# Implementing track & trace technology in a medical environment

*A business case focused Medisch Spectrum Twente*

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# Abstract

The primary purpose of this study is to determine whether or not the Medisch Spectrum Twente can benefit from implementation of track & trace technology. The project was designed to research the effects this technology has on the activities within the hospital. Various technologies were looked into and tested against the limitations that a hospital carries. Data for this study was obtained by determining the current situation and identifying various tasks that could benefit from the technology. A cost analysis was made based on the cooperation from Van Straaten Medical and Tracqtion, companies that offer various solutions. A cost-benefit analysis was produced to estimate how much the MST can benefit from implementing track & trace technology. On the basis of the results, it is not recommended to apply the technology under the current conditions, but does suggest a further look into unresearched benefits.

# 1. Preface

The Medisch Spectrum Twente (henceforth: MST) has undergone a complete makeover in the last few years. For a long time, the heart of the hospital was located at the Ariënsplein and the Haaksbergerstraat in Enschede (the Netherlands) but in 2012, a new construction project was started at the Koningsplein, within throwing distance of the building at the Haaksbergerstraat. This project was started to regain the reputation of the MST being one of the largest and most outstanding non-academical hospitals of the Netherlands.

## 1.1 History

In 1995, the MST originated after a merger between Ziekenzorg, the St. Joseph Stadsmaten, the St. Bernardus hospital, the St. Anonius hospital and the Heil Der Kranken. The real origin however dates back to the 19$^{th}$ century. Back then, Enschede did not have the proper provisions and resources to accommodate and treat sick people. The only available option was to be treated by the Zusters Franciscanessen, who were located in the north of Deurningen and visited people at home. In order to meet the demand of healthcare, a number of nurses were permanently moved to Enschede and were given an outpost in the old presbytery of the St. Jacobus church, cutting down travel times to patients. It wouldn't be for another 25 years, at the eve of the first world war, until they established their first real hospital, the St. Joseph hospital. This hospital was renamed to the St. Joseph Stadsmaten at the end of the 1960s.

In 1892, in the same time period as the start of the Zusters Franciscanessen, a different organization called the Vereniging Ziekenzorg was founded. In their first years, they were only able to visit patients at home due to a lack of financial resources, but a financial donation in 1895 allowed them to build a small medical facility that was completed two years later. Despite various expansions in 1902, 1904 and 1914, the facility was never able to meet demands. Eventually, a new hospital called Ziekenzorg was built and opened its doors in 1941, but even then they weren't able to accommodate all their patients. At the end of the 1960s, it was decided that the hospital had to move to a new location in order to expand.

In cooperation with the government of Enschede, Ziekenzorg eventually decided that the new construction had to be built at the site of the Scholtencomplex, an old building that was deemed unnecessary after the Twentse textile industry collapsed. The building was planned for destruction in 1977, and the new Ziekenzorg hospital was to open four years later.

In 1988, the Stadsmaten and Ziekenzorg decided to merge their powers, with the goal to give each location their own core tasks. In order to connect the two buildings, a 275 meter long roofed bridge would be built between the two locations, a project that would cost around six million guilders. Partnerships were also created with the St. Bernardus hospital in Losser, the St. Antonius hospital in Haaksbergen and the Heil Der Kranken in Oldenzaal. A merger between all these hospitals would be finalized in 1995.

In 2012, it was decided that in order to modernize the facilities, a completely new hospital would have to be built. The construction site would be immediately next to the old Ziekenzorg building at the Haaksbergerstraat, in the Enschede city center. This hospital would see its first patients at the end of 2016. With around 3100 employees (including 220 medical specialists), the MST is currently the largest employer in Enschede. The hospital deals with 57.000 hospitalizations annually, of which 33.000 last multiple days, adding up to a total of around 200.000 hospitalization days. With 660 available beds, the MST belongs in the top 20 largest hospitals in the Netherlands.

## 1.2 Financial situation

Still, the financial situation of the MST is bleak. Despite the fact that the new construction was kept within the estimated budget, it has placed a heavy burden on the financial status of the MST. The hospital posted a net results of -€17.1 million over 2016, down from a net profit of €3.3 million in 2015, €7.3 million in 2014 and €13.7 million in 2013. This marked the first time that the MST posted negative net result since the merger. Revenue dropped from  €433.5 million in 2015 to €418.7 million, a decrease of 3.5%, while the overall costs slightly increased (MST Jaarverslag, 2016).

Early 2017, a cost-reduction package was presented that is supposed to structurally cut around €30 million worth of costs within the next two years. This includes not extending temporary contracts and shutting down the specialized medium care department (and moving it to intensive care). This package originally included the forced resignation of 300 employees, both on a managerial level and on the work floor, but was managed to be brought down to 155 forced layoffs (Tubantia, 2017). This marked the first time in its history that the MST had to forcefully lay off employees.

This can all be traced back to the financial numbers. In the appendix, we see the current financial balance sheet (Appendix A), income statement (Appendix A) and the ratios (Appendix A) of the MST. In there, we see that while revenue has risen €69 million (around an 18% increase), the total costs have increased with €71.2 million, a gain of 20.4% and one that is expected to rise even further in the coming years, after completely moving into the new hospital.

Even compared to other hospitals, the MST jumps out in a negative way. In the annual hospital report by accountancy BDO, the MST is ranked 55th among 68 qualifying hospitals (BDO Benchmark Hospitals, 2016) and is one of four large hospitals with an unsatisfactory rating. Especially the DSCR (Debt Service Coverage ratio, which calculates whether there is a sufficient stream of cash generated to fulfill their regular payments and interest of out-standing loans) and solvability were judged as far below par.

One of the issues the MST faces is that hospitals do not operate as regular businesses. They cannot create their own supply and demand, but mostly rely on patients in the region to take care of. They cannot raise demand by lowering prices or put out advertisements to lure in customers. The MST has a large care coverage area of around 263.000 people, and has a good reach within that area (see figure 4).

The answer for the current financial problems will have the be sought on the other side of the balance sheet: cutting back costs. The MST has already started that process by cutting back the amount of people they employ, but another solution can be found by making them work more efficiently. For instance, time otherwise wasted looking for equipment or walking inefficient routes could be allocated elsewhere to cut back the time it takes for certain procedures to be finished.

One way that could achieve that is by implementing track & trace technology. Through determining the position of an object, one can track down an object and even see how this object has been moved throughout a certain area. On top of that, tags could potentially contain additional information, such as the date it last had maintenance, or which department it is allocated to.

# 2. Problem statement

The financial issues at the MST are pretty clear. They are looking for ways to save costs without harming the quality of their care or damaging their reputation. They are also trying to avoid having to fire employees, something that has been avoided at least until the time this is published. However, this does mean that they will likely have to invest money in order to earn it back through lowered costs, and preferably without too much risk.

## 2.1 Objectives

The MST wants to find out whether track and trace technology can contribute to their cause. They think using the technology can save costs, increase work efficiency and improve the quality of both labor and their healthcare. With the technology, the MST hopes to achieve that:

- Employees can work more efficiently, saving time in the process
- Cut back on new investments in equipment that is already in-house
- Cut back waste of perishable products, such as blood and plasma

In order for the investment to be considered a success, it has to hit on the previously mentioned targets, and has to be earned back within at most three years.

## 2.2 Research questions

In order to find answer to the MST's problem, we need clearly defined research questions. We're trying to discover how the hospital can benefit from using T&T technology, by potentially cutting costs and saving time, both elements of work efficiency. So, we're trying to look for the answer to the following question:

- How can track & trace technology be used to increase work efficiency at the MST?

To answer this question, it has to be divided into separate parts. These will be defined as followed:

- How does track & trace technology work, and which options exist?
- Which qualitative demands will have to be met and which limitations occur?
- Which different benefits could the MST gain from using this technology?
- Which targets have to be met in order to benefit from the technology?

After finding the answers to these questions, there should be enough information to answer the main question, and to find out whether the MST would truly benefit from taking the step towards using T&T technology.

As a part of supporting a follow-up study, an attempt will be made to research which adaptations will have to be made to adopt the technology in other hospitals. While the results from this thesis will be aimed at the specific situation of the MST, it could also feature as a blueprint for other hospitals to consider using the technology.

# 3. Tracing back the history of track & trace technology

While there are two distinctive types of track & trace technologies, active and passive, both of them have roots in the military (Yunck et al., 1999). In World War II, all major sides used radar to identify airplanes, but they had no way to identify whether approaching plane was friendly or hostile. During the war, the Germans discovered that if pilot barrel rolled their planes as they returned to base, it would change the radio signal they reflected back (Rieback et al., 2006). This method alerted the radar crew on the ground that an incoming place was German and not one of the allied forces. Essentially, this was the first type of passive RFID application, a method that is used for passive track & trace systems. As a response, the British developed an active 'identify friend or foe' (IFF) system, which actively transmitted a signal back to the ground once it received signals so that it could be identified as a friendly plane (Bowden, 1985).

While very crude, these two applications signify the difference between passive and active RFID. In the method the Germans used, this is considered passive radio frequency identification (henceforth: RFID) because there was no signal coming from the plane itself, it only relied on reflecting the signal from the ground, acting as a communication beacon. The British on the other hand did have an transmission system which communicated with the beacon onto the ground, meaning it functions as active RFID.

## 3.1 Passive systems

Passive RFID found its first commercial use in the 1960s. Companies began using the technology as anti-theft systems that used radio waves to determine whether an item had been paid for (Roberts, 2006). They used small 1-bit tags that were "on" when an item was in the store, and turned off once the item had been paid for. This system is still used in packaging to this day. Further developments to this technology included giving the tags more data to identify different information, such as valid identity numbers and various levels of security clearance. Over time, the radio frequency at which the tags operated increased from 125 KHz (LF: low frequency) to 960 MHz (UHF: ultra-high frequency) in order to extend the distance at which the tags can be read. Medium range UHF tags can be read from an average distance of about 5-6 meters, long range tags can be reached almost up to 12 meters (Catarinucci et al., 2012).

Today, systems based on radio frequencies are by far the most used passive track & trace systems. Generally speaking, these systems are made up out of three main parts – an RFID reader / interrogator, an RFID antenna and RFID tags. Tags with this technology don't have their own power source, but rely on signal from a reader to be activated once the tag is within the read zone. This signal activates the internal antenna of the tag, drawing energy in from the RF waves. This energy powers the chip inside the tag, causing it to send a signal back to the RF system. This phenomenon is called backscatter and is detected by the reader, interpreting the information (De Vita & Iannaccone, 2005). Appendix D shows how the modern day technology is designed (Zegelin, 2003).

Figure A: An example of a passive tag (the black dot) fit for medical environments

The main advantages passive tags offer is that they are small and cheap, and they technically have an infinite lifetime as they do not require a battery. Wear and tear is still an issue however. The major disadvantage is that these tags do not communicate on demand with a reader, so a network can only detect where an object has been, but not where it currently is.

## 3.2 Active systems

Unlike passive RFID, active RFID tags have transformed into two functionalities. They can be used as either transponders, which sends out a response once a reader signals them, or beacons, which transmit specific information at a predetermined interval. Over time, active RFID has often been combined with other technologies in order to improve its accuracy. In 1998, the term “real-time locating system” was created to describe systems that did not use radio frequencies as their main source of localization. Appendix E shows the virtual model of the technology behind active tags (Zegelin, 2003).

Different methods have delivered accuracy on various scales, from using localizing at a room-level to an earth-level. Common protocols, and the ranges at which they are generally most effective, are:

- Bluetooth (Room-level)
- Infrared (Room-level)
- WIFI (Building-level)
- Satellites (Street level)
- Lora / Sigfox (City-level)
- GSM (world-level)

Tracking by using bluetooth technology is a relatively new method. By transmitting Bluetooth Low Energy (BLE) radio waves, beacons communicate with transmitters to determine the location. The beacons have a short range (around 10 meters), but can be placed near each other to get a good coverage.

Infrared transmitters directly communicate with high-placed sensors. These sensors are connected to a WIFI network and show the location of a device. These sensors can only show that there is a connection with a transmitter, but it cannot recognize direction of motion and is easily disconnected if there is an object in line between the transmitter and the sensor. Sensors are generally placed in such a fashion that there should be a clear path between them and the transmittors

WIFI tracking uses WIFI-hotspots or access points to track the location of a device. It uses triangulation (Appendix F) between three access points to receive the localization data. This is not accurate enough to serve a role in large outside areas, but can be accurate up to 40 centimeters when used with indoor tracking (Kotaru et al. 2015) if sufficient nodes are used. Unlike most techniques, WIFI is not affected by outside weather conditions or walls. It does require complete WIFI coverage and a stable network connection.


Figure B: WiFi tags cleared for medical environments

Tracking by using satellites is the most widely used technique for tacking locations worldwide. The receiver must be connected to at least three satellites to gather accurate information. GPS (global positioning system) is the best known example of technology and uses 32 satellites. Alternatives are available in the Russian GLONASS (29 satellites), and the Chinese Beidou, which is fixated on the area surrounding China and Japan. Other variations are still under development including Galileo, a project by the European Union that is set to be publicly available in 2020. While improvements are being made, satellites are still susceptible to weather conditions and offer poor indoor performance, offering a accuracy range of over 20 meters (Van Diggelen & Abraham, 2001; Zandbergen & Barbaeau, 2011).

LoRaWAN (Long Range Wide Area Network) and Sigfox are other techniques that have just entered the market and are still developing. They feature low power, wide area networks connected by transmission towers. This technology makes it possible to connect millions of devices using  with each other to create an Internet of Things, and offers both national and private coverage. It allows communication over a long distance while still only using a small amount of data. They can even be used to transmit simple commands to an object. It's accuracy is not great, as it can be accurate up to around 11 meters (Henriksson, 2016) in real world applications.

Lastly, GSM uses cellphone towers to track the location of devices. It is a very fast mode of tracking and it does not require any additional information. However, its accuracy is poor as it has an accuracy range of 20-40 meters at best (LaMarca et al., 2005).

## 3.3 Limitations, demands and preferences

In order to consider using specific technologies, the MST has its own limitations and demands that have to be met. Because it is a hospital, strict rules and restrictions are set up, many of which are non-negotiable.

Most importantly, the technology is not allowed to interfere with the equipment, both to machines which they are attached to and other machines in the hospital. These regulations are set up by the European Union and follow the standards set up by the World Health Organization (WHO, 2006). These regulations were put into place to guarantee safe use of equipment (Sergeant et al, 2004). The international standard for RF immunity of medical devices is the International Electrotechnical Commission (IEC) Standard 601-1-2. This standard allows a minimum immunity level of 3 volts per meter.  If these limits are surpassed, dangerous situations could occur that could potentially harm both the medical specialists and their patients.

Secondly, the tags are not allowed to be invasive. This means that the tags are no allowed to alter the shape of the equipment they are attached to. For this reason, the tags have to be small and be able to be connected to objects in various ways. The tags should also be attachable without risking infections. Given the sterile nature of the medical environment, the tags are not allowed to be attached through the use of glue or tape, as these adhesives are susceptible to collecting dust and other germ-infested materials.

As for technical specifications, the tags must be accurate enough to at least be localized within a room, preferably even more accurate. If the tags are not able to give that level of accuracy, they will be deemed unusable. Tags should also be able to communicate with the network / beacons if there is something blocking the connection and should be have a high level of stability.

On top of that, the MST has a couple of preferences of their own. For example, they prefer that the technology uses the current technological infrastructure, instead of having to add new means of technologies. This saves time, money and the necessity of new safety protocol tests.

Also, the tags are preferred to be mostly free from maintenance. If they aren't, this would render equipment temporarily inactive more often (due to maintenance checks) and thus could nullify the potential gain of  needing less equipment

## 3.4 Remaining technological options

Given the limitations set by the MST, a number of technological options will not be pursued.

- Both GSM and satellite/GPS-based technologies will not be researched, because they are not accurate enough to locate tags within a single room. Satellite-based technology also struggles with indoor locations, making it an unfit option for the MST.
- LoRaWAN / Sigfox both offer interesting opportunities for in the future as communication protocols, but they are not accurate enough either in their current form. To fully utilize these resources, the MST would also have to adjust their current infrastructure to set up a private and secured Internet of Things.
- Infrared networks will also not be researched. Active tags are supposed to be connected with sensors the entire time to make them worth their while. Due to the fact that the tags are not allowed to be invasive in the shape of equipment, it cannot be guaranteed that these tags can be attached in a position that offer a clear connection with the sensors, causing a potentially unstable connection.
- Finally, Bluetooth networks will not be researched. Given the MST's preference of not adding new technological infrastructures to their hospital, there are no perceived benefits over WiFi tracking to warrant ignoring this preference, given their relatively short range.

For these reasons, two remaining options will be looked into. Passive RFID offers a basic option of track & trace and still complies with all the MST's demands. The tags do not send out their position unless it passes a beacon, ensuring it doesn't interfere with the medical equipment's own electromagnetic field. The tags do not need a clear path to find a connection with beacons, so they can be attached in any way and still register a signal. Assuming the MST designs their building in such a fashion that there are beacons dividing every room (Appendix G), the technology is accurate enough to differentiate between those rooms. They also don't require any maintenance once they're attached and installed. The downside is that the tags cannot be tracked live, they are only registered once they pass a beacon.

The other remaining technology to be researched is WiFi. Extensive research has not found that WiFi signals interfere with the electromagnetic field of medical equipment, although a reverse relation has been found with active CAT and MRI scanners (Wang et al., 2011). This might require additional preparational work. The tags are larger than RFID tags, but can connect with the MST's WIFI network without needing a clear path, so they are able to be attached in non-invasive fashion. Although it requires a good design, WiFi technology can be accurate up to 40 centimeters under perfect circumstances, making it more than accurate enough under the MST's demands. It also utilizes their current WIFI network, although additional beacons will have to be positioned to meet a sufficient accuracy level, increasing costs of infrastructure. They do require maintenance in the fact that their batteries run out in 2 to 3 years, which is a potential drawback.

## 3.5 Scope

Because of the limited time and resources available, this research will focus mainly on determining the current situation regarding searching times and the expected costs and benefits regarding implementation of the technology. In order to find the results of the other factors, further research must be carried out.

## 4. Implementation

The MST wants to find out if it could benefit from implementing track & trace technology into its organization. There are various levels of integration the MST could decide on.

- They can attach track & trace tags onto their equipment, in order to decide where a specific piece currently is or has been. These tags communicate their location with beacons, that are connected with the facility management software. Through the use of either terminals or mobile applications, everyone can see where either a specific piece of equipment is located, or show where the closest of that type of equipment currently is. The tags feature the data of that specific piece, and can be requested in the management tool.
- There are various options the hospital could opt for in the above situations. There are tags that only communicate with a beacon after they pass one (passive tags) and those who communicate their position at a fixed rate (active tags). The MST can also choose various levels of implementation when it comes to their equipment. It can decide on whatever products groups (beds, oxygen pumps, lifters and many other options) it wants tagged, and combining the passive and active tags is possible as well.
- The hospital can decide to tag disposable products. Disposables are products that aren't any type of equipment or instrument, but can only be used once. This can vary from bags filled with blood, to artificial bones, to simple inventory items. These items are checked in once they come into the hospital and put into storage until they are used, at which point they're checked out of the system. This would clear the tags and prepare them to be re-used. A management tool keeps track of how much stock is available and features information like a product's expiration date.

In theory, there multiple ways how the MST could benefit from implementing T&T technology into their organization structure, depending on how far they want to integrate it.

### Benefits of passive tags:

If the MST chooses the passive tags option, the first three mentioned benefits could apply.

- It can cut back their staff's searching times when looking for the right pieces of equipment

Searching times could be decreased because staff wouldn't have to look for equipment that may or may not be nearby anymore.
The management tool shows where items of the requested category have last communicated their position by passing a beacon. However, a downside is that it can't show whether an item is currently being used or not. Employees might be required to check multiple locations in order to find an inactive one, so cutting back times can be limited.

- It can cut back on new investments in equipment that is already in-house

Implementing technology could also lead to a reduction of in-house equipment. After integration of the technology, equipment will go "off the grid" less often because their current status can always be checked. Because equipment is allocated to a certain department, they won't move between departments as often, leading to fewer shortages at a location. And because searching times should be decreased, you can get away with less equipment and still reach the efficiency target. Requiring less equipment can mean that the MST might not have to invest in new machinery, and maintenance cycles will be shorter and feature smaller batches (saving costs).

- It can improve the overall preparation level before an operation or hospitalization

Because T&T technology can tell employees what is located inside a certain room, it can also tell you what isn't. The MST can enter pre-sets into their management tool with a list of things that should be inside an operation room for a certain procedure. This list can function as an automated checklist that tells you what is missing, improving the overall level of preparation. In an industry where every minute can matter, this is a valuable attribute on top of the possibility of being more efficient.

- It can improve the overall maintenance level

Tags can also improve the level of maintenance equipment will get. In general, the MST estimates that around 5% of their equipment (numbers change depending on the product group) misses their periodic maintenance check because they can't be found or identified. Around half of these will still be missing during the next maintenance cycle, causing their status to be changed to inactive, at which point that machinery is taken out of the maintenance cycle. Apart from re-locating these products and being able to active them again during the installation of the tags, T&T technology also makes it easier to find these items and perform the maintenance they require.

## Benefits of active tags

In case the MST would opt for an option with WiFi tags, it will benefit from a couple more advantages.

- Improved accuracy

Contrary to passive tags, active tags communicate their position at any time, theoretically making it more accurate than passive tags. This increases their effectiveness over passive tags at both cutting down on searching times and collecting machinery during maintenance cycles

- It helps detect whether a device is being used

On top of that, there is an ability to see whether a used is being used or not in some situations, removing the necessity of checking multiple devices. This can be achieved by checking how long a device has been idle, and in some cases these tags can be connected to battery levels of certain devices, reading their output.

- It could improve the various transportation routes in the hospital

These tags can also accurately track what route equipment has traveled before it arrives at its destination. Among equipment that is often exchanged between departments, this could lead to very inactive usage of time and effort. By tracking these routes, it might be possible to discover that certain depots are better off being moved or shared by different departments.

**A hybrid form**

In order to save costs, the MST could also choose for a hybrid form of the technology, meaning it combines both passive and active tags. This implies that larger or more expensive devices are fitted with WiFi tags, while smaller or less important pieces are fitted with passive tags.

**Disposables**

Lastly, there are the opportunities for disposable products. Disposables are different from regular equipment in a tracking sense, because they are usually stored at a central location. However, tags can offer valuable information that can create other advantages. For instance, tags can be linked to the inventory network, and even automatically create a new order once the stock level has dropped below the safety level, as determined by the hospital. They also hold data such as check-in date and expiration dates, making it easier for employees to pick up older products first, which could reduce wasting valuable products like blood or plasma.

# 5. Theoretical framework

To build a solid business case, a theoretical framework has to function as a foundation on which the research can be built. This framework consists of concepts and existing theories out of current literature and functions as the incentive that drives the research. This research will identify the different stakeholders that are relevant to the project, lays out ground rules within the tests to ensure relevant results and details various factors that should be taken into account when describing the relationship between the technology and the output.

## 5.1 Stakeholder analysis

In order to find out what the effect of this technology could be, we have to identify different parties that would be involved in the project, what influence they have and which impact this would have on them. These different personnel groups are called “stakeholders”. There are various definitions of what a stakeholder actually envelops. A common starting point for this is the one business philosopher R. Edward Freeman proposed in his book Strategic Management: A Stakeholder Approach (1984). With this book, Freeman laid out the ground rules for a stakeholder analysis. His definition of a stakeholder was as follows:

> *“'A stakeholder in an organization is (by definition) any group or individual who can affect or is affected by the achievement of the organization's objectives' (Freeman, 1984, p.46).”*

While this touches various bases, this is still a very broad definition because theoretically, everyone can be affected by this research. For example, someone reading about the implementation of new technology in a paper is indirectly influenced by that achievement, but is in no way connected to the technology itself and as such, is no direct stakeholder.
Other authors have tried to build on top of this definition by adding a layer of legitimacy. Donaldson & Preston (1995) defined stakeholders as “persons or groups with legitimate interests in procedural and/or substantive aspects of corporate activity”, which limits the grounds at which someone could be called a stakeholder, but doesn’t classify them. For this reason, this research will add the broadly accepted classification proposed by Mitchell et al. (1997), which attempted to classify a stakeholder’s claim by the influence it has on a project, the legitimacy of their claim and urgency of that claim. By using this classification, stakeholders can not only be identified, but also be given different levels of importance within the research. This helps in prioritizing certain stakeholder groups over others.

By using the definition Mitchell et al. (1997) proposed, we can analyze in what way these stakeholders have an effect on this project, and identify the key stakeholders. Each stakeholder will be judged by the power they have over the project, the legitimacy of their relation and the urgency of their involvement.

Power is defined as the extent to which a party can impose their will over a project, either by physical (in this case, by neglecting the technology), utilitarian (material or financial) or normative means (Etzioni, 1964). A stakeholder is considered to have a high power if their actions alone can shut down a project and medium if they can indirectly influence the success of a project.

The definition of legitimacy is taken from Suchman (1995, p.574) who defines legitimacy as 'a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions'. A stakeholder is considered to have a high legitimacy if the technology directly influences their every day actions and medium if they will come across the use of the technology on an irregular basis.

Urgency is defined as 'the degree to which stakeholder claims call for immediate attention'. The ‘degree’ depends not just on time- sensitivity, but also on how ‘critical’ the relationship is with stakeholder or the importance of their claim (Mitchell et. al, 1997, p.867). A stakeholder is considered to have a high urgency if they should be involved from the beginning of the project, and medium if they should be involved at some point during the implementation.

Important stakeholders are those that have a high ranking on multiple attributes. Mitchel et al (1997) identifies seven different types of stakeholder based on these three attributes. Stakeholder who only rank high on one attribute are considered “latent” stakeholder and do not require much attention. Stakeholders who rank high on two attributes are considered “expectant” stakeholders and do require engagement, although with a lower priority than definitive stakeholders, who rank high on all three attributes.

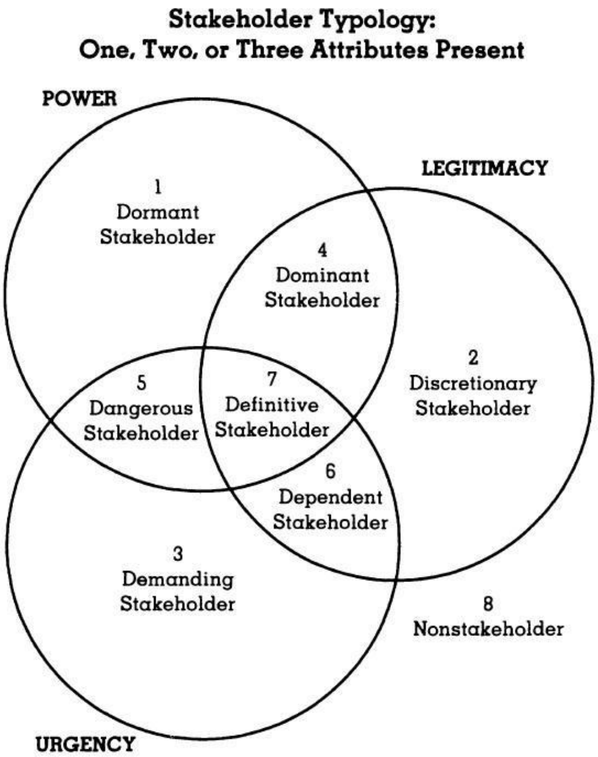


**Figure C**: a visualization of the various types of stakeholders (Mitchell et al, 1997)

Latent stakeholders are groups that generally do not need to be addressed or involved. These include:

- Dormant Stakeholders. This group possesses power to impose their will through coercive, utilitarian or symbolic means, but have little or no interaction / involvement as they lack legitimacy or urgency. An example for this can be media involvement.
- Discretionary Stakeholders, likely to be recipients of corporate philanthropy. No pressure on managers to engage with this group, but they may choose to do so. Examples are beneficiaries of charity.
- Demanding Stakeholders, those with urgent claims, but no legitimacy or power. Irritants for management, but not worth considering. Examples are people with unjustified grudges, serial complainers or low return customers.

Expectant stakeholders do require involvement into the project, often in the form of periodical updates. These include:

- Dominant stakeholders are generally those who oversee an organization or project. They likely require a formal mechanism in place acknowledging the relationship with a project. An example of this group is a board of directors or other management department.
- Dangerous stakeholders, groups with powerful and urgent claims will be coercive and possibly violent, for example through employee sabotage or coercive/unlawful tactics used by activists. Note that Mitchell et al. identify these stakeholders, but don't require them to be acknowledged & thus awarded legitimacy (1997, p.878).
- Dependent stakeholders, who are dependent on others to carry out their will, because they lack the power to enforce their stake. Examples are local residents & animals impacted by the an oil spill. Advocacy of their interests by dominant stakeholders can make them definitive stakeholders.

The last identified group are the definitive stakeholders, who rank high on all three attributes. Often dominant stakeholders with an urgent issue, or dependent groups with powerful legal support. Finally those classed as dangerous could gain legitimacy e.g. democratic legitimacy achieved by a nationalist party.

Within the MST, there are many people that could be influenced by implementing this technology. For the sake of this research, involved groups can be separated in five different groups:

- The nursing staff
- Medical specialists
- The technical staff
- Management
- Patients

The nursing staff is the group that has to effectively use the technology when all is said and done. As such, they score high on each of the three mentioned attributes. The project will have a high impact on them, because the implementation of the technology would change the nature of their work, making their claim legitimate. They would have to learn to use it on a daily basis and as such, also have a high power on the project at the same time. If the nursing staff can't or doesn't want to work with the technology, the project could fail. For this reason, they should be highly involved in the implementation of the technology and can be identified as a definitive stakeholder.

Conversely, the importance of medical specialists in this project is lower. Assuming the earlier mentioned limitations are being taken into account (ie. as to not alter the medical equipment in shape or form and doesn't interfere), the project does not impact their work beyond potentially benefitting from better preparations, decreasing their power over the project. They do not have to work with track & trace themselves, as that is done for them by the nursing staff, so the legitimacy of their relationship with the project is rather low, making them a dormant stakeholder. Because of this, their involvement with the project should be low.

Another definitive stakeholder group is the technical staff. While the impact the technology has on their work isn't as high as that of the nursing staff, their power is just as high. The technical staff is tasked with implementing the technology, connecting it to their database and perform the maintenance work. While they might not use the technology on a daily basis after the initial phase, the success does rely on their work and as such, they should be highly involved in the project.

Management will have to approve the project in order to get it off the ground in the end. As such, they have a high level of power over the success of the project. However, the technology itself barely impacts their own work, as they will not come in direct contact with it and do not have to use it, making their direct involvement less urgent, making them a dominant stakeholder. As such, management should be involved in such a fashion that they should be periodically kept up to date on the status of the project, but not directly involved in the process of implementation.

Finally, patients are a stakeholder group that is mostly only indirectly influenced by this project. The technology could benefit them as it could help them get care faster and more efficient, making their claim legitimate to a certain extend. They rely on how the tech is implemented, but obviously will not use it. As such, their power over the project is practically zero and carries no urgency. As discretionary stakeholders, they should not be involved in the process of the implementation.

Figure D is a more detailed look on this stakeholder analysis. The nursing and technical staff come out as the definitive stakeholders and should be directly involved in the implementation of the technology. Management is another stakeholder that should be involved through periodical updates on the progress of the project and estimations on the expected results.

| Stakeholder name | Nursing staff | Technical staff | Management | Medical specialists | Patients |
|---|---|---|---|---|---|
| **Power:** How much influence do they have over this project? (high, medium, low) | High | High | High | High | Low |
| **Legitimacy:** How much does this project involve them? (high, medium, low) | High | High | Medium | Low | Medium |
| **Urgency:** How critical is their direct involvement? (high, medium, low) | High | High | Medium | Low | Low |
| **Involvement:** How much should they be involved in this project? (high, medium, low) | High | High | Medium | Low | Low |
| **What is important for the stakeholder?** | It has to be easy to use and not produce any additional activities | Equipment should be easy to find, and the tags should be low in maintenance | There has to be significant benefits to justify investing in this technology | Equipment mustn't be altered and should be quickly and readily available | Medical care has to be administered as quickly and efficiently as possible |
| **How could the stakeholder potentially benefit from this project?** | It could save time looking for equipment, and ensure there is sufficient equipment present at their department | It could save time looking for equipment, and make it easier to check its status | It could help save costs, through requiring less staff to be active or using them more efficiently | They could benefit from better prepared staff and equipment, and decrease potential waiting times | Patients could benefit by shorter waiting / preparation times and more efficient care |
| **How could the stakeholder be potentially disadvantages by this project** | There is a risk of not understanding the technology, and a chance that they are tasked with necessary, additional actions | Tags could require additional maintenance, especially considering potential malfunctions and failure of the technology | Savings are only theoretically at this point, they might not weigh up against the costs involved. This could harm them as they're personally responsible for these investments | In case the demand and limitations aren't met, this could harm funcionality of their equipment, making their work more difficult or, in extreme cases, even impossible | Complications in the technology could put more pressure on the healthcare, potentially harming patients |
| **How can the stakeholder potentially contribute to this project?** | The staff will have to test the tech in practice, in order to fully implement later on | They will have to install the technology and keep it running on the background | They will have to approve the investment in the end, and decide whether the project can be continued | | |
| **How could the stakeholder potentially block this project?** | Staff could be incapable or unwilling to use the technology, halting progress | Mistakes could be made by faulty installations or registrations, causing errors | Management can refuse the project, or choose alternative methods | | |

Figure D: a stakeholder analysis

## 5.2 Validity

In order to produce strong evidence, conclusions have to be valid. Validity is the extent to which a concept, conclusion or measurement is well-founded and corresponds accurately to the real world. Ensuring validity is necessary for the research to yield results and be able to draw fair conclusions out of these results.
There are various kinds of validity, that can be divided into two categories: test validity and experimental validity. Test validity is the degree to which it measures what it is supposed to measure (Guion, 1980). Test validity lays down the foundation for a research. Without it, no conclusion that has been made based on the research can be taken at face value. Guion referred to these three paths to validity as his "holy trinity":

- Construct validity, which refers to the extent to which a practical test derived from theory can actually be defined by said theory. This means that the variables mentioned in a theory reflect on the test they are being used in.
- Content validity is designed to determine to what extent a test covers are the relevant bases. This includes sample size of both variables and population. This ensures that there is no bias due to a lack of variety.
- Criterion validity, which involves comparing test variables with other measurables already held to be valid. It looks at whether the relationship between two variables have been described before, and whether they have been deemed valid based on historic evidence.

Meanwhile, experimental validity measures whether or not an experiment was properly designed. This means that the results of an experiment cannot be based on false input, either from the experimental design itself or influences from outside. There are three main elements of experimental validity: internal validity, external validity and statistical conclusion validity.

Internal validity is an estimate to the degree of which an experiment it designed in a fair fashion, to exclude certain biases (Schaie, 1988). According to Schaie, there are a number of factors that affect internal validity:

- History, where events that occur outside of the test environment could account for the observed change
- Reactivity is a major issue for internal validity. Test subjects are generally influenced if they know they're participating in an experiment. (Haynes & Horn, 1982) This effect alone could influence the result of an experiment. A special mention is necessary for the Hawthorne effects, which found that test subjects behave different just due to the fact that they're being watched by an observer.
- Instrumental changes midway through the experiment
- Statistical regression towards the mean. Test subjects can sometimes have extreme outliers during their own tests. If these outliers aren't identified and extrapolated, they can affect results to an extend where they invite false conclusions.
- Mortality and attrition, cases wherein testing subjects drop out of the experiment due to various reasons, such as death or sheer lack of motivation
- Selection bias. To get the best results, sample groups are supposed to be representative of the entire population. If a research group includes too many outliers based on skill level, age or interest, the validity of the research is harmed
- Interactions, either between the observer and a subjects, or between subjects, depending on the nature of an experiment
- Maturation, which can occur through various reasons. In this case, elements like age or physical differences throughout a longitudinal study on the same test subject can account for differences in results.

A high internal validity is necessary in the design of an experiment. The external validity however determines whether or not the result of an experiment can be generalized to other situations and other people (Bracht & Glass, 1968; Calder et al., 1982). Factors that are a threat include:

- Different situations. If situational specifics aren't sufficiently mirrored from real life situations, the conclusions might not be relatable to real world relations.
- Pre- and post-test effects, where only these tests can explain a cause-effect relationship. If these are carried out, this limits the generality of the findings
- The Pygmalion effect (Rosenthal, 1973), which states that higher expectations may lead to better test performances.

The last main element for validity has to do with having correct and reasonable conclusions based on the tested variables. Statistical conclusion validity is guaranteed by having a high statistical power, to follow the assumptions of the test statistics and to remove the notion of fishing for specific statistics.

## 5.3 Contingency factors

Implementing new technology generally comes with various issues. This research has to account for the effects of contingency factors, which are factors that play a part in the difficulties involved in achieving a smooth process. However, the contingency theory suggests that this optimal course is affected by internal and external factors. One of these factors is technology itself (Chenhall, 2003). Chenhall underlines the important of uncertainty when addressing the design of a management control system and the influence of technology on the tasks. He describes three grounds at which technology has an influence on the design of a control system: interdependencies, complexity and uncertainty. While these factors describe the chance of success of a task, it does not account for the delineated nature of certain tasks and the matter in which these can be identified. Without these factors, it can be difficult to differentiate between the different actions that a task requires. Crom (2005) identifies various additional factors that influence the uncertainty involved in order to analyze the relationship between the technology and output. These factors are:

| **Factor** | **Description** |
|---|---|
| Task variety | The amount of different tasks that can be identified, which employees have to perform (Perrow, 1970) |
| Task analyzability | The matter in which tasks can be split up in different, well-defined actions (Abernethy and Brownell, 1997) |
| Task uncertainty | The matter of how often a specific task has to be performed (Perrow, 1970) |
| Task complexity | The amount of different actions that have to be performed to complete the task (Otley, 1980) |
| Task measurability | The matter of how easily single actions within are able to be measured (Birnberg et al. 1983) |
| Task interdependency | The matter in which the success of certain actions depends on other actions (Chenhall, 2003) |

These factors will have to be accounted for when implementing new technology. This helps in determining how difficult implementation will be, how long of an orientation period has to be taken into account and the effect this has on the initial benefits.

# 6. Methodology

After determining the key stakeholders and setting out the guidelines, it is time to collect data. This section will describe the actions taken in order to investigate the research problem. There are two main questions here: how was the data generated, and how was it analyzed? Based on this, a cost analysis can be made based on the data and leads to a cost-benefit analysis, with estimations on the expected results. A fully customizable spreadsheet will be produced that can be kept up to date if the MST gets new data.

## 6.1 Current situation

To get an idea of how much time the MST could save with implementing the technology, an idea about what the current situation looks like is required. This means identifying which tasks could be improved, how long they take to perform and how often they occur.

As a starting point, the MST had a work package available in which a research agency had logged the activities of different employees at the Traumatology department (the C4). The work package they produced is included in Appendix A and includes every task they performed, how long it took and the frequency they occurred with. To determine how much time can potentially be saved through the use of track & trace technology, we have to identify the tasks which would benefit from this and how much time is wasted through those tasks. This means finding a median time that a tasks requires and finding the observed outliers (events that took at least 50% longer for tasks shorter than 5 minutes, or 25% longer for tasks that take longer than 5 minutes). It is estimated that this additional time is due to complications with a patient, a lack of present equipment and broken down equipment.

This research will allocate 50% of all surplus time due to complications with a patient, something the technology will not solve. 40% of all wasted time will be allocated to time wasted by searching for sufficient equipment and 10% will be estimated due to broken down equipment, both of which offer solutions to save time.

Of the time wasted by searching for equipment, this research assumes that 50% of this time can be saved by using passive technology (20% of the total surplus time), and 75% by using active technology (30% of the total surplus). This takes into account the time required to use the management tools and the physical time it takes to walk to the device. Active technology has a higher score due to the higher accuracy and better knowledge on whether a device of being used already.

Finally, broken down equipment is a source of wasted time. This decreases the amount of functional devices in a department. It might also not be clear from the outside that a device has broken down. Track & trace technology can improve this overall maintenance level as the equipment can be internally labeled as “broken”, showing up as such for other staff members and automatically send an alert to the technical staff. Automating this process shortens the down-time of a device and takes it off the work floor faster. It is estimated that the technology can shave 20% off of this process, but for the sake of uncertainty this research assumes a 10% benefit, regardless of the technology used (1% of the total surplus).

As such, it is estimated that passive technology can save a total of 21% on the total surplus time and active technology can save a total of 31% of the surplus time. As a hybrid form has active technology on most of the relevant devices, this research will assume a total saving of 28% of the total surplus time in regards to the hybrid form of this technology.

First, the tasks that would benefit from using the technology need to be identified. These are tasks that include the use of tools that are not a part of the standard equipment of a room, but have to be collected from the department or a depot. These tasks include:

- Mobilizing patients – with passive lifter
- Mobilizing patients – with active lifter
- Hospitalizations
- Emergency admissions
- Administer infusion
- Heavy wound care (through the use of pumps, such as vacuum pumps)
- Changing syringe pumps
- Bladder scanning
- Fixation through Hewitt brace
- Fixation through Vista brace

Second, the data needs to be validated. This means retracing the times it took to perform each task and making sure the numbers aren't significantly changed. This was done by walking alongside nursing staff and timing their performance. In order to make sure valid results were guaranteed, these factors of validity were taken into account:

| **Type of validity** | **Action taken** |
|---|---|
| Selection bias | Each day, a different member of the staff was logged. This ensured that work experience didn't influence the results. |
| Reactivity | Interactions with staff members were limited to a minimum. No other data was logged, including any contact with patients |
| Statistical regression | As most of the tasks occurred multiple times during the week, outliers were able to be filtered out |

Other factors to ensure validity were either taken care of due to the nature of the case or irrelevant to the research at hand.

Attachment A shows that the tasks earlier identified took up 240 of the 2290 minutes in that week in total, or 10.5% of the work week. To get a more complete data set, more measurements of these specific tasks were carried out. These are included in Attachment B alongside the original data. Figure E is a summary of this package and features a "surplus" attribute, which stands for the amount of time identified outliers added on top of the median time it took for a specific task.

| Category | Description | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Caring tasks | | All times in minutes | | | | | | |
| | **Verzorgende taken** | Sum | Min | Max | Average | Median | Frequency | Surplus |
| | Mobilizing patients - with passive lifter | 60 | 8 | 14 | 10,00 | 8,5 | 6 | 10 |
| | Mobilizing patients - with active lifter | 67 | 11 | 18 | 13,40 | 12 | 5 | 6 |
| Admissions | **Opname en ontslag** | | | | | | | |
| | Hospitalizations | 39 | 18 | 21 | 19,50 | 19,5 | 2 | 0 |
| | Emergency admissions | 63 | 30 | 33 | 31,50 | 31,5 | 2 | 0 |
| Preparation actions | **Voorbehouden handelingen** | | | | | | | |
| | Heavy wound care (through the use of pumps) | 116 | 18 | 30 | 23,20 | 22 | 5 | 12 |
| | Administer infusions (through holdings) | 87 | 20 | 26 | 21,75 | 20,5 | 4 | 5,5 |
| | Administer infusions (at department) | 27 | 5 | 9 | 6,75 | 6,5 | 4 | 2,5 |
| | Changing syringe pumps | 26 | 5 | 8 | 6,50 | 6,5 | 4 | 1,5 |
| | Bladder scanning | 29 | 3 | 6 | 4,14 | 4 | 7 | 2 |
| Neuro-surgery | **Afdelingsspecifieke handelingen** | | | | | | | |
| | Fixation through Hewitt brace | 21 | 5 | 10 | 7,00 | 6 | 4 | 4 |
| | Fixation through Vista brace | 46 | 9 | 15 | 11,50 | 11 | 4 | 4 |

Figure E: a summary of the tasks that could benefit from track & trace technology

In the end, a surplus of 47.5 minutes was found on 581 total minutes, or about 8.2%. Based on the earlier results stating that 10.6% of the time is spent on activities that could benefit from the technology, this means that on an entire work week, there is a surplus time of 0.86%. This surplus percentage will be used as the estimate in wasted time that can be saved.

## 6.2 Cost analysis

To calculate the expected costs of this project, there have been negotiations with held with a delegation of members from Tracqtion and Van Straten Medical.

Tracqtion, a company based in Gouda, the Netherlands, is a network organization that aims to bring IT solutions to other organizations. They attempt to connect IT, logistics, sales and finances within an organization. They offer solutions in the areas of resource management, capacity management and AIDC (Automatic Identification and Data Collection) through track & trace. They will provide the management tool software and aid in the installation of the tags and beacons.

Van Straten Medical (located in Nieuwegein, the Netherlands) specializes in building medical equipment. Their product portfolio includes drainage equipment, light optics and minimally invasive surgical tools. They have also built track & trace tags (both passive RFID and WIFI) that are suitable in a medical environment and its complications. They will provide the tags that will be used alongside the equipment.

In association with those parties, an estimation has been made about the amount of labor hours, tags and beacons that would be required to implement their system. Fixed costs to use either system regardless of the chosen technology include the planning of the project, instructing the staff and technical support afterwards. A variable cost in this scenario are the installation of the tags, which is dependent on the amount of tags, but doesn't change in regards to whichever tags are ultimately being used.

The variable numbers are based on using a hybrid system of active and passive tags, with active tags being used for larger types of equipment and passive tags for smaller pieces.

The cost of active (WIFI) technology is calculated by the production costs and the software licensing costs per tag. Fixed costs also include remote control units (one on each floor). Equipment that was selected to use active tags include:

- Anti-decubitus matrasses (that are designed to prevent bedsores), 50 pieces
- Oxygen pumps, 100 pieces
- Lifters, 30 pieces
- Patient monitoring systems, 50 pieces
- Beds, 675 pieces
- Wheelchairs, 270 pieces
- Mobile nightstands, 600 pieces

Passive (RFID) tags costs include the production costs of the tags themselves, plus that of the various readers and antennas (one for each allocated area):

- Infusion and feeding pumps, 1000 pieces
- Separate wheelchair parts, 160 pieces
- Operation table accessories, 450 pieces
- Rigid scopes (like sinus- or endoscopes), 300 pieces

Figure F is a summarized cost analysis for a situation that uses the hybrid form that uses both active and passive tags. Complete figures can be found in attachment C (for passive technology), D (for hybrid technology and E (for active technology)

Hourly wages for MST employees are calculated based on the lowest wage scales that apply to technical staff. The MST is likely to use newer, younger employees to perform these tasks, so we should adjust our calculations to those expectations.

Note that the cost of the connection with Ultimo (the MST's current management tool) is still unknown. While these costs should be taken into account, it is not expected to add a significant burden to the current sum.

| | | Labor | | | | Total costs |
|---|---|---|---|---|---|---|
| | | MST | | Tracqtion | | |
| | | Work Days | Cost | Work days | Cost | |
| *Fase* | Onderdeel | | | | | |
| *1* | **General project** | **37** | € 19.832,00 | **31** | € 41.261,00 | **€ 61.093,00** |
| *2* | **Technique** | **79** | € 42.344,00 | **94** | **€ 125.114,00** | **€ 840.157,50** |
| *3* | **Identification and localisation** | **34** | € 18.224,00 | **34** | **€ 45.254,00** | **€ 207.623,00** |
| *4* | **Instructions** | **29** | € 15.544,00 | **24** | **€ 31.944,00** | € 47.488,00 |
| 5 | **Go-Live and Support** | **17** | € 9.112,00 | **41** | € 54.571,00 | € 63.683,00 |
| | | | | | | |
| | Total | 196 | € 105.056,00 | 224 | € 298.144,00 | € 1.220.044,50 |

Figure F: A summary of the cost analysis for implementing the hybrid option

## 6.3 Cost benefit analysis

Now that a cost analysis has been made, a cost-benefit analysis can be made. In order to make a good estimation of the potential benefits, a couple of assumptions have to be made.

- The number of nursing staff and medical specialists are based on the numbers mentioned in their annual report of 2016 (MST Jaarverslag, 2016)
- Different employees have different wage scales. These different scales are determined by the healthcare CBA (collective bargaining agreement). For the purpose of this analysis, the lowest wage scale will be used for both the nursing staff and for medical specialists to prevent unfairly inflated costs, as was done in the cost analysis as well (CAO-ziekenhuizen 2017-2019)

- FTE’s are determined at 36 weekly hours, the general full time contracts the MST deals with.
- Due to the fact that employees have to get acquainted with the technology and the network might not be flawless at first, it is assumed that the first year will only offer 2/3rds of the expected time savings.
- The “expected savings” assume that the technology works entirely as intended. An “assumed savings” column will be added that adjusts for possible drawbacks, such as down times, staff that can’t adapt the system or disappointing results in general. The assumed savings will be set at 80% of the expected savings.

While the lion’s share of the costs are that of the initial investment (as calculated in the cost analysis), there are also annual costs later in the project. There are annual fees to use both the Tracqtion platform (who own the connection to the management tool) and Ekahau, the software on which the active tags run. Also, WIFI-tags have to be replaced every two to three years due to a limited battery life. To get a fair assessment, it will be presumed that active tags have a lifespan of two years. Passive tags still have an infinite lifespan.
There are also assumptions to be made when it comes to savings that weren’t researched in-depth, but will certainly be included into consideration.

- During the localization of equipment in order to tag them, various equipment that was deemed inactive will be re-discovered. In general, the MST estimates that around 2.4% of all equipment misses their routine cyclical maintenance. The MST protocol is that these items get the status “missing”, although they will still be used. In general, half the items that are missing, will also miss maintenance a second time, at which point items will get the status “inactive” and will virtually be taken off the books. Even though most of this equipment will still be used by the nursing staff, it currently no economic value. During localization and tagging this equipment, many of these objects will be found again, allowing them to come back on the books. In the end, this gives the MST a better idea of their current equipment, allowing them to avoid unnecessary purchases. As the economic value is difficult to estimate without researching the MST’s inventory, a book value of €100.000 is assumed. Expectations are that this will end up significantly higher.
- The technology will also save time during maintenance cycles themselves. In general, the MST has two juniors on their technical staff who are dedicated to collecting various types of equipment to get them ready for maintenance. These cycles generally take around 6 weeks. These searches aren’t ordered, which means they come first come, first serve. As a result, items are easily found during the first four weeks of a cycle, because of the amount of items that haven’t had maintenance yet. However, during the final two weeks, the juniors have difficulty finding items that haven’t had maintenance yet, causing their rate to slow down. Through track & trace technology, the items that haven’t received maintenance yet will be easier to identify and their location will be known. Localizing these items will be easier with active tags than they will with passive tags, so we will assume the technology helps them work 12.5% more efficient with passive tags (0.5 FTE’s) and 25% with active tags (1 FTE) during the final two weeks of a six-week cycle.

In total, the expected savings from the optional prevention of wasting blood are as posted below. Figure E shows a complete cost-benefit analysis can be found based on a hybrid form, also found in attachment G. For separate technologies, these can be found as attachment F (for passive technology) and attachment H (for active technology)

| Afname zoektijden | Verpleging | OK/HCK | Totaal |
|---|---|---|---|
| Aantal FTE in dienst | 1650 | 232 | 1.882 |
| Functiegroep (salarisschaal) | 45 | 55 | |
| Beginsalaris schaal | 2144 | 2665 | |
| Kosten per persoon per jaar | 25.728 | 31.980 | |
| Surplus percentage | | | 0,86% |
| Besparing percentage technologie | | | 28% |
| Percentage besparing op 8-urige dienst | 0,24% | 0,12% | |
| Zoektijdbesparing per dag in minuten | 1,15584 | minuten | |
| Besparing in FTE per jaar | 4,0 | 0,3 | 4,3 |
| Verwachte besparing in Euro's per jaar | 102.222 | 8.933 | 111.155 |
| **Aanname werkelijke besparing** | | | **88.924** |

| Overige besparingen (aannames) | |
|---|---|
| **- Besparing zoektijden onderhoudscyclus** | |
| Ingeschatte besparing: | 1 FTE per 6 weken |
| Loonschaal junior technici | 45 |
| Beginsalaris schaal | 2144 |
| Besparing per cyclus | € 2.144,00 |
| Besparing per jaar | € 18.581,33 |
| **- Activering vermiste apparaten (eenmalig)** | |
| Ingeschatte boekwaarde | € 100.000,00 |

| Jaarlijkse kosten (incl BTW): | Kosten per jaar | | |
|---|---|---|---|
| - Herinvestering refurbished wifi-tags (om de 2 jaar) | € 907,50 | Absolute kosten per 2 jaar: | € 1.815,00 |
| - Beheervergoeding TracQtion-platform | € 10.000,00 | Aanname: refurbished kost 50% van nieuw | |
| - Beheervergoeding Ekahau | € 1.452,00 | | |

| Kosten-/batenanalyse | Opbrengsten | | Kosten | Resultaat per jaar | | Cummulatief resultaat | | |
|---|---|---|---|---|---|---|---|---|
| | Per jaar | Obv aanname | Absoluut (per jaar) | Absoluut (verwacht) | Absoluut (aanname) | Verwacht | Aanname | Resultaat/jr |
| 1 | € 192.684,93 | € 163.043,49 | € -1.246.480,50 | € -1.053.795,57 | € -1.083.437,01 | € -1.053.795,57 | € -1.083.437,01 | € -1.083.437,01 |
| 2 | € 129.736,73 | € 107.505,65 | € -11.452,00 | € 118.284,73 | € 96.053,65 | € -935.510,83 | € -987.383,35 | € -493.691,68 |
| 3 | € 129.736,73 | € 107.505,65 | € -13.267,00 | € 116.469,73 | € 94.238,65 | € -819.041,10 | € -893.144,70 | € -297.714,90 |
| 4 | € 129.736,73 | € 107.505,65 | € -11.452,00 | € 118.284,73 | € 96.053,65 | € -700.756,37 | € -797.091,05 | € -199.272,76 |
| 5 | € 129.736,73 | € 107.505,65 | € -13.267,00 | € 116.469,73 | € 94.238,65 | € -584.286,64 | € -702.852,40 | € -140.570,48 |
| **Gemiddeld per jaar:** | € 142.326,37 | € 118.613,22 | € -259.183,70 | € -116.857,33 | € -140.570,48 | | | |

| | | |
|---|---|---|
| Verwachte break-even tijd | 12,48 | jaar |
| Target besparing voor break-even na 3 jaar: | 6,51 | minuten per dag |

Figure G: a cost-benefit analysis based on implementing a hybrid form of the technology

There is also the option to use the technology to reduce wasting perishable products. Most of the products had an insignificant value that was not deemed worthy to pursue, but the waste of blood is significant to research.

- The MST estimates that around 5% of the 8,400 blood bags that are ordered each year (700 each month) are thrown out because they are past their expiration date. In general, blood can be kept for 35 days, and a bag of blood (which is around half a liter) costs €215.
- In order to make this option work, the MST will need to order a sufficient amount of additional passive tags, which are re-usable each cycle.
- They will also need to dedicate an employee to tag each bag and to get it the proper data input. Tagging will have to happen individually, the data input can happen collectively upon arrival.
- While installing these tags is a one-man day, multiple staff members should be able to perform these tasks. As a result, 2 or preferable 3 staff members should be trained to be able to perform this task.
- In an ideal situation, the entirety of the 5% wasted blood could be spared. However, there are contingent factors at play, most importantly the issue that the blood might be left over from a slow month rather than mishandled due to oversight. For this matter, a more cautious, realistic saving of 2% is assumed, although there is a legit case for further research here.

| **Reducing waste of blood bags** | | |
|---|---|---|
| Blood bags per year | | 8400 |
| Price per blood bad | € | 215,00 |
| Estimated waste per year | | 5% |
| Estimated amount of wasted blood bags per year | | 420 |
| | | |
| Required tags | | 700 |
| Cost per tag | € | 8,00 |
| Total tag costs | € | 5.600,00 |
| Required additional RFID antennas | | 4 |
| Cost of antennas | € | 2.541,00 |
| Required additional RFID readers | | 1 |
| Cost of readers | € | 2.299,00 |
| | | |
| Estimated additional labor | | 1 person, 8 hours per month |
| Wage employee | € | 2.144,00 |
| Wage costs per year | € | 1.286,40 |
| Training employees (one time, three employees, four hours) | € | 160,80 |
| | | |
| Potential savings | € | 89.013,60 |
| Realistische savings (2%) / year | € | 16.516,32 |
| Total original investment | € | 10.600,80 |
| Break-even time in months | | 8,35 |

Figure H: cost analysis for the waste reduction of blood bags

The cost/benefit analyses including waste reduction can be found in attachments I (passive), J (hybrid) and K (active)

## 7. Findings

- None of the three technologies are expected to run break-even within three years or come even close, one of the objectives by the MST. The form with passive RFID comes closest with an expected break-even time of almost 12 years.
- Choosing the active technology runs at a loss under the current data
- There is a significant difference in the amount of time that has to be saved in order to run break-even within three years. Using only low-cost passive tags requires a little under 4 minutes of time saved per staff member, whereas the hybrid form requires six and a half minutes. Meanwhile, using active technology requires 8 minutes of time saved per staff member. However, this still isn't close to the observed data.
- The total investment over five years is significantly lower with the passive technology compared to the other forms. This was expected, as it is also the most basic form. In total, the investment is 56% of the cost for the hybrid form, and only 45% of the total costs of implementing active technology.
- This also reflects on the total gains over five years. Due to the more basic form of technology, passive RFID is expected to save 3 FTEs per year, versus 4 FTEs for the hybrid form and 4.4 FTEs with active technology.
- The total rate of return is highest with using passive technology. The expected return over five years is around a 50% loss on the original investment.

| Technology used | Break-even time with the expected saved time (in years) | Required saved time to run break-even in 3 years (in minutes) | Expected saved FTE per year | Total investment over 5 years | Total gains over 5 years | Return on investment after 5 years | Rate of return after 5 years |
|---|---|---|---|---|---|---|---|
| Passive | 11,83 | 3,90 | 3,19 | € 897.390,00 | € 446.572,91 | € -450.817,09 | -50% |
| Hybrid | 12,48 | 6,51 | 4,25 | € 1.295.918,50 | € 593.066,10 | € -702.852,40 | -54% |
| Active | -6,70 | 8,02 | 4,71 | € 1.967.037,70 | € 535.940,33 | € -1.431.097,37 | -73% |

Figure I: a summary of the comparison between the three forms of technology, before adding waste reduction

When it comes to the optional savings of using tags for disposables, this is expected to be a lucrative option. The expected break-even time is estimated at eight months in calculations that are based on blood bags. In combination with the regular technology, it reduced the expected break-even time by a little over 15-30%. It also reduced that amount of time saved that would be necessary to run break-even within three years by over half a minute. Figure J below shows the effect that adding the option of reducing the waste of blood has on the overall implementation of the technology as a whole. This does not include other possibilities such as plasma.

| Technology used + waste reduction | Break-even time with the expected saved time | Required saved time to run break-even in 3 years | Expected saved FTE per year | Total investment over 5 years | Total gains over 5 years | Return on investment after 5 years | Rate of return after 5 years |
|---|---|---|---|---|---|---|---|
| Passive | 8,72 | 3,39 | 3,19 | € 914.422,80 | € 581.005,44 | € -333.417,36 | -36% |
| Hybrid | 10,84 | 5,90 | 4,25 | € 1.312.951,30 | € 675.647,70 | € -637.303,60 | -49% |
| Active | -7,65 | 7,42 | 4,71 | € 1.984.070,50 | € 618.521,93 | € -1.365.548,57 | -69% |

Figure J: a summary of the comparison between the three forms of technology, after adding waste reduction calculations

## 8. Recommendations

Based on the findings in this research, there is a very questionable return on the total investment. Under cautious estimates, no single technology comes close to meeting the objective of running break-even within three years. Even though these estimates were on the low side by design. The more realistic predictions offer an image that still seems worth it to pursue further research at the very least.

The research states that if the MST would want to move on anyways, it would be best off choosing for either a network based on passive RFID tags or a hybrid form with both RFID and active WIFI tags. The passive option has a lower ceiling but also carries a lower risk. The hybrid option has the most upside, but also requires more actual savings in order to benefit from implementing it and has no guarantee that it will actually pay off. It also involves more maintenance work given the shorter lifespan of the WIFI tags, which goes against one of the preferences the MST had given out.

It is also heavily recommended that the MST looks to implement a system that attempts to reduce the waste of disposable products. While only blood bags have been researched and the fact that there is a good chance this is also the most profitable disposable to reduce, this also opens the path for other disposables, as the system and infrastructure would already be in place.

One potential reason for the disappointing results is that no major outliers were observed. One employee said that they incidentally waste 15-20 minutes looking for certain pieces of equipment. However, this was not observed as these occurrences are rare on an individual basis.

Given these estimates and the fact that the MST can’t afford to take as many risks as they would perhaps like to, it would be unwise to recommend moving on with the current data.

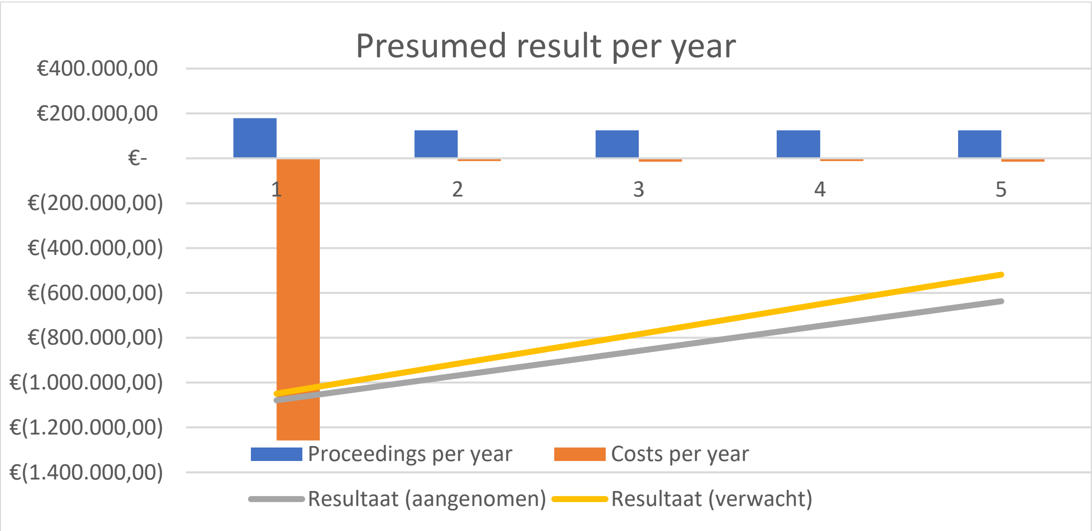


Figure H: expected results, based on passive tech and reduction of blood waste

# 9. Further research

Due to the limited scope of this research, there are various subjects for further research. These subjects can be divided among two groups: relevance for the MST and distribution to other hospitals.

For the MST, it can be beneficial to look into other ways to use track & trace technology to save time and costs. For instance, the current increase in book value is still an estimate. Given the amount of machines and other equipment that are currently registered as "missing", despite likely being used, a significant rise in value seems likely. Currently, 2.4% of all equipment is listed as such, even if most of that includes smaller tools.

Another area of further research for the MST includes the reduction of the work pressure that employees feel. Currently, no significant relation has been found in regards to search times in- or decreasing due to the amount of patients that have to be helped. However, the overall work pressure itself could potentially be lowered if nursing staff can aid their patients faster and more efficient. This itself could lead towards an increase in employee satisfaction. Even if there is no clear-cut numerical value that can be attached to that, it is still something that could be worth pursuing.

In regards to distribution towards other hospitals, the focus will have to be moved towards the differences between the MST and those other hospitals. An important element in this is the infrastructure. When the new building was constructed, it was designed to have complete WIFI coverage throughout the entire building. For this reason, it didn't need too many adaptions towards its network in order for WIFI tags to work. Other factors include the different lay-outs of these hospitals and different amounts of both equipment and staff members.

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# 11. Appendix

| Geconsolideerde balans Stichting Medisch Spectrum Twente | | | | | |
|---|---|---|---|---|---|
| **(x € 1.000.000)** | **2016** | **2015** | **2014** | **2013** | **2012** |
| **Activa** | | | | | |
| Vast | 415,2 | 428,2 | 354,6 | 291,3 | 212,6 |
| Vlottend | 120,2 | 204,9 | 237,6 | 196,0 | 160,1 |
| | 535,4 | 633,1 | 592,2 | 487,3 | 372,7 |
| **Passiva** | | | | | |
| Eigen vermogen | 63,6 | 80,8 | 77,4 | 70,0 | 56,3 |
| Voorzieningen | 31,0 | 34,0 | 21,6 | 21,7 | 14,4 |
| Vreemd vermogen lang | 332,3 | 353,1 | 303,2 | 221,1 | 161,2 |
| Vreemd vermogen kort | 108,5 | 165,2 | 190,0 | 174,5 | 140,8 |
| | 535,4 | 633,1 | 592,2 | 487,3 | 372,7 |

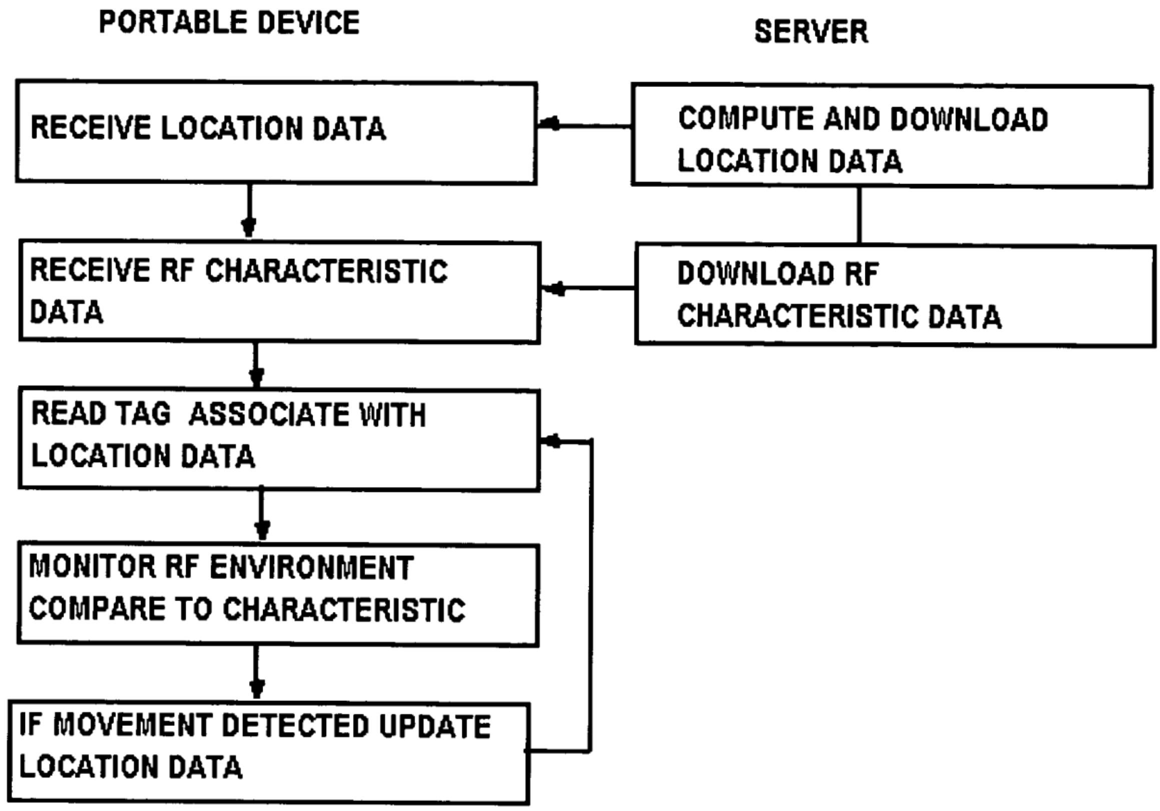
Appendix A: MST balance sheet

| Geconsolideerde resultatenrekening Stichting Medisch Spectrum Twente | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **(x € 1.000.000)** | **2016** | **%** | **2015** | **%** | **2014** | **%** | **2013** | **%** | **2012** | **%** |
| **Bedrijfsopbrengsten** | 418,7 | 100,0% | 433,5 | 100,0% | 365,0 | 100,0% | 362,3 | 100,0% | 347,6 | 100,0% |
| | | | | | | | | | | |
| **Bedrijfslasten** | | | | | | | | | | |
| Personeelskosten | 244,2 | 56,3% | 246,1 | 56,8% | 190,1 | 52,1% | 180,2 | 49,7% | 176,3 | 50,7% |
| Afschrijvingen vaste activa | 32,7 | 7,5% | 21,6 | 5,0% | 22,2 | 6,1% | 25,5 | 7,0% | 24,1 | 6,9% |
| Overige bedrijfskosten | 144,3 | 33,3% | 152,2 | 35,1% | 136,3 | 37,3% | 135 | 37,2% | 133,3 | 38,3% |
| | | | | | | | | | | |
| **Bedrijfsresultaat** | -2,5 | -0,6% | 13,6 | 3,1% | 16,4 | 4,5% | 21,7 | 6,0% | 13,9 | 4,0% |
| | | | | | | | | | | |
| **Financiële baten en lasten** | -14,6 | -3,4% | -10,5 | -2,4% | -9,2 | -2,5% | -8,1 | -2,2% | -7,9 | -2,3% |
| **Resultaat deelnemingen** | 0,0 | 0,0% | 0,2 | 0,0% | 0,1 | 0,0% | 0,1 | 0,0% | 0,2 | 0,1% |
| **Resultaat** | -17,1 | -3,9% | 3,3 | 0,8% | 7,3 | 2,0% | 13,7 | 3,8% | 6,2 | 1,8% |

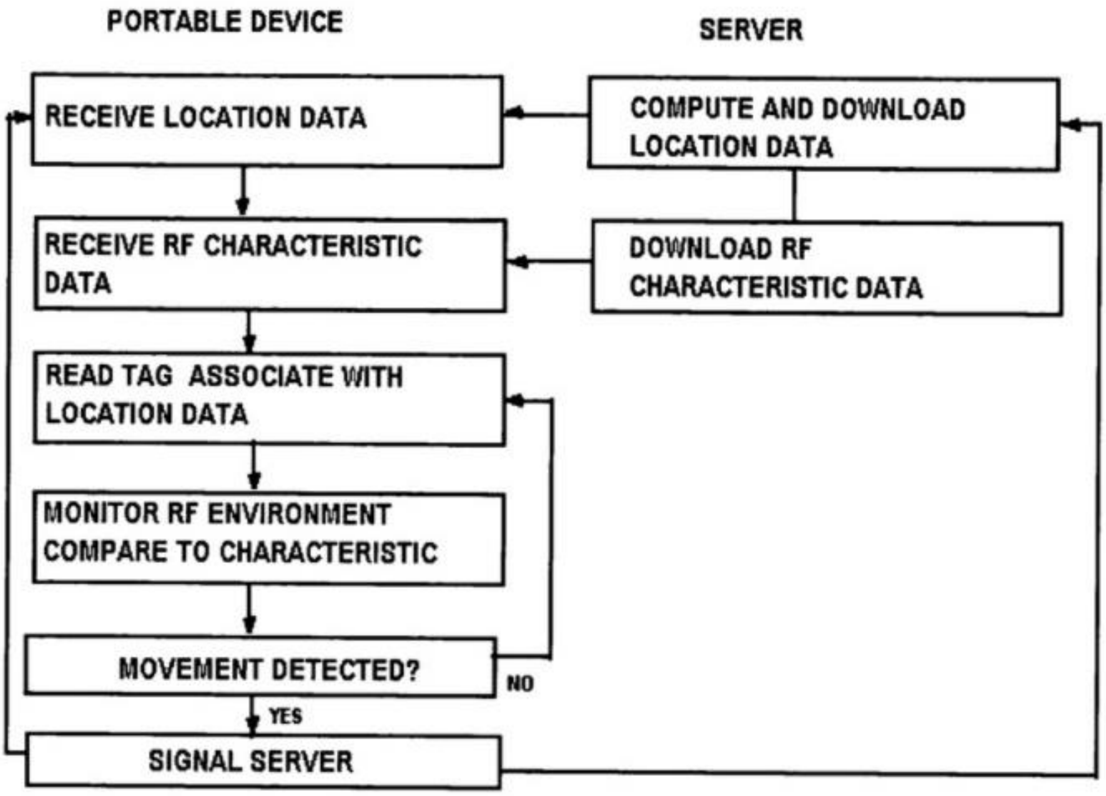
Appendix B: MST income statement

| Ratio's | | | | | |
|---|---|---|---|---|---|
| (x € 1.000.000) | 2016 | 2015 | 2014 | 2013 | 2012 |
| **Resultaat** | | | | | |
| Resultaatratio | -0,04 | 0,01 | 0,02 | 0,04 | 0,02 |
| Resultaat | -17,1 | 3,3 | 7,3 | 13,7 | 6,2 |
| Totale opbrengsten | 418,7 | 433,5 | 365,0 | 362,3 | 347,6 |
| | | | | | |
| Liquiditeit | | | | | |
| Quickratio | 0,00 | 1,16 | 1,20 | 1,07 | 0,72 |
| Currentratio | 1,11 | 1,24 | 1,25 | 1,12 | 1,14 |
| | | | | | |
| Solvabiliteit | 11,88% | 12,76% | 13,07% | 14,36% | 15,10% |
| Totaal eigen vermogen | 63,6 | 80,8 | 77,4 | 70,0 | 56,3 |
| Balanstotaal | 535,4 | 633,1 | 592,2 | 487,3 | 372,7 |
| | | | | | |
| **Vermogen** | | | | | |
| Vermogensratio | 15,19% | 18,64% | 21,21% | 19,32% | 16,20% |
| Totaal eigen vermogen | 63,6 | 80,8 | 77,4 | 70,0 | 56,3 |
| Totaal opbrengsten | 418,7 | 433,5 | 365,0 | 362,3 | 347,6 |

Appendix C: MST financial ratios

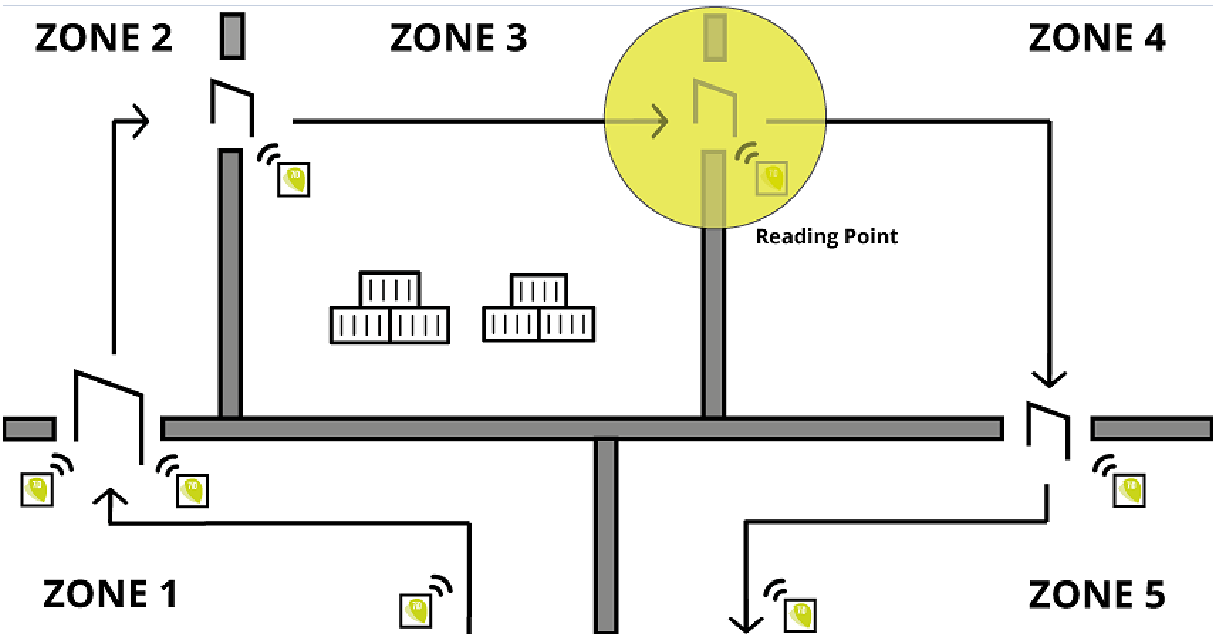



Appendix D: the virtual design of passive RFID tags (Zegelin, 2003)




Appendix E: the virtual design of active tags (Zegelin, 2003)

Appendix F: Triangulation to determine the location of a tag




Appendix G: dividing zones through RFID beacons