technical detail information on the RFID-components.

5.1.1 RFID Tag

General Description

RFID tags are to be mounted onto or embedded into every piece of equipment, fire resistant garment or bundle of items carried by a fire fighting unit in order to make them traceable. As every main piece of equipment already possess a unique identification number in the management system, this number will be linked to the RFID tag. As the equipment is already in place there will have to be a transition period to have all equipment (or bundle) tagged. After this transition phase, the ideal situation would be to have the main equipments supplied with the RFID tags already in place.

Technical Details

For the Fire Department implementation *passive read only low memory* tags will suffice as the assets will mostly be used in a *controlled* and *closed environment*. Long distance, bulk and speedy readings are not

needed. The following tag requirements analysis process is based on the "Buyers Guide to RFID Tags" article (RFID SWITCHBOARD 2009).

Fire engines carry a large variety of tools and equipment that are made of different types of substances, therefore one single type of RFID tag will not always do. In order to decide on which types of RFID tags are needed we divided the assets into certain groups based upon these following characteristics[6]:

Base substance (metal, plastic, wood or paper), Environmental conditions in which an item must operate (heat & humidity), Monetary value (item-bundle is < or > than €10)[7], Disposability (if item gets thrown away after certain times of usage / item lifecycle) and Tagging location[8] (internal / external).

In the following table you can find a summary of the analysis of the assets characteristics. The complete analysis can be found in appendix 4.

Characteristic	Alternative	Assets	Total Count	Total %
1. Base substance	Fabric	4	11	2.4%
	Metal	59	131	28.9%
	Paper	10	66	14.5%
	Plastic	82	191	42.1%
	Rubber	9	42	9.3%
	Wood	8	13	2.9%
2. Heat & Humidity resistant	Yes	152	365	80.4%
	No	20	89	19.6%
3. Monetary Value < €10	Yes	10	22	4.8%
	No	162	432	95.2%
4. Disposable Asset	Yes	11	41	9.0%
	No	161	413	91.0%
5. Tagging Location	Internal	49	143	31.5%
	External	123	311	68.5%

Table 12: Asset characteristics analysis summary

With the general information on the assets that are to be tagged, the needed RFID tag for each asset could be determined. The types of tags to be used were determined based on the following tag selection specifications[9]:

1. Memory & Read- Write capabilities:
   Read Only;
2. Physical tag size:
   Regular general purpose passive tag size;
3. Maximum distance the tag needs to be read from:
   Regular7 passive tag distance (5m);
4. Maximum number of tags to be read simultaneously:
   Not relevant for this specific RFID implementation, relevantly low volume of assets;

[6] KLEIST, CHAPMAN, SAKAI & JARVIS (2005)

[7] In an interview with a materials manager the value of €10 was mentioned as a starting point for items that are crucial their main business operations. "Items such as a screwdriver which has a low monetary value and does not pose such a threat if lost will not have to be tagged individually, the toolbox (carrier / item-bundle) containing multiple tools will have to be tagged."

[8] By tagging location we mean whether the RFID tag can be mounted on the inside of the piece of equipment, therefore the usability of the item will remain the same. Or if the item will have to be tagged externally and item usability issues will have to be taken into account.

[9] RFID SWITCHBOARD (2009)

5. Minimum time available to read the tag(s):
   Not relevant for this specific RFID implementation, not much asset movement;
6. Environmental conditions in which the tag must operate (heat & humidity);
   Heat: -200 to 1000 Fahrenheit ;
7. Programmable tag or pre-programmed delivered:
   Pre-programmed Tag;
8. Permanent or removable tag:
   Permanent, less than 10% of all items are to be disposed after (certain times of) usage.

Conclusion

Based on the RFID Tag requirement details given in this paragraph we applied a tag selection guide, INTERMEC TECHNOLOGIES CORPORATION 2007-2, and concluded that based on the two most used materials (plastic & metal), the needed read range, ruggedness, heat-resistance and tag-size that a *general purpose Gen 2 UHF tag* will suffice for most of the assets which needed to be tagged. As the read range, 5 and 9 meters, of a small (3.1cm x 7.9cm) and large (3.2cm x 15.5cm) Gen 2 passive tag is more than enough within the regulation ETSI Standard frequencies for European countries (865 - 867 MHz).
Of course for some specific items a different shape or model of tag may be needed due to a non standard method of attaching the tags to the asset. If the proposed RFID asset management solution were to be implemented specific research will have conducted by analyzing each individual asset.

For the cost calculations of the proposed RFID solution only one general type of tag will be used, the small general purpose *Gen 2 UHF RFID* tags (ALN-9640) and the *passive laundry RFID tags* (HCT-LDT-20102).

5.1.2 RFID Reader

General Description

The fire engines and fire stations will have to be equipped with RFID readers in order to locate and communicate with the tagged equipment. An RFID tag reader can locate and communicate with RFID tags within a certain radius depending of the type of RFID tag & reader being used and the obstacles in their line of sight.
In order to make the "Smart" Toolbox[10] adaptation possible for the fire engines, RFID reader antennas will have to be placed in certain key locations which are the 7 main compartments. By placing the antennas in every compartment of the fire engine you will be able to pinpoint each item's exact location which enables the system tell if the right item is in its designated compartment or missing. The 7 main compartments of the (TS) fire engine are: the passengers' cabin, the fire engine roof, the pump area and 2 cabinets on the left and right side of the vehicle. The mobile data terminal on the vehicle will function as an interface to communicate with the asset management system. An image of these compartments is given in Figure 10.
In addition to the fixed reader, the fire engines will also have to be provided with handheld and mobile reader nodes to be able to trace equipment deployed at an emergency scene.
Besides the readers on the fire engines, fixed readers will also have to be strategically placed inside the fire station. Based on the processes described in the previous chapter; the number of readers and their positioning depend on the size of the fire engine bay, work floor where maintenance and inspection is

[10] FLÖRKEMEIER, LAMPE & SCHOCH 2003

carried out and repository for spare pieces of equipment & garment laundry. By strategically placing these fixed readers at the right location, the asset management system will be able to know at all times where the items are located and be able to update an items status based on its location inside the premise.

Technical Details

RFID readers will have to be placed in multiple locations. In this section we will specify the needed readers and quantities for a fire station and a fire engine.

Fire Station

When choosing the right fixed RFID readers for a fire station we had to first specify the RFID usage for each process it will be used for at a fire station. The three in-station processes analyzed in §4.2 were:

a. *Vehicle completeness check;*
b. *Periodical maintenance & quality inspections;*
c. *Fire resistant garment laundry.*

In order to be able to carry out these processes, the fire station must have a *fire engine garage*, a *maintenance and inspections area*, a *repository* for spare pieces of equipment and a *garment laundry area*.

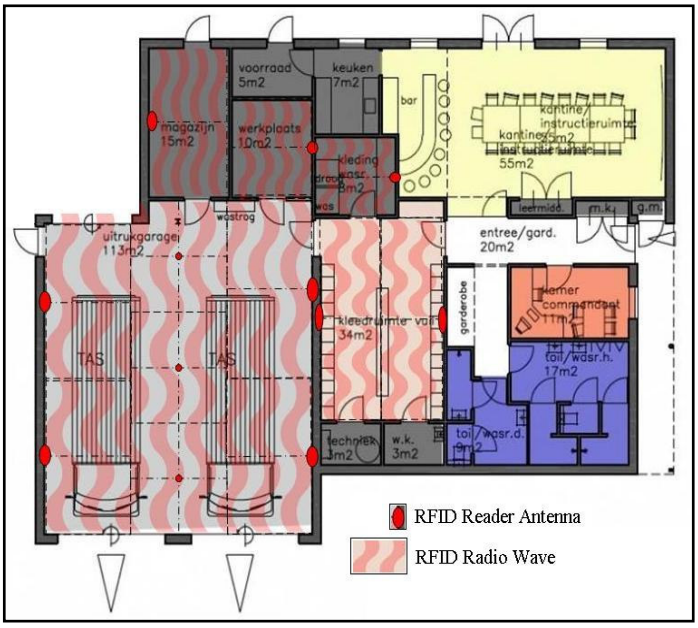

Figure 17: Fire station floor plan with RFID readers and antennas

To provide an idea of the needed RFID readers and antennas and their positions, we analyzed a floor plan[11] of a fire station which has all four areas mentioned above plus a changing room which serves as the repository of the fire protective garment. In the table below a summary of the needed RFID readers and antennas for every area of the fire station is given. With this information we will be able to calculate the fixed reader costs for a Fire Station of 180m^2. The needed readers presented in Table 13 were calculated based on the floor plan model presented in Figure 17.

Area Name	Area (M^2)	Product Type	Additional Antennas
Fire Engine garage	113	UHF Long Range Reader (ALR-9900) 8-channel UHF Multiplexer (ISC.ANT.UMUX)	7
Repository	15	UHF Long Range Reader (ALR-9900) 8-channel UHF Multiplexer (ISC.ANT.UMUX)	1
Maintenance room	10		1
Laundry room	8		1
Changing room	34		2
Total	***180***		***12***

Table 13: RFID Reader/Antenna per area of fire station (+ model number)

[11] Fire Station floor plan of "Kazerne Venhuizen" (Source: http://112venhuizen.nl/brandweer/plattegrond-brandweer-kazerne-venhuizen.html 27-01-2010)

Based on the main type of RFID tag that will be used in the proposed RFID solution, we elected to use *long range UHF RFID readers* for the fire station. The exact models can be found in Table 13.

Fire Engine

A *fixed RFID reader*, a *multiplexer* and *antenna*'s will be needed in order to build the "Smart" fire engine. Reader antenna's will be needed for each one of the 7 main compartments of the (TS) fire engine which are: the passengers' cabin, the fire engine roof, the pump area and 2 cabinets on the left and right side of the vehicle. The reason for 1 reader with 7 antennas is because the asset management application onboard of the fire engine not only needs to know which assets are inside the compartments, but also the exact location of the assets. This way it will also be able to tell if an item is stored in the wrong compartment (to enable this functionality the fire engine compartments will need to be lined with RFID signal blocking plates).

Except for the fixed reader, a fire engine will also be required to carry at least one *handheld RFID reader* and a *mobile reader node* to be able to trace equipment deployed at an emergency scene. The information on the assets will be delivered through the already owned mobile data terminals (see §3.1) carried on board of a fire engine.

Due to the relatively small size of the compartments, the exact location of an antenna in a compartment is not that crucial, therefore we will not include a detailed image of the placement of each antenna. For an image of the fire engine compartments we refer to Figure 10.

To enable the cost calculation in the next chapter we will list actual models that seem to fit for their purpose.

- *Fixed RFID reader*
  The needed reader for building the "Smart" fire engine are opposed to the ones used for the fire station Mid Range UHF Readers (FEIG ID ISC.MRU200) as a read range of 3 meters will suffice for the fire engine compartments.
- *8-channel UHF Multiplexer* (ISC.ANT.UMUX)
- *Reader Antenna* (AN-CIRC86096)
- *Handheld RFID Reader* (FEIG ID ISC.PRHD102 HF-/UHF Handheld Reader)
- *Mobile reader node* (Motorola RD5000 Mobile Gen 2 RFID Reader)

5.1.3 RFID Middleware

General Information

In order to make the "Smart Fire Department" possible, middleware software will have to be implemented and integrated with the asset management system at the fire station and the client application on the mobile data terminals (MDT) of the fire engines. The RFID middleware applies filtering, formatting or logic to tag data captured by a reader so the data can be processed by a software application.

The asset management system will be used for managing the equipment inside the fire station and a client application with a user interface on the MDT's for when on the road.

Technical Details

The middleware needed for the proposed RFID implementation will be in charge of the following middleware functions[12];

- Data filtering & aggregation
- Information Exchange
- Integration of data across multiple sensors

The filtering and aggregations will be based on item location, time (interval), item status and the information exchange issues commands for updating item statuses, locations and such. As for the back-end application integration between the RFID middleware software and the asset management system being used by the RBRR we can say that there are two possibilities for doing this, an integration at the database level of the system or a direct partner integration to the system. As the asset management system being used by the RBRR is a relational database oriented system which runs on a Microsoft SQL server database we can already say, based on the information found in the middleware evaluation article (LEAVER 2004), that a middleware integration at the database level is a possibility and therefore a complete analysis of the system is not needed at the moment and we can already assure that the acquisition of a new asset management system will not have to be incorporated in the costs calculations of this proposed RFID solution. However, if the proposed RFID solution were to be implemented, more research should be done on a direct partner integration which would enable the possibility issuing commands directly on to the asset management system which would mean a more reliable middleware integration which is supported by the application developer and not be dependant of the database management system.
As for building the "Smart" fire engine no additional hardware is needed, just middleware software and a client side software of the asset management system with a user interface is needed to enable the functionalities given in §1.2. These applications will be running on the mobile data terminals (MDT's) on the fire trucks which are driven by a Windows XP operating system.

Conclusion

Only *Data filtering & aggregation* and *Information-exchange* middleware and is needed in order to make the overall RFID solution work. For enabling the needed functionalities of the "Smart" fire engine, a client side software of the asset management system needs to be running on the MDT's of the fire engines.

[12] RFID middleware design: addressing application requirements and RFID constraints by Flörkemeier & Lampe (2005)

5.1.4 Operational Changes

Accompanying the technical changes that the RFID implementation brings are the operational changes for the operational staff (front-office) and the back-office. From the two end-user groups the operational staff will undergo the most changes in their daily operations. The changes presented in this section are based on the process inefficiencies identified in the asset management processes analysis in §4.3.

Step	Operational Processes Change	Information Systems Change	Affects	
			Front Office	Back Office
Process A: Fire Engine replenishment process (at emergency scene)				
A1. Locate Assets	The locations of the deployed items are displayed on the MDT of the commander of the fire engine. Therefore you will always be aware of which items are deployed and what their location is. Locating the assets could be rapidly done.	The MDT's which are currently solely used for navigation and communication of crucial emergency scene information, will also be used for monitoring asset location.	X	
A2. Sort out assets	By reading the RFID tag identification of the item, no need for discussion or time consuming asset sort out process is needed.	The fireman responsible for the materials on board will have to be equipped with a portable tag reader.	X	
A5. Register	The equipment list will not have to be marked by hand. An unreplenishable item will be registered through the MDT.	Item statuses are registered through the MDT's; therefore no input terminal is needed at the back office for processing the item lists.	X	X
Process B: Vehicle completeness check process				
B1. Perform asset check	Daily vehicle completeness checks are no longer needed as the system is already aware of a missing or misplaced item. The back office does not have to process the checklists. Note: Item functionality checks should still be performed.	none	X	X
B2. Check item availability	This is automatically done by the system and it sends a purchase request to the purchasing department.	The purchasing department should receive a notification to order an item.		X

B4. Pick-up item from warehouse	The crew chief and the warehouse keeper should receive a pick-up notification for the items needed for vehicle replenishment.	none	X	X
B7. Add to maintenance list	If items were not placed on the maintenance list when replenishing the vehicle at the emergency scene, this can be done by removing the item from the vehicle and the system automatically knows an item is missing. If the item is taken to for example the maintenance room, the system will automatically update the item status. Manual administration is taken from all areas.	RFID readers should be placed in the different areas of the fire station in order to create the "smart" fire station.	X	X
Process C: Periodical maintenance & quality inspections				
C1. Locate & pickup stand-in asset	The crew chief will receive the order to pickup and location of the item. The system is always aware of the location of the items inside the fire station.	Notification through an email service or the asset management system.	X	X
C4. Update asset(s) status(us)	Asset status is updated automatically. No manual administration is needed.	none		X
C6. Return asset(s) & update asset(s) status(us)	Item statuses are automatically updated when the items are returned to the fire engine.	none	X	X
Process D: Fire resistant garment laundry				
D1. Pickup & scan garments (to be laundered)	Garments are RFID tagged, therefore they just need to be moved to the laundry pickup area and the RFID readers will pickup on their location and their statuses are updated. No more manual administrative tasks are needed.	none	X	X
D4. Check-in and replenish garment stock	RFID readers will notice the returned garments when the garments are returned to the stock area. (no more manual scanning)	none	X	X

D5. Update garments' info	Due to the "smart" RFID system, no more manual administrative tasks are needed.	none		X

Table 14: Operational process changes

5.2 Process Changes Evaluation

The changes accompanying the proposed RFID implementation will have an impact on numerous asset management processes within the fire department. A great deal of the threats that have been identified in the previous chapter will either be eliminated or reduced. Aside of the impact on the risks, the overall process durations will also be reduced due to the automation of lots of time-consuming manual labor. The process re-design will be analyzed by performing a *before and after comparison* of the previously analyzed processes.

The analysis of the impact of these changes will be done by reevaluating the process threats likelihood and inefficiencies which have been analyzed in the previous chapter. The asset management processes to be analyzed are:

A. Fire Engine replenishment (at emergency scene)
B. Vehicle completeness check
C. Periodical maintenance & quality inspections
D. Fire resistant garment laundry

5.2.1 Risk Assessment

The reevaluation of the threat ratings calculated in the previous chapter will be given in the table below. The differences accompanying the business process re-design will be analyzed comparing the before and after situation of the altered processes.

The likelihood before the process redesign is gathered through performing surveys with the operational staff of the fire department and the likelihood after has been determined as follows.

In the previous paragraph we analyzed whether the proposed RFID solution would have an effect on a specific task in an asset management process. Based on the information presented in Table 14 we evaluated in collaboration with the materials management division what the effect of the RFID installation on the asset management processes are.

In most of the situations we could eliminate the likelihood of occurrence and in some cases even eliminate the threat, the textual explanation underpins the decisions that have been taken.

The possible threats likelihood frequencies are:

A. Few times a Year
B. Few times a Month
C. Few times a Week
D. Daily
--. None

The monetary value of the risks will be calculated in the financial analysis chapter of the research.

Step	Threat	Likelihood Before	Likelihood After	Explanation
Process A: Fire Engine replenishment process (at emergency scene)				
A1. Locate Assets	T1. Items cannot be found at the emergency scene.	B	A	With RFID items are spotted more easily, but complete elimination is not guaranteed an emergency scene is still an open field.
	T2. Items missing on a fire engine are overlooked and left back.	B	--	The RFID system will provide the information via the MDT if an item is not present.
A2. Sort out assets	T3. Items get taken by the wrong fire engine.	B	A	You will not be able to take items from another fire engine. But the other fire engine still can take your assets if they leave the emergency scene first.
A3. Replenish vehicle	T4. Items are misplaced.	B	--	The RFID system will provide the information via the MDT if an item is not stored correctly.
	T5. Broken items are put back onboard.	B	B	No effect.
A4. Put equipment into the toxic, maintenance or waste container.	T6. Toxic items are put onboard before cleaning.	A	A	No effect.
A5. Register	T7. Missing items not marked.	B	--	The RFID system
	T8. Wrong findings or annotations because of human errors.	A	--	Human errors will not be possible as the systems takes care of the registrations.
Process B: Vehicle completeness check process				
B1. Perform asset check	T8 (see T8)	A	--	Human errors will not be possible as the systems takes care of the registrations.
	T9. The person performing the check can forget to check some items.	A	--	The RFID system will provide the information via the MDT if an item is not present.

	T10. Checklists can get lost in the document flow before the annotations are processed in the asset management system.	B	--	This will not be possible as the systems takes care of the registrations.
B3. Dispose asset	T11. A wrong item can be disposed of due to registration errors.	A	--	Human errors will not be possible as the systems takes care of the registrations.
B4. Pick-up item from warehouse	T12. Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	B	--	This will not be possible as the systems takes care of the registrations and items are tracked at all times within the fire station.
B5. Place order	T13. Wrong orders can be placed due to wrong annotations on the checklists.	B	--	Human errors will not be possible as the systems takes care of the registrations.
	T14. Orders can be delivered too late, which can result in an incomplete Fire Engine in case of emergency.	B	B	No effect.
B6. Replenish fire engine	T5 (see T5)	A	A	When broken items are not registered the RFID system has no effect on this threat.
B8. Update asset(s) status(us)	T15. Human errors when updating asset management system.	B	--	The "smart" systems take care of the registrations, therefore human errors are not possible
Process C: Periodical maintenance & quality inspections				
C1. Locate & pickup stand-in asset	T12 (see T12)	B	--	This will not be possible as the systems takes care of the registrations and items are tracked at all times within the fire station.
C4. Update asset(s) status(us)	T15 (see T15)	B	B	The maintenance details still have to be manually updated.
C6. Return asset(s) & update asset(s) status(us)	T15 (see T15)	B	--	This will not be possible as the systems takes care of the registrations and items are tracked at all times within the fire station.

Process D: Fire resistant garment laundry				
D1. Pickup & scan garments (to be laundered)	T16. A piece of garment can be overlooked and not be scanned.	A/B	--	This will not be possible as the systems takes care of the registrations and items are tracked at all times within the fire station.
D2. Dispose garments	T11 (see T11)	A	--	Human errors will not be possible as the systems takes care of the registrations.
D4. Check-in and replenish garment stock	T16 (see T16)	A/C	--	Human errors will not be possible as the systems takes care of the registrations.
D5. Update garments' info	T15 (see T15)	B	--	The "smart" systems take care of the registrations, therefore human errors are not possible

Table 15: Threats evaluation after RFID implementation

As no records had been kept on what items were lost, no precise calculation of the risk-impact reducing benefits is possible. Therefore in order to make the RFID solution impact more tangible we will perform a risk rating calculation based on the Risk-Level Matrix method used in an article by the National Institute Of Standards And Technology (STONEBURNER, GOGUEN & FERINGA 2002). Normally you perform this analysis for ranking the priority of risks to be mitigated, but for our research we will focus on the before and after difference (effect) after the RFID asset management system has been implemented.
By providing the risks presented in Table 9 and the likelihood of occurrence analyzed in Table 15 with a numerical value we will be able to calculate the risk-impact for the situation before and after the RFID implementation. By comparing these two situations we will be able to measure the impact of the proposed solution.
The risk-impact is calculated by multiplying the ratings assigned for threat likelihood and threat impact. The ratings that we will use will be almost the same as the ones used in the article: likelihood level is 1.0 for High, 0.5 for Medium, 0.1 for Low and impact level is 100 for High, 50 for Medium, and 10 for Low. As we have five levels of likelihood we will have to use intervals of 0.25 between 0 and 1. In the following table can be seen how we ranked the risk likelihood and impact for our research.

#	Risks	Qualitative Impact	Numerical Consequence Value (CV)
A	Not being completely equipped for an emergency call, which increases the chance for fatalities.	High	100
B	Unsafe equipment or fire resistant garment can be used, which can put fire fighters' lives in danger.	High	100
C	Higher purchasing costs.	Low	10

#	Likelihood of Occurrence	Qualitative Likelihood	Numerical Likelihood Value (LV)
--	None	None	0.00
A	Few times a Year	Low	0.25
B	Few times a Month	Medium	0.50
C	Few times a Week	High	0.75
D	Daily	Very High	1.00

Table 16: Numerical valuation for the effects calculation

In the following table will present the impact calculation for RFID solution if it was to be implemented.

General Risk #	Process Step #	Threat #	LV Before	Risk Rating Before (CV * LV)	LV After	Risk Rating After (CV * LV)	Solution Effect (RRA - RRB)
A (CV = 100)	A1	T1	0.5	50	0.25	25	-25
		T2	0.5	50	0	0	-50
	A2	T3	0.5	50	0.25	25	-25
	A5	T7	0.5	50	0	0	-50
		T8	0.25	25	0	0	-25
	B1	T8	0.25	25	0	0	-25
		T9	0.25	25	0	0	-25
		T10	0.5	50	0	0	-50
	B4	T12	0.5	50	0	0	-50
		T14	0.5	50	0.5	50	0
	B8	T15	0.5	50	0	0	-50
	C1	T12	0.5	50	0	0	-50
	C4	T15	0.5	50	0.5	50	0
	C6	T15	0.5	50	0	0	-50
	D5	T15	0.5	50	0	0	-50
				Average effect per Risk-Threats			**-35.00**
B (CV = 100)	A3	T4	0.5	50	0	0	-50
		T5	0.5	50	0.5	50	0
	A4	T6	0.25	25	0.25	25	0
	A5	T8	0.25	25	0	0	-25
	B1	T8	0.25	25	0	0	-25
		T9	0.25	25	0	0	-25
		T10	0.5	50	0	0	-50
	B3	T11	0.25	25	0	0	-25
	B6	T5	0.25	25	0.25	25	0
	B8	T15	0.5	50	0	0	-50
	C4	T15	0.5	50	0.5	50	0
	C6	T15	0.5	50	0	0	-50
	D1	T16	0.35	35	0	0	-35
	D2	T11	0.25	25	0	0	-25
	D4	T16	0.5	50	0	0	-50
	D5	T15	0.5	50	0	0	-50
				Average effect per Risk-Threats			**-28.75**

C (CV = 10)	A1	T1	0.5	5	0.25	2.5	-2.5
		T2	0.5	5	0	0	-5
	A2	T3	0.5	5	0.25	2.5	-2.5
		T8	0.25	2.5	0	0	-2.5
	B1	T8	0.25	2.5	0	0	-2.5
	B3	T11	0.25	2.5	0	0	-2.5
	B5	T13	0.5	5	0	0	-5
	B8	T15	0.5	5	0	0	-5
	C4	T15	0.5	5	0.5	5	0
	C6	T15	0.5	5	0	0	-5
	D1	T16	0.35	3.5	0	0	-3.5
	D2	T11	0.25	2.5	0	0	-2.5
	D4	T16	0.5	5	0	0	-5
	D5	T15	0.5	5	0	0	-5
				Average effect per Risk-Threats			**-3.46**

Table 17: Risk Impact Effect Calculation

#	Risk	Max Risk Rating	Before & After Impact Effect	Effect %
A	Not being completely equipped for an emergency call, which increases the chance for fatalities.	100	-35.00	-35%
B	Unsafe equipment or fire resistant garment can be used, which can put fire fighters' lives in danger.	100	-28.75	-29%
C	Higher purchasing costs.	10	-3.46	-35%
			Average effect	**-33%**

Table 18: Risk Impact Effect: before and after calculation summary

The risk impact calculation in Table 17 shows that the *risk levels*[13] are generally Low and some Medium, which means that these risks have a low urgency. From the risk impact summary presented above, Table 18, we can conclude that the RFID asset management solution can possibly reduce the risk impact and the costs accompanying these risks by an average of 33%.

Even though more detailed research (such as analyzing the risks value for each risk per asset) is needed in order to calculate the exact risk effect or monetary value, we can definitely conclude that the RFID solution has numerous safety and costs benefits.

5.2.2 Efficiency Evaluation

By comparing the duration of the processes before and after the RFID implementation the impact on efficiency can be evaluated. The improvements given in the table below will later on be used to calculate the monetary value of the efficiency gains.

For the process duration *before* the process redesign we took the mean of the information gathered by performing surveys with the operational staff of the fire department and the process durations *after* were

[13] Very high is from 76 – 100 (max consequence * max likelihood), High (51-75), Medium (26 –50) and Low 0-25 for CV=100. For CV=10 it's a tenth of the values.

calculated as elaborated in the last column of the table. Afterwards these findings were presented to the manager of the materials management department to be reviewed.

Step	Inefficiency	Duration Before	Duration After	Explanation
Process A: Fire Engine replenishment process (at emergency scene)				
A1. Locate Assets	I1: Locating items at an emergency scene after incident is hard. Especially in dark, flooded, smoked-out and full of debris environments.	3,86	3,15	As the ratio[14] between small & large fires (when multiple fire engines are needed) are approx. 85:15. Therefore the RFID implementation does not have much effect on the average time. Like the ratio, 15% is the most we can take off the duration.
	I2: A fire engine should be fully operational as quick as possible and there is not always time to perform a complete check before leaving an emergency scene.			
A2. Sort out assets	I3: Sorting items manually in unfit environments takes a lot of time and is highly sensitive to errors.	7,14	3,57	As items are identified immediately by the handheld RFID readers, the process duration can be cut in half.
A3. Replenish vehicle	I4. No time to mark the items for revision.	5,25	5,25	No effect.
A5. Register	I5: Manual checks and registration of findings take a lot of time.	1,71	0,0	The "smart" systems take care of the registrations, therefore no manual labor is needed.
	Total (in minutes)	**16,38**	**11,97**	
Process B: Vehicle completeness check process				
B1. Perform asset check	I5	33,57	15,0	Missing items are signaled immediately, therefore only the machinery (+/- 50% of all assets see Table 3) should be checked on functionality.
B2. Check item availability	I6. Manual checking in the system can be automated.	6,75	0	The "smart" systems take care of the registrations, therefore no manual labor is needed.

[14] Fire department statistics 2007 (CBS: Brandweerstatistieken 2007 - brandweerkennisnet.nl)

B4. Pick-up item from warehouse	I7. Locating an item manually can take a long time if the item location is incorrect or not available in the asset management system.	3,75	3,75	Items almost never lost at the fire station (see threats likelihood survey Table 15)
B5. Place order	I6	10	2	The "smart" systems take care of setting up the orders, the authorized personnel will only have to approve the orders. (+/- 80:20 rule[15])
B7. Add to maintenance list	I6	7,25	1,45	The "smart" systems take care of the registrations, therefore no manual labor is needed. The items just have to be brought to the maintenance room. (+/- 80:20)
	Total (in minutes)	**55,88**	**22,2**	
Process C: Periodical maintenance & quality inspections				
C1. Locate & pickup stand-in asset	I7	14,00	11,2	Items almost never lost at the fire station (see threats likelihood survey Table 15) (+/- 80:20)
C4. Update asset(s) status(us)	I5	12,50	0,0	The "smart" systems take care of the registrations, therefore no manual labor is needed.
C5. Perform & register maintenance / inspection	I5	9,75	9,75	No effect.
C6. Return asset(s) & update asset(s) status(us)	I5	8,57	1,7	The "smart" systems take care of the registrations, therefore no manual labor is needed. The items just have to be brought back to the fire station. (+/- 80:20)
	Total (in minutes)	**43,75**	**22,65**	
Process D: Fire resistant garment laundry				
D1a. Pickup garments (to be laundered)	I8. Manual scanning of each piece of garment is time consuming and can be	7,50	7,50	No effect.

[15] Pareto principle: The observation (not law) that most things in life are not distributed evenly.

D1b. Scan garments (to be laundered)	automated.	3,25	0,0	The "smart" systems take care of the registrations, therefore no manual labor is needed.
D4. Check-in and replenish garment stock	I8	7,38	1,48	The "smart" systems take care of the registrations, therefore no manual labor is needed. The items just have to be brought back to be brought into the fire station. (+/- 80:20)
D5. Update garments' info	I5	8,13	0,0	The "smart" systems take care of the registrations, therefore no manual labor is needed. The items just have to be brought back to the storage room.
	Total (in minutes)	**26,25**	**8,98**	

Table 19: Process Efficiency after RFID implementation

As for the process duration we can conclude based on the information presented in the table below, Table 20, that the RFID implementation drastically improves the total speed in which these processes are performed. An average of almost 20 minutes per process.
In the following chapter we will calculate what the monetary value of these savings will be, based on the frequency in which these tasks are carried out.

Process	**Process Duration in Minutes**		
	Before	**After**	**Difference**
A. Fire Engine replenishment process (at emergency scene)	16.38	11.97	4.41
B. Vehicle completeness check process	55.88	22.20	33.68
C. Periodical maintenance & quality inspections	43.75	22.65	21.10
D. Fire resistant garment laundry	26.25	8.98	17.27
Total	**159.29**	**65.80**	**93.49**

Table 20: Process duration before and after summary

5.3 Conclusion

After elaborating the proposed RFID asset management solution in detail and analyzing the effect of this implementation on the asset management processes. We can conclude that there are many positive results which help promote the reason for doing this research, both risks and costs reducing. Because of these respectable gains we advise to continue this research if only to calculate the costs accompanying the RFID solution. Even if the investment might not be feasible right now, at least we will know based on which factors this solution might become feasible later on.
Aside from this, the detailed information generated throughout this chapter will facilitate the financial calculations which are to be performed in the next chapter.

6 Financial Calculations

Now that we have researched the technical details of the proposed RFID implementation we will look into financial aspect of the researched asset management system, the costs and its benefits. This chapter is crucial for evaluating the viability of the RFID implementation and drawing the right conclusion.

In this chapter we will start off by calculating the implementation costs by breaking down to the investment and the other startup costs. In order to do so we will apply for many calculations the elements of costs chart presented in the article: "*Solving the RFID Cost-Benefit Equation*" by Shahram Moradpour in 2005. This article was recommended as an information source on RFID implementation costs in an IEEE eBook by the CCIP[16] group. After the investment calculations we will calculate the financial benefits of the RFID implementation by comparing the before and after costs of the yearly asset management operational costs of the RFID implementation. Then we will try to calculate the less tangible financial benefits accompanying this quality improvement investment such as the overall efficiency and safety improvements. At the end we will perform an investment analysis of the RFID solution by calculating the pay-back period and the return on investment.

The basic fire department district facts presented in the following table will be used for the financial calculations in this chapter.

District name	Fire Stations	Fire Engines (TS)	Assets (454 per TS)	Laundry Garments[17]
Waterweg	4	9	4.086	2.800
Rijnmond-Noord	6	14	6.356	4.200
Rijnmond-Oost	4	9	4.086	2.800
Rijnmond-Zuid	7	14	6.356	4.900
Zuid-Hollandse Eilanden	18	24	10.896	12.600
Total	**39**	**70**	**31.780**	**27.300**

Table 21: Basic RBRR district information

6.1 Costs

The costs calculation can be split into two kinds of costs, the *investment costs* and the *operational costs*. These two cost groups are broken down as follows:

- Investment Costs (start-up costs)
  - Hardware (Tags & Readers)
  - Software
  - RFID Solution Implementation (consulting services)
  - Additional system costs (infrastructure)
  - Personnel training

[16] "The Committee on Communications and Information Policy of The Institute of Electrical and Electronics Engineers-United States of America (IEEE-USA), and represents the considered judgment of a group of U.S. IEEE members with expertise in the subject field." IEEE-USA 2005

[17] The amount of pieces of laundry garments is a calculation based on the following 2 facts and 2 assumptions: each fire station has a crew of approximately 10 people, the garment sets consist of 2 pieces (jacket & pants), there are at least 5 sets a day per person and the garments are laundered once a week (for 7 days).

- Operational Costs
  - Additional Support Personnel
  - Supplier Support

In the remainder of this paragraph we will specify the cost components.

6.1.1 Investment Costs

Hardware

The costs of the two main components of this RFID asset management system, the tags and the readers, are meant by hardware costs. All other hardware needed for the infrastructure of this implementation will be later on addressed in the *additional system costs* section.

RFID Tags

The needed amount of RFID tags that will initially be needed for tagging the assets on the vehicles are the same as the total assets across all 70 fire engines plus a 10% margin for replacement tags (35.000 tags). The price of *UHF Passive RFID tags* (ALN-9640) are $3.000 for a bulk of 20.000 tags. The RFID tag costs for 35.000 tags at $0.15 will be $5.250. (around 15 cents apiece, $6.000/40.000).

As for the tags needed for tagging the fire fighter garment we will be needing special laundry resistance garment tags. These special passive *laundry RFID tags* (HCT-LDT-20102) cost about $0.61 per tag and we will be needing about 30.000 pieces. The total laundry-tags costs are $18,300.00.

The total RFID tag hardware costs for all fire stations will be $23,550.00 ≈ *€18,500.00* altogether (regular tags $5.250 + laundry tags $18,300).

RFID Readers

For the researched RFID solution for the fire stations, only one RFID reader type will be needed; the *UHF Long Range Reader*. Aside from the readers, also antennas and multiplexers are needed. The needed amount of RFID readers and their antennas for one fire station have been calculated and presented in §5.3.2. As this calculation was based on a two fire engine fire station and not all fire stations are alike, we will base the total needed readers and antennas on the total number of fire engines. Therefore 70 fire engines make 35 double engine stations.

In the following table we will display the cost calculation of the total needed reader hardware for the fire stations.

Item Type	Unit Price	1 Fire Station		35 Fire Stations	
		Amount	Totals	Amount	Totals
UHF Long Range Reader (ALR-9900)	$1.549,00	2	$3.098,00	70	$108.430,00
8-channel UHF Multiplexer (ISC.ANT.UMUX)	$980,00	2	$1.960,00	70	$68.600,00
Reader Antenna (AN-CIRC86096)	$159,00	12	$1.908,00	420	$66.780,00
		16	$6.966,00	560	$243.810,00

Table 22: Financial Calculation RFID Reader Hardware Fire Stations

As for the RFID reader hardware for the "Smart" fire engines the needed hardware was also calculated and presented in §5.3.2. The financial calculation of the needed hardware for the fire engines is presented in the table below.

Item Type	Unit Price	1 Fire Engine		70 Fire Engines	
		Amount	Totals	Amount	Totals
Fixed RFID reader (FEIG ID ISC.MRU200)	$1,278.50	1	$1,278.50	70	$89,495.00
8-channel UHF Multiplexer (ISC.ANT.UMUX)	$980.00	1	$980.00	70	$68,600.00
Reader Antenna (AN-CIRC86096)	$159.00	7	$1,113.00	490	$77,910.00
Handheld RFID Reader (FEIG ID ISC.PRHD102)	$990.00	1	$990,00	70	$69,300.00
Mobile reader node (Motorola RD5000)	$3,595.00	1	$3.595,00	70	$251,650.00
		11	**$7,956.50**	**770**	**$556,955.00**

Table 23: Financial Calculation RFID Reader Hardware Fire Engines

The total RFID reader hardware costs for all fire engines and fire stations will be $800,765.00 ≈ *€668,500.00* altogether (fire station $243,810 + fire engine $556,955).

The total cost of RFID hardware is €687,000.(Tags €18,500 + Readers €668,500)

Software

The software costs are the purchasing costs of the needed middleware software. "These costs range from $25,000 for a small operation to $100,000 for a large organization"[18].

According to the general classification of company sizes used by the Census bureau, the VRR can be classified as a large organization based on its number of employees (> 2.000 employees).

The software costs can therefore be budgeted at approximately $100,000 ≈ *€80.000*.

RFID Solution Implementation (consulting services)

Solution Implementation costs are all labor costs accompanying the tasks which need to be carried out in order to make the RFID asset solution completely operational. Such as middleware programming, software integration (tailoring the connection of the RFID middleware to the existing asset management software) and hardware installation & tuning.

Based on the rule of thumb on software implementation discussed in several articles including COLLINS 2004: The implementation of software can be estimated by doubling the purchasing costs of the application (1:2 ratio).

The software integration costs can therefore be budgeted at approximately *€160.000* (2 * €80.000).

To confirm the trustworthiness of this calculation we compared it to other RFID project implementation costs and found that the result lies in a possible cost range[19].

[18] The elements of costs chart presented in the article: "*Solving the RFID Cost-Benefit Equation*" MORADPOUR 2005

Additional system costs (infrastructure)

By additional system costs we mean the host computers needed for running the middleware software on and their peripherals in this section. Of the RBRR fire stations only the main fire stations of the districts already have appropriate host computers for running the asset management system. Which means that from the 39 fire stations[20], there are still 34 host computers for the fire stations to be bought. As for the fire engines, no additional system costs will have to made as the fire engines already have a mobile data terminal at their disposal.

According to the costs chart[18] and the dell.com website[21], the price of a basic host-computer is around $1.000 ≈ €750. The additional system costs for all fire stations will be *€25.500 (34 * €750)*.

Personnel training

In order to operate the RFID systems and keep them running, some training will have to be given to the personnel in charge of maintenance and technical assistance. Aside from the technical personnel also the materials managers will need some basic training in order to understand the RFID implementation and manage their divisions optimally.

The training prices were gathered from several RFID training companies[22] on the internet. The course prices were all approximately $3.500 for the more technical detailed courses and $1.000 for the manager's perspective training.

Within the RBRR there are 6 materials management functions, 1 per district. In addition to the material managers we also think it is a good idea for the manager of the IT department to also take this course as his personnel will be in charge of the technical support. Their training costs are $7.000 (7 * $1.000).

For in-house technical support, 2 employees of the IT department will be taking the general course. One employee will be in charge of the application level support and one for the hardware level support. The reason why we opted for 2 full time employees for technical support is based on the calculations made in the business case for the MDT project[23]. These employees will also be in charge of instructing the support team that is present at the fire stations. The costs for the detailed courses will also be $7.000 (2 * $3.500).

The total costs of personnel training will be around $14.000 ≈ *€11.500 (management training* $7.000 + technical support training $7.000*)*.

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[19] Closed Loop Environment RFID Implementation: "The Library Journal asked several library RFID system providers for the cost of implementing a system. The average price was $175,000 in US dollars, approximately $220,000 Canadian." http://www.slais.ubc.ca/courses/libr500/04-05-wt2/www/T_Gnissios/costs.htm

[20] Table 21(39 fire stations divided across 5 fire department districts)

[21] Dell PowerEdge T310 (€746, dell.com, viewed 01-04-2010)

[22] OTA Training - http://www.otatraining.com/schedule.html & RFID4U - http://www.rfid4u.com/services/schedule.asp

[23] Mobile Data Terminal project: "Applicatie beheer 0.5 fte uitgaande van 45 MDT's en Technisch beheer 0.5 fte". This project will be for almost double the amount of fire engines. Therefore double the staff for a comparable project.

6.1.2 Operational Costs

Additional Support Personnel

The yearly recurring support costs for this RFID solution will be for the extra full time personnel needed for technical assistance. These costs will be based on the cost calculations made for the business case[24] written for the recently implemented human resources management system of the VRR organization. The personnel costs for 1 fte application level support are approximately €60.000, therefore the total yearly costs for the additional support personnel will be around *€60.000*.

Supplier Support

Aside from additional support personnel, also yearly maintenance, support and license fees are to be paid to the implementation partner of the RFID asset management system. From the "Guidelines for cost-benefit analysis for IT projects"[25] commissioned by the Dutch Ministry of Economic Affairs, we learned that these additional support cost can be budgeted at 10% of the total project investment costs.

This makes the yearly support costs approximately € 96,400.00 (10% of € 964.000,00; Table 24,).

To have an idea on the trustworthiness of this calculation we compared these costs to the costs of a recently implemented human resources management system of the VRR organization. The 10% is practically the same as the additional support costs of this project[26].

The estimated total costs for the RFID asset management solution can be found in the following table.

Cost Type	**Complete RBRR** (Total: 39 Stations)	**1 District Pilot** (South: 7 Stations)
Investment Costs		
Hardware	€ 687.000,00	€ 124,000.00[27]
Software	€ 80.000,00	€ 80.000,00[28]
RFID Solution Implementation	€ 160.000,00	€ 95.000,00[29]
Additional system costs	€ 25.500,00	€ 4.500,00[30]
Personnel training	€ 11.500,00	€ 9.000,00[31]
	€ 964.000,00	**€ 312,500.00**
Operational Costs		
Additional Support Personnel	€ 60,000.00	€ 30,000.00
Support	€ 96,400.00	€ 31,250.00
	€ 156,400.00	**€ 61,250.00**

Table 24: Total cost calculation

[24] "Aanname Beheer: 2 FTE Functioneel beheer, salarisklasse á € 60.000" - VO Business Case Veilig Over 20090324.doc

[25] ECORYS 2007 – "Percentage kosten onderhoud van software t.o.v. investeringskosten: 10% " p.81

[26] Support project "Veilig Over": 10.3% (project investment €832.000 costs and licence/service costs €86.000) – VO Business Case Veilig Over 20090324.doc

[27] The hardware costs for the south district have been calculated as follows:
(Tags €18,500 * fire engines 14/70) + (Readers €668,500 * fire stations 7/39) ≈ € 124,000.00

[28] The software costs are fixed.

[29] Half of the costs are fixed and the rest are variable depending on the total fire stations (€80,000 + (€80,000 * (7/39))).

[30] 34 additional systems needed of which 6 are for the south district .

[31] Training costs are for the 2 technical support personnel + 2 management staff IT and materials manager (€7,000 + €2,000)

6.2 Benefits

In this section we will present the calculations of the financial benefits accompanying the advantages the RFID asset management solution brings. The advantages being analyzed are the ones stated in the beginning of this thesis in §1.2. These advantages will be grouped and divided in three of the four benefit groups: *Indirect financial benefits*, *Quantified benefits* and *Intangible benefits* (AL-KASSAB et al. 2009). As the RFID solution is primarily a quality improvement investment we do not have *Direct Financial benefits*.

1. Indirect financial benefits
   a. Lower personnel costs
   b. Lower tools & equipments expenses

2. Quantified benefits
   a. Increase of public and personnel safety

3. Intangible benefits
   a. Lower damage costs
   b. More possibilities for other investments

The financial values for these benefits will be calculated in the remainder of this section.

6.2.1 Indirect financial benefits

a. Lower personnel costs

As various business processes will be carried out quicker due to the automation of various manual labor tasks and therefore less personnel costs will need to be made in order to carry out these tasks. In order to calculate the saved personnel costs we will first have to determine what the personnel hour rate/costs are and then compare the process costs before and after the RFID implementation.

For calculating the personnel hour rate/costs we will have to make the generalization that only lower ranked firemen carryout the tasks which the RFID solution will affect. Based on the salary information received from the HR department of the VRR we know that an average fireman is in the salary group Sk. 6-7 of salary chart of the Association of Netherlands Municipalities (VNG). From this chart we can see that the average monthly gross salary of a firemen is around € 2136,- (an hour rate of €13,69). Therefore the actual costs for the employer is €17,80 an hour (30%[32] extra costs due to pension, insurance, etc).

In the table below we will specify the man hours saved by implementing the RFID asset management system. The process duration differences are based on the calculations made in Table 20. The amount of incidents a week were calculated based on the information gathered from the RBRR 2009 year report[33]. With 12.551 fires in a year in the Rotterdam-Rijnmond area plus the information that at least 20% of the incidents were major incidents where more than one fire engine had to be present brings it to a total of 15.062 incidents a year spread across 39 fire stations. The

[32] Chamber of commerce whitepaper: What are the costs of having employees?
[33] De Jaarstukken 2009 - Regionale Brandweer Rotterdam-Rijnmond (pages 3, 24 and 37)

average number of incidents a week for one fire station is approximately 7 (15.062 incidents / 52 weeks / 39 fire stations = 7,4).

Process	Duration Difference (minutes saved)	Times a week	Times a year	Time Saved (hours a year)	Costs Saved	Costs Saved (All 39 Fire Stations)
A. Fire Engine replenishment process (at emergency scene)	4,41	7,4	386	28,39	€ 505,26	€ 19.705,01
B. Vehicle completeness check process	33,68	7	364	204,33	€ 3.636,99	€ 141.842,65
C. Periodical maintenance & quality inspections	21,1	7	364	128,01	€ 2.278,52	€ 88.862,23
D. Fire resistant garment laundry	17,27	7	364	104,77	€ 1.864,93	€ 72.732,26
Total	**93,49**			**465,49**	**€ 8.285,70**	**€ 323.142,14**

Table 25: Benefits man hours saved

Because of the full-time firemen being mandatory stationed for 24 hours a day, not all man hours saved can be seen as an indirect financial benefit. Based on the ratio of full-time personnel costs to the volunteers costs, the average personnel costs of the volunteer firemen are 12% of the total personnel costs of the RBRR[33]. Which makes only about *€39,000 a year* from the total of *€323,000* saved on personnel saved for sure.

For the remaining €285,000 can be said that these costs represent the amount of free time gained by the fulltime firemen in which they can work on other fire department tasks in order to improve public and/or their own safety. These costs account for more than *300 extra hours a week* for the RBRR (€285,000 / €17,80 hour-rate personnel / 52 weeks). Because of this you would be able to say that were the fire department have other tasks they want to have carried out by the firemen that would take up at least 300 hours a week, but do not have the personnel for it; They could save about *€285,000* on these tasks if the fire department were to hire extra personnel to get have these tasks performed.

b. Lower tools & equipments expenses

With the RFID asset management solution implemented it is expected that less tools and equipments will be lost due to the tool tracking component of the system. Less assets will be left back at an emergency scene and also the possibility of theft is reduced. In this section we will calculate an estimation of the costs saved based on the asset loss difference calculation made in Table 18, we calculated that the asset loss will drop by 35%.

Due to the lack of information kept on lost assets due to careless handling or theft we will have to call upon the 80:20 rule[15] in two situations in order to calculate an estimation on the extra costs on lost assets. From an interview conducted with a materials department manager we received the information that when an asset gets lost it is almost never something of much value, therefore we

will use the Pareto principle in order to calculate the asset costs of the group of assets where something might get lost.

The total expenses[34] on replacement tools and equipments were in 2009 €779,454.24 and according to the Pareto principle 20% of all assets make up for 80% of the total asset costs, which makes €155,890.85 (20% of €779,454.24) the costs of the assets where asset loss may occur. From this amount about 20%[15] could have been replacement costs due to loss which makes the total of €31,178.17.

Based on the asset loss effect after implementing the RFID solution we can conclude that the costs saved on replacement assets will be around *€11,000* (35%[35] of €31,178.17).

6.2.2 Quantified benefits

a. Increase of public and personnel safety

The RFID asset management system will provide a higher degree of safety for the firemen and the public. Because of the asset tracking functionalities the fire engines will always be equipped with the needed tools and equipments. In the cases that a crucial piece of equipment is missing, the crew will be aware of this and therefore be able to call timely for assistance and in this way reduce the chances of having to operate in unneeded dangerous conditions which can be harmful for themselves or the public.

Although we cannot monetize these benefits we surely we surely can give a quantification of these benefits. The likelihood of occurrence value (LV) before and after the RFID implementation were calculated in §5.2 in order to be able to quantify the impact of this system. In Table 18 we can see that the effect of the RFID system on the likelihood of occurrence for the threats: "not being completely equipped for an emergency call" & "using unsafe equipment and garments" is expected to drop for at least an average of 32% *(average of 35% & 29%).*

Because of all the possible man hours (300 a year) that will be opened up see §6.2.1.a, a lot of other fire department tasks such as taking preventive measures could be carried out and this way increase public and personnel safety.

6.2.3 Intangible benefits

a. Lower damage costs

Due to the automation of a lot of manual labor in the daily business processes, more time is freed-up and can be spent on other core business activities of the fire department. An operationally better functioning fire department provides a higher quality of service and therefore lowers the costs on damages brought on by accidents.

b. More possibilities for other investments

After the implementation of the RFID system it is expected that a lot less unneeded expenses on tools, equipments and asset management will be made than other fire departments. Because of this a cost efficient reputation will be built for the RBRR and this will open up possibilities for other investments.

[34] The expenses on replacement tools and equipments were gathered from the financial information reporting tool of the VRR (MultiMart: Saldibalans - Parameters:Boekjaar: 2009, Ultimo December, Entiteit: 3 RBRR).

[35] Table 18: Risk Impact Effect: before and after calculation summary

Total Benefits

Because of the uncertainty of being able to save the full costs on personnel we split up the total benefits in two scenario's. Scenario A being the scenario where the RBRR only save the costs on the volunteer firemen en scenario B all saved personnel costs.

The estimated total costs saved due to the implementation of the RFID asset management solution can be found in the following table.

Cost Type	Complete RBRR (5 Fire Department Districts)	
	Scenario A	**Scenario B**
Indirect yearly financial benefits		
Lower personnel costs	€ 39,000	€ 323,000
Lower tools & equipments expenses	€ 11,000	€ 11,000
	€ 50,000	**€ 334,000**
Quantified yearly benefits		
Lower risk likelihood of occurrence	32%	32%
Free time for other tasks	300 hours a week	n/a

Table 26: Indirect financial and quantified benefits

6.3 Investment analysis

In this section we will analyze the costs and benefits for the proposed investment, these analysis enables the possibility of giving a conclusion on the proposed investment based on the financial details. The cost-benefit analyses will be performed by calculating the following key cost–benefit indicators for both benefit scenarios presented in the previous section.

- Pay-Back Period (P.B.)
- Return on Investment (R.O.I.)

Pay-Back Period

By calculating the pay-back period we will be able to tell if or how long it would take to regain the investment before it becomes of no economic value. From an economic life guide[36] found on the web we found that the electronics that best match the RFID hardware have an economic life of 5 years. This means that economically the RFID hardware will have no value after 5 years. Depending on the pay-back period you can consider the investment, the longer the pay-back period, the more risks the investment will involve.

	Scenario A	**Scenario B**	
Yearly Benefits	€ 50,000.00	€ 334,000.00	
Yearly Costs	€ 156,400.00	€ 156,400.00	-/-
Annual cash inflow	**-€ 106,400.00**	**€ 177,600.00**	
Investment Costs	€ 964,000.00	€ 964,000.00	
Annual cash inflow	-€ 106,400.00	€ 177,600.00	/
Pay-Back Period (years)	***-9.06***	***5.43***	

[36] 2008 Economic Life Guide (Alachua County Property Appraiser)- http://www.acpafl.org/pdf/

Unfortunately it is impossible to calculate the pay-back period as there is a negative annual cash inflow for the RFID investment in scenario A. The operational costs are much higher than the yearly benefits and the investment will therefore result in a negative pay-back period (see calculation above). This means that based solely on the financial information, this investment is not a wise one to engage in, because you never get the invested capital in return.

In contrary to scenario A, for the scenario where all financial benefits accompanying the lower personnel costs are taken into account it is possible to calculate the pay-back period on the investment. The operational costs are lower than the yearly benefits and therefore result in a pay-back period of *5.4 years* (see calculation above). As the economic life for this investment is 5 years this means that even though scenario B has a positive pay-back also this scenario will not be a wise one to engage in based solely on the financial information. On top of this, there is a lot of risks involved with a pay-back period of more than 5 years.

Return on Investment

As the yearly costs are much higher than the benefits, calculating the return on investment is useless at this point for scenario A. This will result in a negative ROI value of *-11%*, which means that the investment should be not be undertaken. You will lose 11% of your investment in the first year already.

For scenario B the return on investment will be 18% in the first year which is much better than scenario A, but not that great if it were a profit generating investment. As it is primarily a quality improvement investment this wouldn't be such a bad decision were scenario B to be true. Of course when deciding on whether to engage in this investment all other investments should be compared to each other to see which one has a higher cost-benefit ratio.

The details on both scenarios can be found in the calculation below.

	Scenario A	**Scenario B**	
Yearly Benefits	€ 50,000.00	€ 334,000.00	
Yearly Costs	€ 156,400.00	€ 156,400.00	-/-
Benefit of Investment	-€ 106,400.00	€ 177,600.00	
Investment Costs	€ 964,000.00	€ 964,000.00	/
Return on Investment (ROI)	***-0.11***	***0.18***	

6.4 Conclusion

From the calculations made in this chapter we got to know what the monetary value is of our researched RFID asset management solution, plus an indication on the feasibility of the investment.
At first when we started by calculating the hardware costs, the investment costs looked to be way too much. But after the complete investment was calculated we learned that the hardware cost component was in fact the investment costs driver, it took up almost 70% of all costs.
Due to the fact that this investment will primarily be for quality improvement we knew from the start that the monetizable benefits were not going to be enough with the investment costs being that high. Were the fire department to make use of all the freed up time for the full-time firemen, then the benefits would get to be at a level that the investment would seem less risky.
The ultimate benefits driver in this investment would have been the quantified benefits if we would have been able to monetize these. This would have made this investment seem much more lucrative. Therefore we will be recommending the financial calculation of the costs made on material damages or injuries/casualties caused by accidents due to the fire department being not fully equipped at an emergency scene as a future research. For this reason we did not go through with the casualties cost calculations we wanted to make based on the "Economic Value of Life"[37] when performing the literature study at the beginning of this research.
The bottom line on this chapter is that this investment is one to be undertaken only if the complete benefits can be realized when you solely look at the investment analysis result.
In the next chapter we will provide an answer to the main research question, review the initially proposed benefits, present a solution advice and conclusion plus provide some future research topics.

[37] §1.4.4 Quantification of Public safety: Economic Value of Life

7 Conclusion & Advice

In this final chapter we will provide an answer to the main research question, give our final conclusion and advice on the research. At the end of this chapter we will list some topics for future research that would enhance this research.

7.1 Research Answer

The main research question for this research is:

> *Will an RFID asset tracking & management system be a technically viable solution and financially sound investment for mitigating the main research problem?*

The main research question can be split-up in two sub-questions. By answering these two question we will have the answer to the main research question.

Q1. Is the use of RFID technology technically possible and logical for asset tracking and management of fire department equipment and tools?

- The RFID technology is the most likely technology for wireless asset tracking at the moment. Only the proposed setup for the fire department is not yet a common one and therefore not yet a proven solution. Part of the proposed implementation is being experimented with by a few fire departments in the US, the UK and Germany. The "smart" toolbox fire engine adaptation has not yet been experimented with to the extent that we know of.
  What we can say is that theoretically the RFID technology should work for the asset management solution researched in this thesis.

Q2. Are the increase of public safety and the decrease of asset management costs worth the investment in an asset management RFID system for the Fire Department?

- As it was not possible to give the increase on public safety a financial value we could only analyze the investment by researching the benefits on the lowered personnel and asset purchasing costs. Based on these two benefit components the financial investment can be slightly positive. Depending on the possibilities to max-out the benefits on lowering personnel costs and the fact that the investment is for quality improvement the investment can be a worthwhile one.

Based on these two answers we can say that the general answer on the main research question would be; yes. At the moment RFID technology is in theory the most likely technology for mitigating the research problem, but there still needs to be some technical issues to be tested in practice before going through with the investment, especially the "smart" fire engine adaptation.

7.2 Conclusion

We can conclude on the whole research that the RFID technology is an expensive but interesting solution to the research problem due to its technologically groundbreaking characteristics. It poses benefits such as:

- Lower asset costs: 35% asset loss[38].
- Lower personnel costs: Almost 350 man-hours[39] less needed a week at the RBRR.
- Increases public and personal safety: 35%[38] less chance of a fire engine not being fully equipped at an emergency scene and 29%[38] less chance that the firemen are using unsafe fire resistance garment.
- New opportunities due to an efficient performing fire department: More than 350 man-hours[39] a week gained for other tasks.

On top of the benefits listed above, the benefits that would have pushed this RFID asset management solution to be a must would have been the benefits on gained public safety. But as no data is kept on extra costs on material damages or injuries/casualties caused by accidents due to the fire department being not fully equipped at an emergency scene, these benefits could not have been calculated and taken into account for this investment.

7.3 Solution advice

As we do not have a guarantee that the RFID system will perform in practice as theoretically expected and the investment has a pay-back period of more than 5 years it will be a much too risky investment at the moment. The "Smart" toolbox adaptation of the fire engine should first get thoroughly tested and if the results are positive then this investment could be considered by the fire department.
The bottom line for this and each other investment should always remain the question whether the investment the one is that would return the most financial or quality benefits for a certain period per invested capital.

7.4 Future research

As future research recommendations I will list 3 topics related to this research that could enhance it.

- ***Safety costs for not being properly equipped***
  In order to calculate the research benefits more accurately, a financial calculation of the injury and the material damage costs due to not being properly equipped at an emergency scene could be performed. By allocating a financial value to this component a rough estimate could calculated based on the improvement percentage of 33% calculated in §5.2. This could really raise the priority level on this investment were there substantial positive economic values accompanying the saved lives to be added to this equation.

[38] Table 18: Risk Impact Effect: before and after calculation summary
[39] §6.2.1.a Lower personnel costs: €323,000 (total saved personnel costs) / €17,80 (personnel hour-rate)

- ***Pre-tagged assets***

  Because of the early stage in which the RFID asset management technology for the fire department is in we did not look into the possibilities of ordering pre-tagged assets from the suppliers. By making such agreements with your suppliers you could save even more labor costs on the additional asset tagging task created within the fire department.

  The reason why such agreements are a must for retail businesses is because their products come and leave their stores in bulk packing, therefore a retailer would not want the costs of unpacking each item just to tag them. But with the fire department there are much less assets in circulation and they remain in a closed loop environment.

- ***Smarter "smart" Fire Engines***

  The proposed "smart" toolbox adaptation for the fire engine could even be made smarter. The proposed RFID solution only monitors the availability of the assets and if they are placed in the right location and are proprietary to the fire engine. With this implementation you always know whether an asset is available or not, but it does not tell you anything on the physical condition of the asset. With the availability information you save lots of time reloading the fire engine at an emergency scene and doing your daily availability check rounds but still have to perform at least once a week a physical status check.

  By monitoring usage statistics the systems can be made even smarter. The system can be programmed to weigh certain assets such as jerry cans to tell when they should be refilled, log the absence duration of a piece of equipment so it can automatically signal the maintenance team for servicing based on the usage-hours calculated by logging the equipment absence at an emergency scene and such. With the addition of these enhancements more costs on routine manual checkups will be saved, and the higher service level can lead to saving even more lives.

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Appendices

Appendix 1: Checklist Fire Engine TS 22-2

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	Artikel	Leverancier	Aantal
Ingedeeld			
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Cabine/			
houders met 5 refraklemmen			2
acculaderportofoon + 3 accu's			1
Ademluchttoestel pss 100			7
bandenspanningsmeter met slang			1
Checklist inzetprocedure			1
Citoplan			1
Citoplan			1
Daklijnenset			2
drager pac 3000			1
drager pac 7000			1
drager x-am 3000			1
erickaartenboek			1
formulierenmap			1
Gelaatstukken			7
gereedschapsgordel			3
gevaarlijke stoffenkaart			1
glaspotlood			1
goodbear			2
handboek bevelvoerder			1
Handlamp streamlight			6
Lader pager			1
leardalkap + faceshield			1
Liftsleutel , voor het openen en bedienen van een brandweerlift.			2
Mobiele Telefoon			1
Mobilofoon TS 22.2			1
onderzoekhandschoenen 1 doos			20
onderzoekhandschoenen 1doos			20
Portofoon Bev RAC			1
Portofoon nr1 TS 22.2			1
Portofoon nr2 TS 22.2			1
Portofoon nr3 TS 22.2			1
Portofoon nr4 TS 22.2			1
Portofoon nr5 TS 22.2			1
Portofoon nr6 TS 22.2			1
Portofoon nr7 TS 22.2			1
redklos			1
Schijnwerper 24volt			1

vrijdag 27 maart 2009

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	*Artikel*	*Leverancier*	*Aantal*
Schijnwerper 24 volt			1
slang tbv vorstvrij zetten			1
sleutel wegneembare paaltjes			1
Streamlight met toebehoren			6
vakkaarten + straatmappen			12
verlengslang ademlucht			1
Verrekijker			1
viltstiften			3
voltstick			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Cabine/kast onder de bank/			
accuboormachine			1
Afzetlint rol			1
drager measering proke 90			1
oogdouche			1
pelikoffer			1
positioneringslijn			2
refinders			4
Veiligheidsvest			4
Werklijn 20 mtr			2
Zwemvesten secumar			7
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Cabine/sleutelkluis/			
Sleutels keso octro + pasjes			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Dak/			
schoorsteenladder			1
Schuifladder, 2 delig aluminium			1
Sloophaak 4 tands			1
Sloophaak amerikaans model			1
zuig / persslang 75mm + ontlastkraan stijgleiding			2
Zuigslang			3
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 1 links/			
Accu tbv teklite statief			1
Ademluchtcilinder			7
Bats			2
Berryhaak			1
Bijl groot			1
Bijl klein			2
boomzaag			1
Borstel + borstelplank			1
boshelmen			2
Chemicaliën handschoenen per paar			2
CO2 blusser, 5 kg.			1

vrijdag 27 maart 2009

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	*Artikel*	*Leverancier*	*Aantal*
draadschaar			1
Dreg met lijn			2
Emmer, zink 10 liter			1
Gereedschapset motorkettingzaag			1
Gereedschapset motorslijpschijf			1
Handschoenen paar, hittebestendig			1
Hosemaster			1
Kraansleutel voor ondergrondse brandkraan			1
Kunststofzemen			2
lader tbv teklite			2
Motorkettingzaag			1
motorslijpschijf			1
Oordoppen 5 paar			10
Opzetstuk			1
Poederblusser 9 kg, ABC.			1
Poederblusser, 12 kg, ABC.			1
positioneringsset in tas			2
Riek			1
Schijnwerper teklite hand			1
Schijnwerper met statief teklite			1
Schuimstraalpijp 400 l/min.			1
Slijpschijf, reserve voor metaal, voor doorslijpmachine			2
sloopbeitel 400mm			1
Straalpijp Akron			4
Straalpijp Holleman			1
Veiligheidsbril, type ruimzichtbril			5
Verloopkoppelingen 65-81mm storz			2
Verloopkoppelingen 81-89mm			2
Verzamelstuk tbv scum kanon			1
Vluchtmasker			1
Waterkanon skum oscilerend			1
Werkhandschoenen			4
Zaagbroek			2
Zaagketting			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 2 rechts/			
Afzetlint rol			1
Airbaghoes			1
Beschermhoes Holmatro			1
Beschermplaten kunststof			2
Blusdeken			1

vrijdag 27 maart 2009

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	Artikel	Leverancier	Aantal
Bomenzaag			1
Chemicaliënpak + toebehoren			2
Dekens			2
Dekzeilen			2
Deurforceerder			1
Gamtool blikopener			1
glasmaster			1
Handschoenen elektrisch			1
Keggen kunststof smal			4
Keggen kunststof breed			4
Koevoet, 1000 mm			1
Koevoet, 600 mm			1
lijkhoezen			2
putdekseltrekker			1
puttenpomp			1
Rambo			1
rubber hamer			2
Rubberlaarzen per paar			4
Trapezeblokken			4
Werklijnen			4
Wervelplank lang			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 2 rechts/HV koffer wit/			
Accukabelschaar			1
Gordelsnijder			1
onderzoekhandschoenen per paar			5
ratelspanband			1
ring-steeksleutelset 10 t/m 15			1
stanleymes			1
stofmasker			10
Zijkniptang			1
Zuignappen			3
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 2 rechts/Kleine gereedschapkoffer/			
Blikschaar			1
Bouwsleutel			1
combinatietang			1
Drevel			1
Duc tape			1
Engelse sleutel 10inch			1
Gasfles / zuurstofsleutels			2
inbussleutels			1
Kist met spijkers en schroeven			1

vrijdag 27 maart 2009

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	*Artikel*	*Leverancier*	*Aantal*
Klauwhamer			1
kruiskopschroevendraaier klein			1
kruiskopschroevendraaier groot			1
nijptang			1
Schroevendraaier groot			1
Schroevendraaier klein			1
vuisthamer			1
waterpomptang			1
Zijkniptang			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 2 rechts/Grote gereedschapkoffer/			
allleszaag			1
Avegaar			1
Engelse sleutel 15inch			1
Gevarendriehoek			1
Hakvermoor			1
handzaag (hout)			1
ijzerzaag			1
ijzerzaagblaajes			10
Koevoet, 600 mm			1
Kraansleutel voor bovengrondse brandkraan			1
Liftsleutel , voor het openen en bedienen van een brandweerlift.			1
pijpentang			1
rubber hamer			1
schrobzaag			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 3 links/			
aansteker			1
berryhaak			1
Gasfles 5 kg			1
Gasfles met brander			1
Hoge Druk Haspel 90 meter + nepiropistool			1
Kraansleutel voor ondergrondse brandkraan			1
Leegloop			1
Opzetstuk			1
slangen 75mm			8
slinger voor haspel			1
Straalpijp Akron			1
Vat met strooizout			1
Verloop 2-2'5 storzkoppeling			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 3 links/Aanvalskorf op wielen/			

vrijdag 27 maart 2009

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	Artikel	Leverancier	Aantal
Koevoet, 600 mm			1
Koppelingssleutel			2
slangen 38mm			4
Straalpijp			3
Verdeelstuk			1
Werklijn			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 4 rechts/			
berryhaak			1
Hoge Druk Haspel 90 meter + nepiropistool			1
Kraansleutel voor ondergrondse brandkraan			1
Opzetstuk			1
slangen 52mm			3
slangen 75mm			8
slinger voor haspel			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 4 rechts/Aanvalskrat groot/			
Koppelingssleutel			2
Kraansleutel voor bovengrondse brandkraan			1
slangen 38mm			2
slangophouder			1
Straalpijp			2
Verdeelstuk klein (voor inzet hoge gebouwen)			1
Vulslang kort 75mm			1
Werklijn			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Kast 4 rechts/Aanvalskrat klein/			
slangen 38mm			2
slangophouder			1
Straalpijp			1
22 Rotterdam-Frobenstraat/Uitrukhal/TS 22-2/Pompruimte/			
aanzuigslang SVM dubbele koppeling			1
aanzuigslang SVM enkele koppeling			1
AED tas			1
Bendelstuk			3
Driehoeksleutel			1
Drijver met ketting			1
Koppelingssleutel			3
Koppelingssleutel groot			2
Kraansleutel voor bovengrondse brandkraan			1
Papierhouder			1

vrijdag 27 maart 2009

Overzicht Materiaal

Korps Regio Roterdam Rijnmond-

Inhoud van TS 22-2

Alle categoriën

Telefoon:
Fax:

Omschrijving	*Artikel*	*Leverancier*	*Aantal*
pionnen			8
Slangophouder			3
Verlengstuk kraansleutel			2
Verzamelstuk			1
vulslang			1
Zadelhout			1
Zeep automaat			1
Zuigkorf			1
Zuigkorfnet metaal			1
zuigslanglijn met musketon			1

vrijdag 27 maart 2009

Appendix 2: Interviews Materials Manager RBRR

Interview District North
Datum: 06-05-2009
Locatie: Frobenstraat 8, Rotterdam
Contact: Bas Pronk

1. Organisatie MHL Noord
    1.1. MHL Noord beheert decentraal al het materiaal voor alle kazernes van district Noord?
    Nee, wel zetten ze de lijnen uit vanuit de kazerne Frobenstraat en beheren ze het materieel beheer systeem PREBEAR.

    1.2. Worden ook zaken omtrent materiaal beheer VRR-breed besproken/uitgevoerd?
    Ja, vanuit afdeling EXO (Executieve Ondersteuning).

    1.3. Onder materiaal beheer Noord vallen alle gereedschappen, apparaten, bepakkingen en voertuigen?
    Materieel: Voertuigen
    Materiaal: Van alles op de kazernes, van de gereedschappen tot stroom.

2. Bepakkinglijst brandweer voertuigen BZK
    2.1. Hoe strikt wordt deze op Noord gevolgd?
    Leidend, maar niet bepalend. (±95%)

    2.2. Zijn er eigen toevoegingen die specifiek voor een bepaald district?
    Ja, speciale apparaten en gereedschappen voor stedelijk gebied. Denk aan tram/trein schakelaars of apparaten voor hoogbouw.

    2.3. Zijn er ook aanpassingen die alleen voor een kazerne gelden?
    Ja, in principe in de basis wel hetzelfde, maar er zijn wel kazernes met enkele specialismen.
    Voorbeeld: Kazerne Frobenstraat doet de hulpverlening voor district Noord.

    2.4. Hoe verloopt het proces van een item toevoegen?
    Plan moet bij de directie in gediend te worden en mocht het goedgekeurd worden dan wordt het item toegevoegd.

    2.5. Zou er besloten kunnen worden om een item voor een kazerne/district officieel van het lijstje af te halen?
    Ja, bijvoorbeeld apparatuur voor duinbranden.

3. Materiaal management systeem

3.1. Welke systeem wordt er gebruikt?
Vroeger werd het systeem IMS gebruikt, maar deze was niet functioneel. Momenteel zit het systeem PREBEAR van AVD-ICT in de inrichtingsfase en zal in zeer korte termijn in gebruik worden genomen.

3.2. Wat voor type systeem is het?
Het is een systeem met een Access database op de achtergrond en deze zal centraal op de Frobenstraat worden beheerd.

3.3. Sinds wanneer wordt het gebruikt?
Het streven is om de komende week live te gaan.

3.4. Door wie wordt het gebruikt?
Het MHL personeel zal ervoor zorgen dat het systeem operationeel blijft en het personeel op de kazernes zal het gebruiken.

3.5. Welke gegevens zitten er in? Ja op alles.
- Productgegevens
- Aantallen
- Locatie
- Onderhoudsgegevens
- Keuringsgegevens

3.6. Wordt ieder product individueel geregistreerd? Ja

3.7. Zou ik een overzicht van de in het beheer hebbende materiaal mogen? (Als het te veel moeite wordt, misschien beperkt toegang tot het systeem mogen om zelf wat informatie op te vragen?)
Ja, een uitdraai van de checklist van een TS (tankautospuit).

4. Materiaal Beheer

4.1. Hoe verloopt het beheer hiervan?
Materiaal centraal via de Frobenstraat en materieel centraal via de afdeling EXO.

4.2. Worden er inventaris tellingen uitgevoerd?
Volledige inventaristellingen worden wekelijks door de wacht gedaan en dagelijks worden echt basis dingen gecontroleerd.

4.3. Wat voor gegevens worden er vastgelegd?
- Aanwezige aantallen of vermissingen. De aantallen.
- Wordt er ook gekeken naar de status van het materiaal? Ja
- Worden de bevindingen in een rapport verwerkt?
  M.b.v. een checklijst worden de vermissingen inzichtelijk gemaakt en worden ze direct besteld.

4.4. Hoe worden de bevindingen in het systeem verwerkt?
De bevindingen worden direct in PREBEAR door de wachtcommandant verwerkt.

4.5. Hoe gaat men om met niet meer te gebruiken materiaal?
- Wordt er voor ieder item een soort verwijderingrapport bijgehouden?
  Wanneer? Nog niet.
  Reden?
  Automatisch bijbestelt of magazijnafgifte bon?
  De wacht geeft het door aan de wachtcommandant en deze plaatst de bestelling.

4.6. Hoe gaat men om met verlies van materiaal?
- Wordt er voor ieder item een soort verliesrapport bijgehouden?
  Wanneer? Nog niet.
  Reden?
  Verantwoordelijke? Geen
  Automatisch bijbestelt of magazijnafgifte bon?
  Met een magazijn afgifte bon kunnen de goederen afgehaald worden bij de magazijnmeester.

4.7. Materiaal voorraad
- Is er een centrale voorraad voor district Noord?
  Ja, centraal voor het hele district op de Frobenstraat, maar wij willen dit liefs centraal bij de EXO voor de hele regio.

- Staat ieder item van het bepakkinglijst standaard op voorraad?
  Nee, niet alles. Een basisvoorraad van ± 80% van de bepakkinglijst.

- Is er ook een voorraad beheerder waar alle fysieke materiaalafgifte of opname langs gaat?
  Ja, dat is de magazijnmeester.
  Worden afnamen/leningen middels een goedgekeurde afname bon afgenomen?
  Ja.

- Mag iedereen een afname aanvragen?
  Nee, alleen een wachtcommandant of een postcommandant.

- Hoe komen de voorraad mutaties is het systeem te staan?
  Door wie? Door de projectleider.

4.8. Inkoop materiaal
- Hoe worden inkopen gesignaleerd?
  Door wie? Door de wachtcommandanten.
  Standaard format? Ja.
  Wanneer? Op ieder moment.

- Hoe vaak wordt er ingekocht? Dagelijks.

Centraal ingekocht?
Ja, voor district Noord bij de afdeling MHL op de Frobenstraat.

Door wie? Inkoper
Wie moet een inkoop goedkeuren? (zit er een drempel op?)
Kleine inkopen tot €300 mogen door de wachtcommandanten worden geplaatst. Inkopen tot €12.000 moeten door de postcommandant worden goedgekeurd worden. Inkopen boven de €12.000 moeten door de districtcommandant worden goedgekeurd.

- Zijn het vooraf (contractueel) afgesproken leveranciers waar bepaalde producten van worden besteld?
  Ja, het zijn vaak leveranciers met doorlopende contracten.

- Binnenkomst goederen? Gebeurd centraal.
  Worden voorraadmutaties centraal geregistreerd?
  Gelijk op de Frobenstraat door de projectleider en magazijnmeester geregistreerd.

4.9. Onderhoud en Keuringen

- Hoe vaak onderhoud?
  Er zijn verschillende onderhoudsdagen sommige per dag, maand of kwartaal.
  Worden deze expliciet getriggerd?
  Ja, nu nog m.b.v. outlook agenda, maar in de toekomst zullen de signalen van Prebear komen.

  Eigen (gecertificeerd) personeel of extern? Heel veel extern.
  Komt dit in een rapport te staan? In de toekomst in Prebear.

- Hoe vaak Keuring?
  Varieert, bijvoorbeeld de TS jaarlijks door de leverancier.
  Worden deze expliciet getriggerd? Ja.
  Eigen (gecertificeerd) personeel of extern? Beiden.
  Komt dit in een rapport te staan? In de toekomst in Prebear.

- Hoe worden de onderhoud- en keuringsdata bijgehouden?
  In de toekomst in Prebear, ook wil men met de komst van het nieuw systeem veel meer preventieve onderhoudstaken uitvoeren.

Interview District South
Martin vd Leun
Pottumstraat
Maandag 23 Maart
8:00 – 9:00

Materiaal

1. Bestaat er zoiets als een algemeen lijstje van verplichte items waarover een brandweer kazerne moet bezitten?
   Niet echt, wel bestaat er een standaard historische bepakkinglijst vanuit het BZK, maar in de binnenstad van Rotterdam hebben we met andere omstandigheden te maken dan op ander plekken, zoals hoge gebouwen, het havengebied, olierampen, etc, etc. Waar wij bijvoorbeeld niet echt op ingesteld zijn, dat zijn bosbranden, dat zal een ander veel beter op voorbereid zijn. Dus van het standaard lijst hanteren wij ongeveer 95% van in ons eigen bepakkinglijst. Aanvulling wordt bepaald aan de hand van de risico's die aanwezig zijn in het gebied.

   a. Bestaat ook een algemeen lijstje met een aantal specifieke items dat een voertuig te allen tijde bij zich moet hebben?
      Het voertuiglijst is de algemene lijst. Al het verplichte materiaal moet op het voertuig beschikbaar zijn.

2. Hoe ziet het inkoopproces van materiaal er uit? (wat voor leverancier en met welke frequentie)
   Kazerne Pottumstraat koopt centraal in voor district Zuid. (of beter gezegd, wil dit worden, men is met het proces bezig.
   Momenteel wordt de inkoop lokaal gedaan en af en toe gezamenlijk.

   Er zijn niet zoveel leveranciers op de markt, dus worden de benodigdheden bij de gene die men meestal zaken mee doet ingekocht. Voor sommige specifieke spullen, zoals adembeschermingsapparatuur / ademluchttoestel , is de leverancier al bepaald via een aanbestedingstraject.

   Sommige spullen moeten vaker dan anderen worden besteld zoals bijvoorbeeld spuitslangen minder snel opnieuw besteld moeten worden als gereedschapsgordels.

3. Hoe ziet het onderhoudsproces van het materiaal er uit? (wat voor leverancier en met welke frequentie)
   Alles moet jaarlijks onderhouden en gekeurd worden.

4. Wordt het materiaal m.b.v. een bepaald materiaal management systeem beheerd?
   Nee, alles wordt beheerd met Excel sheets. Wat wel lastig is doordat niet iedereen een excelsheet op hetzelfde manier invult. Als het maar door 1 iemand beheerd moest worden, dan zou het geen probleem zijn, maar er zijn een aantal magazijnmeesters nodig.

Er was ooit een materiaal managementsysteem IMS ingekocht, maar op district Zuid wordt het niet meer gebruikt of is het nooit geïmplementeerd. Zelf ben ik sinds kort hier manager materiaal en de weet de reden hiervoor niet precies.

a. Wat voor gegevens worden in dit systeem vastgelegd?
   De basisgegevens als serienummers en dergelijke, voorraadstatus ed.

b. Lokaal per kazerne?
   Ja, ieder beheerd zijn eigen Excel lijsten.

c. Wie zorgt voor het beheer hiervan?
   De medewerkers Materieel

5. Wordt het verlies van materiaal expliciet bijgehouden? (reden en locatie voor verlies en de verantwoordelijke)
   Er worden schade en vermissingrapporten bijgehouden d.m.v. wekelijks te inventariseren. Verder wordt niemand verantwoordelijk gehouden doordat er teveel mensen dienst draaien in een week en men niet weet wanneer iets kwijt is geraakt. Wat ook gebeurd is dat men spullen lenen en later weer terugbrengen, dit vervuilt ook de inventarisatietellingen. (In principe zouden deze uitleningen niet mogelijk moeten zijn, maar men doet het toch. Het hoort een beetje bij het cultuur van de brandweermannen. Alle generaties voor hun hebben het zo gedaan en men verandert niet zo snel.)

6. Zou ik een overzicht van de in het beheer hebbende materiaal mogen? Als het te veel moeite wordt, misschien beperkt toegang tot het systeem mogen om zelf wat informatie op te vragen?
   Ja, deze stuur ik wel per mail op.

Voertuigen

7. Wordt het algemeen beheer van de voertuigen ook door de jouw afdeling gedaan?
   Ja, de voertuigen horen ook tot het materieel.

   De voertuigen die het meest voorkomen zijn de tankautospuit (TS) en de hulpverleningsvoertuig (HV).

8. Hoe worden deze voertuigen beheerd?
   De basis onderhoudsdingen worden dagelijks gedaan, maar voor de grote onderhoudsbeurten moet de brandweerwagens gewoon naar de dealer.

Het probleem is dat de brandweer niet vrij is om een bepaald merk voertuigen standaard aan te schaffen en hierdoor hun eigen personeel tot monteur op te leiden. De reden hiervoor is dat de voertuigen middels een Europese aanbestedingstraject aangeschaft moeten worden en dus verschillende type en merk voertuigen moeten inkopen.

9. Hoe ziet het inkoopproces eruit?
   Via een Europese aanbestedingstraject de minimale eisen opgeven. (neemt 5 a 6 maanden voor in beslag)

10. Is er een bepaald systeem waarmee de voertuigen mee beheerd worden?
    Ook de voertuigen worden met Excel sheets beheerd.

    Wat is de waarde aan materieel op een tankautospuit (TS)?
    Ongeveer 50.000 euro exclusief de gereedschappen.

Appendix 3: Threat Likelihood & Process Duration Surveys

3.1 Threat Likelihood Survey

3.1.1 Survey

Vragenlijst 2: Risico Frequentie

De vragen voor dit onderzoek hebben betrekking to 4 (deel)processen, voor ieder proces heb ik een aantal vragen die bij de scenario's horen.

Proces A: Materiaal inruimen en vertrekken

Scenario:

Een brandweerploeg is klaar op een groot incident waar meerdere ploegen actief waren en zullen de gebruikte spullen moeten inruimen om het plaatsincident te kunnen verlaten.

	Hoe vaak komt het gemiddeld voor dat:	Nooit	Paar keer per jaar	Paar keer per maand	Paar keer per week	Dagelijks
1	men gebruikte spullen niet terug kunnen vinden op het plaatsincident.					
2	gebruikte spullen over het hoofd gezien worden bij het inruimen en men spullen laat liggen.					
3	gebruikte spullen van een bepaalde ploeg door een andere ploeg worden meegenomen.					
4	items per ongeluk op het verkeerde plek/kast op het voertuig worden bewaard.					
5	ontbrekende items niet geregistreerd of doorgegeven worden aan de verantwoordelijke op de kazerne.					
6	er per ongeluk de verkeerde onbrekende items doorgegeven of gemarkeerd worden op de actuele materiaallijst.					

Proces B: Materiaal controleren

Scenario:

De brandweerploeg moet op de kazerne middels een checklist hun voertuig nalopen om te controleren of al het benodigde materiaal wel op het voertuig zit en ook inzetbaar is.

	Hoe vaak komt het gemiddeld voor dat:	Nooit	Paar keer per jaar	Paar keer per maand	Paar keer per week	Dagelijks
7	men tijdens een incident er achter komt dat een bepaald item niet aan boord is.					
8	de ingevulde checklist zoek raakt (de informatie kan niet verwerkt worden).					
9	verkeerde informatie overgenomen wordt in het systeem door onduidelijke markering op de checklist.					
10	een (op voorraad) item niet teruggevonden kan worden in de voorraadkast/-ruimte.					
11	er per ongeluk de verkeerde ontbrekende items doorgegeven of gemarkeerd worden op de checklist.					
12	bestelde items te laat worden geleverd en dat een voertuig incompleet de straat op moet.					
13	de status of locatie van een item niet goed staat in het materiaal systeem / materiaaldossier (niet-digitaal).					

Proces C: Materiaal onderhouden en keuren

Scenario:

Vanuit het materiaal management systeem wordt er gesignaleerd dat een item die om een brandweervoertuig zit onderhouden of gekeurd moet worden.

	Hoe vaak komt het gemiddeld voor dat:	Nooit	Paar keer per jaar	Paar keer per maand	Paar keer per week	Dagelijks
14	een item dat onderhouden of gekeurd moet worden niet teruggevonden kan worden op het voertuig of kazerne.					
15	de keuring- of onderhoudsgegevens van een item niet goed staat in het materiaal systeem / materiaaldossier (niet-digitaal).					

Proces D: Bluskleding wassen

Scenario:

De bluskledingstukken (blusbroeken & blusjassen) moeten worden gewassen.

	Hoe vaak komt het gemiddeld voor dat:	Nooit	Paar keer per jaar	Paar keer per maand	Paar keer per week	Dagelijks
16	een blusjas of blusbroek ongeregistreerd (op beschikbaarheid) bij de wasserij is.					
17	een (beschikbaar geregistreerd) blusjas of blusbroek niet teruggevonden kan worden op de kazerne.					

3.1.2 Survey Results (4 responses)

Survey 2: Threats likelihood of occurrence		**Never**	**Few times a Year**	**Few times a Month**	**Few times a Week**	**Few times a Day**	**No Response**	**Total**
A1	Items cannot be found at the emergency scene.	1	3	0	0	0	0	4
A2	Items missing on a fire engine are overlooked and left back.	1	3	0	0	0	0	4
A3	Items get taken by the wrong fire engine.	0	4	0	0	0	0	4
A4	Items are misplaced.	1	2	1	0	0	0	4
A5	Missing items not marked.	1	3	0	0	0	0	4
A6	Wrong findings or annotations because of human errors.	3	1	0	0	0	0	4
B7	Missing items not marked.	2	2	0	0	0	0	4
B8	Checklists can get lost in the document flow before the annotations are processed in the asset management system.	4	0	0	0	0	0	4
B9	Wrong findings or annotations because of human errors.	4	0	0	0	0	0	4
B10	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	0	3	0	0	0	1	4
B11	Wrong findings or annotations because of human errors.	3	1	0	0	0	0	4
B12	Orders can be delivered too late, which can result in an incomplete Fire Engine in case of emergency.	0	4	0	0	0	0	4
B13	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	1	2	1	0	0	0	4
C14	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	2	2	0	0	0	0	4
C15	Human errors when updating asset management system.	2	2	0	0	0	0	4
D16	A piece of garment can be overlooked and not be scanned.	2	2	0	0	0	0	4
D17	Item is not found (on time) due to misplacement or incorrect item location in the asset management system.	2	1	1	0	0	0	4
	Total	**29**	**35**	**3**	**0**	**0**	**1**	**68**

3.2 Process Duration Survey

3.2.1 Survey

Vragenlijst 1: Schatting Procesduur

De vragen voor dit onderzoek hebben betrekking to 4 (deel)processen, voor ieder proces heb ik een aantal vragen die bij de scenario's horen.

Proces A: Materiaal inruimen en vertrekken

Scenario:

Een brandweerploeg is klaar op een groot incident waar meerdere ploegen actief waren en zullen de gebruikte spullen moeten inruimen om het plaatsincident te kunnen verlaten.

Vraag:

Hoeveel tijd heeft men gemiddeld nodig om alle gebruikte spullen bij een incident weer in te ruimen op een voertuig en weg te rijen?

A1	Gebruikte items op plaatsincident terugvinden.	
A2	Items sorteren (in geval dat er meerdere ploegen actief waren geweest).	
A3	Items weer op het voertuig op de juiste plek plaatsen.	
A4	Ontbrekende en onbruikbare items noteren.	
	Totaal Aantal Minuten	0

Proces B: Materiaal controleren

Scenario:

De brandweerploeg moet op de kazerne middels een checklist hun voertuig nalopen om te controleren of al het benodigde materiaal wel op het voertuig zit en ook inzetbaar is.

Vraag:

Hoeveel tijd heeft men gemiddeld nodig om een voertuig controle met checklist uit te voeren en weer een compleet voertuig te hebben?

B1	Voertuig rondgaan met de checklist	
B2	Controleren of ontbrekende of ter vervanging item op voorraad is of besteld moet worden	
B3	Benodigd item bestellen	
B4	Item uit voorraad halen en op het voertuig plaatsen	
B5	Checklist registraties in het systeem of mappen (niet digitaal) verwerken	
	Totaal Aantal Minuten	0

Proces C: Materiaal onderhouden en keuren

Scenario:

Vanuit het materiaal management systeem wordt er gesignaleerd dat een item die om een brandweervoertuig zit onderhouden of gekeurd moet worden.

Vraag:

Hoeveel tijd heeft men gemiddeld nodig om onderhoud of keuringen uit te voeren aan het materiaal?

C1	Het te onderhouden of keuren item op voertuig of op kazerne vinden.	
C2	Stand-in (tijdelijke vervangende) item vinden op de kazerne en op het voertuig plaatsen	
C3	Onderhoud of keuring uitvoeren	
C4	Gekeurde of onderhouden item terugplaatsen op het voertuig	
	Totaal Aantal Minuten	0

Proces D: Bluskleding wassen

Scenario:

De bluskledingstukken (blusbroeken & blusjassen) moeten worden gewassen.

Vraag:

Hoeveel tijd heeft men gemiddeld nodig om de bluskleding (blusbroek & blusjas) gewassen te krijgen? (m.u.v. het wassen zelf)

D1	Te wassen items klaarzetten om meegenomen te worden voor de was.	
D2	Items registreren/markeren. (zodat men op de hoogte is van welke stukken onbeschikbaar zijn)	
D3	Gewassen stukken op de kazerne ter gebruik plaatsen (wanneer ze weer terug zijn).	
D4	Registratie van de weer bruikbare stukken. (om te weten of items weer ter gebruik beschikbaar zijn en dat alles weer geretourneerd is)	
	Totaal	0

3.2.2 Survey Results (7 Responses)

Survey 1: Process Duration		R1	R2	R3	R4	R5	R6	R7	R8
A1	Locate Assets	6	2	2	6	3	6	2	20
A2	Sort out assets	10	3	3	8	6	10	10	
A3	Replenish vehicle	8	4	5	3	2	7	3	10
A5	Register items' statuses	2	1	2	2	6	1	2	2
	Totals (minutes)	26	10	12	19	11	24	17	12
B1	Perform asset check	20	30	90	45	20	30	30	60
B2	Check item availability	3	10	10	9	3	7	7	5
B5	Place order	2	4	5	4	4	5	4	2
B6	Replenish fire engine	15	10	5	14	5	15	6	0
B8	Update asset(s) status(us)	10	5	5	10	5	10	8	5
	Totals (minutes)	50	59	25	82	37	67	55	72
C1	Locate & pickup stand-in asset	2	20	30	5	15	15	20	5
C3	Locate, pickup asset & replace with stand-in	15	10	10	10	10	10	15	20
C5	Perform & register maintenance / inspection	2	5	15	5	12	5	14	20
C6	Return asset(s) & update asset(s) status(us)		20	5	10	10	5	5	5
	Totals (minutes)	19	55	60	30	47	35	54	50
D1a	Pickup garments (to be laundered)	10	10	10	5	10	5	5	5
D1b	Scan garments (to be laundered)	3	4	5	2	5	5	2	0
D4	Check-in and replenish garment stock	2	8	10	9	10	10	5	5
D5	Update garments' info	8	7	5	10	10	10	10	5
	Totals (minutes)	23	29	30	26	35	30	22	15

* The responses marked in Red were not used for the statistical calculations, these were outliers (boxplot).

Appendix 4: Fire Department Assets Characteristics

Nr.	Product Description	Material Type	RFID-chip In/Ex	Chip Size Micro / Regular	Heat resistant	Disposable	Monetary Value < 10
1	AED Kit	Plastic	In	R	Y	N	N
2	Airbag Cover	Plastic	Ex	R	Y	N	N
3	Allen keys	Metal	Ex	M	Y	N	Y
4	Anchor hook with line	Metal	Ex	R	Y	N	N
5	Anti-leak hose strap	Plastic	Ex	R	Y	N	N
6	Awnings	Plastic	Ex	R	Y	N	N
7	Barrel of defrosting salt	Metal	Ex	R	N	Y	N
8	Battery for teklite tripod	Plastic	Ex	R	N	N	N
9	Battery operated cable scissors	Plastic	In	R	Y	N	N
10	Belt cutter	Plastic	Ex	R	Y	N	N
11	Berry Hook	Metal	Ex	R	Y	N	N
12	Binocular	Plastic	In	M	Y	N	N
13	Blankets	Plastic	In	R	Y	Y	N
14	Body bags	Plastic	In	R	Y	Y	N
15	Box with nails and screws	Plastic	In	R	Y	Y	Y
16	Breathing Air Cylinder	Metal	Ex	R	Y	N	N
17	Breathing Air Unit 100 pss	Metal	Ex	R	Y	N	N
18	Brush + brush pile	Plastic	Ex	R	Y	N	N
19	Bucket (zinc 10 liters)	Metal	Ex	R	Y	N	N
20	Caution tape	Paper	In	M	Y	Y	N
21	CB Radio TS 22.2	Plastic	In	M	Y	N	N
22	Ceiling tearer	Metal	Ex	R	Y	N	N
23	Chainsaw	Plastic	In	R	Y	N	N
24	Chainsaw chain	Metal	Ex	R	Y	N	N
25	Chainsaw Trousers	Fabric	In	R	Y	N	N
26	Charger for teklite	Plastic	Ex	R	Y	N	N
27	Checklist deployment procedure	Paper	In	R	N	N	N
28	Chemical gloves (pairs)	Plastic	Ex	R	Y	N	N
29	Chemical suits + accessories	Plastic	In	R	Y	N	N
30	Chimney Ladder	Metal	Ex	R	Y	N	N
31	Cito Plan	Paper	In	R	N	N	N
32	Claw Hammer	Metal	Ex	M	Y	N	Y
33	CO2 extinguisher (5kg)	Metal	Ex	R	Y	N	N
34	Collection Unit regular and for foam gun	Metal	Ex	R	Y	N	N
35	Combination hose	Rubber	In	M	Y	N	N
36	Commander Manual	Paper	In	R	N	N	N
37	Conduct 2-2'5 STORZ coupling	Metal	Ex	M	Y	N	N
38	Construction Key	Metal	Ex	M	Y	N	N
39	Controlled Impact Rescue Tool (Rambo)	Metal	Ex	R	Y	N	N
40	Cordless drill	Plastic	In	R	Y	N	N
41	Coupling Keys regular and large (2)	Metal	Ex	R	Y	N	N
42	Crowbar 1000mm (1) and 600mm (3)	Metal	Ex	R	Y	N	N
43	Demolition Chipping 400mm	Metal	Ex	M	Y	N	N
44	Demolition hook 4 cogs & American model	Metal	Ex	M	Y	N	N
45	Door Forcer	Metal	Ex	R	Y	N	N
46	Drager measering proke 90	Plastic	Ex	M	Y	N	N
47	Drager pac 3000 & pac 7000	Plastic	Ex	M	Y	N	N

48	Drager x-am 3000	Plastic	Ex	M	Y	N	N
49	Drift	Metal	Ex	M	Y	N	N
50	Duc Tape	Paper	In	M	Y	Y	Y
51	Dust mask	Plastic	Ex	R	N	Y	N
52	Earplugs (5 pairs)	Plastic	Ex	M	Y	Y	Y
53	Elevator Key (fireman lift)	Metal	Ex	M	Y	N	N
54	ERIC chart book	Paper	In	R	N	N	N
55	Examination Gloves (2 boxes & 5 pairs)	Paper	Ex	R	N	N	N
56	Exodus	Metal	Ex	M	Y	N	N
57	Extension cable air supply	Plastic	Ex	M	Y	N	N
58	Extension valve key	Metal	Ex	M	Y	N	N
59	Extention coupling 65-81mm STORZ (2) & 81-89 mm (2)	Metal	Ex	M	Y	N	N
60	Eye cleaner	Plastic	Ex	R	N	Y	N
61	Facial Pieces	Plastic	Ex	R	Y	N	N
62	Felt-tip pens	Plastic	In	R	Y	N	N
63	Filling hose regular and short (75mm)	Rubber	Ex	R	Y	N	N
64	Fire Escape Mask	Rubber	Ex	R	Y	N	N
65	Fire extinguish blanket	Plastic	Ex	R	Y	N	N
66	Fireman profession charts + street directories	Paper	In	R	N	N	N
67	Float Rope	Plastic	Ex	R	Y	N	N
68	Float with chain	Plastic	Ex	R	Y	N	N
69	Floodlight with tripod teklite	Plastic	In	R	Y	N	N
70	Foam nozzle (400 l / min)	Metal	Ex	R	Y	N	N
71	Forms folder	Paper	In	R	N	N	N
72	Gamtool can opener	Metal	Ex	M	Y	N	N
73	Gas Cylinder (5kg)	Metal	Ex	R	Y	N	N
74	Gas Cylinder / oxygen keys	Metal	Ex	R	Y	N	N
75	Gas Cylinder with burner	Metal	Ex	R	Y	N	N
76	Glass Master	Plastic	Ex	R	Y	N	N
77	Gloves electrician	Plastic	Ex	R	Y	N	N
78	Goggles (wide vision types)	Plastic	Ex	M	Y	N	N
79	Good Bear	Fabric	In	R	N	Y	N
80	Hand Lamp stream light	Plastic	In	R	Y	N	N
81	Handheld teklite spotlight	Plastic	In	R	Y	N	N
82	Handsaw (wood)	Wood	Ex	R	Y	N	N
83	Hardcover Box (water-tight)	Plastic	In	R	Y	N	N
84	Hatchet large (1) and small (2)	Wood	Ex	R	Y	N	N
85	Hayfork	Wood	Ex	R	Y	N	N
86	Hazardous Substances Map	Paper	In	R	N	N	N
87	Heat Resistant Gloves (pair)	Plastic	In	R	Y	N	N
88	High pressure reel 90 meters + nepiro gun	Plastic	Ex	R	Y	N	N
89	Holders with 5 refra clamps	Plastic	Ex	M	Y	N	N
90	Hose (for defrosting)	Rubber	Ex	M	Y	N	N
91	Hose Master	Plastic	Ex	R	Y	N	N
92	Hose suspender	Plastic	Ex	R	Y	N	N
93	Hoses 38mm (8) & 52mm (3) & 75mm (16)	Rubber	In	M	Y	N	N
94	Iron saw	Metal	Ex	M	Y	N	N
95	Iron saw blades	Metal	Ex	M	Y	Y	N
96	Keso octro keys + cards	Metal	Ex	M	Y	N	N
97	Key for movable bollards	Metal	Ex	M	Y	N	N
98	Keyhole hacksaw	Plastic	Ex	R	Y	N	N

99	Leardal hood + faceshield	Rubber	Ex	R	Y	N	N
100	Life jackets (secumar)	Plastic	In	R	Y	N	N
101	Lighter	Plastic	Ex	M	Y	N	N
102	Manhole Key (for lifting drain covers)	Metal	Ex	M	Y	N	N
103	Mobile phone	Plastic	In	R	N	N	N
104	Motor grinding wheel	Plastic	In	R	Y	N	N
105	Multipurpose saw	Plastic	In	R	Y	N	N
106	Nozzle regular (6) and Akron (5) & Holleman (1)	Metal	Ex	M	Y	N	N
107	Pager charger	Plastic	Ex	R	N	N	N
108	Paper Holder	Plastic	Ex	R	Y	N	N
109	Pencil	Wood	Ex	M	Y	N	N
110	Phillips screwdriver big & small	Plastic	Ex	R	Y	N	Y
111	Pinchers	Metal	Ex	M	Y	N	Y
112	Pipe splitter regular & small (for deployment tall buildings)	Metal	Ex	R	Y	N	N
113	Pipe Tongs	Metal	Ex	M	Y	N	N
114	Pipe wrench	Metal	Ex	M	Y	N	Y
115	Plastic Kegs wide (4) and narrow (4)	Plastic	Ex	R	Y	N	N
116	Plastic protective planks	Plastic	Ex	R	Y	N	N
117	Plastic shammy	Plastic	In	R	N	N	N
118	Positioning line	Plastic	Ex	M	Y	N	N
119	Positioning set in bag	Plastic	In	R	Y	N	N
120	Powder extinguisher (9kg & 12kg ABC)	Metal	Ex	R	Y	N	N
121	Protective Case Holmatro	Plastic	In	R	Y	N	N
122	Pump hose SVM dual coupling	Plastic	Ex	M	Y	N	N
123	Pump hose SVM single coupling	Plastic	Ex	M	Y	N	N
124	Ratchet strap	Metal	Ex	R	Y	N	N
125	Reel crank	Metal	Ex	R	Y	N	N
126	Reflective tracer cord	Plastic	In	R	Y	N	N
127	Rooftop safety line set	Plastic	In	R	Y	N	N
128	Rope clamp	Metal	Ex	M	Y	N	N
129	Rope regular (2) and 20m (2)	Plastic	Ex	M	Y	N	N
130	Rubber Boots (pair)	Rubber	In	R	Y	N	N
131	Rubber hammer	Wood	Ex	R	Y	N	N
132	Safety Cones	Plastic	In	R	Y	N	N
133	Safety Triangle	Plastic	Ex	R	Y	N	N
134	Safety Vest	Fabric	In	R	Y	N	N
135	Screwdriver large & small	Plastic	Ex	M	Y	N	Y
136	Shovel	Wood	Ex	R	Y	N	N
137	Side nippers	Metal	Ex	M	Y	N	N
138	Slide Ladder, 2 piece aluminum	Metal	Ex	R	Y	N	N
139	Soap dispenser	Plastic	Ex	R	N	N	N
140	Socket wrench set 10 to 15	Metal	Ex	M	Y	N	N
141	Spanner (10 & 15 inch)	Metal	Ex	M	Y	N	Y
142	Spare grinding wheel for grinding wheel cutter	Metal	Ex	R	Y	N	N
143	Spinal board (long)	Plastic	Ex	R	Y	N	N
144	Spotlight (24 volts)	Plastic	In	R	Y	N	N
145	Stand pipe	Metal	Ex	R	Y	N	N
146	Stanley knife	Plastic	Ex	M	Y	N	N
147	Stream Light with accessories	Plastic	In	M	Y	N	N
148	Suction / pressure pipe 75mm & relief valve	Plastic	Ex	R	Y	N	N
149	Suction cups	Plastic	Ex	M	N	N	N
150	Suction hose regular (3) & with snap	Rubber	Ex	M	Y	N	N

	link (1)						
151	Suction strainer	Metal	Ex	M	Y	N	N
152	suction strainer net (metal)	Metal	Ex	M	Y	N	N
153	Tin Shears	Metal	Ex	M	Y	N	N
154	Tire pressure gauge with hose	Plastic	Ex	R	N	N	N
155	Tool Belt	Fabric	In	M	Y	N	N
156	Tools set chainsaw	Plastic	In	R	Y	N	N
157	Tools set grinding wheel	Plastic	In	R	Y	N	N
158	Tree Saw	Metal	Ex	M	Y	N	N
159	Triangular Key	Metal	Ex	M	Y	N	N
160	Two-handed hammer	Wood	Ex	R	Y	N	N
161	Valve Keys streetlevel (3) and underground (3)	Metal	Ex	M	Y	N	N
162	Volt Stick	Plastic	Ex	M	Y	N	N
163	Walkie-talkie (pop, 1, 2, 3, 4, 5, 6, 7)	Plastic	In	R	Y	N	N
164	Walkie-talkie batteries	Plastic	Ex	R	Y	N	N
165	Walkie-talkie charger	Plastic	Ex	R	N	N	N
166	Water cannon	Metal	Ex	M	Y	N	N
167	Well Pump	Plastic	Ex	R	Y	N	N
168	Wimble	Metal	Ex	M	Y	N	N
169	Wire cutter	Rubber	Ex	M	Y	N	N
170	Wood saddle	Wood	Ex	R	Y	N	N
171	Woods helmets	Plastic	In	R	Y	N	N
172	Work gloves (pairs)	Plastic	In	R	Y	N	N