A study of possible use of Radio Frequency Identification (RFID) in Abu Dhabi Sewerage Directorate

by

Vidar Bekken
Bjørnar Landheim

Master Thesis in
Information and Communication Technology

Agder University College
Faculty of Engineering and Science
Norway

Abu Dhabi, June 2004

Abstract

This report describes the possible use of RFID in a business case such as the Sewerage Directorate at Abu Dhabi Municipality & Town Planning Department. The prototype phase is developed using the ethnographic study which is called Contextual Design Methodology.

RFID is not a new technology, but a technology that now widely increases its marked share by large companies recently looking at the potential of RFID implementations. It will still take several years to see if this newly found interest will lead into a RFID success story. RFID is set to replace barcodes that are much used for pricing and/or identifying objects.

Our investigation started in the Sewerage Directorate looking from the top of the organization and down to the assets that are candidates for support of RFID.

The methodology Contextual Design is a system development method which can be used when implementing new systems. It is customer based and it recommends a full acceptance of the system to the organization.

Evaluation and recommendation for an improved system will be described.

A prototype is made including a Pocket PC and a self made application to control reader communication with the tag. In addition, experimental work is done both in laboratory and in the field.

An ideal process of making the prototype was not achieved, due to problems obtaining the necessary equipment in time. Communication with sellers in general was a problem, since contact with desired sellers failed. For the seller where we made contact, we didn’t get what we ordered and the delivery was delayed.

Preface

This thesis was written as a part of the Norwegian Master degree in Information and Communication Technology. The work started at Agder University College in January 2004 with a pre-study of RFID and then continued at Abu Dhabi Higher Colleges of Technology from February 2004 to May 2004. There has also been a close co-operation with the Sewerage Directorate in Abu Dhabi Municipality during the entire period of our research.

We would like to thank our supervisors, Ph.D. Lars Line (Agder University College), Dr. Itihad Abd Al Amer and Arif Bin Hewail Al Nahdi (Both from Abu Dhabi Higher Colleges of Technology) for their supervision, guidance, and support throughout this research. We would also like to thank Mustafa Abdulla Almusawa (Head of Automation & IT Division, Sewerage Directorate in Abu Dhabi Municipality) for his willingness to share his knowledge.

Last but not least we would like to express our special thanks to Hussain Al-Mousawi, a student colleague who has been a good friend and provided valuable assistance throughout.

Abu Dhabi, June 2004

Vidar Bekken and Bjørnar Landheim

Table of Contents

List of Abbreviation

ADM	- Abu Dhabi Municipality
AIMS	- Asset Information Management System
CD	- Contextual Design
EPC	- Electronic Product Code
GIS	- Geographical Information System
GDP	- Gross Domestic Product
GPS	- Global Positioning System
HiA	- Agder University College
IC	- Integrated Circuit
ICT	- Information and Communication Technology
IR	- Infra-Red
I/O	- Input/Output
ISO	- International Organization for Standardization
MACE	- Mechanical And Civil Engineering
MTP	- Mafraq Treatment Plant
PLC	- Programmable Logic Control
PPM	- Parts Per Million
QA	- Quality Assurance
RFID	- Radio Frequency Identification
RSxxx	- Recommended Standard – Type xxx
RTU	- Remote Terminal Unit
SCADA	- Supervisory Control And Data Acquisition
SPC	- Sewerage Project Committee
TPD	- Town Planning Department
UAE	- United Arab Emirates
UED	- User Environment Design
UDS	- User Detection and Survey
US	- United States
USB	- Universal Serial Bus
VB	- Visual Basic
VDC	- Volt Direct-Current

List of Figures

All Figures are self-made except Figure 3.1, 5.12, and 5.14 which are downloaded from the internet.

List of Tables

Chapter 1

Introduction

1.1 Background

This assignment is proposed by Professor Lars Line at Agder University College in co-operation with Automation & IT Division of Abu Dhabi Municipality which is headed by Mustafa Abdulla Almusawa [1].

This work of research is carried out by the following two groups:

- Vidar Bekken and Bjørnar Landheim (authors of this thesis) who have explored the possible use of Radio Frequency Identification Technology (RFID).

- Hussain Al-Mousawi [2] who will use our developed case to investigate the performance and reliability of the RFID Technology.

The focus of this thesis is to explore possible uses of Radio Frequency Identification Technology (RFID) in supporting work processes for the Sewerage Directorate. By analysing how the Sewerage Directorate works today, a suitable business process will be found, fitting RFID. This goal may be accomplished by using Contextual Design Methodology, which will be explained later.

During the entire working period for this thesis, there has been a co-operation with student colleague Hussain Al-Mousawi, who is writing a thesis on the performance and reliability of RFID using this case.

1.2 Schedule

The estimated time span for this thesis is from January to June 2004 and is scheduled in Table 1.1.

Period (Year 2004)	**Task**
January	RFID review
February	Business case review
March – April	General report writing and equipment selection
May-June	Prototype testing and final report work

Table 1.1: Estimated time schedule.

The schedule during the entire thesis was followed with the exception of small deviation.

1.3 Thesis Definition

The final definition of the project is:

> *The Sewerage Directorate in Abu Dhabi Municipality is responsible for the provision and maintenance of surface water drainage networks, sewerage collection networks, pumping stations, treatment plants and treated effluent distribution systems to recycle treated wastewater for irrigation. The network systems comprise the Abu Dhabi Island and parts of the mainland. The Sewerage Directorate is responsible for a substantial network construction activity as well as maintenance and asset management of the existing infrastructure.*
>
> *Radio Frequency Identification (RFID) is a wireless technology for tagging and identification of materials and components. The focus of this thesis is to explore possibilities by use of Radio Frequency Identification technology in support of Sewerage Directorate work processes.*

The thesis title:

> *A study of possible use of Radio Frequency Identification (RFID) in Abu Dhabi Sewerage Directorate.*

This thesis will comprise:

- *A review of RFID; technology, standards, research and business cases.*
- *An inception study of the Sewerage Directorate, focusing on Business processes that are candidates for support by RFID.*
- *An ethnographic study of selected work processes.*
- *Evaluation and recommendation for improved process.*
- *Development and pilot testing of a prototype for RFID process support.*

1.4 Radio Frequency Identification

Radio Frequency Identification (RFID) is a wireless technology for tagging and identification of materials and components, without the necessity for line-of-sight. RFID is a relatively new technology and the experience from use in different environments is limited. The technology up-to-date is still in a development phase, and in lack of experience.

The technology consists of two main elements; a reader (source) and a tag (target). The reader is used to communicate with all tags within range. By mounting a tag to an object, and giving it a unique number, it can then be identified by the reader.

1.5 The Case

Our customer, the Sewerage Directorate is part of Abu Dhabi Municipality (ADM) & Town Planning Department (TPD), which provides different kind of vital services to the Abu Dhabi Emirate community.

This thesis will show how RFID can be used in a business case to improve the efficiency and reduce cost for the Sewerage Directorate. The Directorates main concern with the usage of RFID is for the management of their assets which are spread around the Abu Dhabi Emirate.
In order to present a good case for the implementation of RFID, which may be used as an asset management identification system, an evaluation of the Sewerage Directorates candidates will be carried out.

The Sewerage Directorates asset candidates can be divided into:

- Utility network for sewerage, irrigation and storm water.
- Manholes with chambers and valve chambers.
- Pumping stations with equipments.
- Treatment plant with equipments.
- Reservoirs.

All assets are linked to each other in one way or another. After the evaluation one asset will be chosen for implementation of RFID by using Contextual Design Methodology.

1.6 Contextual Design

Contextual Design is used when implementing new systems. It is a system development methodology. The method is customer based and it recommends an adoption of the system to the organization. The method is based on six parts which are coherent to each other. These include understanding the customer needs from scratch to testing and prototyping.

1.7 Budget

The budget for this project is funded by Agder University College (HiA). The required RFID equipment should be within the budget of 20000 Norwegian Kroner (around 2300 Euros).

1.8 Report Outline

The remaining part of this report describes how a business case in the Sewerage Directorate, where implementation of RFID could be used. The implementation phase until prototyping is then developed with an ethnographic study called Contextual Design Methodology.

Chapter 2 describes a review of the RFID technology including its relevant features and capabilities.

Chapter 3 describes an inception study of the Sewerage Directorate, identifying cases which are candidates for support by RFID. The last section describes the final case chosen, for further work.

Chapter 4 describes the Contextual Design as a system development methodology. This method, which consists of six parts, was overviewed and discussed.

Chapter 5 documents an ethnographic study of the business process using the Contextual Design. In order to improve today's system all six parts were included.

Chapters 6 and 7 describe Discussion and Conclusion including evaluations and recommendations for improvement of future work.

Chapter 2

RFID Technology Review

2.1 Introduction

Before travelling to Abu Dhabi our level of understanding of the Radio Frequency Identification (RFID) technology was not sufficient. Therefore the kick-off phase for this thesis was done at Agder University College January 2004, to search, read, and improve our knowledge of RFID. This research was done in co-operation with our student colleagues Jan Harald Hole Mortensen, Tom Are Pedersen, and Hussain Al-Mousawi who also are in the process of writing their Master thesis about RFID technology.

The remaining part of this chapter provides a review of the material we found.

2.2 Radio Frequency Identification

Radio Frequency Identification (RFID) is a wireless technology for tagging and identification of materials and components, without the necessity for line-of-sight. RFID is a relatively new technology and its use in different environments is limited. The technology is still in a development phase, and therefore lacks a wide range of industrial applications.

The technology consists of a reader (source) and a tag (target), where the reader is used to identify and communicate with all tags within range as shown in Figure 2.1.

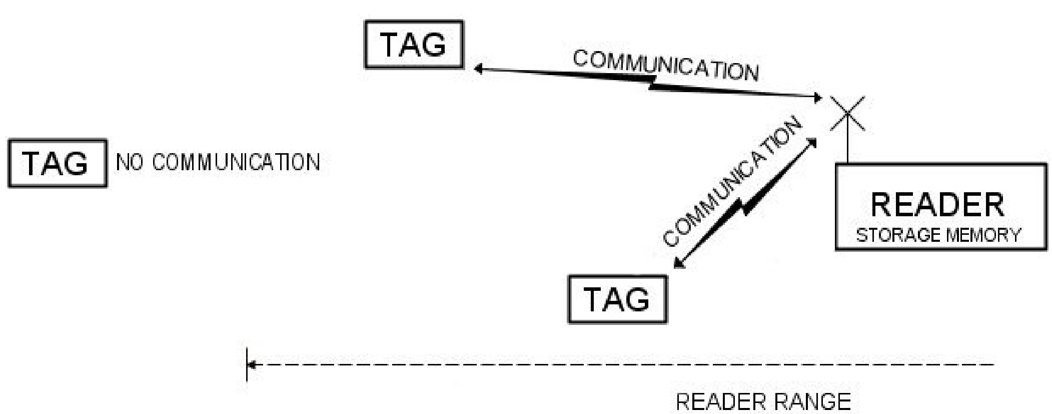


Figure 2.1: RFID reader versus tag communication.

Tag and reader consist of an antenna/coil, a transceiver, and a transponder. The tag also contains an integrated circuit for reading and/or writing data while the reader has a storage memory. Information/data is coded into the radio waves which will be transmitted through the air for communication.

For further information about the RFID technology, please refer to Klaus Finkenzeller's RFID Handbook [3] and for up-to date information about RFID in today's market, refer to articles in RFID journal [4].

2.3 Reader

The antenna sends out radio signals to activate the tags and read and/or write data to it. The antenna is a channel between the tag and the transceiver, which controls the system's data access and communication. Antennas are available in all kinds of forms and sizes and they can be configured as either a handheld or a stationary mounted device. It is also optional to have a reader with read-only or read/write properties from the tag.

The reader can send radio waves to an area from one inch to several hundred feet. The range will mainly depend on the power and the radio frequency that is used as mentioned in section 2.5.

The reader can also be connected to a computer with different kinds of serial communication for downloading and/or uploading data from the tag, as shown in Figure 2.2. This makes it possible to computerize the data which are received, for analysis and database work.

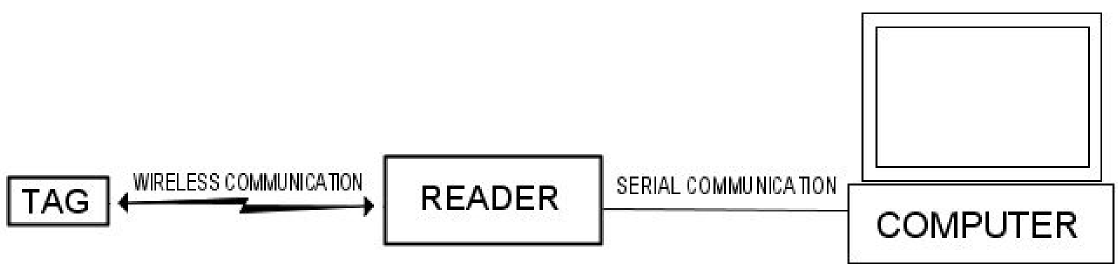


Figure 2.2: RFID tag versus computer communication.

2.4 Tag

The tag is a small electronic device with an antenna which is capable of transmitting information upon request from a reader. It comes in many shapes, sizes, ranges, and can be as small as the head of a pin and with a thickness of a sheet of paper.

Tags can be powered with or without using a battery. Tags without batteries are smaller, lighter, and less expensive than the tags with batteries. In addition, they are maintenance free and will last almost infinitely. However tags with batteries are able to produce more power, and are therefore able to produce a greater range than tags without batteries. But when the battery is flat, the tag also becomes useless.

In order to power up the tags without batteries, a coil is embedded to catch and amplify the energy in the electromagnetic signal which is transmitted by the reader. This will produce enough power to store and transmit data back to the reader. Outside the range of the readers, all tags turn passive (with or without battery).

All the tag parts are encapsulated by a laminate cover to enable it to resist harsh environments such as wet weather, dusty condition and corrosive environment. It also allows the tags to withstand mechanical issues such as vibration and shock.

Tags can hold different types of information. Some tags can't hold more than a serial number while others can hold several megabytes of information.

2.5 Frequencies

RFID operates in several frequency bands. The RFID frequency for each country is controlled by The Radio Regularity Authority (Post- og teletilsynet in Norway equivalent to the Ministry of Communication in the United Arab Emirates).

RFID frequencies can be divided into three major categories [5]:

- **Low Frequency:** The range is between 30 to 500 kHz, with a maximum distance range of 8 centimetres. 134.2 kHz is the most ordinary frequency. Low frequency systems have short reading ranges and lower system requirement costs. The vast majority of the low frequency systems operate without the need for an integrated battery in their tags and are not too sensitive to metal and electrical noise. They are most commonly used in applications such as security access, asset tracking, and animal identification.

- **High Frequency:** The range is between 10 to 15 MHz, with a maximum distance range of 3 meters. Penetrating through solid materials will reduce the range considerably. 13.56 MHz is the most commonly used frequency within the range. Higher frequency systems have longer read ranges and higher reading speeds than the low frequency systems. The cost of this system is relatively more expensive than the low frequency system. The vast majority of the high frequency systems operate without the need for an integrated battery in their tags and are not too sensitive to metal and electrical noise. They are most commonly used in access control and smart cards.

- **Ultra High Frequency:** The range is between 400 to 1000 MHz and GHz to 2.5 GHz, with a maximum distance range of 100 meters. Ultra high frequency systems have longer read ranges and higher reading speeds than the low frequency systems. This technology is very expensive compared to low and high frequency systems. All ultra high frequency systems require a battery, and need line-of-sight between tag and reader. They are most commonly used in applications such as railroad, car tracking, and automated toll collection.

Equipment with low frequency can penetrate through metal and/or other materials. When the frequency is increased, the range and the capacity of penetration will increase too [6], (i.e. the range and the capacity of penetration is directly proportional with the frequency range).

2.6 Standards

There are many RFID standards but till today there is no common global standard yet. Many firms such as Philips, Motorola, Texas Instruments, and others are now working to make this happen. The two most commonly used standards are Electronic Product Code (EPC) and International Organization for Standardization (ISO). EPC and ISO have different range of incidence and they do not cover similar requirements.

ISO makes several different standards including ISO 18000 that covers the air interface for the major frequencies used around the world [7]. This will soon be published as an international standard. There are also other ISO standards which deal with different areas of the system, such as formatting of the data on the tag or on how the reader and tag communicates with each other. None of these are close to be finalized at this stage.

EPC is a more open standard than ISO and is more focused on the data that are sent. It is built up as a series of numbers, a header, and three sets of data. The header has a size of 8 bits and identifies the EPC's version number, thereby allowing for different lengths or types of EPC later on. It is proposed to use 64 and 96 bits. The 96 bit number provides unique identifiers for 268 million companies. Each of these companies can have 16 million object classes (often used to identify a specific product), and 68 billion serial numbers in each class, which will be sufficient for years to come.

2.7 Privacy

Privacy in RFID is not too good. Several people and organizations have expressed their concerns over the possible misuse of RFID tags for identification of customers. This represents a public relation problem that has to be solved before RFID offers wider applications.

Today it is possible, with the right equipment and knowledge, to scan the items inside a handbag/a suitcase tagged with an RFID chip. A person walking by can identify exactly the contents inside the bag. This can be avoided by a limitation of the information stored on the tag, using code lists with a separate database for detailed information. In our case this is not a problem since there won't be saved any sensitive information on tags that will be used for our research.

2.8 Security

When a tag is read there is a possibility that someone with malicious intention may intercept the data that is being transmitted. Consequently, it is recommended not to store excessive amounts of data on the tag.

The prime concern of today's tag technology is to protect the following properties [6]:

- Data stored on tag.
- The integrity of the tag
- Data related to the serial number on the tag.

Till now the work done to make standards for the above properties is still on a 'proposal level'. In our case this is not a problem, since our target range of assets should not have an urgent need for security.

2.9 Business cases

Today RFID is already introduced for some business cases. This section shows two cases among many where RFID is used; a previously developed case for animal tracking and a newly proposed case for Wal-Mart.

2.9.1 Animal tracking

Consumer concern about the cleanliness and wholesomeness of food over recent years has been an important driving force for change. In the mid 1990s, the Australian meat and livestock industry and Australian Government recognized the need to provide 'paddock to plate' traceability [12].

Australia's Cattle ID system at that time was based on a compulsory system of transaction tags, which were applied to an animal before it left a property for sale. The tags show a property ID number that identifies the parcel of the land on which the cattle recently grazed. In the event that trace back is required, a meat processor has records that show the slaughter number of the animal, which can be used to link with the transaction tag and enable tracing of the producer who offered that animal for slaughter. Using this information, inspectors can visit the owner of the property from which the cattle were sent [9].

By introducing RFID for the identification, they are now able to read and store the data from a huge mass of animals coming back from the grazing ground in a short time.

2.9.2 Wal-Mart

Wal-Mart is among the world largest companies in today market with several giant supermarkets. Every year they receive 8 billion cartons. By January 2005 they want to track the distribution of merchandises for their top 100 retailers, of one billion a year cartons. The ambition is to demand this from all retailers by 2006 [10]. Because Wal-Mart is a big customer to all their retailers, they are able to have influence on them to follow. RFID will be implemented by tagging cartons and pallets, with 10 centimetres by15 centimetres labels and follow the EPC standard.

In addition they are planning to introduce the smart shelves, meaning merchandise with some degree of intellect. Cartons are now able to tell the retailers where they are in the system, like in transport, in stock or in the shelves, by linking up to common databases using RFID. And the retailers can send out new cartons, from the measure of sale. This will also make tracking of theft easier.

There is an estimate of how much Wal-Mart might save annually when RFID technology is deployed [10]:

- **$6.7 Billion:** A reduction in labour costs by 15 percent since no labour are required for scanning bar codes on pallets and cases in the supply chain and on items in warehouses.

- **$600 Million:** Even with the most efficient supply chain available, Wal-Mart suffers from items being out-of-stocks. The company boosts its bottom line by using smart shelves to monitor on-shelf availability.

- **$575 Million:** Knowing where products are at all times makes it harder for employees to steal goods from warehouses. Scanning products automatically reduces administrative error and vendor fraud.

- **$300 Million:** Faster tracking of more than one billion pallets and cases that move through its distribution centres each year produces significant savings.

- **$180 Million:** Improved visibility of what products are in the supply chain, its own distribution centres, and its suppliers warehouses lets Wal-Mart reduce its inventory and the annual cost of carrying out such an inventory.

- **$8.35 Billion:** Total pre-tax saving is higher than the total revenue of more than half the companies on the Fortune 500.

The current retailer price of a tag is 0.40$ and as a result of huge amount of ordering, it is expected a reduction in the price to about 0.05$ in the future as mentioned in section 2.10. This will also lead Wal-Mart to increase their profits.

2.10 Cost

When considering the cost of RFID technology it is important to take into account all the various factors that might occur. The obvious costs are the immediate expenditure for buying the technical equipment, tags and readers. In this cost it would be logical to include the necessary infrastructure to relay the signals from the reader to a central unit. Less often are the costs for implementing a system for handling the massive amounts of data that the RFID system might give, included. Equally the costs for creating a link between the existing data systems are often overlooked as an expense when planning the RFID implementation. Finally it is important to look at the costs for planning the implementation and training the personnel that are going to use the equipment.

There exists a wide diversity of tags and readers with prices ranging from somewhere under 10 US cents to well over 100 US dollars for tags and several thousand dollars for some readers. It is expected that the market will fall down to 5 US cents for the majority of tags and 100 US dollars for the majority of readers in the future. This depends on RFID becoming a success, with big orders. And it is expected to take almost a decade [11].

2.11 Research

Research on RFID today is concentrated around areas where the technology could be useful, and standardization for a global platform. By successfully introducing RFID to a wider market and increase the market shares; the expenses for implementation will decrease, and could cause the interest to increase.

Information about improvements and new plans today is share through the World Wide Web or through conferences that are regularly held by the big participant on the market.

2.12 Advantages and Disadvantages of RFID

In order for the companies to find value in RFID, it needs to be viewed as more than a bar code replacement; successful companies have overhauled their business processes to take advantage of the process automation capabilities it offers [12]. If RFID is properly used within its potentials, it is possible to achieve best benefits from the technology, but there are also limitations that give produce drawbacks. This section will look closer into that.

The main advantage of using RFID technology can be summarised as follows:

- Provides reliable operation in harsh environments (e.g. wet, dusty, dirty conditions; corrosive environments; or applications where vibrations and shocks are possible).
- Provides faster data collection and a non-contact operation.
- Has freedom from line-of-sight constraints (transponders can be read irrespective of orientation; through paint, even through non-ferrous solids).
- Reduces labour and paperwork required to process data.
- Reduces clerical errors in the process of recording data.
- Realizes gains in labour efficiency and productivity by automatic registration of all items inside a truck, passing through a portal.
- Automates quality control processes by providing information of all the links in supplier chain, from the farmer to the store.
- Reduces waste and keep inventory levels at a minimum; by stores giving automatic feedback to about what’s on stock and sales rates to the supplier.

- Increases customer satisfaction by lowering prices, caused by reduced expenses in automatically done procedures, as mentioned in the points above.

- Improves profitability by better results, caused by the points mentioned above

The possible disadvantages or drawbacks of using RFID technology are listed below:

- Privacy is not yet at a satisfactory level. For more details, see section 2.7.

- Security is not yet at a satisfied level. For more details, see section 2.8.

- Both the tags and the reader are costly. In addition, there may be substantial redesign required in the infrastructure. This can be weighed against the possible savings when implementing RFID, see section 2.10.

- RFID is a relatively new technology, so it may be said that it has not been thoroughly tested yet. This may make someone hesitant about implementing it, but RFID has proved to work in several business cases so far.

- RFID is also plagued with competing standards such as ESP and ISO, so companies may have to wait for this until this has been resolved. However, if the company decides to implement a closed-loop solution, this will not be a problem. For more details, see section 2.6.

Chapter 3

The Case

3.1 Introduction

To find a case where RFID can be used as a tool, we had to learn more about how the Sewerage Directorate of Abu Dhabi Municipality works and runs their business. This research is based on verbal conversations, internet sits, and field visits which includes the following events:

- Several conversations with Mustafa Abdulla Almusawa [1], about all relevant aspects around the Sewerage Directorate.
- Conversations with Jacek Mierzejewski [13], about the Asset Information Management System (AIMS).
- Conversations with Hassan Ahmed Al Kurbi [14], about the AIMS and the pipe network.
- Conversation and demonstration with Aminol Kaibia [15], about the Close Circuit TeleVision (CCTV) pipe surveys.
- Conversation and demonstration with Jerzy Augustyniak [16], about the SCADA, a remote control and alarm system for pumping stations.
- Conversations with Ghassan Koujan [17], about arranging field trips and the pipe network.
- Conversations with Ken Vaheesan [18], about Mechanical and civil Engineering Contractor (MACE).
- Conversation with Frank Mueller [19], about an old RFID project at the Sewerage Directorate.
- Visit the official internet sites for the municipality [20].
- Searching for general information about the municipality on the internet.
- Searching for general information about the United Arab Emirates and Abu Dhabi, on the internet and in books.

- Field trip with guide at Mafraq Treatment Plant.
- Field trip with guide at irrigation reservoirs.
- Field trips with guide to different types and sized pumping stations.
- Field trips with guide to regular manholes, during maintenance work.

All conversation was carried out face to face with the people in charge at their offices. Some of the conversations have also been supplemented with demonstrations in the field, on computers or with billboards. There has also been contact with some of the concerned persons after the conversation with follow-up questions over phone or in person at their offices.

During our field trips we spoke with several people who work as contractors or are regular employees for the Sewerage Directorate. This provided us with valuable information about the general operations.

Collected data was written down in an internal report (see Appendix A) and sent to Mustafa Abdulla Almusawa [1] for verification and corrections to ensure quality and accuracy. In addition, several documents and brochures were presented to gather information.

All conversations and field trips were carried out in February 2004. The research was done in co-operation with our colleague Hussain Al-Mousawi [2].

The remaining part of this chapter describes and analyses the material we found and with focus on subjects that are relevant for this thesis.

3.2 Case Limitation

Early on, in the evaluation for a business case, the Sewerage Directorate showed massive expression for using RFID in asset management. Complying this request, will set some limitation to our business analyze. Since the Sewerage Directorate are the customer, we followed this advice.

We will therefore focus on how to use RFID as an asset management tool; by examine and evaluate what kind of asset the Sewerage Directorate got in possession. Since the expense of tagging items and buying equipment is not for free, we only look closer into assets that have at least, some degree of value and importance.

3.3 United Arab Emirates

Once an obscure corner of the Arabia, the United Arab Emirates have transformed themselves into an Arabian success story through a mix of oil profits, stability and a sharp eye for business. This started in 1958, when oil was found for the first time in the emirate of Abu Dhabi. During this period the area was strongly influenced by the ruling of the British. Export began 1962 and, with a population at the time of only 15000, Abu Dhabi was on its way of becoming a very rich emirate [21].

After gaining independence from the British in 1971, the seven emirates were united and formed the United Arab Emirates (UAE) as we know it today as shown in the Geographic map of Figure 3.1 [22]. The country became very wealthy and went through many progressive phases and programmes.

Figure 3.1: Geographic Map of United Arab Emirates.

This enormous wealth provides the nation and its wise leadership to invest and upgrade every aspect of the country with up-to-date technology.

3.4 Abu Dhabi Municipality & Town Planning Department

Abu Dhabi Municipality (ADM) & Town Planning Department (TPD) is a local Government organisation that was established in 1966. At that time Abu Dhabi Emirate was a pure desert with a small population. After more than 30 years of hard work, Abu Dhabi now is one of the most modern cities in the world. ADM & TPD is serving more than one million people

(The Island and Mainland population). There are about 40000 employees taking care of all services that a modern society must have.

ADM & TPD consist of two main Departments; ADM and TPD. ADM is divided into several Directorates among them there are four vertical technical Directorates for engineering; Sewerage, Roads, Building Engineering, and Public Health, as shown in Figure 3.2.

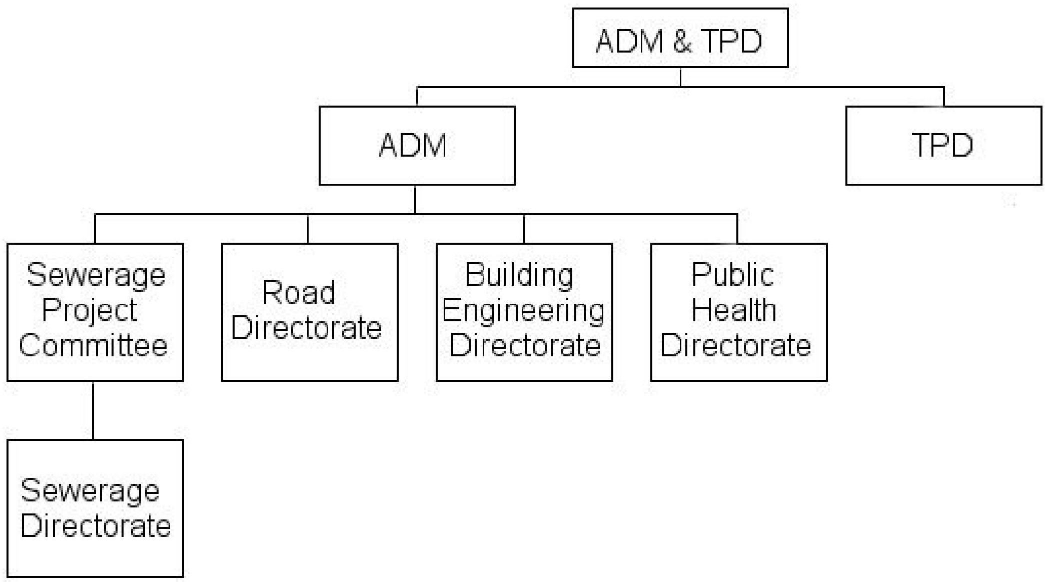


Figure 3.2: ADM & TPD organisation chart.

The Sewerage Directorate stand out from the other, by having a Sewerage Project Committee (SPC) on top. This was included several years ago, to effectively make decisions during a critical period for the Sewerage Directorate. SPC is still the decision centre for the Sewerage Directorate.

Operation areas for each Department are [23]:

- The ADM is divided into four Directorates:
    - **Sewerage Directorate:** for more details refer to section 3.5.
    - **Roads Directorate:** Planning, design and construction of all transportation facilities within the City of Abu Dhabi.
    - **Building Engineering Directorate:** Engineering design and control works for the Municipality projects in different phases from design to completion of work on site.
    - **Public Health Directorate:** Ensure the safety and fitness commodity entering the UAE. In addition, it proposes and implements environmental policies, legislations and guidelines for the Emirate of Abu Dhabi.

- The TPD is divided into eight technical Sections:
    - **Planning Section:** Prepares overall layout plans and subdivisions. Also provides permanent co-operation with other governmental departments on roads and infrastructure. Moreover, it provides site investigation and land survey on all public developments.
    - **Land Section:** Carries out site surveys for detailed plans, participates in land distribution to citizens, issues site plans and land licenses and advises in land-related legal actions by the Municipality.
    - **Urban Design Section**: Advises on building appearance for developments schemes, designs and supervises special building projects and issues site plans and land licenses.
    - **Execution/Projects Section:** Supervision and construction of public projects designed by TPD.
    - **Study and Research Section:** Evaluates projects, prepares feasibility studies and site appraisals, carries out social and economic analysis and forecasting, collects and maintains statistical data, and maintains consultant's registration.
    - **Building Permit Section**: Formulates building regulations and co-ordinates with developers, reviews projects for conformity with Building Regulations, issues building permits, and provides design advice and supervision assistance to citizens for house extensions.
    - **Service Co-ordination Section**: Provides and maintains information on utilities, co-ordinates infrastructure projects, provides approvals for utility routes, and carries out inspections in connection with building permits procedures.
    - **Master Plan Section:** Follows up and updates the Master Plan for Abu Dhabi City and other settlements.

This project will be carried out for the Sewerage Directorate under the ADM.

3.5 The Sewerage Directorate

The Sewerage Directorate of Abu Dhabi Municipality is a Government organisation responsible for developing, maintaining, and operating sewerage, storm water, irrigation, and a treatment plant in Abu Dhabi Emirate (except Al Ain).

The Directorate works under the jurisdiction of Abu Dhabi Municipality and under the guidance of the Sewerage Project Committee (SPC). The Directorate is divided into four sections; Technical Service, Operation & Maintenance (O&M), Project, and Irrigation & Landscaping. All sections are reporting directly to the head of Sewerage Directorate, as shown in Figure 3.3.

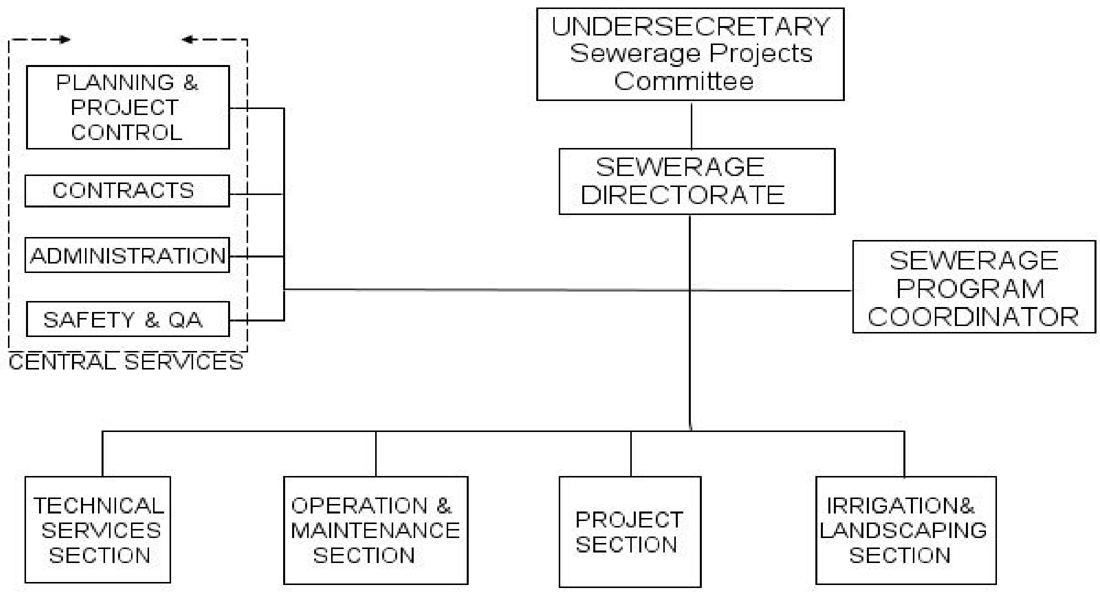


Figure 3.3: Sewerage Directorate organisation chart.

The Central Services section is an organisation which is under construction and will be responsible for communicating the Directorates channel with the users and the contractors.

The Directorates four business sections contain [23]:

- Technical Service Section.
    - Provides utilities co-ordination, building licensing and control of property internal drainage and its connection to public system, trade waste inspection and control, public reception/call centre, document management and archiving and the general management of the requirements of local applicable bylaws.
    - IT & Automation; for operation and support of the IT system, operation of the AIMS centre (see section 3.7) and remote control of all pumping stations with the Supervisory Control And Data Acquisition (SCADA) system.

- Projects Section.
    - Design and constructions of new assets comprising pipelines and associated structures, pumping stations, wastewater treatment work, storage reservoirs and irrigation projects.
    - Rehabilitation of old assets.

- Operation and Maintenance Section (see section 3.10).
    - Manages the proper function of existing network and surface asset.
    - Involves the private sector in the day-to-day work running of the facilities.

- Irrigation & Landscaping Section.
    - Distribution, Construction, Design & Landscaping, and Operation & Maintenance for irrigation.

Sewerage Directorates main focus is [1]:

- ‘Provide quality service to public with maximum protection of environment and with cost effective operation’. The directorate’s staff will put all their efforts to satisfy the public, and at the same time respect the environment and operations cost.

As part of the Directorates vision to provide a quality service that is dynamic and responsive, identifies the need to computerise the recording and management of its infrastructure assets by implementing an Asset Information Management System (AIMS) (see section 3.7). This is done by the Technical Services Section, which also employs our contact person in the Sewerage Directorate, Mustafa Abdulla Almusawa [1].

3.6 Assets

3.6.1 Introduction

As mentioned in section 3.2, we will look closer into the assets owned by the Sewerage Directorate, for possible use of RFID. The assets are spread over a huge area as pipelines, manholes, chambers, pumping stations with equipment, valves, reservoirs, and a treatment plant with equipments.

We have divided today’s assets into five different groups (see section 3.6.2 – 3.6.6). Section 3.6.7 shows a summary about how the assets work together.

3.6.2 Utility network

The sewerage, storm water, and irrigation network stretch over a huge area with little or no record. Most of the pipes in the network lies buried up to 3 meters beneath the earth surface and some lies on top of the sand outside the cities.

The Sewerage Directorate operates three utility networks:

- **Sewerage network:** This network covers the transport of sewerage from homes, buildings, shops, factories to the pumping station, which direct it to the treatment plant. The network pipe length is about 2440 kilometers.

- **Storm and surface drainage network:** This network transports the collected water from the storm and surface and transfers it directly to the sea, because it is not good enough for irrigation. The network pipe length is about 416 kilometers.

- **Irrigation network:** The treated effluent from the treatment plant will be transported back to the city in the irrigation network and used for irrigation of plantations and greening. The network pipe length is 244 kilometers.

The sewerage and irrigation network has a tree-structured hierarchy, were the top is at Mafraq Treatment Plant (MTP), with a fan-out ration going all over Abu Dhabi, as shown in figure 3.4.

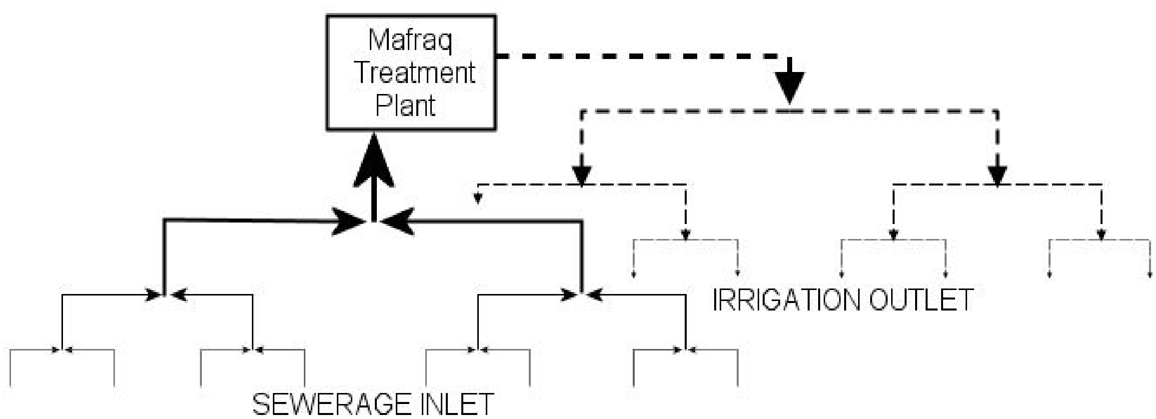


Figure 3.4: Sewerage and irrigation tree-structure.

3.6.3 Manholes with chambers

There are more than 96880 manholes with chambers operating in Abu Dhabi Municipality. There are many kinds of manholes and chambers, coming with different shapes and functionalities. Manholes with chambers, is build above the pipelines, to secure access to the pipes underground. They are located every 60 meters for small pipes and every 200 meters for big pipes. There are also manholes with chambers for every pipe node.

A chamber is a room with one pipeline coming in and another going out. These rooms are used to inspections and maintenances of the pipelines.

The manhole is the entrance to the chamber from above. Chamber goes up to 3 meters beneath ground. Manholes are normally covered with two manholes covers, so people don't fall in by accident. One is located at the surface; the other is located some centimetres beneath.

There are also 260 chambers containing valves, for directing irrigation water to the correct pipe line or reservoir as mentioned in section 3.6.6. These valves are under high pressure, and in case of an accident, with high pressured water streaming out, a little manhole could by very dangerous. Instead, the chamber is covered with plates going from wall to wall over the chamber. This is normally defined as a valve chamber. For further evaluation of manholes with chamber, we also talk about valve chambers. Since manholes with chambers and valve chambers are similar facilities, containing assets underground.

3.6.4 Pumping Stations

There are 175 pumping stations operating under the Abu Dhabi Municipality, and more are under construction. These stations are distributed all over Abu Dhabi Island and Abu Dhabi Emirate except Al Ain. Each station operating with one to six pumps. The pumping stations collect and distribute or redirect the flow.

Pumping stations can be classified according to the following subheadings:

- **Flow:** Includes irrigation pumping stations, surface water pumping stations, and waste water pumping stations.
- **Structure:** Includes drywell pumping stations and submersible pumping stations.
- **Pumping:** Includes lifting stations and pumping stations.
- **Pump types:** Includes centrifugal pumping stations, screw pumping stations, and vacuum pumping stations.

The pumping stations also have other important assets:

- **Flow meters:** For flow measurements.
- **Standby power generator:** In case of a blackout or emergency.
- **Air purifier system:** To make the air around the station environmentally safe and odour free.

A pumping station is a junction with two pipelines with one coming in and one going out, to the next junction or pumping station. This repeats itself until the sewerage is at MTP. Since the flow are increasing from pumping station to pumping station, the size of the pumps also have to become bigger, the closer they are to MTP in the structure.

In order to keep the environment around the facilities clean, toxic and bad smelling gasses are removed at the pumping stations.

All pumping stations are monitored and can be remotely controlled with the SCADA system that is located at the Sewerage Directorates main centre.

3.6.5 Mafraq Treatment Plant (MTP)

The Mafraq Treatment Plant (MTP) is located 40 kilometres from Abu Dhabi Island and serves the whole of the greater Abu Dhabi area. All sewerage flows to MTP is pumped from three main pumping stations. Sewerage treatment comprises a number of physical, biological and chemical processes to ensure that required standard of effluent quality is achieved. The processes are linked together to treat the wastewater. The treated effluent is re-used all over Abu Dhabi as part of the irrigation and greening program. The solids are processed to Class A fertilizer by a composting facility. The result of composting is an environmentally safe and odour free product that can be sold to farmers or in the market place.

MTP contains several different assets, which are located on a relative small area:

- Tanks.
- Reservoirs.
- Pumps.
- Valves.
- Pipes.
- Flow meters.
- Trapdoors.
- Gates.
- Emergency power generators.
- Composting facilities including compost dry fields.

3.6.6 Reservoirs

There are 182 reservoirs operating under the Abu Dhabi Municipality, and more are under construction. The size of some of the reservoirs is huge, with wall raising 3-4 meters above the surface of the ground and stretching up to 100 meters along the ground.

After the cleaning process at MTP, the water is sent back for storages in several different reservoirs. This water is used for irrigation when needed. Normal irrigation schedule is after sunrise and before sunset. If the capacity of the reservoirs is reached, the water is piped directly to the sea. This is controlled by valves, located in chambers before the reservoirs.

3.6.7 How these facilities work together

All assets described in section 3.6.2 to 3.6.6 work together to make the environment clean from pollution and to make irrigation in the desert. It is a total system from sewerage to clean water and compost.

The sewerage from end-users (houses, shops, etc) will be transported to the nearest pumping station by using gravity. Small pumping stations carry forward sewerage and pump it to the main pumping stations. From the main pumping station the sewerage will be transferred to MTP.

After treating the sewerage at MTP, the treated water will be pumped to the Abu Dhabi city and the connected roads for irrigation. Before the water is used for irrigation, the irrigation water is stored in reservoirs. The solid materials are dried and used for compost.

Underground- and rain water are not treated in Abu Dhabi Municipality. This water is polluted and not good enough for irrigation. Therefore it is piped directly to sea.

3.7 Asset Information Management System (AIMS)

AIMS is an enterprise computer system being developed for the Sewerage Directorate of Abu Dhabi Municipality, consisting of a suite of integrated applications which are designed to:

- Enable easy exchange of information with Government and other institutions.
- Provide an easy access to documents.
- Provide an easy access to up-to-date information on location, condition and technical characteristics of sewerage, storm water and irrigation assets.

- Assist in operating and maintenance of these assets.

The Sewerage Directorate is aiming to improve efficiency and decision made by implementing AIMS.

AIMS is a new implementation for the Sewerage Directorate to establish a state of the art computerized Asset Information Management System. The implementation contains of three phases:

- Phase 1, Foundation (1997-1999).
- Phase 2, Development (1999-2006).
- Phase 3, Integration (2006-2007).

This means that AIMS is in a trail phase, during the entire Master thesis period.

As shown in section 3.2, the Sewerage Directorate, is looking for an asset management system for there assets. The ideal solution would be to connect our choice of asset, i.e. data that is obtained from RFID, with the AIMS. Since AIMS is not yet up and running properly, this solution may corrupt the data. To avoid this potential problem we will make our own separate database for testing out our thesis. Still our intention is, to integrate this with AIMS at a more suitable time. This is up to the Sewerage Directorate to complete, after this thesis is finished.

3.8 User Detection and Survey (UDS)

User Detection and Survey (UDS) is a project focusing on verification of the location and attribute information in the Sewerage Directorates network asset database. This will be done by determining and marking the horizontal position as well as measuring the depth of subsurface network utility assets by means of electromagnetic, magnetic, sonic, radar or other applicable surface geophysical techniques and equipment.

The UDS project depends on the progress for the AIMS project shown in section 3.7, because this is the target for all the data acquired. It can still take years until AIMS is ready for implementation from the UDS project, and therefore it is still only in a planning phase and has not actually started yet.

3.9 Mechanical And Civil Engineering (MACE)

As part of the privatization process in the UAE, the Abu Dhabi SPC signed private companies for the operation and maintenance of the sewerage, drainage and irrigation networks in Abu Dhabi Island. The Municipality has today 12 main contractors. Each of these contractors has a specific task to do for the municipality's facilities. Mechanical And Civil Engineering (MACE) is one of the main contractors for Abu Dhabi Municipality. MACE comprises the operation and maintenance of all sewerage, storm water drainage and irrigation networks in Abu Dhabi Island under the control of the Operational and Maintenance (O&M) Section (see section 3.6). MACE also delegating work tasks to all the other contractors.

The number of contractors under the Municipality is unstable. For different reasons some contractors are replaced. With the consequence that valuable experience gets lost.

3.10 Operations & Maintenance (O&M)

A part of the AIMS includes O&M applications, which are designed to control the following activities:

- **Repairing works of sewerage, storm water and irrigation lines**: General repair work on pipe lines.

- **Repairing works of collapsed sewerage and storm water manholes**: General repair work on manholes.

- **Construction of new storm water lines and manholes:** Including commission new assets and merging new and old assets.

- **Construction of property connections:** By connecting new subscribers to the network.

- **Close circuit television (CCTV) surveys:** This is achieved by using a mobile camera on wheels that is fitted inside the pipes to check and prevent blockade inside the pipes. In addition it can be used for monitoring potential weak points in the network.

- **Maintenance and inspection of sewerage, storm water and irrigation valves**: Includes removing any obstruction and local debris, visual inspection, flush pipelines, using cleaning trucks, carry out minor repairs, cleaning/painting of components, and recording and reporting work performed and asset condition.

- **Conductivity monitoring of faulty sewerage in the selected places of the sewerage network:** Includes manually sample and record sewerage at different locations, report faulty values to correct sections, regular calibration of portable meters, recording and reporting work performed and asset conditions.

- **Repair of pumping main failures:** Including general repairs on pumps.

- **Dewatering operations:** Includes removal of water any obstruction, and local debris, visual inspection, calibrate flow meters, minor repairs, recording and reporting work performed and asset condition and cleaning/painting of components.

During all the above activities, the traffic in the area must if necessary be controlled or redirected to avoid dangerous situations. Flow in the network with an influence on the work must also be controlled and/or redirected. When the work is completed, traffic and flow is set back to normal and the site is cleaned.

History shows that a lot of wrongs and unnecessary work has been done, due to problems of identifying the correct assets. This is mainly caused by the huge and complex size of the pipelines underground together with old and inaccurate system drawings. To access these pipelines, localization and identification of the correct manhole is therefore important. If the manhole where tagged with an RFID tag, giving correct information about what's beneath, in order all this unnecessary work could be avoided.

3.11 Old RFID projects

There was an RFID project going on in the Sewerage Directorate five years ago. The Sewerage Directorate and a local company in collaboration with a German company tried to implement a RFID system in the sewerage network by tagging the manhole covers. They succeeded to apply some of these tags in the network, but the work was suspended because of the user's requirements and changing layouts. One of the most important requirements was the tags storage capacity. The user demanded that the tag should store many types of information about the manholes, something that was not possible at that time. The storage of each tag was 64 kbit.

Now, five years later, RFID tags are smaller, lighter, cheaper, and with bigger storage capacity. Storage problem should not be an obstacle for the next implementation.

3.12 Identification of Possible use of RFID

3.12.1 Introduction

As mentioned in section 3.6, the Sewerage Directorate controls several different assets. We need to pick out one for our business case.

History shows that contractors have been replaced many times including loss of experienced workers. This makes the need for an accurate identification of assets important, since previous working crews knowledge about the assets are no longer employed.

The Sewerage Directorate is still expanding there network, with new assets. This asset can easily be tagged before installation. For old assets already in operation, the assets have to be located and identified before tagged. Therefore considerations about how easy it is to tag assets already in use have to be evaluated.

3.12.2 Utility network

Identifying the network pipes for retaining maintenance records on work done and other useful data is a relevant case for the Sewerage Directorate.

Using RFID tags to mark these pipes, is hard caused by limitations of the RFID technology. The tags available to penetrate sand and soil have a very limited range. Reading the tag from the surface of the ground is not possible, since the pipes could be up to 3 meters underground, and RFID don't support this, as described in section 2.5. The only way is to mount a tag at each pipe end, which is connected to a chamber. Reading the tag is now possible by removing the manhole cover and read the tag mounted to the pipe-end. In this case it could be equally good to identify the manhole and storing information about the pipes connected to it. Mounting the RFID tag on the pipe ends in use is not an easy job, since working above running liquid is difficult.

3.12.3 Manholes with chambers

All manholes are connected with a chamber beneath. Identifying a manhole is synonymous with identifying the chamber connected to it. Therefore we only describe this constellation as manholes in the future. This also includes valve chambers, as mentioned in section 3.6.3.

Identifying the manholes with RFID tags to locate and keep records on work done should be an interesting case for the Sewerage Directorate. Records for the pipes connected and/or the assets inside the manholes could also be included, as described in 3.12.2.

Mounting the RFID tag on, in, or around the manhole should not cause any problems.

3.12.4 Pumping stations

Identifying these assets for retaining maintenance records on work done and other useful data is a relevant case for the Sewerage Directorate. Different types of pumps were installed over a period of time which makes it hard to have a clear overview of the specification for each pump. RFID could help identify these assets including pumping station facility.

Mounting the RFID tag on the assets at the pumping stations should not cause any problems, since all assets are easily accessible.

3.12.5 Mafraq Treatment Plant (MTP)

Identifying the assets to keep maintenance records on work done is an interesting case for the Sewerage Directorate. Different types of assets were installed over a period of time which makes it hard to have a clear overview of the specification for each asset. RFID could help in identifying these assets.

Mounting the RFID tag on the assets at MTP should not cause any problems, since all assets are easily accessible.

3.12.6 Reservoirs

Identifying the assets to keep maintenance records on work done is an interesting case for the Sewerage Directorate. Keeping records on technical data are not so important, since the structures of the reservoirs are simple.

Mounting the RFID tag on assets at MTP should not cause any problems, since all assets are easily accessible. The place where to mount the tag must be considered as the reservoirs are vast in sizes.

3.13 Business Case Selection

Identifying all assets described in section 3.6 comes within the Sewerage Directorate plan for asset management. Tagging all the assets with RFID tags and link them to a database with particular specification, location and maintenance records will optimise the performance and records. Assets such as manholes, pumping stations, Mafraq Treatment Plant and reservoirs could all represent excellent business cases for using the RFID Technology.

Five years ago, when RFID still wasn't a well known identification system, the Sewerage Directorate started a project tagging manholes with RFID. This failed due to disagreements inside the Directorates wall and the storage capacity of the tag.

During conversations with employees about the possible use of RFID at the Sewerage Directorate, manholes were most frequently mentioned as a good case of investigation. This is because manholes are becoming more and more difficult to identify, and is centrally situated towards all the other assets under the Directorates authority. Based on previous experiences, the maintenance crew and contractors should be certain that the manhole they are working on is the right one. The manholes are sometimes also hard to find because of sand, dust, rubbish, or old inaccurate maps. Locate and identify these assets is one of the central problems that the directorate wants to solve using RFID technology.

Through all our verbal conversations with people working at the Sewerage Directorate, we have learned that; explaining about how RFID work with radio waves between the reader and the tag gave the impression to most people, that RFID could be used for long distance location. This was not the case and caused a misunderstanding for the proposed system. The reader will not be able to locate the exact position of tags that are placed within radius. It only identifies tags within the specified reader range which may go down to about a few centimetres. Hence the rest of the thesis will focus on the identification and not the location of assets using the RFID technology.

Easy and accurate identification of manholes will reduce expenditure cost of unnecessary work, if working with wrong manhole. The effect of earnings for the Sewerage Directorate by correcting this should be considerable. Therefore identifying manholes are selected as the asset for our business case and for our further investigation. This will also include the pipe-ends connected to the chamber beneath the manhole and valves in valve chambers. This can be done during the UDS project.

Chapter 4

Contextual Design as a System Development Method

4.1 Introduction

Our master thesis is set to use the method Contextual Design. The source used for the method is a book called Contextual Design, by Hugh Beyer and Karen Holtzblatt [24]. The group has read the book, compressed the contents and given our understanding of the method.

Contextual Design is a system development method which can be used when implementing new systems. It is customer/user based and it recommends a full acceptance of the system to the organization. The method is based on six parts and it works through qualitative conversations with the customers and inquiries during work. This is how the first part is performed and where the foundation is formed. The next part depends on the former completed part. A result will be output after every single part. Should a problem occur, you can easily go back and change the setting in preceding part. Figure 4.1 shows an overview of all parts involved in using this method.

4.2 Ethnographic development methodology

Contextual Design is often referred to as an ethnographic development methodology. This method is focusing on the user context. The benefit of using this method is that system developers will be able to collect more qualitative data from the users. This will allow us to collect qualitative data from the people who are involved in the Sewerage Directorate. Ethnographic development method means research at a specific area, such as the one in the field, monitoring the customer doing his work. It is important that the customer acts natural as is we were not there.

Other ethnographic development methods are Requirements Engineering and User [25] and Task Analysis methods [26]. Contextual Design is a different method to use because of its focus on the real customer. These methods will not be used by us as our thesis is defined to use Contextual Design. For more details see section 4.3.

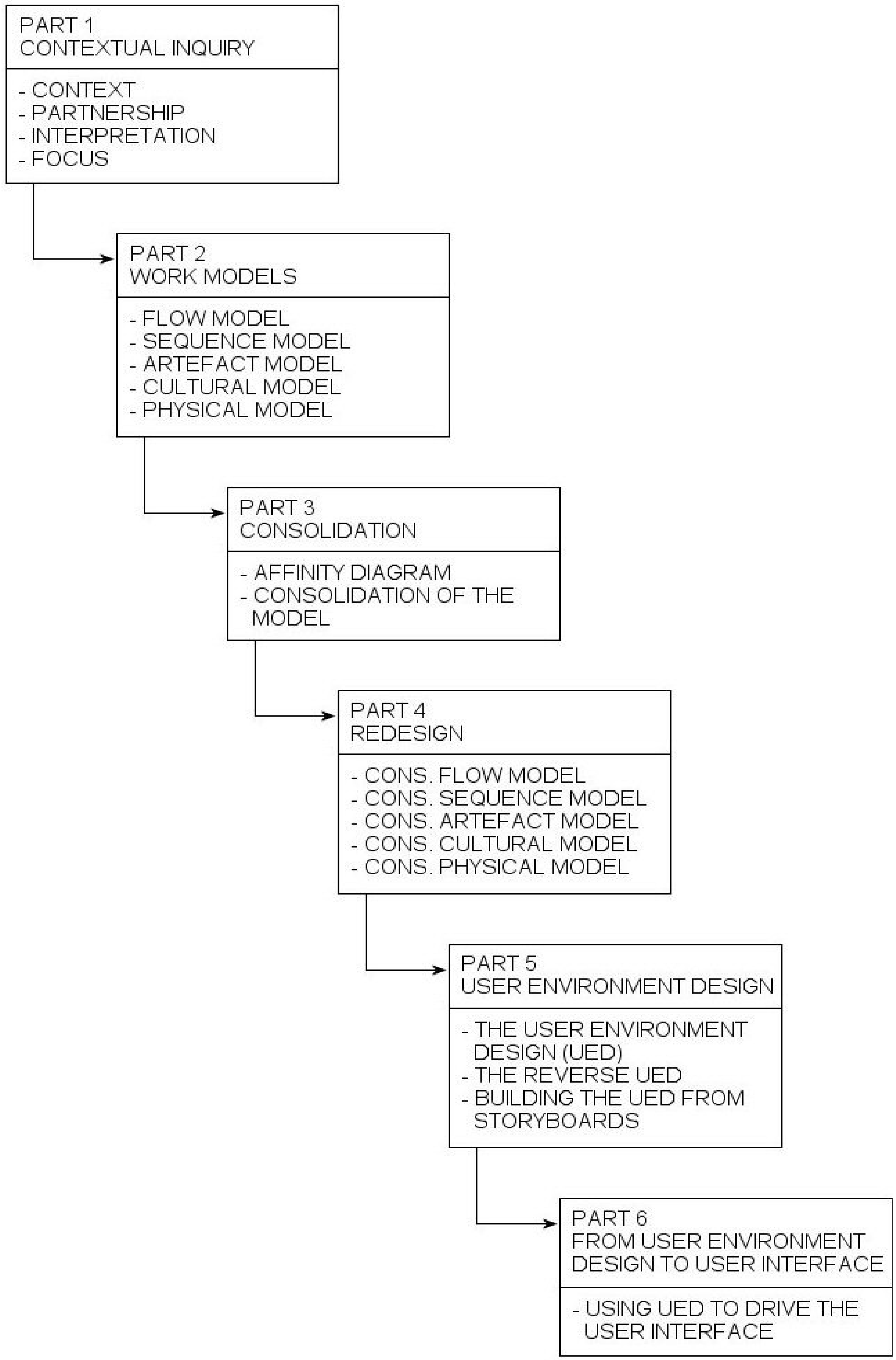


Figure 4.1: Contextual Design diagram.

4.3 Methods in use

As mentioned earlier the Contextual Design method will be used. In this section, a comparison between the Contextual Design method and the Requirements Engineering and User and Task Analysis methods will be presented and can be summarized as follows:

- The Contextual Design method is more comprehensive than the other two methods.
- Requirements Engineering method is well suited for analysing the system requirements during the development of a new system.
- The data collection in the Requirements Engineering method is done in an interrogative form rather than in a more appropriate manner.
- User and Task Analysis method is unlike Requirements Engineering method. It is more like contextual inquiry where you attend the actual process. The interviewer asks questions to the user when involved.

The problem is that often the user is in an administrative position and they may not represent the actual users. Another problem is that it is not a client based method.

4.4 Contextual Design Overview

Contextual Design is a customer based method, which consists of the following six parts:

- Part 1 – Contextual Inquiry
- Part 2 – Work Modelling
- Part 3 – Consolidation
- Part 4 – Working Redesign
- Part 5 – User Environment Design
- Part 6 – Testing and Prototyping

The above parts are listed in a sequential manner and each part depends on the previous part. For instance, the second part is dependent on the first part, meaning that the first part must be completed before starting on the second part.

4.5 Contextual Inquiry – Method part 1

This part represents the collection of data from the customers. There are many ways of doing so by:

- Dealing directly with the customer involved.
- Oversee the customer working structure during working hours. This will enable the developer to monitor and improve the provision of data collection.

The developer should play a key role in collecting data. This can be achieved by allowing the user to be the master and the developer as an apprentice. However the Contextual Inquiry has the following four principle elements:

- Context means that the developer should obtain all relevant and concrete data that is required.
- Partnership means that the developer and the user involved should work as a team in understanding the users work.
- Interpretation means to determine what user's words and action mean together. The design is built upon interpretation of facts so the interpretation had better to be correct.
- Focus means that the interviewer asking the user to focus on another case even if the user is the master. The master decides what to focus on and what to do.

4.6 Work models – Method part 2

This part concerns with the data collected from part one and implement them in work models. The work models enable the user to see what the interviewer is thinking of. It is a kind of a simple language for the user to use without the need for software or hardware skills. The work models can also be considered as a way of communicating between the developer and user to enhance and improve this structure of work. There are five types of work models and these are as follows:

- Flow model.
- Sequence model.
- Artefact model.
- Cultural model.

- Physical model.

These models will briefly be presented as follows:

4.6.1 The flow model

The flow model defines communication between people and coordination to get the work done. This model relays on the following aspects:

- Coordination.
- Strategy.
- Roles.
- Informal structures.

A flow model gives an overview of the organization by describing the user's and their responsibilities, and communication in the organization. The developer has to try to create a bird's eye view of the organization, to easier see what is going on. The idea is to represent locations, things, and systems when they make a place to coordinate. By doing this it is easier to find a work practise and to implement it into a system.

4.6.2 The sequence model

It is important to collect sequences during an interview. The interviewer can either watch the customer work or obtain a detailed retroactive explanation of their work. It is difficult to find out what or who to pay attention to, but the following aspects may help such a model:

- **Steps:** To find out of the user's step to do his work.
- **Hesitations and errors:** The interviewer has to find out of hesitations and errors which indicates that the tools aren't working.
- **Triggers:** The interviewer has to find out the sequence of the trigger, since all these triggers can be the same in a new system.
- **Intents:** To find out what is the cause the sequence to be trigged. This is often showed through work by user.

4.6.3 The artefact model

People create, use, and modify things in the course of doing work. This will make things to become artefacts. Each of the artefacts has its own story/information about the work.

Analysis of artefacts
The best way to make an artefact model is through talking directly with the user. Here are some important aspects:

- **Structure:** It is important to find the structure of the artefact, because it is probably good since the user use the artefact.
- **Information content:** The content of what is written shows a lot of the demands of the work, and what's important to remember.
- **Informal annotations:** What is important to remember is that the artefacts are being used for something and if they are eliminated they must be replaced.
- **Presentations:** The artefact must be well presented to draw audients attention.

4.6.4 The cultural model

There will always be a culture factor in a working environment. The culture defines parameters such as expectations, desires, policies, values, and the whole approach people take to their work. A successful system should fit with user's culture. The cultural model makes influences definite.

Recognition of the cultural influence
This process has the following directions:

- **Tone:** The user's wishes for a system that fully reflects the work place. A well defined system makes the user to be well represented.
- **Policies:** There are both formal and informal rules.
- **Organizational influence:** A user is often part of an organization and that is important to focus on when developing the system. This will result in avoiding personal friction.

4.6.5 The physical model

Work happens in a physical environment that either supports and enables the work or gets in the way. The physical environment involves among walls, pictures, buildings and roads.

Seeing the impact of the physical environment
This model relays on the following aspects:

- **Organization of space:** It is the way the working place is organized.
- **Division of space:** It is important to see how the working place is divided, because it is easier to see who has a communication need and who hasn't.
- **Grouping of people:** Grouping of people is important because user working in a group is jointed as a group.
- **Organization of workplaces**: It is the way the working area is organized and how do they support work.
- **Movement**: Movement in premises is also important and most not prevent with a system.

4.7 Consolidation – Method part 3

Consolidation is about designing models for a population and not only for individuals. Same type of work is being done differently in municipalities. Even in the same municipality the same work is being done differently. The main goal is to collect information about the work from different areas, and then use it to for improvement. This is what consolidation is all about. We will not go into depth with this method, because our case will be focused on the municipality in Abu Dhabi.

The method collects data from a lot of people which is doing the same kind of job. These data will have a new perspective, and the developer looks other ways than to the existing data. Contextual design thinks that this will lead to more creative solutions. Here are some important aspects:

- Affinity diagram
- Consolidation of the models

These aspects will briefly be presented as follows:

4.7.1 Affinity diagram

The affinity diagram organizes the individual notes captured during interpretation sessions into a hierarchy revealing common issues and themes [24]. With the diagram the scope of the user problem is showing. In one place it reveals all the issues, worries, and key elements of work practise relevant to the team's focus. It also defines the key quality requirements on the system: reliability, performance, hardware support, and so forth [24].

4.7.2 Consolidation of the models

The flow model reveals the common roles in different job definitions. It shows who the users are, what they do, and how they interact with each other. The different working models have different rules, principles and directions for consolidation. For instance if four different municipalities, which lead to 20 different models, it would face out 5 complete models after a phase with consolidation. They will produce an overview of the work at all the municipalities. These data is being called consolidated and are going to be used in part 4. As mentioned earlier this will not be followed up in depth here.

4.8 Work redesign – Method part 4

This part is located in the systems engineering process. It is the part where the developers invent the new work practise. To do this consolidated data from part 3 is used. The new ideas here will also be sketched as work models.

4.8.1 The consolidated flow model

New flow model will be sketched. The following aspects are important by changing of working place.

- **Role switching:** Most people play several roles daily. The role has different responsibilities and set of tasks to be carried out.

- **Role strain:** The role strain can be hard, because they simply have to play too many roles. Every role has its own needs and tasks and its own demands on time and concentration. That is why some of the roles have to be automated.

- **Role sharing:** Role sharing is when several people with different job responsibilities are all playing a role. They can do equal work in different ways.

- **Role isolation:** Sometimes people can’t manage their role and they end up blaming other people involved for not doing the job correct. This is called role isolation.

- **Process fixes:** There are a lot of fixes available when needed. The developer can redefine job responsibilities; reassign roles to different people or putting new procedures in place. It is also possible to eliminate a role.

- **Target the customer:** It is important to target the user while working, so problems can be solved if changing of the roles is required.

- **Pitfalls:** The method also describes how to avoid pitfalls. Don't include problems with the new amendments.

4.8.2 The consolidated cultural model

The cultural model reveals values, standards, constraints, the emotional and the relationships among people and groups, and how they all intermix, conflicting and supporting each other [24]. The model shows what to change and what not to change. Here are some aspects to follow:

- **Interpersonal give-and-take:** The cultural model shows in a way the emotional aspects of the relationships between people.

- **Pervasive values:** The user values must be maintained and respected because you don't want any friction between them. If the developer doesn't take this into consideration, maybe the new system won't be accepted of the user's.

- **Public relations:** The kind of relationships between the user and the developer.

- **Process fixes:** Process fixes is about improving parts of the system which require updating.

- **Pitfalls:** There are also methods which sorts out pitfalls. For instance customers should not be taken to places where they don't want to go [24].

4.8.3 The consolidated physical model

The consolidated physical model defines the physical space restrictions. The model shows both the constraints imposed by the environment and the structure that people create within those constraints to get their work done [24]. Here are some aspects to follow:

- **The reality check:** To check out how the physical working environment looks like.

- **Work structure made real:** The developer also has to find out how to set out the way of communication among user's. This will reveal what aspects need to be changed.

- **Movement and access:** Movement and access at the working area must not be impediment. It is difficult to put everything online. People still use the paper mail even if the electronically mail is available.

- **Partial automation:** The new system must keep up with the paper work, or it has to be replaced. This can result in work not being done properly.

- **Process fixes:** To deal with processes, the developer can change environment by moving walls or restructuring working area.

- **Pitfalls:** To avoid pitfalls it is important to consider the reality of the working environment [24].

4.8.4 Consolidated sequence models

The sequence model is about the structure of a work. The task is being divided into activities, and that is rising in the models. Activities can for instance be the way the users do their task. Here are some aspects to follow:

- **What the user is up to:** It is important to consider the user intent. There are several levels of intent including the system manager answering a phone to deal with a request is one level of intent, but in another level the user should show responsibly towards his organization so that systems would be under control [24].

- **How users approach a task:** The developer must look into the user tactics and how to approach a task.

- **Unnecessary steps:** Unnecessary or redundant steps should be avoided to consolidate the models. The user should find out what step to drop or to remove to ease the work task.

- **What gets them started:** Triggers are a tool for the user to work with. There are several ways to achieve that, but the issue here is to produce user-friendly tools.

- **Process fixes:** Process fixes is about procedures for improving the work.

- **Pitfalls:** The method has several ways to avoid pitfalls including avoiding extra work for the user to carry out each task.

4.8.5 Consolidated artefact models

These models are showing the artefacts being used in the system. They are indicating the common structure and intents for the artefacts. There are several aspects to follow:

- **Why it matters:** To improve the artefacts intents.
- **What it says:** The effective artefacts should provide information free of redundant information.
- **How it chunks:** The developer will see from the artefact how the structure is and what kind of distinctions to work with. The way the artefacts rises are important.
- **What it looks like:** The presentation of the artefacts should be well presented and focused on essential aspects.
- **Pitfalls:** Possible pitfalls are to avoid redundant data.

4.9 User Environment Design – Method part 5

The whole idea with this part is to support work practise. Focus areas are important here. They can be seen as rooms in a house. They all connect and represent activities in one way or another. There must be a link between the structure designed and the structure of the work.

4.9.1 The User Environment Design

The key factor in User Environment Design is to structure the system and to make the work coherent. The User Environment Design includes key differences around the work practise. The method implements the parts that are familiar with the user, satisfaction, and relationships of the parts. For checking a User Environment Design, the following appropriate questions may be addressed:

- **Are focus areas coherent?** Focus areas must have a purpose and should be part of the system.
- **Do focus areas support real work?** If the focus area doesn't have a purpose the structure of the system may not be good enough.
- **Are functions correct?** The functions must be at the proper place.
- **Are focus areas distinct?** The functions must support the context of the focus area.

- **Do links make sense?** A link between the consolidated and the redesigned models and the focus areas, should be considered.

- **Is the work supported by the user?** The work design must be supported by the user and to achieve this is by taking a look back on the consolidated models.

4.9.2 The Reverse User Environment Design

There are two ways to use the User Environment Design, one is when implementing a new system and the other is when you do a reverse User Environment Design of an existing system. It will not be focused on the reverse User Environment Design.

4.9.3 Building the User Environment Design from storyboards

When implementing a new system, storyboards are key elements to the User Environment Design. They give information of how a part of the system supports one work task. Storyboards can be for instance a drawing, sketching the user do a specific work task. The coherent structure must support different kinds of work tasks. The storyboards are frameworks for what and how to do a work task.

4.10 From User Environment Design to user interface – Method part 6

The results from the User Environment Design will be used to develop an interface. User interface is called prototype in Contextual Design. This method is not representing how to develop a good user interface, but is looking at the user interface to be clear, and that the user gets a good overview of the system. There are other methods to do this such as usability methods, used to achieve good usability. The prototype will be represented in paper format. By doing this the user can see what is going on, and implement changes to the system. The communication between the user and the developer will be improved and a feedback from the user can be produced.

4.10.1 Using the User Environment Design to drive the user interface

In order to develop the user interface, the developer should employ the structure obtained from the User Environment Design. The developer collect data from the User Environment Design and to accomplish his tasks including on how to organize the interface, what functions are required, and where to use these functions. There are several user interfaces and only two of them will be presented here:

- **A command-line user interface:** A command-line interface such as DOS can be used for mapping data. With this type of interface the user should be familiar with commands.

- **A windowing user interface:** Windowing interface such as Microsoft based applications can be used for mapping data where a mouse is used to route to the next step. The user doesn't need to write anything. The need for writing commands is eliminated.

Windowing user interface is well arranged where all options may be viewed at the same time. The drawback of this interface is that the user can be distracted by the pop-up windows or sub-windows and the user may loose his point of focus.

Command-line interface is a faster method to use where you can write instructions in one line, but the interface is not suitable for a new user who is not familiar with the system.

4.11 Verifying

The Contextual Design method is not specific on how to develop a good user interface but it recommends that the user interface should be clear so the user gets a good overview of the system. Other methods as usability methods can be used to guide the development of a good user interface. Due to a limitation in our schedule, only a short overview of the methods is made.

The definition of usability:

- 'The ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a system or component' [27].

Usability testing can be classified in 5 general categories:

- The willingness to learn.
- The efficiency of performance.
- Flexibility.
- The margin of errors and integrity of the system.
- User satisfaction.

To test the usability there are a lot of methods:

- Heuristic Evaluation Method.

- Pluralistic Walkthroughs.
- Formal Usability Inspections.
- Empirical Methods.
- Cognitive Walkthroughs.
- Formal Design Methods.

Collecting data methods for usability testing:

- Observation.
- Interview/verbal report.
- Thinking high.
- Questionnaire.
- Video analysis.
- Automatic data log application.
- Software support.

Chapter 5

System design using Contextual Design

5.1 Introduction

Chapter 4 describes the Contextual Design Methodology. This chapter consists of reporting results which are obtained using the Contextual Design in the field. Each part includes practical work, results, and discussions.

5.2 Contextual Inquiry – Method part 1

5.2.1 Practical work

As documented in section 3.1 of chapter 3 that a sufficient amount of information were collected using verbal conversation, field trips, and internet search are described. This information was represented in terms of notes, memories, and pictures from different occasions. After choosing the manhole in an asset management system to be our objective, all information where processed one more time with the focus on manholes versus the Contextual Design method. This was complemented with additional visits to old and new sits resulting in more conversation and more accurate observation about the manhole as an asset. This enabled us to understand how the work process looks like today.

5.2.2 Results

For further work with Contextual Design, it is important to collect as much relevant information as possible about the case manhole. The information, conversation, and observation provided us with the capability of categorizing the work with the manhole into four categories as follows:

- **Tasks**: Work done and analysis at the manholes with today's condition for later improvements.

- **Physical measurements:** Description and documentation of the manhole for later investigation to observe the optimum location for the RFID tag.

- **User recommendation:** Feedback from the user on how to implement RFID tags.

- **Environment versus RFID:** Setting limitation for RFID equipment.

TASKS
In section 3.10 of chapter 3, O&M applications were listed. Common to all tasks is the identification of the asset which is represented by the manhole, where RFID can be used. It also mentioned that history showed that a lot of incorrect and unnecessary work has been done, due to problems of identifying the correct assets. This was not a common view for all workers, but has frequently occurred from several incidents.

To identify a manhole the crew first have to locate it. The location is given on the work order (task) and contains a work number with up to 12 digits. Some times the location is a problem since some of the manholes are covered by waste or several manholes are located within a small area. When the manhole is located, it should be identified to be the correct manhole for the task. If not, the crew have to keep searching. In order to identify the correct manhole for the task, by using:

- Knowledge.
- Maps.
- Provided description to locate the manhole, by name.

Knowledge from the crew who have been visited the same manholes before and are familiar with the area are the best way to identify the manholes. Newly built manholes with maps and description of the locations caused no problem. But with older manholes with little or inaccurate documentation, a problem will often exist in locating and identifying the manhole.

All manholes are documented with a 16 digit long identification number, supplied with a description of the area where it is located. When a new asset is constructed, proper documentation is digitized into the AIMS (see section 3.7 of chapter 3) for later location, identification, and recording. Earlier documentations, which are recorded on paper, are also supposed to be processed into the AIMS over time with the UDS project (see section 3.8).

The identification process repeats itself for location and identification for the asset as described in the bullet points in section 3.10. For further work with Contextual Design we select three tasks with the following properties:

- **CCTV survey:**
    - A pipe has to be checked for blockage.
    - Using a CCTV van with camera and monitor.

  - Identify the manhole where, the camera should be used.
  - Stop flow through the manhole.
  - Control traffic if necessary.
  - Regular work using the camera inside the pipe.

- **Routine inspection:**
  - Using an inspection car.
  - Identify the manhole.
  - Stop flow through the manhole if necessary.
  - Control traffic if necessary.
  - Record manhole status.
  - Minor repairs if necessary.

- **Construction:**
  - Using construction vehicles.
  - Control traffic.
  - Build a new manhole.
  - Document properties for the new manhole.
  - Connect the new manhole to the network.

To do CCTV survey and routine inspection, the crew needs to locate and identify the asset where they intend to do the work. For construction, the crew needs to located and identify the assets that shall be connected with the new asset.

MACE is responsible for most of the tasks. The rest are delegated by MACE to other contractors. All tasks that occur are given a 12 digit long number to identify the work. This is printed on a work order and is supplemented with description of what to do and which asset to work on. When the work is completed the work order is returned to MACE.

PHYSICAL MEASUREMENTS

Section 3.6.3 and section 3.12.3 of chapter 3 show the description of the manhole as an asset.

The actual manholes are constructed in several different ways but common features may possibly be specified. The following paragraphs describe the general manholes properties:

- Manholes have an inlet pipe and an outlet pipe at the bottom of the chamber.

- Manholes entrances are at the surface of the ground and sometimes it is hard to locate as they may be covered with rubbish or other obstacles.

- Concrete is always used around the entrance.

- The entrances are always covered with manhole covers that are mostly are made of iron. This represents the first manhole cover.
- 10 centimetres beneath the first manhole cover there is a second manhole cover made of plastic, except manholes used for storm water or with valve chambers.
- Manhole cover usually has small holes at the top for lifting up and removing the cover from the manhole.
- Manhole covers come in three shapes; square, round or rectangular.
- The diameter of a manhole cover is in the range of 30 to 120 centimetres.
- The thickness of a manhole cover, which is made of iron, is about one to 3 centimetres.
- The thickness for a manhole cover, which is made of plastic, is about 50 millimetres.
- Each chamber is up to 3 meters deep.
- The distance from the entrance to the chamber is from 30 to 120 centimetres.

From the properties above, the sketch shown in Figure 5.1 was made.

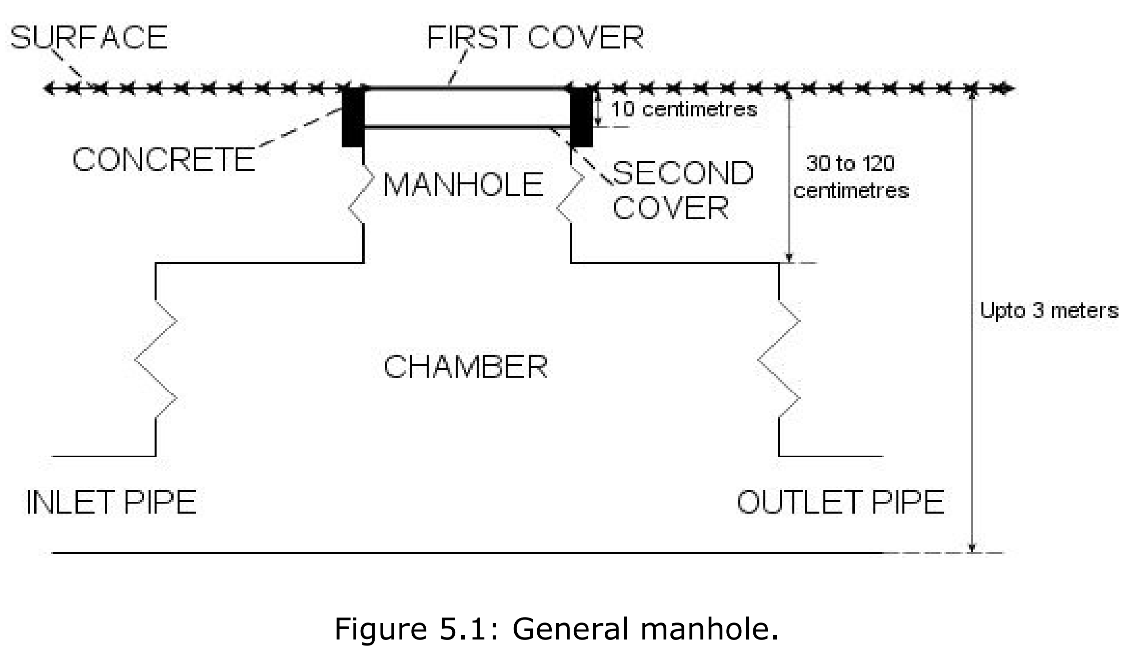


Figure 5.1: General manhole.

User recommendation
The tag implemented should contain information with identification data of the assets and records of work that is done recently. In order to ease the location when attending the manhole for work, GPS coordinates for the manhole must be recorded for identification during the mounting of the tag. The recording of recent work done is important as it shows when the crew was given the work order or locating the manhole or saving data in the tag. This can be checked when the next crew attends the manhole and further be reported back to the MACE. In addition special information can also be stored on the tag if required.

Mounting the RFID tag on the manhole cover could cause problems if the manhole cover has been damaged or replaced. In this case the new manhole cover has to be tagged with a new tag. Mounting the tag on the manhole cover or beneath it could damage the radio waves, as they are sensitive to metal, if high or ultra high frequency was used. If the tag is mounted beneath the manhole cover, the cover must be removed before reading the tag.

The customer recommended the use of RFID to identify asset. They also expressed their opinion about where to mount the tag. For simple and protected implementation it is recommended to use tags that fit inside small cylinders. To do that, a hole adjacent to the manhole in the concrete with a diameter that is greater than the diameter of the cylinder, should be drilled. Also, the cylinder should be fitted inside the hole and closed with new concrete. The layer of concrete above the cylinder should be 5 centimetres to make the concrete withstand heavy loads as shown in Figure 5.2, which may damage the concrete over time.

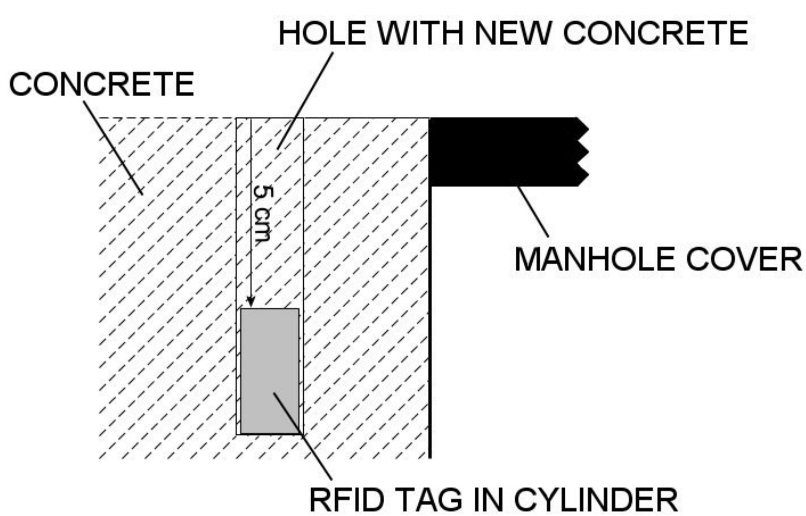


Figure 5.2: RFID cylinder mounted in concrete.

Removal of a great amount of concrete could possibly damage the concrete frame surrounding the manhole. Therefore using large tags which require large holes in the concrete are not practical and also costly.

It was also recommended to do the implementation together with the UDS project mentioned in section 3.8 of chapter 3.

Environment versus RFID
Some of the limitations for the RFID equipment are already set in section 3.13 of chapter 3. The rest of the limitations are due to common sense and the operation environment.

The approved RFID system should fit in the implementation environments and has to work in rough environment circumstances. Middle East has one of the harshest and hottest environments in the world. This is contributed by the following **environment** factors:

- **High temperature:** In the range of 0 to +60 ºC.
- **High Humidity level:** Caused by the sea and the liquid inside the pipes.
- **Tag placing:** To protect the tag it must be placed below the manholes covers or in the concrete surrounding the manhole, meaning the system have to handle condition without line-of-sight. It will be mounted in the concrete as recommended by the user.
- **Solid Material:** The RFID tags will be attached on materials like metal, concrete, plastic and other similar substances.

The **tags** should have the following important properties:

- **Small and light:** It can be easily placed and fitted.
- **Cylinder shaped**: To fit inside a drilled hole in the concrete.
- **Passive:** These tags are cheaper, smaller, maintenance free, and have unlimited battery life.
- **Rewritable:** It is an option for the user to overwrite the tags stored data such as maintenance date, assets information, etc. by using the reader.
- **Storage capacity**: The tag should be able to store some information about the assets/objects. 128 bit – 2 kbit will be a reasonable choice.

- **Range**: A range between 50 and 100 centimetres will be quite enough for the approved system. 100 centimetres is the maximum reading range for high frequency tags and it also got the ability to read without line-of-sight.

The **readers** should have the following important properties:

- **Environment**: Able to read tags without line-of-sight
- **Portable:** Easy to move between locations.
- **Standard Support:** No need for a complex RFID reader that supports more than one standard.
- **Interface:** Host interface options such as RS232 and USB for possible communication with other systems.
- **Size and weight:** Less size and weight for portability.
- **Power supply:** The reader should support 12 VDC power supplies which may be connected to a vehicle battery to support portability.

The **total RFID** system should have the following relevant properties:

- **No Line-of-Sight:** The reader should be able to read the tags even if there is an object between. The tag should not be mounted uncovered on the top of the manhole cover as it may easily be removed or damaged. Mounting the tag in the concrete beside the manhole is the recommended solution from the user and will be followed.
- **13.56 MHz High Frequency:** The line-of-sight is not required with this type of frequency but the range will be limited to about one meter which is sufficient for our research.
- **Range:** Up to 1 meter, the maximum range with use of 13.56 MHz equipment.
- **Reading speed**: This will not be a big issue for the approved system as all the assets and objects, which will be tagged, are stand-still.
- **RFID Standard:** The reader and tags must have the same standard otherwise communication will be interrupted.
- **Power Density:** Choosing either European (0.5 W) or American (2 W) power density is optional in the United Arab Emirate.

- **Price:** Referring to budget described in section 1.7 of chapter 1.

5.2.3 Discussion

The validity of the data is very important since it makes the foundation for the rest of this chapter. In order to achieve this goal; site trips, live conversions, and observation with the customer were carried out to provide valuable ways of gathering concrete data for processing. This also provided us inside information about what was done, how it was done, and working conditions of the site.

If this part were carried out only through conversation and papers outside the work site, which might seems to be good enough; the information gather might be inaccurate. Nevertheless we are aware of that the information gathered at the work site during normal operation may not be hundred percent accurate. This could be caused by our present on site which allows the employees to be formal with our studies.

From O&M point of view, only three tasks out of several were selected to work within the next parts. This should be sufficient for the identification as it is almost the same from task to task. Routine inspection and CCTV is equal by identifying the asset where the work should be done, while construction has to identify the location of manhole adjacent to the site under construction. However, the similarity between routine inspection, CCTV, and construction is very close and will be considered as same for further work with Contextual Design.

Already at this early stage of the process we were lead by recommendations from the customer. The validation of this is important to the rest of the work due to the customers experience in the field.

Data gathered in this section will be used in section 5.3, Work modelling - Method part 2.

5.3 Work modelling – Method part 2

5.3.1 Practical work

Work models are made from data collected in section 5.2, Contextual Inquiry – Method part 1.

5.3.2 Results

The following three situations chosen for further work are CCTV, routine inspection, and construction. The collected data are evaluated with different models recommended within the Work modelling part.

Artefact model

Artefacts are tools used around the manholes to identify the manhole. The artefact model contains the following two procedures:

- **Papers to locate the manholes:** Includes work orders, map for location, and descriptions for location.

- **Vehicles used for transportation to and work on the manholes:** Includes CCTV van for camera survey in the pipes, inspection car for recording, and equipment in the vehicles for different work.

Flow model
Flow model shows how different parts work in the Sewerage Directorate as shown in Figure 5.3. Artefacts are also included in this model.

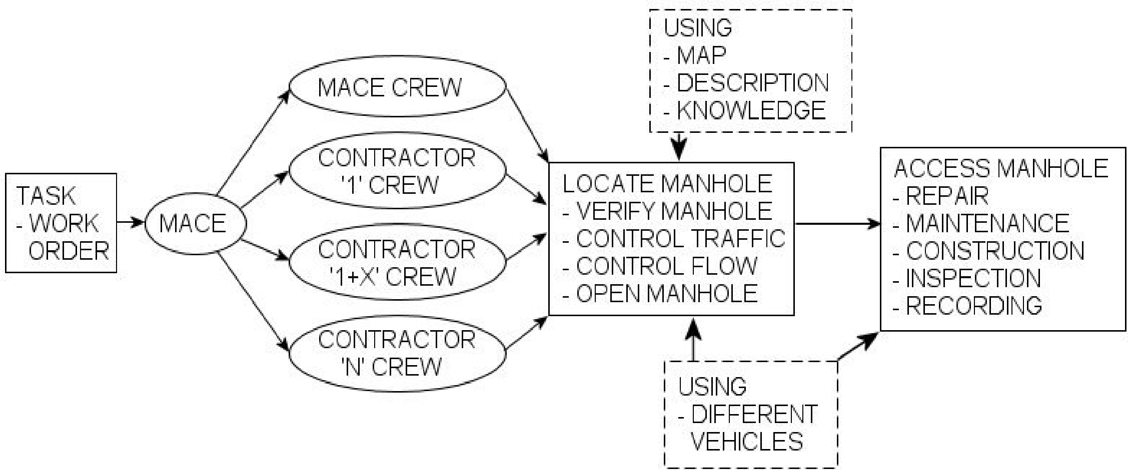


Figure 5.3: Flow model.

Figure 5.3 can be described as a task occurrence. MACE will be accountable for doing the job itself or redirects it to any of its contractors. The manhole site is accessed by using a vehicle together with the guides of maps, descriptions, or personal knowledge. The vehicle and the equipment it carries play an important part in completing the task at the manhole.

Sequence model
This model shows the order of commands and actions done to complete a task for the Sewerage Directorate. It is a sequence based model as shown in Figure 5.4.

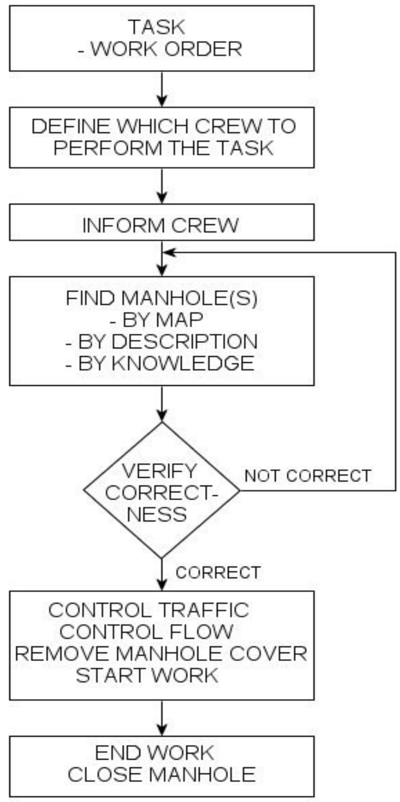


Figure 5.4: Sequence model.

Figure 5.4 can be described as a task occurrence. A crew is selected and will be informed to complete the task. A manhole is located and if it is not identified as the correct manhole another one will be located and this process will go on till it finds the correct one. As soon as a correct manhole is located and identified, a go ahead will be set to start the work. When the correct manhole is located, traffic are controlled if necessary, flow are controlled if necessary, and work starts.

Cultural model

The model shows how the different units of a manhole have an effect on each other. It is done by drawing circles and how much they overlap each other indicate degree of influence as shown in Figure 5.5.

The main influence of the Sewerage Directorate surrounds all the other. Artefacts, MACE and the contractors will all have equal influence on the manhole. They also have equal influence between each other. The culture factor must be focused on. The Sewerage Directorate has different skilled labours working for them and with different culture and background. The customers who are using this system are people from Asia and most of them have little experience in computers or other relevant areas. They follow tasks that are instructed by their managers. As a result it is important that the system is easy to use in such a way that the customers can perform the tasks with minimum instructions.

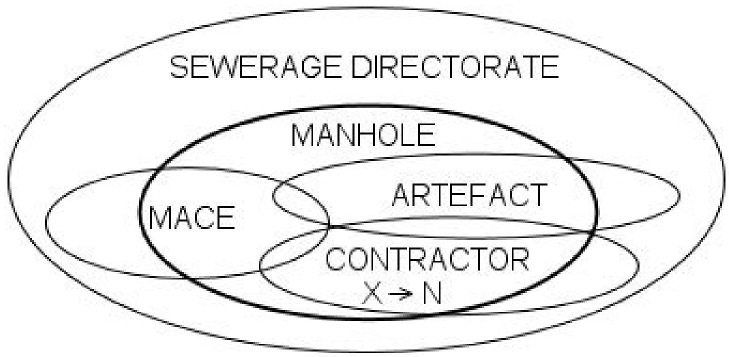


Figure 5.5: Cultural model.

Physical model
Below is a sketch of a specific work place. Access to the manhole will always be done from the top/surface. The top part of the manhole is shown in Figure 5.6.

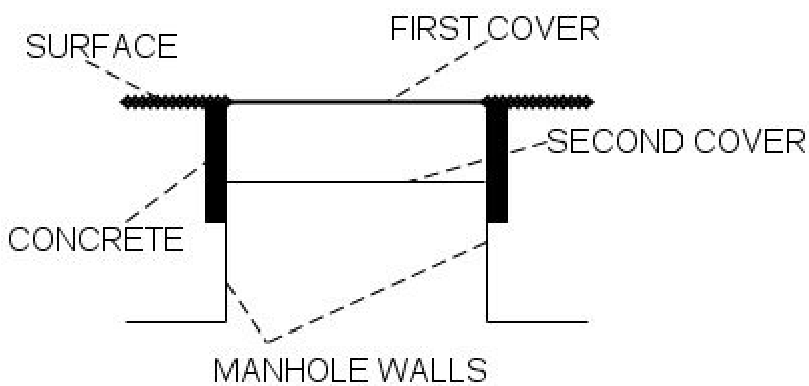


Figure 5.6: Physical model.

5.3.3 Discussion

The models make it easier for the user to see what intensions we have with the new system. It is a new technology we are dealing with which they will probably not be familiar with.

Artefact model
The artefact model tells which artefacts are involved to carry out a task. It also describes what they do and the benefits of using them. They are all important to manage a task. Paper works are used to locate the manholes where the vehicles are used for transportation to and from the manholes.

Flow model
The flow model provides an overview about the different parts that are being executed in the Sewerage Directorate, more exactly in the MACE. By using the flow model it is easier to understand these parts and what changes they might require. The degree of influence for each part is different.

Sequence model
The sequence model is similar to the flow model in terms of the information contents. However this model is based on how the users do a task step by step and the way on how to process certain parts to accomplish a task. The structure is approximately equal for each task.

It is not a simple task to locate a manhole as it may seem as some of the manholes are covered with sand or rubbles, and this is why Figure 5.4 shows a feedback for the searching of manhole if the required is not found.

Cultural model
We are focusing on the manholes which are showed through the cultural model. The other units; Sewerage Directorate, artefacts, MACE and contractors indicate that they play parts regarding the manholes. All mentioned units influence the manholes in one way or another. MACE uses the contractors to perform tasks for the Sewerage Directorate, or they do it themselves. The users who actually do the tasks are people from other Asian countries. Most of them are not familiar with computers or other relevant technologies. They are used to perform manual labour at commands from others. The people involved have a different culture and so forth different expectations and values to the work.

Physical model
The physical model shows the physical restrictions at a typical manhole. All manholes are at surface level and surrounded by a concrete frame. The model is well arranged with necessary attributes.

5.4 Consolidation – Method part 3

5.4.1 Practical work

Consolidation means to compare and gather data from other municipalities in order to achieve a common understanding of a whole population. The developer will gather more data about the users and by doing so; the system should be suitable for different municipalities and not just for Abu Dhabi Municipality.

5.4.2 Results

A comparison with other municipalities is not done as time is limited and the consolidation method is not considered in this research. The data from section 5.3 will be further used in section 5.4.

5.4.3 Discussion

To use the Contextual Design method, the developer is not required to use all the methods available. This is why this part of the method is not used. The consolidation method would probably help the developer to develop a better system by getting more responses and different point of views from users. This system is only developed for Abu Dhabi Municipality and that was our focus.

5.5 Work redesign – Method part 4

5.5.1 Practical work

The models made in section 5.3, Work modelling – Method part 2 will be redesigned. These models will include the new RFID technology. That means implementation of the tags in the new models.

5.5.2 Results

These models are redesigned and will support the RFID technology.

Artefact model
The artefact model will obtain extra artefacts which are represented:

- **RFID Tag:** To be mounted on the manhole for identification.
- **RFID Reader:** To read and write the data to the tag.
- **GPS:** To locate the manhole with coordinates.

All the new artefacts will improve identification of the manholes, while the GPS will improve the localization.

Flow model
The flow model is now supported with a tag, reader and GPS. This will be an integrated part of the process of identifying the manholes as shown in Figure 5.7.

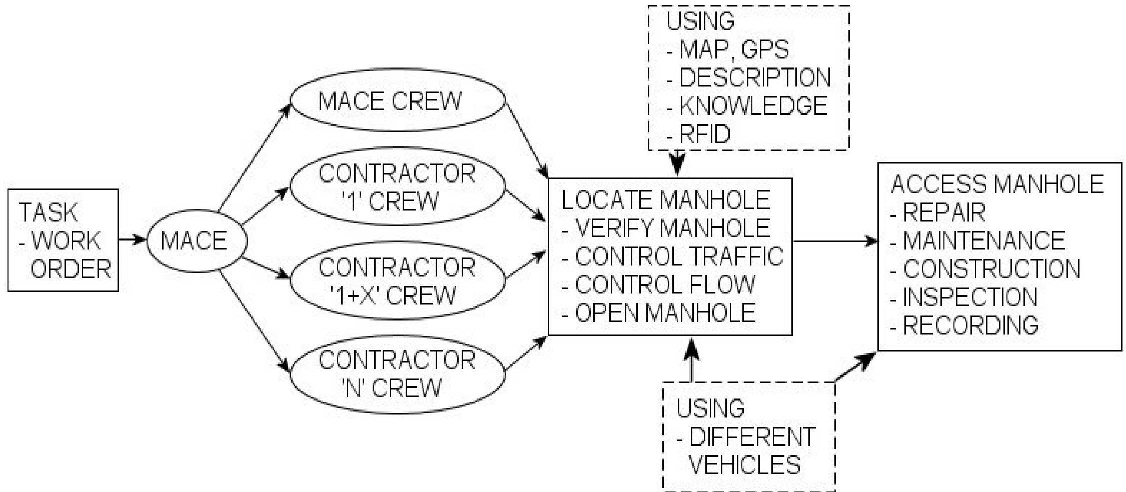


Figure 5.7: New flow model.

Sequence model
The sequence model will also be supported by the tag and the reader. This will be an integrated part of the process of identifying the manholes as shown in Figure 5.8.

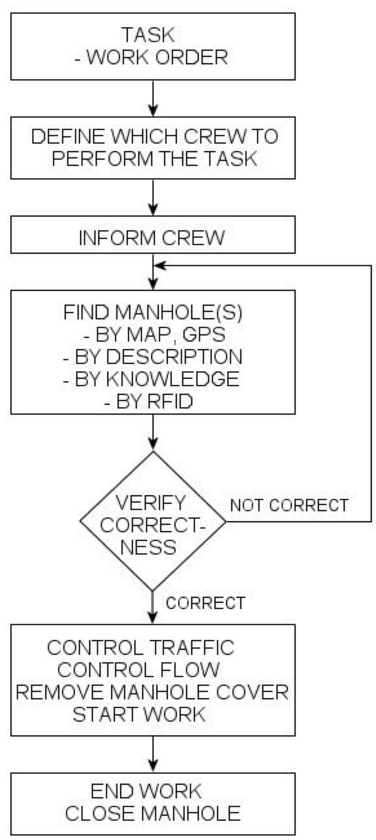


Figure 5.8: New sequence model.

Cultural model
The cultural model will have a different pattern of culture. Some of the crew will have the skill to understand it, while others won't have it, because of technical knowledge. The routine work of the contractors for identifying manholes will be changed with the extra tool available. The model will look equal to Figure 5.5 used in section 5.5.2. The new system must be easy to use, and the users must attend a course to understand the use of the new system.

Physical model
The manhole now have a tag which will be integrated in concrete frame around the manholes for identification as shown in Figure 5.9, as recommended by the user.

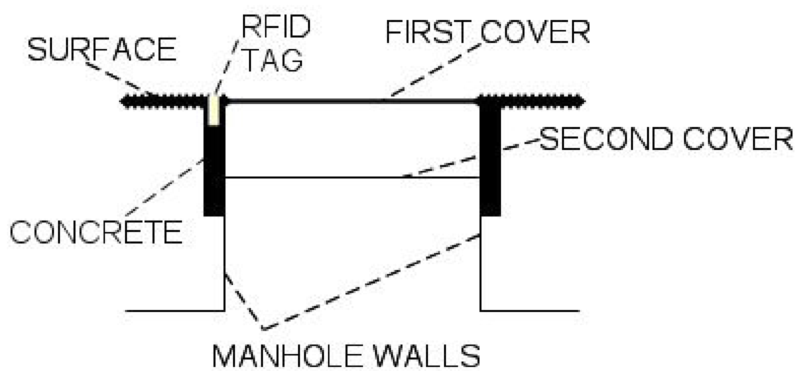


Figure 5.9: New physical model.

5.5.3 Discussion

The implementation of the reader and the tag in the system will make the identification process easier. The contractor will be able to identify the manhole when located. It is important for the contractors to learn how to use the tools and be familiar with the new technology.

Artefact model
The implementation of a tag, reader, and GPS will cause some changes to the routines in the daily work. The contractors will now have one more tool to identify the manholes. As mentioned it is important for the contractors to learn how to use the tools and be familiar with the new technology.

Flow model
The tag and the reader will be a useful tool in the identification of the manholes. It will be easier to identify the manholes without the need for the contractors to open the manhole to check the ID.

Sequence model
The sequence model will be similar to the flow model. The tag and the reader will also be a useful tool for identifying the manholes.

Cultural model
The cultural model will be changed, and there will be a new tool available to identify the manholes. Prior of using the new system, the users should be trained. That is very important because if they don't understand how to use it, they will probably be more reluctant to do the tasks or they may use it incorrectly. The workers different culture and background should be considered and proper training sessions are required regardless of their education and technical knowledge.

A new cultural model will not be created here as the new tools will come under the unit manhole.

Physical model
The tag and the reader are now implemented in the model, which is a supplementary tool for the implementation of the manholes. The tag is located in the manhole.

5.6 User Environment Design – Method part 5

5.6.1 Practical work

New models are made to show how to use the models made in section 5.5, Work Redesign – Method part 4. This shows how the crew must consider RFID in their daily work practise.

5.6.2 Results

The crew working for the Sewerage Directorate have to be familiar of using the RFID technology. Old assets should be located and tagged and new assets must be tagged as soon as they are completed.

The data stored in the tags are separated into the following three parts:

- **RFID address:** Shows the ID of the tag that is difficult to change. This is pre-set by the manufacturer during production.

- **Description data:** Shows additional information to the address ID and is a description of the location, other assets connected, and the GPS coordinates for the manhole. This is critical data and it should not be possible to change it by users. The data is stored in the tag during implementation and should not be changed later; unless asset connected to the manhole is removed or added.

- **User data:** Shows information of previous work done at the manhole. The user should have read access or privilege to change and add more information after the work is completed.

The user must be able to access the tag and report that work has been done. To avoid damage by the user of critical data stored in the tag, the user access must be limited. By critical data we mean description data of the manhole that should not be changed during normal work. This is done by using different software:

- **Software no.1:** Write initiate description date on tag during implementation at the manholes, with full read and write access.

- **Software no.2:** Read all data stored on the tag, with limitations that only enable the user to write user data to none critical part of the tag.

In addition to learning on how to operate tag and reader, the user also needs to know how to operate a GPS. The implementation scenario will be as shown in Figure 5.10.

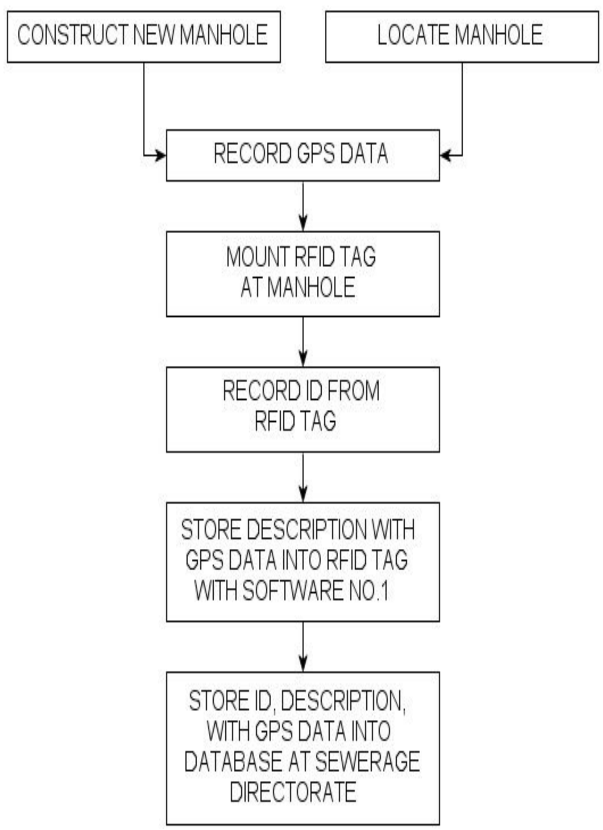


Figure 5.10: Implementation scenario.

The user scenario will be as shown in Figure 5.11.

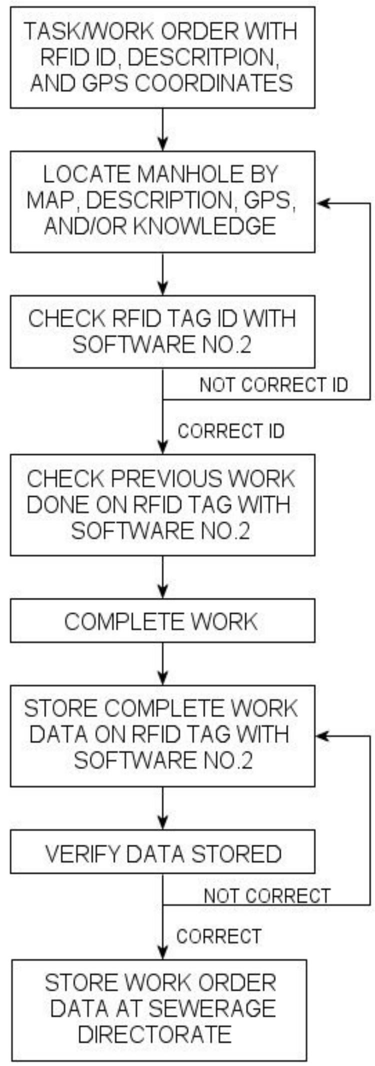


Figure 5.11: User scenario.

5.6.3 Discussion

The models show the new system structure by two different scenarios, one for normal use and another for implementation. Both require the user to learn how to operate a tag, read a communication, and transfer data to the Sewerage Directorate. The implementation scenario requires that the user must know how to use a GPS. For the user scenario this is optional since there are other tools available to locate the manholes.

5.7 Testing and Prototyping – Method part 6

5.7.1 Practical work

The models made in section 5.6, User Environment Design – Method part 6 are used to make a prototype for testing. The equipment needed for the prototype must first be acquired, then appropriate software must be developed and finally the system must be tested.

Before purchasing the RFID equipment an evaluation of different products which were available on the internet were viewed. The Environment versus RFID in section 5.3.2 limited the search.

This was done in co-operation with our colleague Hussain Al-Mousawi [2].

5.7.2 Results

This section may be divided into the following categories:

- Acquire GPS.
- Evaluation of different RFID systems
- Acquire RFID system.
- What we got.
- Software preparation.
- Software development.
- Test preparation.
- Testing.
- Lab testing consolidation.

Acquire GPS

A GPS type Garmin GPS12 [28], which is shown in Figure 5.12, was provided by the Sewerage Directorate for testing during the thesis period.

Figure 5.12: Garmin GPS12.

Evaluation of different RFID systems
The result of the products found on the internet is shown in Appendix B which includes a selection of RFID tags and readers with antennas that is most relevant for our system queries. In addition, brief description and general information of each product are also included. It contains eight different types of tags and six different types of readers.

The following eight **tags** contain:

- **Tag 1 - SL1ICS3001 & SL1ICS3101; I-CODE1 Label IC - Philips**
    - **Application:** I-CODE1 label IC is a chip for logistics, retails and identification.
    - **Reading distance:** I-CODE1 is designed for long range applications with a range of up to 1.5 meter.
    - **Memory:** Good memory size of 512 bit.
    - **Temperature:** Working in high temperature up to +70°C.

- **Tag 2 - 211 13.56MHz Passive Tag - Microchip**
    - **Application:** 211 tags are used for item-level tagging.
    - **Reading distance:** Can carry up to 1 meter range.
    - **Memory:** The tag has large storage capacity of 1 kbit.
    - **Temperature:** Working in temperature up to +60 °C.

- **Tag 3 - Sample RFID Transponder KIT - Philips**
    - **Application:** These tags are used for identification and asset management.
    - **Reading distance:** Information is not available.
    - **Memory:** The storage capacity is from 384 and up to 1024 bit.
    - **Temperature:** From -20 to +70°C depends on tag type.

- **Tag 4 - 13.56MHz Encapsulated Transponder – Texas Instruments**
    - **Application:** Encapsulated transponder can be used in harsh environments such as laundry tracking.
    - **Reading distance:** Information is not available.
    - **Memory:** Very large storage capacity of 2 kbit.
    - **Temperature:** Working in very high temperature up to +90°C.

- **Tag 5 - Tag-it HF-I Transponder Inlays – Texas Instruments**
    - **Application:** Can be used in product authentication, ticketing, library management, and supply chain management applications.
    - **Reading distance:** Information is not available.
    - **Memory:** Very large memory of 2 kbit.
    - **Temperature:** Working in high temperature up to +70°C.

- **Tag 6 - Tag-it Inlays – Texas Instruments**
    - **Application:** Can be used as identification, such as airline baggage identification.
    - **Reading distance:** Information is not available.
    - **Memory:** Very small memory of 256 bit.
    - **Temperature:** Working in high temperature up to +70°C.

- **Tag 7 - LRP125HT-FLX RFID Tag – Escort**
    - **Application:** For industrial environments.
    - **Reading distance:** Short reading range of 0.203 meter.
    - **Memory:** The storage capacity is 384 bit (48 Bytes).
    - **Temperature:** Working in very high temperature up to +93°C.

- **Tag 8 - LRP125 (HT) / LRP250 (HT) Passive Read/Write RFID Tags - Escort**
    - **Application:** For industrial environments.
    - **Reading distance:** Short reading range of 0.216 meter.
    - **Memory:** The storage capacity is 384 bit (48 Bytes).
    - **Temperature:** Working in very high temperature, up to +93°C.

The comparison of above tags is listed in Table 5.1. Red cells indicate that there was no information available, while green cells indicate that it is the best among the group.

Tag No.	Application	Memory (bit)	Reading Distance (m)	Temperature (°C)	Price (£)
Tag 1	FIT	512	**1.5**	-25 to +70	1.17
Tag 2	FIT	1024	1.0	-10 to +60	1.10
Tag 3	FIT	384-1024	**No Info**	-20 to +70	**0.84**
Tag 4	FIT	**2048**	**No Info**	-25 to +90	**?**
Tag 5	FIT	**2048**	**No Info**	-25 to +70	**?**
Tag 6	FIT	256	**No Info**	-25 to +70	**?**
Tag 7	FIT	384	0.203	**-40 to +93**	**?**
Tag 8	FIT	384	0.216	**-40 to +93**	**?**

Table 5.1: Tag comparison.

All listed tags operate in very high temperature environments and can fit in with the approved RFID system. Tag four and five from Texas Instrument have the biggest storage capacity, but unfortunately some information about reading distance and price is missing. Tag seven and eight from Escort have the lowest and the highest temperature levels, however these tags have the shortest reading range (about 0.2 meter).

It can be seen from the table above that tag one and two are the best components for our RFID system. Philips' I-Code1 (tag one) labels have the longest reading range of all the tags and also a great operating temperature range. On the other hand, Microchip's passive transponders have a great memory size and with a reasonable price.

The following six **readers** contain:

- **Reader 1 - Sentinel-sense MPR-1530 - AWID**
  - This portable reader reads transponders at the range of 5-8 inches. The reader has only RS232 interface. The reader's size is 20.3 X 9.25 X 4.0 centimetres and the weight is 680 g.
- **Reader 2 - Memor2000 RFID/HT - Minec**
  - Portable reader which also reads and writes to Tag-it and I-CODE smart labels. It has a range of up to 70 millimetres. The weight is 235 g and the size is 186 X 52 X 27 millimetres. Connections are available in IR and RS232. The datasheet doesn't say anything about the standards supported or the environment, but it will probably be ISO-15693 because of Tag-it and I-Code smart labels.

- **Reader 3 - 211 13.56MHz ISO Single Point Reader - Avonwood**
    - This reader provides interfaces like USB, RS232 and isolated RS485/RS422 as standards. The reader from Avonwood supports long range ISO-15693 and ISO-18000. The size is 300 X 200 X 80 millimetres.

- **Reader 4 - Ridel5000 - Softrónica**
    - Ridel5000 supports interfaces like RS232 and RS485, and standards like ISO-14449 and ISO-15693. The reader can support a range of up to 1.2 meter, dependent of the antenna. Softrónica says the reader is the world smallest and most advanced for the frequency 13.56 MHz. The size is 120 X 120 X 38 millimetres.

- **Reader 5 - CT-MR100-A DEVELOPMENT KIT - Copytag**
    - CT-MR100-A development kit is based on a CT-MR100-A reader, a CT-ANT340/240 pad antenna, a 12 VDC power supply, a RS232 cable, a power socket cable, and a software development kit (SDK) 5 sample tags. It supports I-CODE, Tag-it and ISO-15693. Interface is RS232 or optional TCP/IP. The size is 145 X 85 X 31 millimetres, and the weight is 1.5 kg. The read and write range is maximum 30 centimetres.

- **Reader 6 - CT-LR200 -A DEVELOPMENT KIT - Copytag**
    - CT-LR200-A development kit is based on copy tag SL 13.56 MHz, an antenna, and a CT_LR200-A long range reader. This kit will read/write to ISO-15693 I-Code and Tag-it transponders at 40 centimetres. There are no datasheets available for this product.

The comparison of above readers is listed in Table 5.2. Red cells indicate that there was no information available, while green cells indicate that it is the best among the group.

Reader Number	Applic ation	Reading Distance (m)	Size (mm)	Weight (kg)	Interface RS232
Reader 1	FIT	0.203	203 X 92.5 X 40	0.680	YES
Reader 2	FIT	0.07	**186 X 52 X 27**	**0.235**	YES
Reader 3	FIT	1.0	300 X 200 X 80	No Info	YES
Reader 4	FIT	**1.2**	120 X 120 X 38	No Info	YES
Reader 5	FIT	0.3	145 X 85 X 31	1.500	YES
Reader 6	FIT	0.4	No Info	No Info	YES

Table 5.2: Reader comparison.

All above readers are qualified and suitable for the new RFID system with the opportunity of connecting to a host system through a RS232 interface.

A portable system is the main objective in choosing a RFID reader. Hence size and weight should be considered to make the system more mobile and easy to handle. Reader one and two are the smallest and lightest with integrated display and keys. On the other hand, these readers have a very short reading range. Softrónica reader (reader four) from EHag is the one with the longest read distance since an extra antenna was added. Reader's weight information was not available. Reader three from Avonwood has the second longest reading range with up to 1 meter using extra antennas.

Acquire RFID system

The tag should be selected first since a good tag is more critical to the process than the reader.

In practise, product specifications were not the only factor that counted during the decision of choosing one of these tags. The sellers' co-operation also played a key role in this stage. Requesting the missing details by email was the first step. Quick replies from companies were appreciated and gave them more credits. In fact the only two companies we were able to attain contact with were Avonwood and Copytag. Avonwood responded very fast and while it took more than a week for Copytag to respond. The problem was that most of their internet links to their RFID datasheets weren't functional.

The Sewerage Directorates recommendation for use was small cylinder formed tags fitted for tag four, seven, or eight. Those were therefore our first choice even if the range was among the lowest as shown in Appendix B and the evaluation above. Because of the failure to get in contact with any companies that sells these tags and the time limit to finish this thesis, we were forced to choose among the tags where we actually achieved contact with the company selling tags.

The two companies we were able to make contact with were Copytag (tag one) and Avonwood (tag two). They had the only two tags with full details. Conversations with Avonwood were very successful and the response was very good and helpful. Their tags were selected as they also have the largest storage capacity and with reasonable range. This is a tag formed like a label and with glue on the backside for mounting.

Reader one and reader two are the smallest and the lightest readers if compared to others, and also with an integrated display they are probably the best choice for a portable reader. The main concern for buying a reader is on the communication and on exchanging information with the chosen tag. This depends on many factors such as communication standards, protocols, encoding and decoding. Buying a reader and tags from different producers may not be compatible and very risky.

The selection of reader three is based on tag selection and Avonwood confirming their reader would work together with tag two, and that they could be supplied together.

Choosing reader three caused some problems to overcome. To achieve the goal for the reader to be portable, it must be supplied by a 12 VDC battery and a Pocket PC, communicating on RS232 for read/write functions and display. A good design is to remove the reader card from the heavy steel cabinet, which the reader is mounted into it, and replace the cabinet with a light plastic cabinet that is capable of withstanding damage and also carry the battery and the Pocket PC inside. The cabinet should then be mounted on top of a pipe with the antenna at the end of the pipe. The antenna cable should be inside the pipe as shown in the sketch of Figure 5.13.

Because of the time limit with this project we are not able to put this design into practice. Instead we will concentrate on making software for testing between the Pocket PC and the reader. The whole system including the antenna and the cabinet may be carried around with a supporting string, which may be connected to the sides of the cabinet, to use around the neck.

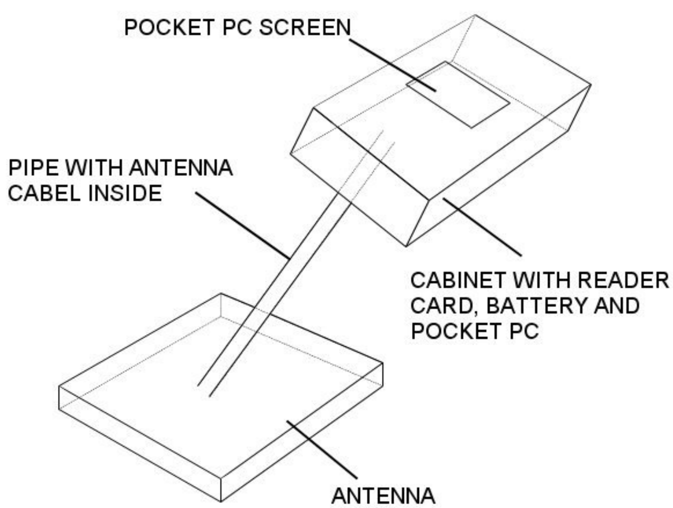


Figure 5.13: Reader Design.

The ordered tags and reader are purchased from Avonwood, based in England and are called Eureka.
The company promised us that the product should meet our requirements, and they were co-operative in processing our request. They also promised

us that the equipment should be sent to Abu Dhabi before the end of April.

In addition to the 30 tags and the reader with an antenna, an extra antenna was on order for the Thesis of Hussain Al Mousawi [2]. For product acquisition, see Appendix C. For official documentation regarding the reader and the tag, refer to the following Appendix:

- **Appendix D:** Datasheets Eureka 211 – 13.56MHz Tags (two pages).
- **Appendix E:** Datasheets Eureka 211 – 13.56MHz Readers (two pages).
- **Appendix F:** Installation & Operation Manual (sixteen pages).
- **Appendix G:** 211 Decoder Firmware (22/3138) Manual (twenty-six pages).
- **Appendix H:** Smart Label ISO IC (sixteen pages).

The total purchase was within our budget.

To complete the system a 12 VDC battery was provided from the Sewerage Directorate and an HP iPAQ h5555 Pocket PC [29], as shown in Figure 5.13, was borrowed from the Abu Dhabi Men's College of Technology for the prototype testing.

Figure 5.14: HP iPAQ h5555 Pocket PC.

The size of the battery didn't fulfil our requirement to be portable, but for the prototype testing it was sufficient.

Since we were able to borrow the rest of the equipment the total system stayed within our budget.

Figure 3.15 show the final system connected together, with the Pocket PC connected by a cable (RS232) to the RFID reader card, which is powered from a 12 VDC battery. The antenna cable is linked from the reader card to the antenna.

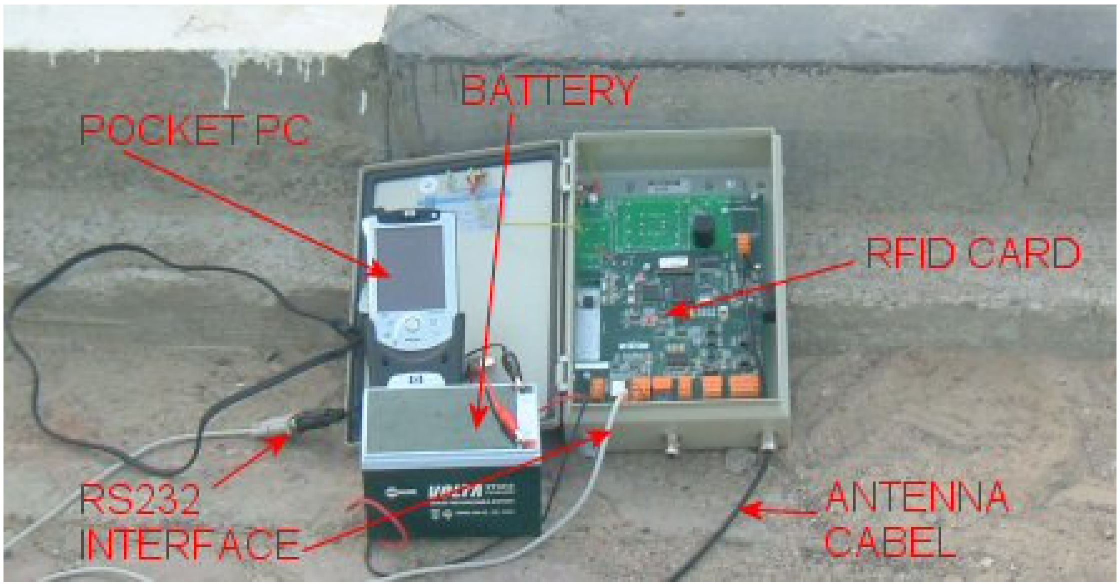


Figure 5.15: Final RFID system.

What we got
We were promised by Avonwood and the specifications that the tag had a range up to 100 centimetres from the antenna. This was not correct as open environment testing has showed that the range was up to 35 centimetres.

The tags that we received were of another brand that we ordered, but had the same properties as the one ordered. Instead of the ordered 30 tags, 50 were delivered.

Software preparation
To check that the equipment was working correctly, we connected the reader to a laptop and with a USB cable.

From the internet we downloaded a 30 days trail version for a terminal emulator called Koala Term [30] and installed it on the laptop. The communication was set to the following properties:

- Baud rate 9600.
- Data Length 8.

- Stop bit 1.
- No parity check.
- Flow controlled by hardware.

The program will now set all communication from the reader, and a command can be sent to the reader from the laptop. Commands to the reader can be sent by the command line at the bottom of the screen, using the commands listed in Appendix G. (e.g. sending 'DY' will reset the reader).

Next step was to make an interface between the Pocket PC and our laptop. In order to be able to make a program on the Pocket PC to communicate with the reader, the following software was installed on the laptop with the following necessary sequence:

- Microsoft ActiveSync 3.7 [31].
- eMbedded Visual C++ 4.00 and eMbedded Visual C++ 4.00 Service Pack 3 [31].
- Visual Studio .NET 2002 [32].

Pocket PC 2003 SDK [31]. There is a README file in the folder, Pocket PC which guides you through the installation instruction.

The first step is to get a connection between the Laptop and the Pocket PC using the software mentioned above. The ActiveSync [31] is used to communicate between the Pocket PC and the Laptop. ActiveSync also synchronies files when sending/receiving.

The next step is to make a new interface between the Laptop and the Pocket PC as we were unable to use ActiveSync for the reader. We had to change software from Visual Basic (VB) .NET 2002 to VB 6. The option was to upgrade from 2002 to 2003, but we didn't manage to get the program in time. Another application we used were the Appforge Crossfire [33] which consists of a program called Booster which is installed at the Pocket PC. This program will let the user run mobile VB programs at the Pocket PC. The mobile VB programs were developed in VB 6. ActiveSync was used to send the programs made in VB to the Pocket PC. We also used ActiveSync to send Booster to the Pocket PC.

The last step is to connect the Pocket PC with the reader by developing an application in the Pocket PC. Through this application we could send and receive information about tags in the range. We called the application

SerialChat and the functions are described below, and are also shown in Appendix I.

Software development
The result of the development is presented in Appendix I.

The software code, SerialChat (RFID Reader.vbp) was developed to support the relevant functionalities between the Pocket PC and the reader as because of time is limited to finish this thesis. The user interface at the Pocket PC is as shown in Figure 5.16.

Figure 5.16: RFID program for Pocket PC.

Figer 5.16 shows the user interface we have developed for the pocket PC. The application is dependent on the program Booster which is a part of the program Appforge. Through the program Booster at the Pocket PC it is also possible to use the SerialChat program. The SerialChat is enabling connection and communication with the RFID Reader through the RS232.

SerialChat consist of two forms and one class module. Form 1 is Comone.frm and form 2 is Helpfrm.frm. The name of the class module is Sleeper.cls.

Form 1 enables the user interface at the Pocket PC. The program instructs first the user to connect the Pocket PC to the reader by pressing ‘Connect’. When the communication is achieved, the user may press ‘Disconnect’ for disconnecting the communication. When the connection is open, the user has the following options:

- Search for tags.
- Stop the application in searching, and keep the tag it found.
- Select the tag.
- Read the tag; All, GPS, Asset ID, Description, Main Date or Comments.
- Write to the tag; GPS, Asset ID, Description, Main Date or Comments.

Form 2 makes a help function available for the user of the Pocket PC.

The class module delays the procedures with the method Sleep. It is called when transferring data between the reader and the Pocket PC is required.

Test preparation
The tests were performed in the field on two of the Sewerage Directorate manholes. One tag with and one with some protection was tested, in two different scenarios as shown in Figure 5.17. The transparent fabric acre line with a thickness of 3 millimetres was used for protection. The tag was buried under 5 centimetres concrete with the front side up. The following two protection arrangements were made:

- **Protection 1:** Acre line plate mounted to the backside of the tag connected to the tags glue. No protection on the front side.
- **Protection 2:** Acre line plate mounted to the backside of the tag connected to the tags glue, with another acre line plate mounted directly on the front side.

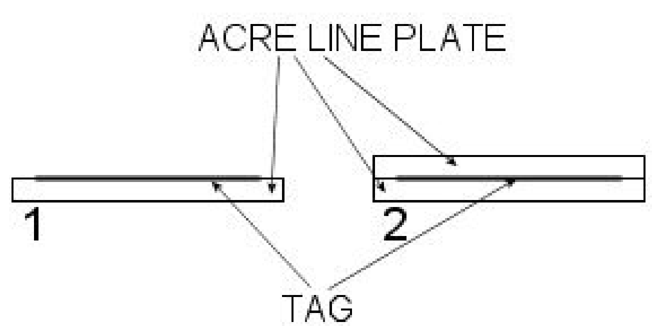


Figure 5.17: Tag protection.

The tags with the acre line plates were buried under concrete four days before the official test to make the concrete dry up. Because of the possibility of damaging the concrete frame surrounding the manhole, it was decided not to make a hole in the concrete frame. Instead it was placed on top of the frame with a 5 centimetres concrete layer above it, as shown in Figure 5.18.

Figure 5.18: Tag under concrete at manhole.

A set of parallel tests were prepared in the lab at Abu Dhabi Men's College by Hussain [2]. Hussain used 2.5 and 7.0 centimetres of concrete above the tag to test the performance.

Testing

The reader with the antenna was tested by moving the antenna towards the tag. Different angles towards the tag were used and the range reached was at its best when operating in parallel with the tag. The different position without parallel condition was not far from the optimal range, but it was still noticeable.

The testing in the field was done as shown in Figure 5.19.

Figure 5.19: Field testing.

By observing the indicator on the reader card (see Appendix G) or the indication on the Pocket PC, connection between the antenna and the tag could now be observed. When the antenna was in range, the different functions for the Pocket PC were tested. The results were as follows:

- **With protection 1:** No signal.
- **With protection 2:** 15 centimetres above the 5 centimetres concrete layer. The range is 10 centimetres shorter than for maximum range. All functions worked without the writing to the tag function where the range had to be reduced by another 3 centimetres.

The same tests were done in the lab.

Lab testing consolidation
The lab tests done by Hussain [2] in the lab showed that the reader range where reduced by the concrete when using protection 2. With 7 centimetres of concrete the range was almost reduced to zero.

For protection 1, there were no signals.

Hussain found out that by testing with an air pocket between the acre line plate on the front side and the tag for protection 2, better range was achieved as shown in Figure 5.20. There was no more time left to test this out further at the manholes, caused by the late delivery of the equipment. For proper testing the concrete needs to be dry.

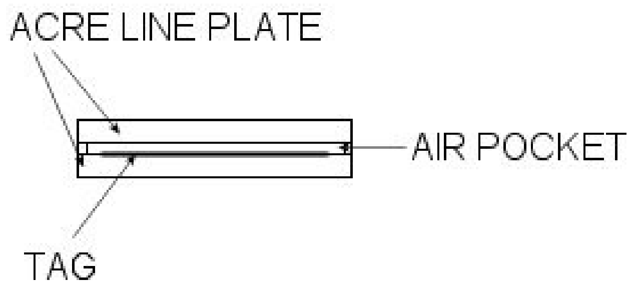


Figure 5.20: Tag protection with air pocket.

5.7.3 Discussion

Many of the seller's websites contain insufficient information about the product of concern.

Acquire GPS
GPS is a tool to locate assets for identification by using coordinates. It can be useful to relocate previous locations.

Evaluation of different RFID systems
The tags and the readers should match several criteria's. None of them matched all the criteria's. We chose those which fitted our need best.

Acquire RFID system
The basis of the tag and the reader was chosen because of the compatibility with the tag. The design of the system will not be ideal, because of the time limit, and that we had to acquire the RFID system for the only seller that we manage to contact.

This resulted in a RFID system where additional software, a battery and a Pocket PC were needed. A good design will be to mount this together and carry it with a string around the neck. The Pocket PC was borrowed from the Abu Dhabi Men's College and the battery from the Sewerage Directorate.

What we got
We were promised by Avonwood and the specifications that the reader had a range up to 100 centimetres from the antenna. This was not correct as open environment testing has showed that the range was up to 35 centimetres.
The tags were from another company, but had the same properties.

Software preparation
The software process can be divided into the following steps:

- We tried to get contact with the reader through the laptop.
- Obtained a connection with the Pocket PC through the laptop.
- Made a user interface using Visual Basic 6 for the Pocket PC to use towards the reader.
- We Connected the Pocket PC and the reader. An application was developed in Visual Basic 6 for that.

Software development
The software code will be available on a CD.

RFID testing preparation
We tested the equipment at the lab at the Abu Dhabi Men's College and in the field at the Sewerage Directorate. Two scenarios for testing were made. The fabric acre line was used as protection and was provided by Abu Dhabi Men's College. One test was constructed to check the tags ability to withstand concrete. For the other test the tag was totally protected.

The best area to place the tag was on the top of the concrete, to not damage the concrete frame surrounding the manhole, caused by the size of our tags.

Testing
The best range between the tag and the reader was when holding the antenna in parallel directly above the tag. The results were as follows:

- **Protection 1:** No signal was obtained from the tag. This is probably caused by the tag getting condemned by the concrete.
- **Protection 2:** The range was reduced by the concrete. Operating range was 12 centimetres. This is less than half the total range in open environment.

Lab testing consolidation
With protection 1 the tag was also condemned. When putting the tag into wet concrete and letting it dry the tag will be damaged.

With protection 2, 5 centimetres looks like the ideal distance beneath the surface. If any shorter the new concrete is not strong enough as mentioned from the Sewerage Directorate. Longer distances will reduce the range too much.

Probably the protection with an air pocket inside is the best. This was only tested in the lab. The difference between using an air pocket due to protection 2 is probably caused by the plate pressing the chip on the tag, and reducing its performances.

Chapter 6

Discussion

6.1 Introduction

This thesis started by presenting a review of the technology RFID and an inception study of the Sewerage Directorate in Abu Dhabi, focusing on business processes that are candidates for support by RFID. In addition, the focus was singled out to one business process. Contextual Design Methodology is described and used as a tool in co-operation with the customer to make a RFID prototype for the business process. Finally the prototype is tested.

The purpose of the work was to find out if RFID can be used in the Sewerage Directorate as an asset management tool to help their daily operation of the system.

The following issues will be discussed in this chapter.

- RFID expectations.
- Business processes.
- Contextual Design Methodology.
- Practical use of Contextual Design.
- Prototype development.
- Testing and evaluation of the prototype.
- Problems
- Further work.

6.2 RFID expectations

Before starting our research, we had very little knowledge about RFID. The first phase of our research study was to gather information and knowledge of the technology. We gained a lot of information and we envisaged that the technology had an enormous potential. The technology is suitable for tagging and identification of materials and components.

RFID is not a new technology but a technology that now increases its marked share by large companies recently looking at the potential of RFID implementations. It will take several years to see if this newly found interest will lead into a RFID success story. RFID is set to replace barcodes that are much used for pricing and/or identifying objects. RFID is able to read objects that are not in line-of-sight and located in harsh environment if compared to barcodes. Barcodes have the advantage of full operation when the object is surrounded by metal while the radio waves used for RFID will be distorted.

An ideal RFID system would be able to detect the location and information of all tags within a large area, e.g. warehouse or construction site. This is not possible with current available technology. In order to determine the location of the tags, at least three readers must be connected to each other for separate locations and with synchronised data communication. The coordinates of the tag location can be found by calculating the time that it takes the radio wave to request an answer from the tag and the time it takes the actual tag to send its reply. The maximum range from the tag to the reader will be limited as harsh environment could contribute to the line-of-sight condition, with a range of less than 1 meter.

RFID is most suited to register/identify objects passing the range of the reader for different purposes. This can be implemented into several business cases.

6.3 Business processes

Early on in the selection of a business case for this thesis we were advised by the Sewerage Directorate to choose manholes as assets for identification using the RFID technology. Other cases can still be used and some of them are evenly good to use.

A manhole is located on the surface of the earth and covered with a manhole cover and surrounded by a concrete frame. Underneath the manhole there are other assets such as chambers, pipes and valves.

The number of manholes is enormous and it will be an extensive job to tag all of them. This can be done later in cooperation with the Sewerage Directorates UDS project where all manholes could be located.

The way they locate the manholes today is by driving around to find the manholes. They are dependent of maps and descriptions for location. The covers must be removed to find out the identification of the manhole. In the desert it is even harder to find the manholes, because manholes are often buried below sand.

The RFID equipment will achieve less work to identify which manhole it is, since they don’t have to remove the covers at the manholes.

6.4 The method Contextual Design

Contextual Design method is based of the collection of data from the user for the purpose of designing a new system. Because of the way they are being collected, the data is considered as qualitative and is collected either by dealing directly with the user involved or oversee the user working structure during working time.

Data gathered is used to develop models that will help the communication process between the user and the developer. They are easy to understand as they are written in a simple language and that the models are well organized.

In order to improve the system to multiple users and to obtain a feedback, a consolidation with other similar users is required.

The primary developed models will be used to redesign the new system. The user will go through the models and may give a constructive feedback or remarks to improve the system and to make it more flexible to the user need.

Contextual Design also includes a method of structuring the system and to build a coherent model. The method includes key words to ask to obtain a better result and is called User Environment Design.

To make a prototype for testing purposes, the results that were obtained from the User Environment Design, were used. In Contextual Design, the user interface is called a prototype.

The Contextual Design method is an excellent method for developing a prototype but not for supporting developing on how to make a user interface. Other methods can be used for that purpose.

The Contextual Design method consists of various parts that are well arranged. These parts should be followed in sequence and hence the developer can not start at the next part before the previous part is done. Every single part has an output that will be used as input for the next part.

The reverse User Environment Design, which is not used for this thesis, is one part of the User Environment Design (UED). The reverse User Environment Design is based on an existing system. Another method can be when implementing a new system. The former method is used because it is most relevant to our research.

6.5 Practical use of Contextual Design

The collection of data from the user was done through observations including interviewing, making notes during user working time, and using a digital camera to capture pictures. The data were presented as work models to make it simple for the user to understand. Work models are easy to make and edit and the user should not have to know about type of the software or hardware that are used for this process. As a result, the communication with the user is made simple.

The consolidation part was not done as time and access were limited. It is about collecting data through wider investigations within an organization, and then using the data to improve our own system. The potential for this method is good because of the possibility of comparing different kinds of systems.

Adding the RFID tag has changed the method models. Tags became an important part in the new work practise. By using this method we evaluate the whole system including the artefacts, the culture, the flow, the sequence and the physical environment. The flow model and the sequence model are very similar and as a sequence one of the two models could be used in our research. Beyond that we have used other models which are more relevant to our case. The developer doesn't have to follow the method Contextual Design precisely. There are methods which is less important than others. That will vary from one developer to another. In our research we chose to drop the sketching of a new cultural model as the new tool came under the unit manhole.

We used the User Environment Design method to structure the system and to make the work more coherent. The structure from the User Environment Design was used to make a prototype.

The method Contextual Design is a good method for developing a prototype. It is not supporting on how to develop a user interface as that are other methods can be employed to do that. Usability theories are methods which can be used, but by using these methods extra time is needed. As a result, these methods will not be used, but an overview will be presented in the report as described in section 4.11 of chapter 4.

The Contextual Designs way of gathering data from the user is very sufficient and accurate as it deals directly with the user during working time.

The User Environment Design has a method called the reverse User Environment Design and this method is not in this research because we haven't focused at other relevant areas.

6.6 Prototype development

The final prototype was not a result of our ideal specifications. This was basically caused by problems such as the difficulty in obtaining direct conversations with the companies in concern and time was required for software development for the Pocket PC.

The challenge to develop our own software for the Pocket PC to control the reader showed us the possibilities of making custom based software for the Sewerage Directorate. This was done in Microsoft Visual Basic 6 and included all the essential functions for normal use.

During the last part some of our time had to be used to gather proper literature. Also previous experience, intensive manual reading, the understanding and pre-testing of the tag to reader communication and the software development were helped to complete the work with minor problems.

Making a good and useful design for the reader was eliminated due to time. Two tag's designs will be tested by using acre line as protection.

6.7 Testing and evaluation of the prototype

The testing was carried out in the laboratory and in the field at the Sewerage Directorate. Hussain [2] was in charge of the lab testing while we were in charge of the field testing.

In the field, the tags were attached on the top of the concrete beside the manhole and then the tags were covered by concrete. This is not the best solution but enough to avoid damage of the framework around the manhole. The tags were buried 5 centimeters under the top of the new concrete, and the maximum range above the concrete should be within 30 centimeters. The system was tested by moving the antenna towards the location of the tag.

The following two different combinations with label tags were tested:

- **Only plate on the backside:** Didn't work. The tag was probably damaged by the concrete pressed towards the front side of the tag.

- **Plates on both sides:** Did work with a range of up to 12 centimeters above the concrete for all functions. A maximum range was not reached. This could be caused by the pressure of the concrete on the front side of the tag.

Similar outcome and results were obtained from Hussain's lab testing, by the concrete reducing the operation range for the tag.

In addition, it was found that optimum range can be obtained when the antenna was directly above the tag in parallel.

The prototype was not done according to the original plan. We wanted to design a model with a pipe between the antenna and the reader. At the top of the reader we wanted to have the Pocket PC for display purpose. Because of the delay in receiving the equipment, we didn't have the time to do this accordingly. We used the equipment differently where we had the reader on the ground, the antenna was moved through our hands, and the Pocket PC was held by another person. By doing this the scenario will not affect the range of the antenna or the capacity of the system.

The test software was required as the reader has no display screen. It worked out fine and a connection to the reader was established. The tags were also detected and we were able to read and write to them. The test software in use is not ideal with a simple design for communication. For further work two kinds of software may be required; one for writing/reading, and another for reading. We only manage to make one and that is only supporting the most necessary functions.

A GPS was used to document the location of the manhole.

6.8 Problems

During our research, problems were encountered due to the prototyping and the testing phases. Adding to that are the changing specifications of projects within the Sewerage Directorate. However, the following major problems were encountered:

- **Tag selection:** The appropriate tags found for this project was not ordered since we were not able to get in touch with any sellers. Also the size of the tags could damage the concrete frame of the manhole during implementation; we were not able to complete a 100% realistic test.

- **Reader selection:** For the tag chosen it was difficult to order a reader with all required functions. The reader available caused a lot of extra time in making suitable test software, which may have been used to develop and test a reliable database for the prototype testing. Reader range was also far from what we were promised from the specification and made the total system more difficult to use.

- **Delivery:** The final order was delayed several weeks from the schedule despite promises from Avonwood to deliver equipment on time. In addition, a different tag to the specified one was delivered but this did not cause a serious problem to our research.

All above problems caused delay in the process of finishing our thesis on time but it probably represent the real-life working environment, and it is a realistic experience.

6.9 Further work

For future work, further developments and modifications may be required to improve the outcome of the potential research. These may include the following:

- **Improvement of the equipment:** Testing with small cylinder formed tags that are more suited to be mounted in the concrete frame surrounding the manhole.

- **Pocket PC versus Reader software:** Developing complete software with essential functions to read/write. Instead of converting HEX to ASCII directly, more efficient decoding algorithm should be used to increase the capacity of the tag.

- **Database Software:** Developing a main database for all assets, with attributes that are stored on the tags.

- **Serial interface from Pocket PC to Server:** Developing a program for establishing communication between the main computer that contains the database and the Pocket PC. When a work task is required, the Pocket PC should download the necessary information about assets and when the work is finished updated data on the tag should be downloaded back to the main database.

- **Pocket PC versus GPS functions:** Connecting a GPS to the Pocket PC and develop a program showing the GPS-coordinates of the assets on a map over Abu Dhabi. This can be done by using the software OziExplorerCE [34] on the Pocket PC. With a map showing the location of assets on the Pocket PC screen with zoom in/out utilities, the asset can easily be located.

- **Design:** Developing a mobile and a user-friendly design for the reader, Pocket PC, battery and an antenna mounted together. The total product should be light in weight, practical and easy to carry.

- **UDS:** Developing a structure on how to implement the tags during the UDS implementation.

- **AIMS:** Including all information about the assets in the AIMS database, with access to read/write asset information from the Pocket PC.

Some of the assets that we evaluated during the inception study of the Sewerage Directorate can also be used for further work and could be based on our investigation.

It should be mentioned that Sewerage Directorate and/or other students doing their master thesis have the final decision in expanding such work.

Chapter 7

Conclusion

This thesis has evaluated the operation of the Sewerage Directorate with intention of finding out one asset to use jointly with RFID technology in an asset management system. Manholes were chosen as the assets. In addition we used Contextual Design the Methodology as a tool to develop and test a prototype. The testing was done under real conditions with the tag embedded inside concrete.

The Sewerage Directorate philosophy is to use asset management to have full overview of all their assets, where identification of the assets is an important part. RFID is proved to be a good technology for identification.

Our experience with RFID for identifying manholes is that we only achieved a maximum range of 35 centimetres which is far less than what was promised by Avonwood, the supplier. The concrete didn't hamper the range when the tag was 5 centimetres inside the concrete. We were unable to purchase the exact equipment of our first choice as contact with the suppliers was very difficult if not impossible. This resulted in 'big' label tags instead of 'small' cylinder tags that could fit inside the concrete surrounding the manholes, without damaging the concrete framework.

The RFID was working as expected during the testing phase. A fabric called acre line was used around the tags to protect the chip at the tag from the concrete. Two scenarios were tested in the lab and in the field. In addition, the prototype was working as expected during the testing phase. The reader was laid on the ground while the Pocket PC and the antenna were held. The antenna was angled towards the tag by hand and this was not representing the ideal design for a prototype, but there was not time to do extra work. The ideal prototype will be done by using a solid straight pipe between the reader card and the antenna. The Pocket PC should work as a user interface at the top of the reader card.

For further ideal work the prototype can be improved and implemented during the Sewerage Directorates UDS project, and linked with the AIMS database.

The methodology Contextual Design was the framework for the prototype. It is good for collecting data from the user. The data will be further used in work models. The work models are used to ease the communication with the user. To consolidate the models, extra time was required. In Work Redesign, the models were changed to include the new system. The UED is about the structure of the new system. Testing and prototyping are the final part of the methodology Contextual Design.

We felt that the methods in Contextual Design were comprehensive but time-consuming. The method is not influential on making a good user interface and other methods such as usability methods may be employed to do that. We have not used any of the usability methods as time was limited.

References

[1] Mustafa Abdulla Almusawa, Head of AIMS & SCADA Division – Sewerage Directorate, Abu Dhabi, UAE.

[2] Hussain Al-Mousawi
"Preformace and reliability of Radio Frequency Identification - Theoretical evaluation and practical testing in relation to Requirement from use in Abu Dhabi Sewerage Directorate"
Master Thesis ICT, Ageder University College, 10-06 2004.

[3] Klaus Finkenzeller
RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, 2nd Edition
Carl Hanser Verlag, 2003.

[4] RFID journal (for RFID updates/happenings)
URL: http://www.rfidjournal.com/ (visited January-May 2004)

[5] Association for Automatic Identification and Mobility, RFID basic
URL: http://www.aimglobal.org/technologies/rfid/resources/papers/rfid_basics_primer.htm (visited January 2004).

[6] Association for Automatic Identification and Mobility, RFID overview
URL: http://www.aimglobal.org/technologies/rfid/what_is_rfid.htm (visited January 2004).

[7] High Tech Aid, ISO/IEC 18000 - RFID Air Interface Standards
URL: http://www.hightechaid.com/standards/18000.htm (visited February 2004).

[8] RFID Journal, RFID, Privacy and Corporate Data
URL: http://www.rfidjournal.com/article/articleview/442/1/3/ (visited January 2004).

[9] Livestock identification by using RFID
URL: http://www.animalagriculture.org/Proceedings/1998_ID/Livestock%20Identification%20Initiatives%20in%20Australia.htm (visited February 2004).

[10] Windley's Weblog, Wal-Mart's Move to Use RFID
URL: http://www.windley.com/2003/09/17.html (visited February 2004).

[11] Future of RFID
URL: http://www.forrester.com/Research/Document/Excerpt/0,7211,33905,00.html (visited March 2004).

[12] Animal tracking by using RFID
URL: http://www.amrresearch.com/content/resourcecenter.asp?id=438&bhcp=1 (visited February 2004).

[13] Jacek Mierzejewski, AIMS Systems Analyst – Hyder Consulting Middle East, Abu Dhabi, UAE.

[14] Hassan Ahmed Al Kurbi, Head of AIMS unit – Sewerage Directorate, Abu Dhabi, UAE.

[15] Aminol Kaibia, CCTV Engineer – Sewerage Directorate, Abu Dhabi, UAE.

[16] Jerzy Augustyniak, Instrumentation & Control Engineer – Sewerage Directorate, Abu Dhabi, UAE.

[17] Ghassan Koujan, M & E P.S.D Chief Engineer – Sewerage Directorate, Abu Dhabi, UAE.

[18] Ken Vaheesan, Project Manager, Operation & Maintenance Division – Mechanical And Civil Engineering, Abu Dhabi, UAE.

[19] Frank Mueller, Engineer, Specialised Technical Services Est, Abu Dhabi, UAE.

[20] Abu Dhabi Municipality
URL: http://www.adm.gov.ae/english/default.asp (visited February 2004).

[21] Lonely Planet: Middle East
Page 706-707, 4th Edition
Lonely Planet Publications Pty Ltd, 2003.

[22] UAE Info Database
URL: http://www.greatestcities.com/Middle_East/United_Arab_Emirates.html (visited February 2004).

[23] Mustafa Al Musawa
"GIS at Abu Dhabi Municipality & Town Planning Department. Current Status and Vision for the Future"
The 6th annual ESRI Middle EAST & African (MEA) user conference, October 8-10, 2002.

[24] Hugh Beyer, Karen Holtzblatt
Contextual Design: Defining Customer – Centered Systems, 1st Edition
Morgan Kaufmann Publishers, 1998.

[25] Richard H. Thayer and Merlin Dorfman
Software Requirements Engineering, 2nd Edition
Wiley – IEEE Computer Society Press, 1997.

[26] JoAnn T. Hackos and Janice C. Redish
User and task analysis for interface design, 1st Edition
John Wiley & Sons, 1998.

[27] Definition of usability
URL: http://www.sei.cmu.edu/str/indexes/glossary/usability.html
(Visited May 2004)

[28] The Garmin GPS 12 Personal Navigator
URL: http://www.garmin.com/products/gps12/ (visited May 2004).

[29] HP IPAQ h5555 Pocket PC
URL: http://www.shopping.hp.com/cgi-bin/hpdirect/shopping/scripts/product_detail/product_detail_view.jsp?BV_SessionID=@@@@0439899887.1086561446@@@@&BV_EngineID=ccchadcljiedjlecfngcfkmdflldfjl.0&landing=handhelds&category=handhelds&subcat1=handhelds&catLevel=3&product_code=FA146A%238ZP (visited April 2004)

[30] FOXIT software, Koala Term 4.2
URL: http://www.foxitsoftware.com/ (Visited May 2004).

[31] Windows Mobile software
URL: http://www.microsoft.com/windowsmobile/default.mspx
(Visited May 2004).

[32] Microsoft Visual Studio Developer Centre
URL: http://msdn.microsoft.com/vstudio/support/ (Visited May 2004)

[33] AppForge Crossfire software
URL: http://www.appforge.com/ (Visited May 2004).

[34] The official website for OziExplorer, GPS Mapping software
URL: http://www.oziexplorer.com (visited May 2004).

APPENDIX A – Data collecting report

This appendix presents an overview of several meetings we had with Mustafa Al Musawa and other people within our research. Some of these meetings were held at Al Mousawa's office and other in the Sewerage Directorate. During the meetings sufficient information about the Sewerage Directorate were obtained from Al Mousawa and his colleagues. Al Mousawa has guided us to the right direction and has given us an excellent support and co-ordination.

Here is a brief description from some of the meetings and conversations/demonstrations we attended:

Minutes 09.02.2004

Item

- This was the first meeting with Al Mousawa.

Discussions

- We presented our plan for the master thesis.
- We discussed how the Sewerage Directorate can help us to gain knowledge about its facilities.
- We agreed to have regular meetings every Monday at eight o'clock.

Present

Mustafa Abdulla Almusawa
Bjørnar Landheim
Hussain Al Mousawi
Vidar Bekken

Conversation/Demonstration

With Hasan Ahmed Al Kurbi. **Date: 09.02.2004**

We were at a tour around the building where Al Mousawa's office is. Asset Information Management System (AIMS) was the subject.

There are three isolated networks:

- Storm water (represented by a blue colour) for drainage.
- Irrigation (represented by a green colour) for water.
- Sewerage (represented by a red colour) for treatment.

The municipality is serving more that 700000 inhabitants in Abu Dhabi alone. Sections within the municipality are:

- O&M (operation and management)
- TSS (Technical service section)
- MSTV in Mafraq (Treatment plant)
- CCTV (Checking pipes).

About 15 % of Abu Dhabi budget were spent on services with 25 years of high-quality achievement.

Conversation/Demonstration

With Jacek Mierzejewski Date: 11.02.2004

The fundamentals of AIMS.

Presentation

With Mr. Mierzejewski Date: 23.02.2004

The location was at the Science Club. The presentation focused on three phases:

- Foundation (Phase 1)
- Development (Phase 2)
- Integration (Phase 3)

The first phase was successfully completed, while the second phase is currently under preparation.

Minutes 16.02.2004

Item

- Frank Muller talked about the RFID system (Pilot project) which was used and tested for ADM and was rejected five years ago.
- Despite such cancellation it is still of interest for the Sewerage Directorate to connect their assets with identification up to the AIMS.

Discussions

- We will look closer into the old system starting from scratch for our thesis evaluation.

- ADM offered to help us to get access to the spare parts that are still stocked since the cancellation of the last system.

Present
Aminol Kabia
Bjørnar Landheim
Frank Mueller
Hussain Al Mousawi
Jerzy Augustyniak
Lars Line
Muhamed Kazem
Mustafa Abdulla Almusawa
Vidar Bekken

Conversation/Demonstration

With Aminol Kabia 16.02.2004
CCTV survey's main function is checking the suspected pipes for blockages. They are using electrical cars which carry cameras to monitor blockages. The first procedure is to clean the suspected pipes. Then wired cars will be sent into the pipe to clear the blockage.

Minutes 23.02.2004

Item
- Al Mousawa overviewed the GPS system and on how to use such a system.

Discussions
- There was a problem in getting the appropriate people who can well fit into the business cases. Al Mousawa had solved this problem by making few phone calls with the concerned people.

- An overview on SCADA system was presented to us.

The next step was to obtain information about the sewerage network.

Present
Mustafa Al Mousawa
Bjørnar Landheim
Hussain Al Mousawi
Vidar Bekken

Conversation/Demonstration

With Jerzy Augustyniak Date: 24.02.2004
The SCADA system is in the control centre. The control centre consists of several local sections which control three main areas:

- Sewerage
- Irrigation
- Storm water.

Their network system will show if there are some problems with equipment such as pumps and pressure instruments. These equipments are supplied with ID number, number of starts, timer and so on. RTUs, which are elements of the SCADA system, control the pump stations and transmit status information concerning the pumps. The largest pumps uses 4 bars of pressure while the smallest one use one bar for the start up process. SCADA system is using oxygen plant to reduce the bad odour and use the pumps to reduce the chemicals waste. Contractors in charge are Hunterwaterteck and CITECT.

Conversation/Demonstration

With Ghassan Koujan Date: 28.02.2004

We were around the Sewerage plant. Here are examples of where to put the tags:

- Catachment manholes and lines.
- Subsideview manholes and lines.
- Trunking manholes and lines.
- Pressure line, rising main.
- Valve chamber.
- Lifting pump stations.
- Pumping stations (inlet sump and wet sump).
- Treatment plant.
- Sewerage network.
- Storm and surface drainage network.
- Irrigation network.
- Outlet for surface drainage.
- Reservoirs for irrigation.

We looked at three different pumping stations; a small one, one for the east side and one for the whole island. There are two types of sensors; flow meter and salinity.

Ghassan recommended us to consider the treatment plant as a good solution for our project, as many tags can be placed within several scattered areas.

Conversation/Demonstration

At Mafraq treatment plant with Mahmoud Ahmed Ebrhim **Date: 29.02.2004**

The sewerage water is going through a multi-process. It first goes through a screening process which filters the unwanted material. After that it goes to the primary reservoirs and into separation process. One will turn into water and another to sludge. The water will be treated with chlorine and used for irrigation purposes while the sludge is headed back again to the irrigation. Further it will be dried up from water and will be used as a fertilizer. Final treatment is the filtering process before distribution. After the filtering, the water is 3-4 ppm (parts per million). Accepted amount is 10 for irrigation. There is also a decanter process where gas is used to add pressure in the tanks to avoid vacuum risk. The gas will be burnt.

Minutes 01.03.2004

Item

- We collected the reader/tag from Mustafa a week ago but the problem was that we didn’t have the software or the cable to operate the reader/tag equipment.

Discussions

- Mustafa suggested to us to call Frank Mueller to set up a meeting with him to collect the software and the cable.

Present

Mustafa Almusawa,
Bjørnar Landheim
Hussain Al-Mousawi
Vidar Bekken

Conversation/Demonstration

With Ghassan Koujan **Date: 01.03.2004**

Ghassan sent us to MACE (Mechanical and civil engineering contractor), where we got an overview by Ken Vaheesan.

Maxima are a local company and its main function is to control and record manholes. They are using SQL as database and works with AIMS.

Typical scenario:
The customer calls to report a fault. The person who responds on the call will fill out a work order. They will find out the appropriate asset and record its cause. MACE will do the maintenance including painting, cleaning, etc. They have a call centre with their own tools. Crystal application is used to draw graphs and diagrams. It works well together with Maxima.

The irrigation system is coming from the treatment plant. Jalani (Worker at MACE) explained how it works and showed us detailed drawings and physical observation of the tanks. We saw different manholes and took pictures of the different manholes.

Minutes 08.03.2004

Item

- Frank provided us with the software and the cable that are needed for the reader/tags.
- Hussain presented a draft version for the requirement analysis document.

Discussions

- First of all Mustafa explained to us on how to install the software. He mentioned that a problem could exist because the program is out of date. We are using Windows XP so we just have to investigate whether it is going to work or not. An alternative solution is to take the software to the science club for testing.
- After that we will start to use the equipment. We will try to track a sequence with some attributes.
- We have discussed the analysis document with Mustafa and he advice us that Hussain should first write a user analysis before documentation. Hussain will try to find a solution for this problem.

Present

Mustafa Abdulla Almusawa,
Frank Mueller
Hussain Al Mousawi
Vidar Bekken

Minutes 20.3.2004

Item

- Mustafa advice us to focus on the manholes as assets.

- He also advice us to focus at the software OziExplorer.

Discussions

- Mustafa suggest to us to call Frank to get reports from their scenario with the reader/tag.
- We agreed on the need for a range on at least 1 meter for the product.
- Task for this week is to implement the interface between OziExplorer and the access.

Present

Mustafa Almusawa
Bjørnar Landheim
Hussain Al-Mousawi
Vidar Bekken

Conversation/Demonstration

With Jalani from MACE **Date: 27.04.2004**

We were in the irrigation plant looking at chambers and manholes. There were different kinds of chambers:

- Circle
- Rectangular
- Small ones (surface boxes)

Surface boxes were 30/30 (length/width) and 3 centimetres in depth. The rectangular was 120/80 and 1-3 centimetres in depth. Circles had the same depth as the rectangular and about 1/1 (length/width). Both circles and the rectangular have some space underneath, and can easily be used to place the tag. An alternative place is between the plastic and the metallic, as there are 5 centimetres in space. There were about 50 centimetres concrete around the chambers. The plastic cover was about 0.5 centimetres and the metal cover about 2 centimetres.

We also looked at the storm water chamber, in addition to the outlet pipe which is used for air realizing. The last two are not relevant to our study. We took pictures of all the chambers.

Here are some other manholes we looked at:
The circle manhole was about 5 centimetres in depth and 1 meter in diameter. Manholes come in different shapes including rectangular, square

and triangular and the thickness is about 5 centimetres. We also looked at flash inlet cover and discharge chambers (2-3 inches in depth).

APPENDIX B – Assortments of tags and readers

This appendix includes a selection of RFID tags and readers with antennas, which we found most relevant for our system queries. Brief description and general information about each product are also included. It contains eight different types of tags and six different types of readers. All internet sites are visited in February/April 2004:

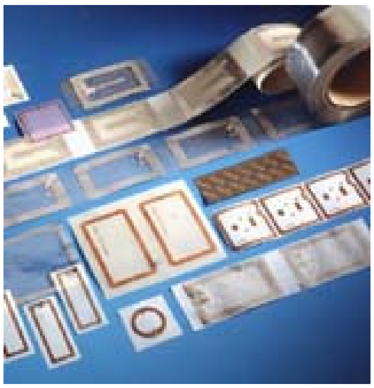
Tag 1

 ??x?? mm	**SL1ICS3001 & SL1ICS3101; I-CODE1 Label IC** The I-CODE1 label IC is a dedicated chip for intelligent label applications for logistics and retail (including EAS) and for baggage and parcel identification in airline business and mail services. The I-CODE system offers the possibility of operating labels simultaneously in the field of the reader antenna (anti-collision). It is designed for long range applications. Whenever connected to a very simple and cheap type of antenna (due to the 13.56 MHz carrier frequency) made out of a few windings printed, wound, etched or punched coil, the SL1ICS3001 operates without line of sight up to a distance of 1.5 m (gate width).
Producer	Philips
Product link	http://www.semiconductors.philips.com/pip/SL1ICS3001W_N4D.html
Data Sheet	http://www.semiconductors.philips.com/acrobat/datasheets/SL1ICS3001_2.pdf
Application	Identifying
Seller	http://www.copytag.com
Price	9.99 £ (Excluding: VAT at 17.5%) for 10 labels
Delivering time	14 – 21 days
Tag Specifications	
Memory size	512 bit
Operating Temperature	from -25 to +70°C
Reading range	Up to 1.5 m
Standard	ISO 15693
Tag Evaluation	
Long Reading range	
Operates on very warm environments	

Tag 2

 82x49 mm	**211 13.56MHz Passive Tag** Low cost high performance tags for item-level tagging, combining security with inventory, retail, video stores, airline baggage, parcel tracking, anti-counterfeiting and document management are just some of the applications requiring a reliable and low cost alternative to bar coding. · High performance · Read/write · Large memory · Low power consumption · High data rate · Up to 1m read range · Customer specific packaging
Producer	http://www.microchip.com/
Product link	http://www.avonwood.com/products/product_details.asp?id=2#8
Data Sheet	http://www.avonwood.com/pdf/web243044B13.56MHztags.pdf http://ww1.microchip.com/downloads/en/DeviceDoc/40232h.pdf
Application	Identifying
Seller	http://www.avonwood.com
Price	1.1 £
Delivering time	From 2 to 7 days (with DHL)
Tag Specifications	
Memory size	1 kbit
Operating Temperature	From -10 to +60°C
Reading range	Up to 1 m
Standard	ISO 15693 & 18000
Tag Evaluation	
+ Large memory	−
+ Long reading range	−
+ Operates on high temperatures	−

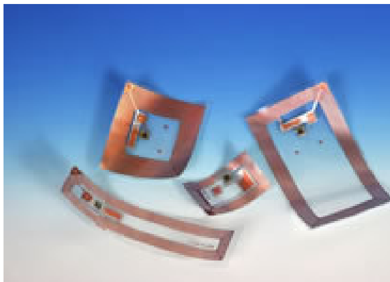
Tag 3

 from 82x49 mm to 105x58 mm	**SAMPLE RFID TRANSPONDER KIT** A selection of RFID Smart Label Transponders working on a frequency of 13.56 MHz. Technical sheets and fitting guide included where applicable. 10 off 49 x 82 x 0.3 mm ICode 1. 10 off 49 x 82 x 0.3 mm ICode SLI. 10 off 55 x 55 x 0.3 mm ICode SLI. 10 off 43 x 43 x 0.3 mm ICode SLI. 10 off 60 x 20 x 0.3 mm ICode 1. 10 off 36/17 x 0.3 mm CD/DVD Round ICode 1. 10 off 18 x 36 x 0.3 mm ICode SLI. 10 off 58 x 105 x 0.3 mm I-Code SLI In-mould transponder (IMT)
Producer	Philips
Product link	http://www.copytag.com/acatalog/Sample_RFID_Transponders.html
Data Sheet	http://www.copytag.com/acatalog/sampletags.pdf
Application	Identifying
Seller	http://www.copytag.com
Price	£67.20 (Excluding: VAT at 17.5%)
Delivering time	14 – 21 days
Tag Specifications	
Memory size	384 – 1024 bit (depends on tags type)
Operating Temperature	From -20 to +70°C Depends on tags type
Reading range	Not Available
Standard	ISO 15693
Tag Evaluation	
+ Good package, with different tag types	− Some tags are not suitable
+ Good price	−

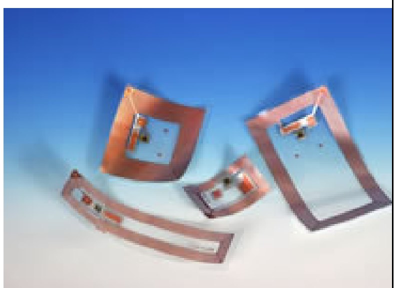
Tag 4

 22 mm in diameter	**13.56MHz Encapsulated Transponder** The 13.56MHz Encapsulated Transponder from Texas Instruments is compliant with the ISO/IEC 15693 standard, a global open standard that allows interoperability of products from multiple manufacturers. With a user memory of 2Kb, organized in 64 blocks, the rugged 13.56MHz Encapsulated Transponder allows for advanced solutions in demanding supply chain management applications such as laundry tracking. It is especially designed and tested for applications that require a ruggedized transponder that can withstand harsh environments.
Producer	Texas Instruments
Product link	http://www.ti.com/tiris/docs/products/transponders/1356mhz-encapsulated.shtml
Data Sheet	http://www.ti.com/tiris/docs/manuals/pdfSpecs/1356mhz-encapsulated.pdf
Application	Chain management
Seller	Not Available
Price	Not Available
Delivering time	Not Available
Tag Specifications	
Memory size	2 kbit
Operating Temperature	From -25°C to +90°C
Reading range	Not Available
Standard	ISO 15693
Tag Evaluation	
+ Designed for harsh environments	−
+ Large memory	−

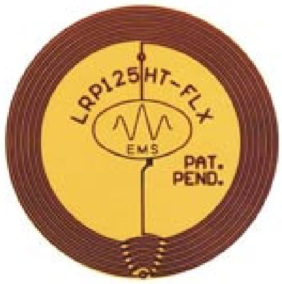
Tag 5

 96x48 mm	**Tag-it HF-I Transponder Inlays** The Tag-it HF-I Transponder Inlay family is compliant with the ISO/IEC 15693 standard, a global open standard for contactless integrated circuits cards (vicinity cards) operating as 13.56MHz which provides also the basis for consumable smart labels. With a user memory of 2k bits, organized in 64 block, the Tag-it HF-I Transponder Inlays offer advanced solutions for product authentication, ticketing, library management and supply chain management applications. To cover the specific requirements of different applications, the thin and flexible Tag-it HF-I Transponder Inlays are offered in different antenna shapes and can be easily converted into paper or plastic labels.
Producer	Texas Instruments
Product link	http://www.ti.com/tiris/docs/products/transponders/RI-I02-112A.shtml
Product Bulletin	http://www.ti.com/tiris/docs/manuals/pdfSpecs/TagitHF-IProdBulletin.pdf
Data Sheet	http://www.ti.com/tiris/docs/manuals/pdfSpecs/RI-I02-112A.pdf
Application	Authentication, ticketing and managment
Seller	Not Available
Price	Not Available
Delivering time	Not Available
Tag Specifications	
Memory size	2kbit
Operating Temperature	From -25°C to +70°C
Reading range	Not Available
Standard	ISO 15693
Tag Evaluation	
+ Large memory	− Missing information about reading range and price

Tag 6

 96x48 mm	**Tag-it Inlays** The Tag-it inlay, a new generation of TI-RFid transponders, is the basis for the first consumable smart label for industries needing quick and accurate identification of items such as express parcels and airline baggage. Ultra-thin and battery less, this general purpose read/write transponder is placed on a polymer tape substrate and delivered in reels. It fits between layers of laminated paper or plastic to create inexpensive stickers, labels, tickets and badges. Tag-it inlays can be embedded into products and items, and can include magnetic stripes, barcodes or other printed information. User data is read and stored in a 256-bit non-volatile user memory that is organized in eight blocks. Each block is user programmable and can be locked to protect data from modification. Tag-it inlays are available in four sizes for standard labelling requirements.
Producer	Texas Instruments
Product link	http://www.ti.com/tiris/docs/products/transponders/RI-I02-112A.shtml
Product Bulletin	http://www.ti.com/tiris/docs/manuals/pdfSpecs/TagitHF-IProdBulletin.pdf
Data Sheet	http://www.ti.com/tiris/docs/manuals/pdfSpecs/RI-I02-112A.pdf
Application	Industrial environments
Seller	Not Available
Price	Not Available
Delivering time	Not Available
Tag Specifications	
Memory size	256 bit
Operating Temperature	From -25°C to +70°C
Reading range	Not Available
Standard	Not Available
Tag Evaluation	
+	− Missing information
+	− Small memory

Tag 7

 22 mm in diameter	**LRP125HT-FLX RFID Tag** The FastTrack™ family of RFID Tags/Labels/ PCBs use Philips Semiconductor I-CODE Reader/Writer chips, but most important, use EMS' unique, patented design and manufacturing technology to create the most advanced industrial RFID Tags. EMS' reusable (or disposable) FastTrack™ Series Passive Read/Write RFID Tag, LRP125HT-FLX, is specifically designed for demanding manufacturing environments. The Tag is available in a compact .88in diameter. This FastTrack Tag also features high temperature surviving capabilities, Long-Range Read and Write distances and Multiple-Tag-In-Field Read/Write. The LRP125HT-FLX is compatible with EMS's LRP-Series Reader/Writers.
Producer	http://www.ems-rfid.com/
Product link	http://www.ems-rfid.com/support/lrp125ht-flxsup.html
Data Sheet	http://www.ems-rfid.com/support/dsheets/lrp125ht-flx.pdf
Application	For industrial environments.
Seller	http://www.ems-rfid.com/
Price	Not Available
Delivering time	Not Available
Tag Specifications	
Memory size	384 bit (48 Bytes)
Operating Temperature	From -40 to +93°C
Reading range	UP to 0.203 m
Standard	ISO 15693
Tag Evaluation	
+ Tolerate high temperature	− Short reading range
+	− Small memory

Tag 8

 25 mm in diameter	**LRP125 (HT) / LRP250 (HT) Passive Read/Write RFID Tags** Escort Memory Systems FastTrack line of RFID Tags and Reader/Writers (or Antennas) provides outstanding RFID solutions for demanding industrial environments. From scorching paint ovens to post office parcel tracking applications in which 99 Tags must be read and written at the same time, the FastTrack family of RFID tags and Reader/Writers will be your complete RFID solution. The Tags use I-CODE chips, but most important, use Escort Memory Systems unique patented design and manufacturing technology to create the most advanced industrial Tags.
Producer	http://www.ems-rfid.com/
Product link	http://www.ems-rfid.com/support/lrp125-250htsup.html
Data Sheet	http://www.ems-rfid.com/support/dsheets/FastTrack_Tags.pdf
Application	http://www.ems-rfid.com/support/appnotes/Ryton.pdf
Seller	http://www.ems-rfid.com/
Price	Not Available
Delivering time	Not Available
Tag Specifications	
Memory size	384 bit (48 Bytes)
Operating Temperature	From 40° to 93°C
Reading range	Up to 0,216 m
Standard	ISO 15693
Tag Evaluation	
+ Tolerate high temperature	− Short reading range
+	− Small memory

Reader 1

	**Sentinel-Sense™ MPR-1530** ▪ 5-8 inches read range with smart tags ▪ Multi-Protocol: I-Code™, MicroID™, Performa™, Tag-It™ and ISO-15693. ▪ License-Free ISM (Industrial, Scientific and Medical) band ▪ Dual Technology Design: Bar code (optional) and 13.56 MHz RFID ▪ Read, Write and Search RFID tags, and read bar code labels ▪ Palm OS Operating System and Industry-standard RS-232 output ▪ Capability to adapt and accept other PDA families		
Producer	http://www.awid.com/		
Product link	http://www.awid.com/product/mpr-1530/mpr-1530.htm		
Data Sheet	Not Available		
Application	Tracking and asset management		
Seller	Not Available		
Price	Not Available		
Delivering time	Not Available		
Reader Specifications			
Reading range	12.7-20.3 cm (5-8 inches)		
I/O Control	RS-232		
Standard	ISO-15693		
Reader Evaluation			
+ Support many types of tag		− Missing information	
+ Hand held with Palm OS		− Short reading distance	

Reader 2

 	**Memor2000 RFID/HF** The Memor2000RFID hand-held terminal reads and writes to Tag-it (Texas Instruments) and I-Code (Philips Semiconductors) smart labels. Smart labels employ radio frequency identification (RFID) technology. Each printable and flexible label is a transponder with an integrated circuit and an antenna. The label does not require a battery as it receives energy together with information from the Memor2000 read/write module at distances of up to 70 mm. Smart labels can be programmed with production information such as date and place of manufacture, distribution history and guarantee details, which ensures traceability from production line to point of sale. Contact Minec if your company is considering the introduction of a smart label identification system. We have the hand-held terminals, software and know-how to set up smoothly running smart label systems.
Producer	http://www.minec.com/
Product link	http://www.minec.com/products/m2000/tagit.html
Data Sheet	http://www.minec.com/products/m2000/rfid_high2.pdf
Application	Inventory control, Genuine Brand identification
Seller	http://www.minec.com/
Price	1400 € (exclusive works)
Delivering time	Not Available

Reader Specifications	
Reading range	Up to 70 mm
I/O Control	Infrared link, RS-232
Standard	ISO 15693

Reader Evaluation	
+ Support many types of tag	− Short reading distance
+ Hand held	−

Reader 3

	**211 13.56MHz ISO Single Point Reader** Conforming to the current and emerging ISO standards, ISO 15693 and ISO 18000, the Eureka 211 13.56MHz single point readers are available in industrial and commercial versions. · Configurable USB, RS232 and isolated RS485/RS422 interfaces as standard · Standard operating modes and features · Optimised for speed, range and anti-collision
Producer	http://www.avonwood.com
Product link	http://www.avonwood.com/products/product_details.asp?id=2
Data Sheet	http://www.avonwood.com/pdf/211/web%20243388A%20211%20industrial%20decoder%20copy.pdf
Application	Supporting a wide variety of applications
Seller	http://www.avonwood.com
Price	680 £ plus 620 for external antennas
Delivering time	2 to 7 days (DHL)
Reader Specifications	
Reading range	Up to 1 meter
I/O Control	USB, RS232 and isolated RS485/RS422
Standard	ISO 15693 and ISO 18000
Reader Evaluation	
+ Good reading range	− High price
+ Supports many interfaces	−

Reader 4

	**RIDEL 5000** - Radio-Frequency Identification module (RFID) for contact less reading and encoding of labels or cards with ISO 14449 and ISO 15693-Protocol I-CODE, Tag-it, PicoTac, Mifare etc. - Compact size, smallest 8W Reader/Encoder available. - Anti-theft (EAS) bit activation/deactivation. - 4-channel I/O port. - Long range reading/encoding with the anti-collision feature a large number of tags or labels can be treated simultaneously, reading and/or encoding one, several or every label in the working field. - RS232 or RS485 communication up to 115200 baud. - Wysiwyg calibration with fine tuning for critical environment.
Producer	Softrónica
Product link	http://www.ehag.ch/prod/rfid/sof/ridel5000.htm
Data Sheet	http://www.ehag.ch/prod/rfid/sof/pdf/RIDEL5000%20Manual/120001110-RIDEL-Manual°.pdf
Application	Any application requiring long-range reading
Seller	http://www.ehag.ch/
Price	€ 1 673.00
Delivering time	Not Available
Reader Specifications	
Reading range	1.2 meter with antenna
I/O Control	RS232 and RS485
Standard	ISO 15693
Reader Evaluation	
+ Good reading range	− Not portable

Reader 5

	**CT-MR100-A DEVELOPMENT KIT** 1 x CT-MR100-A reader, 1 x CT-ANT340/240 Pad antenna, 1 x 12 VDC Power supply (UK or EU Only) 1 x RS232 Cable and power socket cable, 1 x Software development kit (SDK) 5 Sample tags
Producer	http://www.copytag.com/
Product link	http://www.copytag.com/acatalog/actinic.html
Data Sheet	http://www.copytag.com/acatalog/ct-mr100-a-dev-kit.pdf
Application	Application retail, EAS, Logistics and warehouse management.
Seller	http://www.copytag.com/
Price	£377.99 (Excluding: VAT at 17.5%)
Delivering time	14 to 21 days
Reader Specifications	
Reading range	Up to 30 cm
I/O Control	RS232, or optional TCP/IP
Standard	ISO 15693
Reader Evaluation	
✚ Cheap solution	− Short reading distance

Reader 6

	**CT-LR200 -A DEVELOPMENT KIT** CopyTag SL 13.56 MHz ISO 15693 compatible CT-LR200-A long range reader and the 300/300 mm external antenna that will read/write to ISO 15693, I-code and Tag-It tags at 40CM . Including power supply and industrial case. Sample tags and SDK software Included.
Producer	http://www.copytag.com/
Product link	http://www.copytag.com/acatalog/Evaluation_Kits.html
Data Sheet	Not Available
Application	Not Available
Seller	http://www.copytag.com/
Price	£1,667.93 (Excluding: VAT at 17.5%)
Delivering time	14 to 21 days
Reader Specifications	
Reading range	40 cm
I/O Control	Not Available
Standard	ISO 15693
Reader Evaluation	
+	− Short reading distance
+	− Expensive solution
+	− Missing information

Appendix C – Product Acquisition

AVONWOOD DEVELOPMENTS LTD.
Eureka Radio Frequency Identification Systems
KNOLL TECHNOLOGY CENTRE, STAPEHILL ROAD, WIMBORNE, DORSET, BH21 7ND
TEL: +44 (0)1202 868000 FAX: +44 (0)1202 868001
Website: www.avonwood.co.uk email: sales@avonwood.co.uk

PROFORMA INVOICE No. 00101

CONTRACT No. E 02962 | INVOICE DATE 25/03/2004
REF. GM | PAGE 1
ORDER No. | DATE 25/03/2004
CONSIGN TO:

NAME AND ADDRESS
Mostafa Almusawa
PO Box 70799
Abu Dhabi
United Arab Emirates

CARRIAGE: DHL
CUST. VAT No.

PART No.	QTY	DESCRIPTION	UNIT PRICE £ STERLING	NET PRICE £ STERLING
EUR211D3308	1	211 Single Point Decoder 24v DC	680.00	680.00
EUR211T3713	30	13.56MHz Labels 82mmx47mm (R14 Adhesive)	1.10	33.00
EUR211A3581	1	211 Antenna 0.3m x 0.3m Industrial	340.00	340.00
ADL	1	211 Parasitic Antenna 0.3x0.3	280.00	280.00
PP	1	Export Carriage/Packing/Insurance DHL Courier (2 days depending on Custom's clearance)	116.75	116.75
		NOTES Payment of Pro Forma before goods are despatched. Telegraphic Transfer Payments to be paid by customer. Payment to be made to: Lloyds TSB Bank plc, 84 Victoria Road, Ferndown, Dorset BH22 9JB, UK Sort Code 30 93 25 Account No 01576426 Order Acceptance upon receipt of payment. Please supply a full delivery address for Courier delivery.		
			Net	£ 1449.75
			Vat	£
			Total	£ **1449.75**

Credit transfer payments to: Lloyds TSB Bank plc, 84 Victoria Road, Ferndown, Dorset, BH22 9JB
Sort Code: 30 93 25 Account No: 01576426

VAT No. UK 579 9365 63