UNIVERSITY OF VAASA

FACULTY OF TECHNOLOGY

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EVALUATION OF BUSINESS EFFECTS OF MACHINE-TO-MACHINE SYSTEM

Master's Thesis in

Industrial Management

VAASA 2012

CONTENTS

SYMBOLS AND ABBREVIATIONS

3G	Third-generation mobile communications
ADC	Analog-To-Digital Converter
AES	Advanced Encryption Standard
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
API	Application Programming Interface
AVL	Automatic Vehicle Locator
BMS	Building Management System
CAN	Controller Area Network
CBO	Condition Based Operations
CBM	Condition-Based Maintenance
CDMA	Code Division Multiple Access
CFO	Chief Financial Officer
CRM	Customer Relationship Management
CSV	Comma-separated Values
DOCX	Microsoft Word document format since Word 2007
ERP	Enterprise Resource Planning
GIS	Geographic Information System
GPS	Global Positioning System
GPRS	General Packet Radio Service
HTML	Hypertext Markup Language
HVAC	Heating, Ventilation and Air Conditioning
IEC	International Engineering Consortium
IP	Internet Protocol
IRR	Internal Rate of Return
ISA	International Society of Automation
ISO	International Organization for Standardization
J1708	Serial communication standard in heavy duty vehicles
J1939	Vehicle bus standard in car and heavy duty vehicle industry
J2EE	Java 2 Platform, Enterprise Edition
JDBC	Java Database Connectivity
LAN	Local Area Network
M2M	Machine-to-Machine
MRO	Maintenance, Repair and Operations
NPV	Net Present Value

O&M	Operations and maintenance
OSA	Open Systems Architecture
PC	Personal Computer
PDF	Portable Document Format
PLC	Power Line Carrier
RC4	Ron’s code #4
ROI	Return On Investment
RTF	Rich Text Format
SMS	Short Message Service
TCO	Total Cost of Ownership
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VPN	Virtual Private Network
WAN	Wide Area Network
XHTML	Extensible Hypertext Markup Language
XLS	Microsoft Excel File Format
XML	Extensible Markup Language

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Opintojen aloitusvuosi: 2007
Tutkielman valmistumisvuosi: 2012 **Sivumäärä:** 150

TIIVISTELMÄ
Kiristyvä kilpailu ja paineet projektien aikatauluissa eivät useinkaan jätä mahdollisuuksia investointien ja projektien liiketoimintavaikutusten arviointiin. Lisäksi monessa tapauksessa arviointi voi olla haastavaa ja yrityksissä ei ole asiantuntemusta käytettävissä sen tekemiseen. Tämän vuoksi yritykset usein sitoutuvat erilaisiin projekteihin tai investointeihin ilman huolellista suunnittelua ja näkemystä kustannuksista, joita ne voivat aiheuttaa.

Tämän työn tarkoituksena on esittää työssä suunnitellun sovellusalustan mahdolliset sovellutukset. Sen mahdolliset hyödyt ja käytön laajuus on myös arvioitu. Myös potentiaalisten markkinoiden koko arvioidaan ja takaisinmaksuajan pituus määritetään. Lisäksi investoinnin järkevyys ja kannattavuus arvioidaan asiakkaan näkökulmasta käyttäen useita investoinnin päätöksentekomenetelmiä. Käytännönläheisen liiketoimintavaikutusten arvioinnin tekemiseksi alustaa sovelletaan laivueenhallintaan. Työssä luodaan myös päätöksentekojärjestelmä liiketoimintavaikutusten arvioinnin helpottamiseksi ja lisäämiseksi. Se on rakennettu sen ymmärryksen pohjalta, joka on hankittu laivueenhallinnasta ja kolmesta muusta koneiden välisten järjestelmien tapauksesta.

Työn perustaksi esitetään katsaus olemassaoleviin ratkaisuihin ja muutama tunnettu palvelumalli käydään läpi. Myös perusteet kolmeen myynnin ennustamismenetelmään esitellään lyhyesti. Päätöksentekojärjestelmän rakentamiseksi esitellään myös muutama investointien päätöksentekomenetelmä.

Työn tuloksena saatiin hyvä ymmärrys alustan käyttömahdollisuuksista. Se todettiin sopivaksi sellaiseen toimintaan, jossa on mukana ajoneuvoja, koska niistä löytyy yhteisiä ominaisuuksia, kuten sijaintitieto, polttoaineenkulutus, nopeus ja tilatiedot. Sen markkinapotentiaali arvioitiin lupaavaksi pienestä markkinakoko-oletuksesta huolimatta. Takaisinmaksuaika havaittiin erittäin houkuttelevaksi ja investointi myöskin järkeväksi. Luotu päätöksenteon tukijärjestelmä nähtiin onnistuneeksi. Se voidaan nähdä luotettavaksi työkaluksi, koska se koostuu useista investointien päätöksentekomenetelmistä. Sovellusalueen tunteminen on edelleen tarpeen, koska mikään järjestelmä ei takaa kattavia keinoja kaikkien investointiin vaikuttavien ratkaisevien tekijöiden löytämiseen.

AVAINSANAT: koneiden välinen, laivueenhallinta, päätöksenteon tukijärjestelmä

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Year of Completing the Master's Thesis: 2012 **Pages:** 150

ABSTRACT
The tightening competition and pressure in the project schedules often leave no time or space for the assessment of business impacts of different investments and projects. In addition, in many cases the assessment may be challenging and there is no experience available to undertake it. Therefore, companies often commit to different projects and investments without careful planning and vision of the costs it may cause.

The goal in this thesis is to present and clarify the possible applications for the designed platform. The different benefits and its scope of use are also evaluated. Its potential market size is also assessed and its payback period calculated. Moreover, the investment eligibility from customer point of view is evaluated using several investment decision methods. In order to enable the practical business impact assessment, the designed platform is applied to fleet management business. In order to facilitate and increase the assessment of business impacts, a decision support system is also created. It is built on the understanding gained from the cost-benefit analysis conducted in the fleet management case and three other cases from the machine-to-machine business.

As a background for the thesis, an overview of the existing solutions is presented and few well-known service models are described. Also an introduction to three sales forecasting methods is given. In order to build a basis for the decision support system, few investment decision methods are presented.

As a result, a good understanding of different applications of the platform was gained. It was found to be suitable for any business in which vehicles are involved as they share several common properties such as location information, fuel consumption, speed, and status information. Its potential market size was assessed very promising despite low market share assumption. The payback period was found as very appealing and the investment strongly eligible. The created decision support system was found to be successful. It can be seen as a reliable tool as it consists of several investment decision methods. However, experience from the business area is still needed because any system cannot provide thorough means to identify all the crucial cost factors involved in an investment.

KEYWORDS: machine-to-machine, fleet management, decision support system

1. INTRODUCTION

Machine-to-Machine (M2M) refers to devices using network resources to communicate with remote application infrastructure for the purposes of monitoring and control, either of the device itself, or the surrounding environment. It is sometimes defined simply as data communication between machines without human interaction. M2M has a multitude of applications such as automatic meter reading (AMR) and advanced metering infrastructure (AMI), building control or management systems, condition monitoring of machines or people, environmental monitoring, industrial automation, fleet management, for example, with trucks, and many others. (Lucero 2010; Asif 2011; Lu, Li, Liang, Shen & Lin 2011; Boswarthick, Hersent & Elloumi 2012, 2, 24-25.)

M2M applications are gaining tremendous interest from mobile network operators, equipment vendors, device manufacturers, as well as research and standardization bodies and there are numerous M2M solutions already in use all over the world. For example, over the last three decades, AMR based on one-way or two-way communication has evolved. AMI broadens the scope of AMR beyond just meter readings with additional features enabled by two-way data communication. AMR and AMI systems are replacing the manual meter reading and providing more reliable reading with greater accuracy and overall reduced cost. In the 2000s, Enel completed the first nationwide rollout of AMI meters to more than 30 million customers in Italy. Later deployments followed in the Nordic countries and at the beginning of the 2010s, Spain, France and the UK are the most active markets. The forecast is that the installed base of AMI electricity meters will grow at a compound annual growth rate of 19.4 per cent between 2010 and 2016 to reach 130.5 million units at the end of the period. (Steklac & Tram 2005; Berg Insight 2011b; Foschini, Taleb, Corradi & Bottazzi 2011.)

An example of another M2M application of which market has entered a growth period that will last for several years to come, is fleet management. It provides several benefits for a trucking company such as better operational efficiency and reduced fuel costs. According to a forecast, the number of fleet management systems in active use will grow at a compound annual growth rate of 20.7 per cent from 2.0 million units at the end of 2010s to 5.0 million by 2015. Masternaut is ranked as the largest fleet management player overall in terms of installed base with close to 200 000 units deployed, mainly in France and the UK. TomTom has surpassed 143 000 subscribers and the number one in heavy truck industry, Transics has 65 000 units in active use. All major truck manufacturers on the European market offer a product that supports the fleet management standard. Mercedes-Benz, Volvo and Scania launched their first products in the 1990s and followed by MAN in 2000, Renault Trucks in 2006 and IVECO in 2008. (Delehaye, Hubaux, Guedria, Legat, Delvaulx & Goffard 2007; Berg Insight 2011a.)

There are numerous adoption drivers that speed up the market size growth of M2M applications. A major factor is that mobile network coverage is being expanded worldwide. For example, In North America, mobile coverage was, for many years, insufficient for long-haul trucking. Instead satellite connectivity was used, which was both higher in cost and had lower bandwidth. As mobile coverage has expanded in North America, a corresponding shift away from satellite towards terrestrial mobile connectivity in commercial telematics has occurred. It is also a significant adoption driver that telematics and telemetry are seen increasingly as sources of greater operational efficiency and increased incremental revenue. Remote equipment connectivity enables businesses to provide enhanced after-sale service and support, such as remote vehicle diagnostics. The third substantial driver is technical advances in air interface standards as they enable new 3G M2M market opportunities such as remote video surveillance, remote information display and multimedia content delivery. (Lucero 2010; Lu et al. 2011.)

Moreover, government mandates are increasingly requiring the use of telematics and telemetry functionality enabled by M2M. For example, Sweden mandated that all of its national utilities must read their electricity meters at least once a month, starting in 2009. Swedish utilities are using mobile connectivity as part of the AMI solution, and other Scandinavian countries are expected to follow the model. The European Commission is promoting an EU-wide e-Call telematics initiative with the goal that all vehicles sold in Europe by 2013 will use a combination of GPS, sensors, and mobile communications to automatically inform authorities in the case of an accident with location and details of the incident, and establish an automatic voice call between passengers and emergency personnel. (Lucero 2010.)

A fundamental question when considering whether to invest in a M2M system is what kind of business impacts it may provide. In this thesis, this issue is addressed from two points of view. Firstly, it is examined how the customer can assess the impacts of the investment. Secondly, it is discussed how the service provider can estimate the market size and how to optimally fulfill a customer’s business needs.

1.1. Background of the study

The need for this thesis arose when it was realized in some industrial companies how little the business impacts of different investments and projects are generally assessed and how difficult it may be in many cases. It was also noticed that the goal of a project is not defined well enough and therefore unnecessary amount of resources are spent to create such a generic solution that will fulfil all needs of any customer. However, the reality is not so straightforward. Many customers do not want to pay any extra for an extensive solution or device that contains a large set of high-tech features especially if a simplified option is enough for their needs.

Moreover, too generic product may also make things more complex and error-prone. Therefore, it is necessary to clarify the methods how to assess market potential for a solution with a specific set of features and how to decide whether a development project is worth investing. When some concrete assessment is conducted and numerical results are produced, it most probably helps to understand if the goal of the project should be discussed and defined in more detail.

1.2. Objectives of the study

The aim of the thesis is to present and clarify the possible applications for the platform designed in this thesis. In order to find the solution for the research problem, three questions have to be solved. The questions are:

- What are the applications and benefits of the platform and the scope of its use?
- What is the market size of the solution?
- What is the payback time and is the investment profitable?

In addition to the platform, three practical cases from different M2M domains are also presented in the thesis. They facilitate to outline solutions to the questions from wider point of view and thereby enable creating more reliable, robust and general-purpose decision support system for investment eligibility analysis. The financial analysis in this thesis is conducted from the customer point of view. Analysis from the solution provider side is excluded. This thesis neither contains detailed technical specification of any system as the purpose is to keep the focus in more general level.

2. EXISTING SOLUTIONS

In this chapter six existing M2M solutions such as fleet management are presented. A fleet management solution is defined as a vehicle-based system that incorporates data logging, data communication and satellite positioning to a back office application. In a typical solution, there may be a GPS tracker device mounted on the vehicle being tracked. The tracker contains GPS receiver, GPRS modem, a microcontroller and a local memory for storage of position, time, speed, and telemetry data. The tracker device sends the data periodically or on request via wireless communication network to the control centre's server. There the data are stored and processed within a database system and application components. A demonstrative example of such system is shown in figure 1. (Stojanović, Predić, Antolović & Đorđević-Kajan 2009; Berg Insight n.d.)

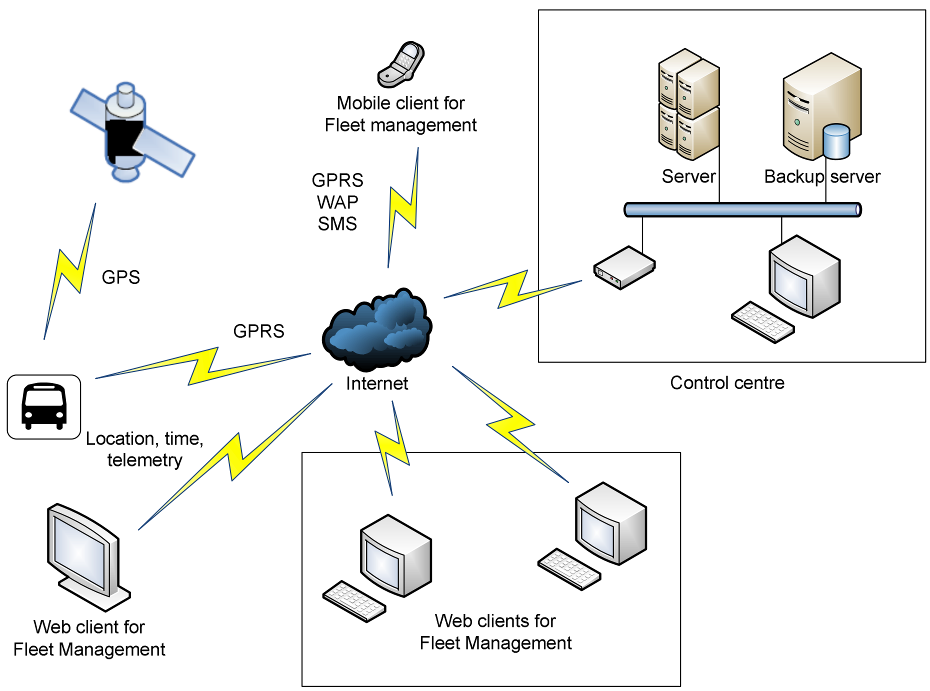

Figure 1 An example of fleet management system (Stojanović et al. 2009).

M2M systems can be applied in numerous areas. A few of them is selected for more careful discussion and are described in table 1. All the presented systems do not exactly match with the definition of fleet management, but are closely based on same technologies and thereby are essential to enable handling the main question in more generic way.

Table 1 Some applications of M2M systems (Morales 2002; OpenO&M 2007; MIMOSA 2010; Tibbo Technology Inc. 2011b).

Application	**Description**
AMR	A system that collects consumption, diagnostic and status data from water, gas, heat and electric meters and stores it to server database for billing, troubleshooting and analyzing.
BMS	A system that controls all systems of an intelligent building, such as HVAC, lighting, pumps, boilers and motors, energy management, IP network infrastructure and fire safety.
CBO	The aim of a CBO system is to enable better informed operational decision-making, resulting in optimal production by leveraging CBM-oriented information. At the company level, CBO extends both the accuracy and the time period of the forecasts that are critically dependent on equipment resources in order to enable the economic optimization of the entire production process.
CBM	The aim of CBM systems is to try to maintain the correct equipment at the right time. CBM system enables improvement of maintenance agility and responsiveness, increases operational availability, and reduce life cycle and TCO. Maintenance to monitored system is performed after one or more indicators show that equipment is going to fail or that equipment performance deteriorating.

2.1. Industry standards and applications

Before any actual solutions are presented, it is beneficial to discuss about few standards associated to M2M solutions. Any engineer or designer implementing condition-based maintenance systems has to take on the task of integrating a wide variety of software and hardware components as well as developing a framework for these components. OSA-CBM is a standard that simplifies this process by specifying a standard architecture and framework for implementing condition-based systems. It defines the six functional blocks of CBM systems, as well as the interface between the blocks. The OSA-CBM functional blocks are shown in figure 2. (MIMOSA 2006.)

The standard provides a means to integrate many disparate components and facilitates the process by defining the inputs and outputs between the components. Basically, it defines a standardized information delivery system for condition-based monitoring. It describes the information that is moved around and how to move it. It also has built-in meta-data to describe the processing that is being done. (MIMOSA 2006.)

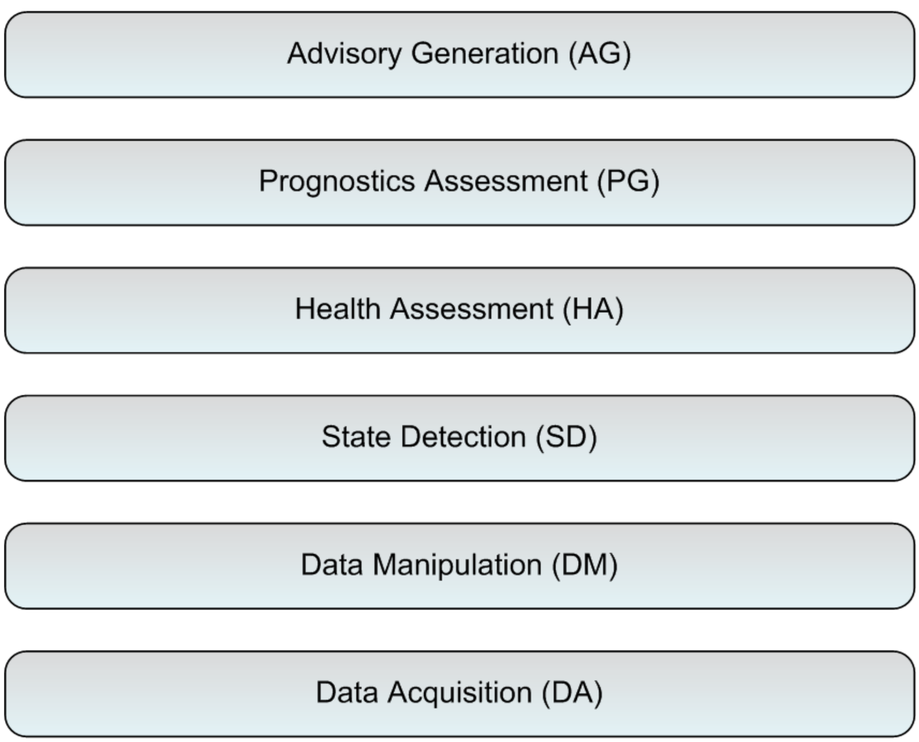

Figure 2 OSA-CBM Functional Blocks (MIMOSA 2006).

The upper three blocks are typically technology-specific, for example, vibration monitoring, temperature monitoring and electrochemical monitoring. They provide the functions below (MIMOSA 2006).

- Data Acquisition (DA) – converts an output from the transducer to a digital parameter representing a physical quantity and related information, such as time, calibration, data quality and sensor configuration.
- Data Manipulation (DM) – performs signal analysis, computes meaningful descriptors and derives virtual sensor values from the raw measurements.
- State Detection (SD) – eases the creation and maintenance of normal baseline profiles, searches for abnormalities when new data are acquired, and determines in which abnormality zone, if any, the data belong, for example, alert or alarm.

The lower three blocks combine human concepts with monitoring technologies in order to assess the current health of the machine, predict future failures and offer recommended action steps to operations and maintenance personnel (MIMOSA 2006).

- Health Assessment (HA) – diagnoses the faults and assesses the current health of the equipment or process, considering all state information.
- Prognostics Assessment (PA) – determines future health states and failure modes based on the current health assessment and projected usage loads on the equipment and/or process, as well as remaining useful life.
- Advisory Generation (AG) – provides actionable information concerning maintenance or operational changes required to optimize the life of the process and/or equipment.

In addition to OSA-CBM, OSA-EAI is also an important standard in area of monitoring solutions. Interconnectivity of islands of engineering, maintenance, operations, and reliability is embodied in MIMOSA's OSA-EAI specifications. Previously, these separate information islands were built using specialized proprietary systems that provided value as they were optimized for certain task or tasks and they provided best results and value for those purposes. However, their combined value can be multiplied if they can be merged into a network that complies with MIMOSA OSA-EAI standard. (MIMOSA 2007.)

OSA-EAI defines the data structures for storing and moving collective information about all aspects of equipment, including platform health and future capability, into enterprise applications. This includes the physical configuration of platform as well as reliability, condition, and maintenance of platforms, systems and subsystems. OSA-CBM uses several data elements that are defined by OSA-EAI. In figure 3 the areas of information encapsulated by the OSA-EAI are shown. The outermost green ring defines the three main areas and consists of Open Reliability Management, Open Maintenance Management and Open Asset Health and Usage Management (MIMOSA 2006, 2007.)

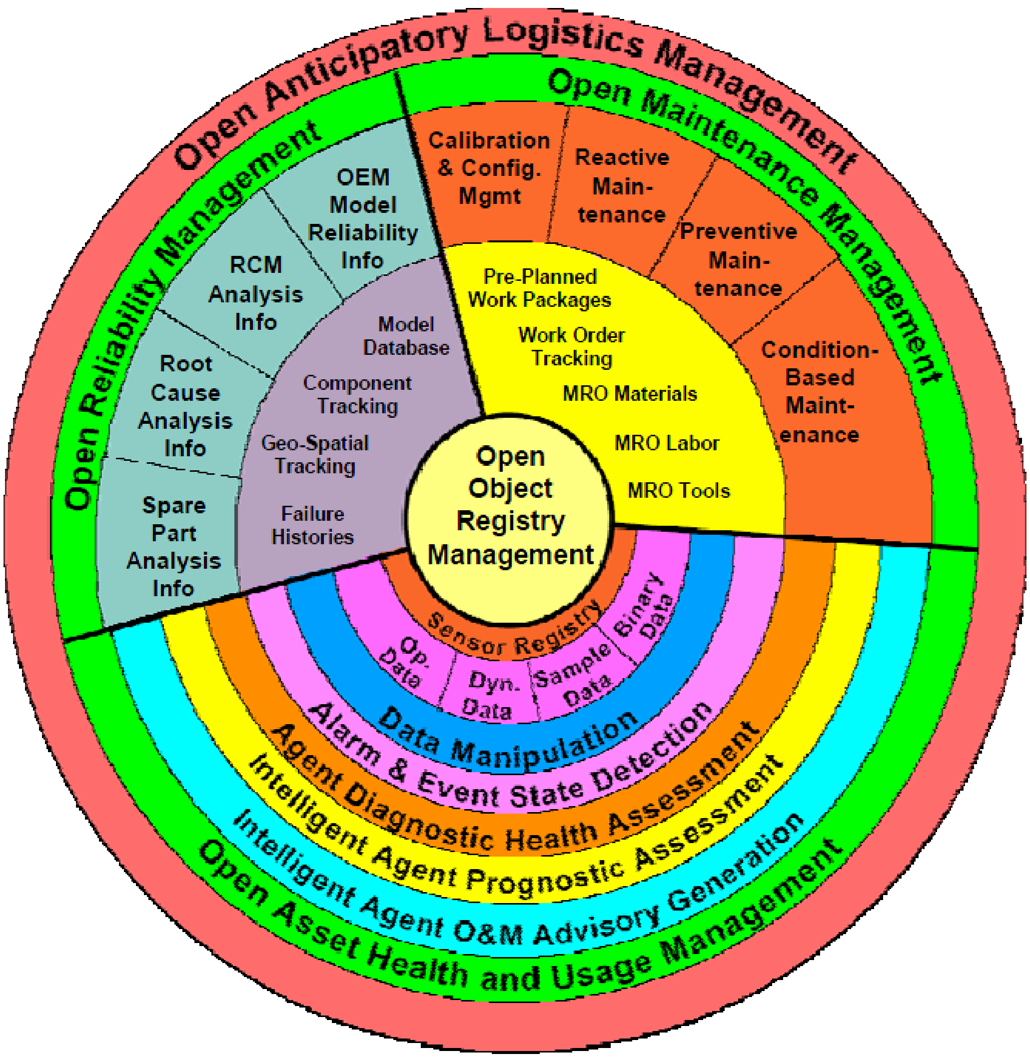

Figure 3 Major functions of OSA-EAI (MIMOSA 2006).

OSA-CBM falls into the Open Asset Health and Usage Management. Data obtained from the sensors is the Data Acquisition block and each subsequent block in OSA-CBM is shown as an additional layer on the OSA-EAI figure. In figure 4 an example of how OSA-CBM and OSA-EAI can be integrated using web services is shown. (MIMOSA 2006.)

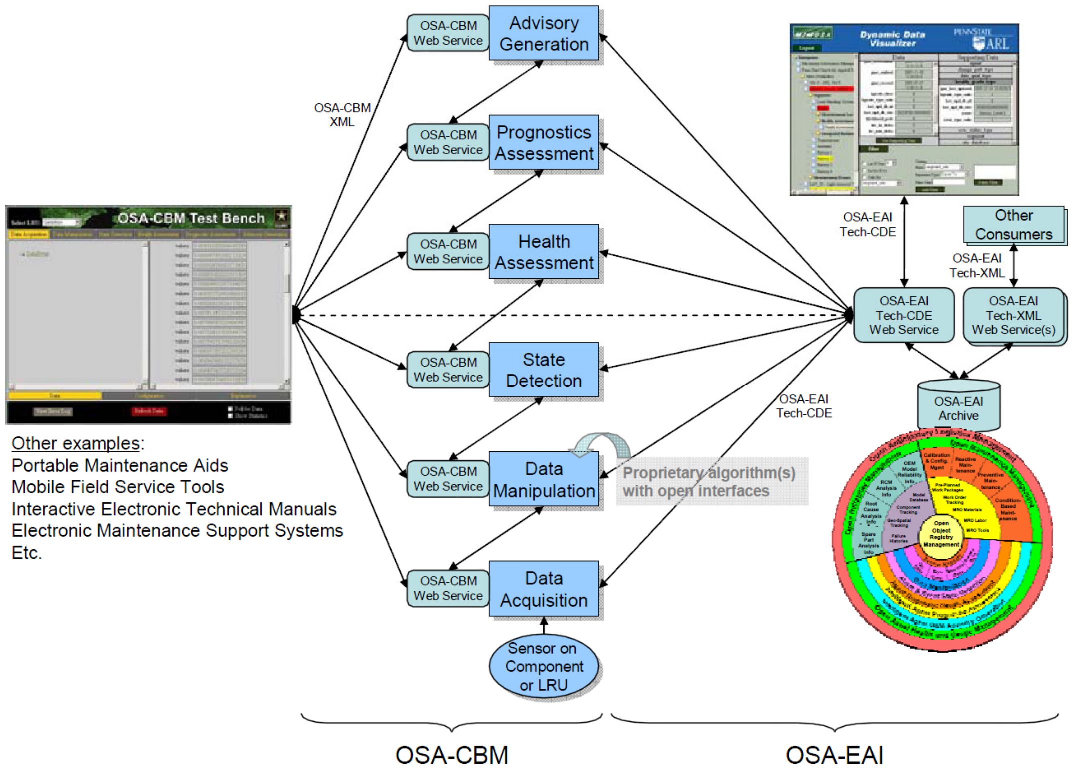

Figure 4 OSA-CBM integrated with OSA-EAI (MIMOSA 2006).

There are also numerous other pertinent standards in remote management, manufacturing and business operations area. A list of most significant ones is presented in table 2. (OpenO&M 2007).

Table 2 List of essential standards (OpenO&M 2007).

Standard	Description
IEC 62264	Enterprise – control system integration (International version of ISA95).
ISA95	Enterprise-control system integration.
ISO 13374	Condition monitoring and diagnostics of machines – data processing, communication and presentation.
ISO 15296	Industrial automation systems and integration – integration of life-cycle data for process plants including oil and gas production facilities.
ISO 18435	Industrial automation systems and integration - diagnostics, capability assessment, and maintenance applications integration.
ISO 18436	Condition monitoring and diagnostics of machines – requirements for training and certification of personnel.

2.2. Truefficiency Basic

Truefficiency Basic is a remote monitoring service that enables inspection of performance of machine tools in a factory. It is provided by KCI Konecranes of which history dates back to 1910 when Kone Corporation was founded. Kone's crane operations were organized into Kone Cranes division in 1988 and KCI Konecranes was formed in 1994. The headquarters of Konecranes is in Hyvinkää, Finland. The company is a group of lifting businesses that offers a complete range of advanced lifting solutions to many different industries worldwide. (Konecranes 2009, 2011.) Truefficiency Basic user interface is shown in figure 5 and its main features are described in table 3.

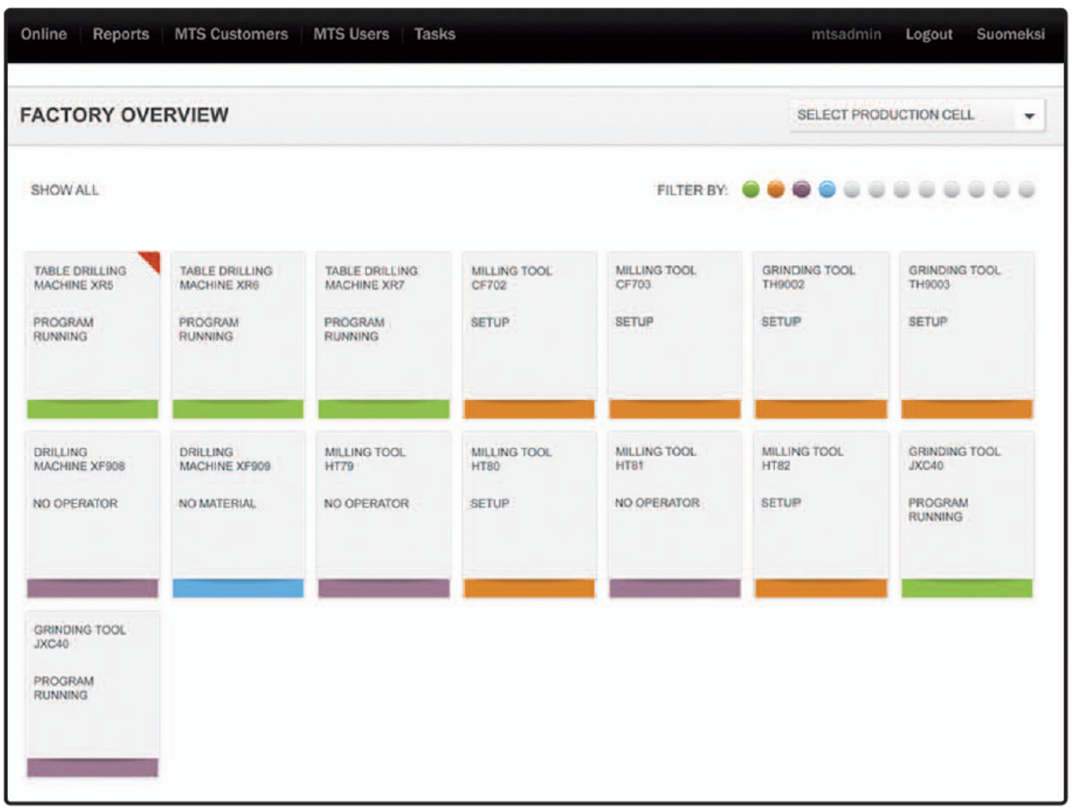

Figure 5 Truefficiency Basic user interface (Konecranes 2011).

Table 3 Truefficiency Basic main features (Konecranes 2009b).

Feature	**Description**
Fleet management	The software has functionality to manage and monitor the machine tools of the customer. Therefore, the hierarchy in the data model starts from the customer that has a factory and each factory may have arbitrary number of machine tools. The hierarchy is in short form Customer.Factory.Machine tool. In addition, each machine tool can linked to a specific production cells and organized according to them in the user interface.
Vehicle tracking	The machine tool location is not tracked as it is not changed but they are in fixed place. In the user interface the status of the machines and other details such as whether a program is running in the machine, is setup going on, what grinding tool is in use at the moment are shown. This information enables making decisions on capacity adjustments, actions to reduce the stops in the production lines and making new investments.
Reporting	There are timeline report and summary report available. The former indicates, for example, whether there is material available, when a program has been running, when preventive maintenance or corrective maintenance has taken place, when the machine operator has been in place and so on. The latter shows summary data from specific time range and how the manufacturing has been distributed over the machines in particular plant. These reports facilitate identifying the bottlenecks of the production, getting information of usability of the machines, comparing production lines and plants and identifying the critical machines in need of maintenance.
Service model	The service is provided as a web portal to the customer. All the data obtained from customer's factories and machine tools are transferred to the Konecranes data center. The service model is not explicitly mentioned but it fits quite well to definition of SaaS concept. The service is offered only from Konecranes data center so it is not available for the customer in on-premise model.
Pricing	The service is available as fixed fee, but the price has to be asked from Konecranes.

In the customer's premises, there is a PC that that collects the data from the machine tools via local area network and sends them to Konecranes data center via a secured VPN connection.

2.3. SKF @ptitude

SKF @ptitude Monitoring Suite is a condition monitoring software that forms the basis of integrated approach to condition monitoring, enabling fast, efficient and reliable storage, manipulation and retrieval of large amounts of complex machine and plant information. SKF is a global supplier of products, solutions and services within rolling bearings, seals, mechatronics and lubrication systems. SKF was founded in 1907 and it is headquartered in Gothenburg, Sweden. The suite contains SKF @ptitude Analyst, SKF @ptitude Observer and SKF @ptitude Inspector applications. SKF @ptitude Analyst is presented here in more detail. It is a comprehensive software solution with powerful diagnostic and analytical capabilities. It is scalable to the customer's needs, for example, operator inspecting rounds, on-line and periodic condition monitoring data collection, or in-depth vibration analysis. (SKF 2007, 2012.) The user interface of the application is shown in figure 6 and the main features are described in table 4.

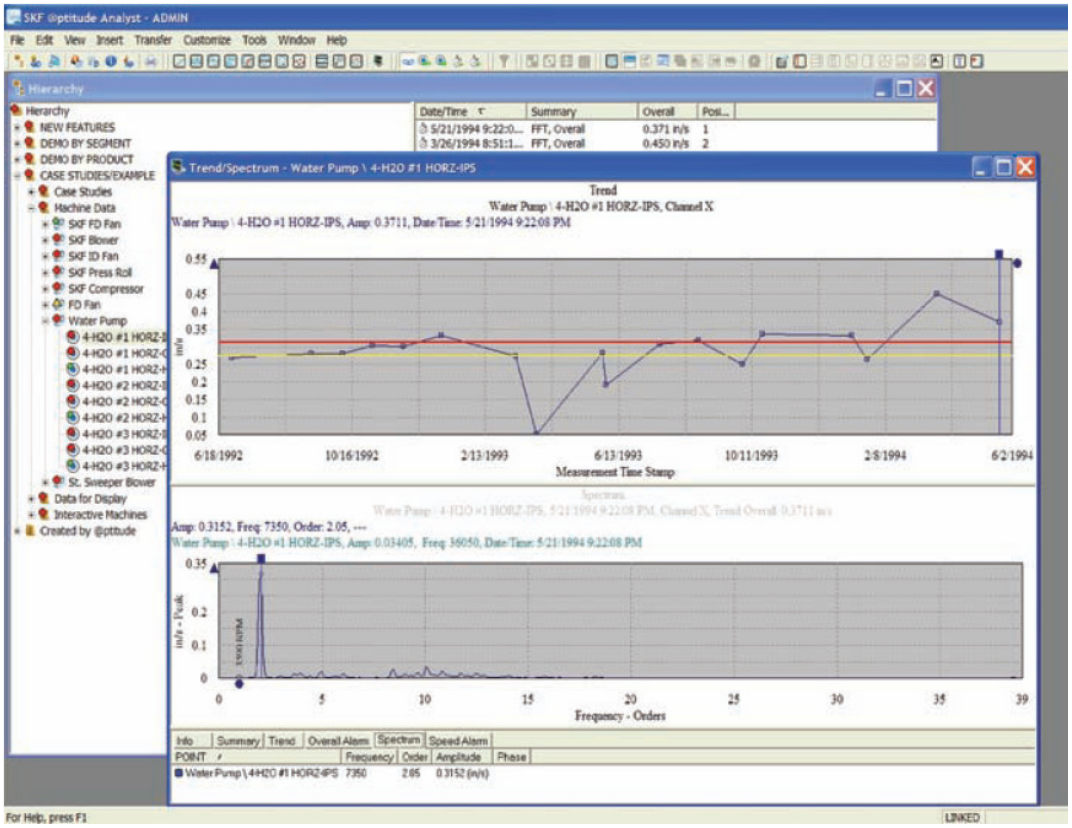

Figure 6 SKF @ptitude Analyst user interface (SKF 2007).

Table 4 SKF @ptitude Analyst main features.

Feature	**Description**
Fleet management	The user interface supports user management and has four security levels according to which it is defined what a particular user is allowed to do and what data he/she can access. The assets can be managed hierarchically. Specific groups can be created in order to facilitate the management of the assets. Any group can have arbitrary number of subgroups and each group can have any number of devices. Each device can have arbitrary number of measurements. The hierarchy in short form without subgroups is Group.Machine.Measurement.
Vehicle tracking	The user interface does not provide a graphical map where to show plants or machines. An interesting machine or measurement can be selected from the hierarchy view for more detailed analysis.

	The user interface can handle a multitude of measurement types including acceleration, velocity, displacement, amps, volts, temperature, flow, high frequency detection, pressure and numerous others. The machines and values of their measurements can be viewed and analyzed graphically in several ways. These are, for example, graph linking, baseline spectrum, waterfall spacing and on-screen integration and differentiation. Numerous alarms are also supported like overall forecast, overall percentage change, spectral envelope, phase angle, inspection, machine condition detection, variable speed alarms and statistical alarm calculation.
Reporting	There are a lot of report templates available, such as last measurement, exception, overdue / noncompliant, collection status, route history and route statistics, set statistics, upload statistics, work notification and compliance. The application also provides extensive report customization features. There are report templates available that can be customized or design entirely new report including data plots, supplemental information and digital images. The history of reports also can be easily maintained and preconfiguring report content and formatting to share with selected users is also possible. The reports are generated in HTML format.
Service model	The software is provided as a standalone installation and network-based installation. In the latter model the software is installed to the customer's servers and it can be used in LAN, WAN and thin-client environments.
Pricing	The pricing has to be negotiated with the local SKF supplier or representative.

SKF @ptitude Analyst software can obtain the data from several devices such as the SKF Microlog, SKF Microlog Inspector, SKF Marlin, and SKF Multilog data collection devices. The devices support, for example, up to 16 analog inputs and eight digital inputs, simultaneous measurement of all channels, digital peak enveloping, adaptive alarm levels and data buffering in non-volatile memory when communication is down. The devices support communication via several intefaces such as Ethernet, RS-485 and RS-232 service interface. (SKF 2011.)

2.4. Wialon

Wialon is a software platform for GPS vehicle tracking. It is manufactured by Gurtam of which headquarter is in Minsk, the capital of Belarus. Gurtam is founded in 2002 and it is specialized in the development and distribution of software solutions for fleet management and GPS tracking based on GPS and GSM/GPRS technologies. In figure 7 the user interface is shown and in table 5 the main features of Wialon solution are described. (Gurtam 2012.)

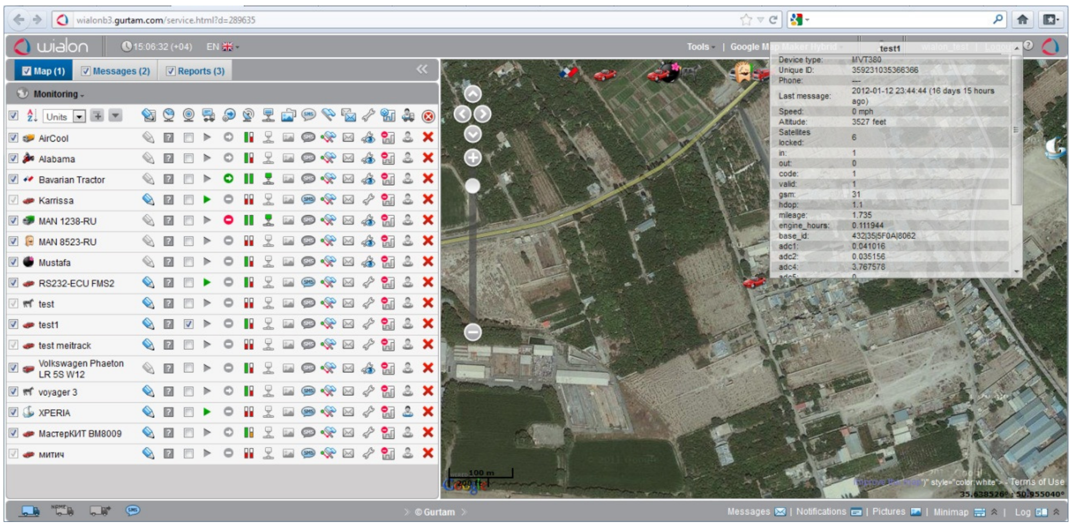

Figure 7 Wialon user interface (Gurtam 2012).

Table 5 Main features of the solution (Gurtam 2012).

Feature	**Description**
Fleet management	The software has functionality to manage the user accounts, users, unit groups and units and assign rights for the users. The hierarchy in the data model starts from account that may contain arbitrary number of users. Each user may have arbitrary number or unit groups and each unit group may consist of arbitrary number of units. There can also be several sensors in each unit. The AVL device sets limits for number of sensors. The hierarchy in short form is: Account.user.unit group.unit.sensor.
Vehicle tracking	In the user interface, there is a map in which the vehicles are marked with a particular icon. By holding the mouse pointer over

	the icon the detailed information of the unit can be seen in a popup info tip. For example, the speed, fuel level, voltage and unit sensor values can be shown in the tip. The location of the vehicles their detailed information are updated real-time. The system supports different types such as OpenStreetMap, Yandex Maps, Google Maps and Yahoo Maps.
Reporting	Wialon supports editable report templates. Any user can create a template that best meets his requirements. A report can contain any number of user-specified tables and charts and display the information over the set period of time. Examples of data the reports may contain are details on trips, stops, engine hours, rides, visited streets and geofences, sensor tracing and violation of speed limits. The reports can be exported into HTML, PDF, Excel, XML or CSV formats.
Service model	Wialon is available as two models, Wialon Pro and Wialon hosting. The former allows the customer to install the software to its own server and in the latter case the hosting service is provided by Gurtam. It has a data center it Netherlands. Both models allow the customer to offer tracking services to its own customers. Gurtam does not explicitly define whether Wialon complies with SaaS service model but the criteria of SaaS is quite closely met. In Wialog Pro case Gurtam's customer provides the application from its own server remotely to its end users. In Wialon Hosting case Gurtam specialists install the system for the customer at Gurtam's data center, support the service, ensure physical and electronic security of it and update the software when new releases are out. However, it is not known whether Wialon complies with multi-tenant architecture as Gurtam does not mention whether the same instance of application is shared to all users. Thereby the service model can be ASP or SaaS.
Pricing	Wialon Pro costs 2 300 € for 50 tracking units. More units can be ordered in bump packs of 25 units. Wialon Hosting costs 120 € per month and allows connecting up to 50 units with any number of sensors. The quantity can be increased at any time by ordering a bump pack of 50 additional units.

Wialon solution allows tracking of the vehicles with multitude of devices. Gurtam does not manufacture the devices itself, but there are numerous devices from different manufacturers that Wialon supports. There are currently more than 290 devices compatible with Wialon Pro and Wialon Hosting platform available on the market. The devices vary from GPS trackers to Automobile Vehicle Locators and specific software installed on pocket PC and cell phones with GPS function. The functionality supported by the devices ranges from very simple ones with just a few functionalities to very extensive entities. There are devices with just a TCP connection but the more versatile ones may have ADC and digital sensors, CAN bus support, iButton support, built-in odometer, SMS support and and communication via TCP and UDP. (Gurtam 2012.)

2.5. iTrak Fleet Executive

iTrak Fleet Executive is a web-based GPS tracking system for commercial fleets of 5 to 15 000 vehicles. The system is developed by iTrak corporation. It was founded in 1995 and its headquarters is in Colorado, USA. The user interface of the system is shown in figure 8 and the main features are described in table 6. (iTrak 2012.)

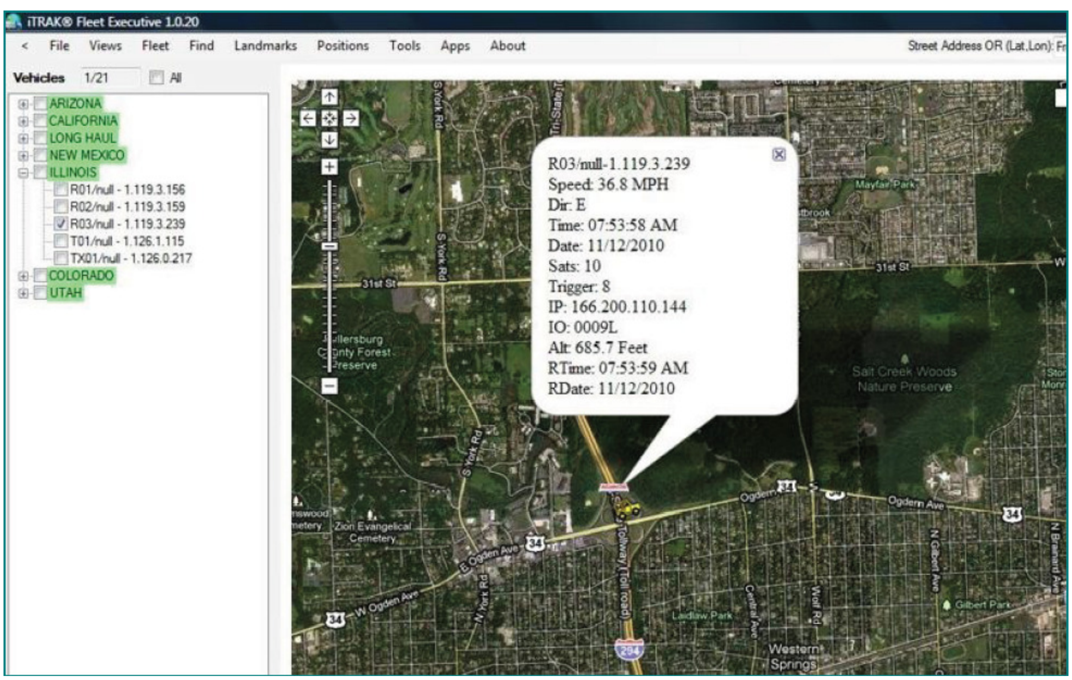

Figure 8 iTrak Fleet Executive (iTrak 2012).

Table 6 Main features of iTrak Fleet Executive (iTrak 2012).

Feature	Description
Fleet management	The application provides a user interface for managing the customer's vehicles organized by sub-fleets. A customer can have arbitrary number of fleets and each of them may be contain arbitrary number of vehicles. Therefore, the hierarchy is Customer.Fleet.Vehicle.
Vehicle tracking	The user interface utilizes 2D and 3D Google maps and provides users with street views, geofences, weather overlays, traffic monitoring, and route management assistance. Detailed information of a single vehicle can be viewed on the maps. Examples of such data are latitude, longitude, altitude, speed, direction of travel, date, time, and number of satellites in the view. Sending of the data from a vehicle to server is event-based in order to reduce data transfer. The events can be configured according to customer's needs. The most common events that trigger the data transmission are vehicle starts, stops, distance travelled and application-specific on-board sensors.
Reporting	There are numerous ready-made reports available in the system. Report customization is not possible. Examples of supported reports in the system are trails of the vehicles, summary reports, exception reports, landmark reports, stop reports, over speed reports, maintenance alerts and route alerts. The reports can be produced from a single-vehicle or fleet-wide. Reports can be exported to Excel files.
Service model	The service is provided as SaaS model. The application is SaaS .NET based application. The service is hosted in iTrak's data center but the service can be delivered also as an in-house enterprise system, with no monthly tracking fees. Usage of the service can be started as hosted first but it can be migrated to an in-house at later date. A third-part API is also provided to customers and partners at no charge allowing full integration with other software packages.
Pricing	Recurring costs of less than 1 $ per day per vehicle. All features of the software are included in the base price. The base price has to be discussed with iTrak corporation sales representatives.

iTrak corporation designs and manufactures itself the tracking modules to be used with iTrak Fleet Executive system. There is no support for devices of other manufacturers. There are several device models available, but by default the tracking device contains GPS receiver and antenna, cellular modem/transceiver, and computer board that controls the storage and transmission of all position data. Examples of features that the tracking modules support are that they can be extended with an optional wiring harness to support up to eight inputs and eight outputs. The units can optionally also be extended J1708/J1939 interface capable to capture engine diagnostics. The trackers can communicate with the data center servers using SMS, GPRS at UDP level and CDMA. (iTrak 2012.)

2.6. Fleetilla vehicle tracking solution

Fleetilla's vehicle tracking solution consists of FleetOrb online web-based fleet tracking application and a vehicle tracking unit installed to each vehicle to be tracked. The solution is developed by Fleetilla LLC that is a Michigan based organization founded in 2000. The user interface is shown in figure 9 and the main features of the FleetOrb application are described in table 7. (Fleetilla 2009.)

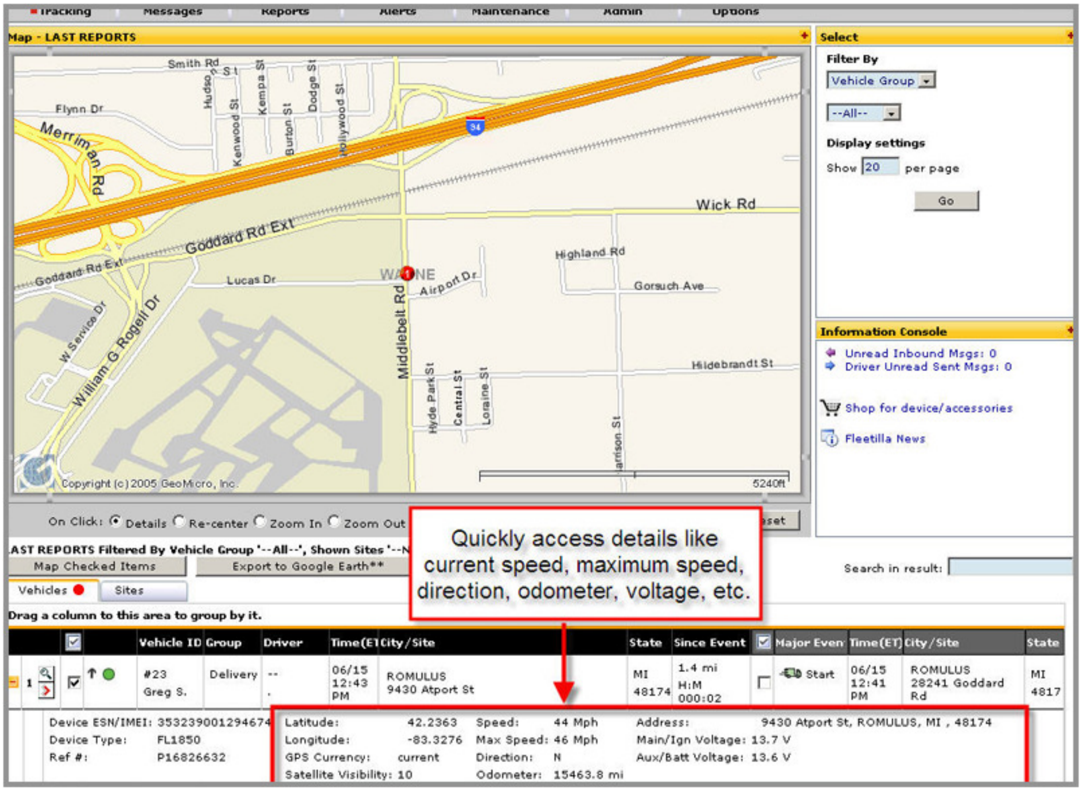

Figure 9 FleetOrb user interface (Fleetilla 2009).

Table 7 Main features of FleetOrb application (Fleetilla 2009).

Feature	**Description**
Fleet management	FleetOrb provides user interface for managing the fleet by vehicle groups. Each vehicle group may contain arbitrary number of vehicles and each vehicle may contain several sensors. The hierarchy in short form is Customer.Vehicle group.Vehicle.Sensor.
Vehicle tracking	FleetOrb uses GeoMicro maps in the user interface but also supports export of vehicle information to third part GIS system such as Google Earth. The details shown for each vehicle in the user interface are location, current speed, maximum speed, odometer, voltage, direction, and other parameters.
Reporting	FleetOrb provides a lot of different reports such as tracking reports, position reports, trip summaries, trip details and trip stops, site activity, event history, operating time detail and summary, upcoming maintenance, miles by state, speed violations, driver per-

	formance, temperature sensors and alerts. Reports can be scheduled to run at specified intervals such as every day or week and can be set up to be sent via e-mail to designated personnel. Fleetilla can create custom reports for the customer if needed.
Service model	The FleetOrb website is accessible over the Internet using a web browser. The website is managed at Fleetilla's network operations center. It consists of Tier-1 carrier grade facilities with secure access, redundant power and ISP connectivity. FleetOrb is provided only as SaaS service and an on-premise installation to customer is not supported. Fleetilla provides a real-time XML interface to for integrating location and other data for example dispatching, payroll, CRM and ERP systems.
Pricing	The price has is dependent on customer's needs and has to be negotiated with Fleetilla.

Fleetilla provides two tracking devices to be used with the solution, FL1850 and FL1200. They is designed and developed by Fleetilla. The first one is more advanced and the former is simpler with less functionality. They both support GSM and GPRS communication. FL1850 contains GPS functionality with antenna open/close detection. There are three serial ports for interfacing to external accessories by which the customer's specific needs can be met. The device can be extended, for example, with emergency/status notification keypad, J1708/J1939 vehicle bus interface unit, starter disable kit and temperature sensor. The device supports also data buffering when it is out of coverage and tamper detection. FL1200 has internal cell/GPS antennas and deep power saving modes. FL1200 also supports data buffering when out of coverage. (Fleetilla 2009.)

2.7. Telogis Fleet

Telogis Fleet is a fleet management solution scalable to fleets of all sizes. It is designed and developed by Telogis that is headquartered in California, USA and founded in 2001. Telogis Fleet is available as standard, professional and enterprise editions. In this chapter the features of enterprise edition are in focus. The user interface is shown in figure 10 and the main features are described in table 8. (Telogis 2012.)

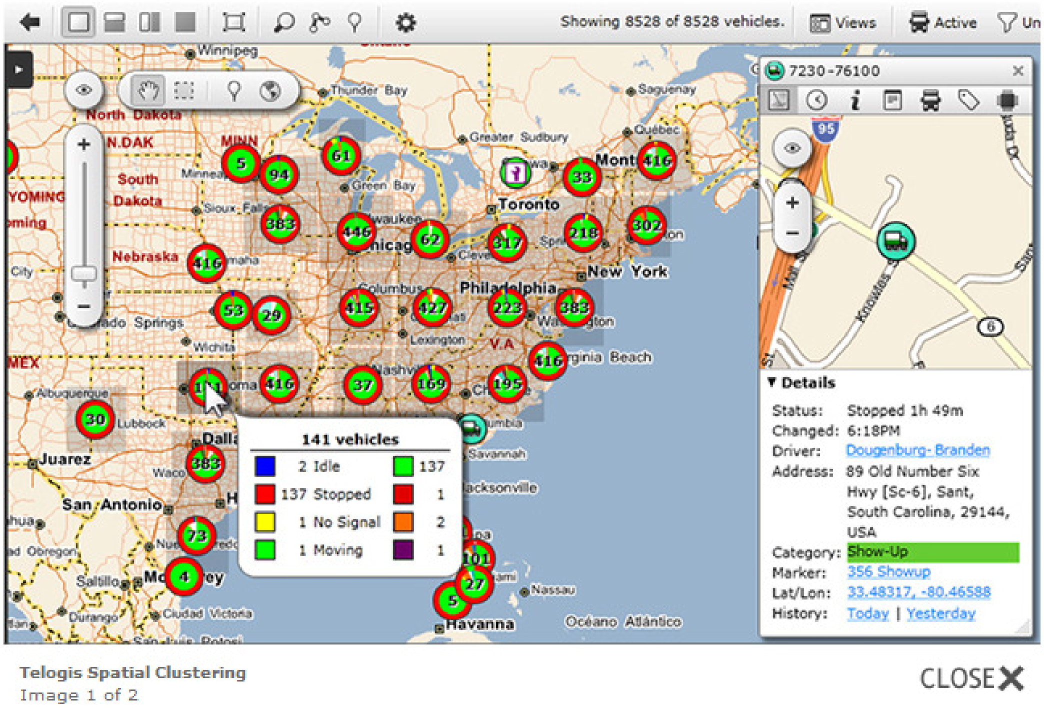

Figure 10 Telogis user interface (Telogis 2012).

Table 8 Telogis Fleet main features (Telogis 2012).

Feature	**Description**
Fleet management	The hierarchy in Telogis Fleet is role-based. For this reason, for example, the views can be configured so that the relevant information can be quickly seen. Some basic hierarchy can be outlined from data model perspective. The root is company that can have arbitrary number of fleets. Each fleet may contain arbitrary number of departments and each department may have arbitrary number of unit groups. Each unit group may have arbitrary number of units. The hierarchy is shortly Company.department.unit group.unit.
Vehicle tracking	Telogis Fleet uses Navteq maps in the user interface. Large groups of vehicles can be seen as clustered on one screen and drill down to a single vehicle very quickly. Examples of the details shown for a single vehicle are status, current location, driver, latitude, longitude, current speed and so on.
Reporting	Telogis Fleet comes with a suite of more than 50 reports ranging

	from detailed to high level. The reports can be run by vehicle, fleet, driver or team. Most reports allow the user to jump to the detailed map view in one click. The reports can be scheduled to run at specific time and they can be set up to be sent via e-mail to defined group for example in PDF or Excel format. Report customization is not possible.
Service model	Telogis Fleet comes with SaaS service model. On-premise installation for the customer is not available but Telogis Fleet can be integrated with the customer's back office applications via Telogis Integration API. This is possible as the solution adheres to an XML-based open architecture. The integration may be useful for example to establish payroll, supply chain to insurance or asset management to document management systems based on the data the Telogis Fleet solution provides.
Pricing	The pricing has to be negotiated with Telogic's sales team.

Telogic does not design or manufacture tracking devices itself. The solution is a wireless and hardware independent platform. The purpose is that the hardware is selected from the compatible devices that suit best to the customer's business requirements. There are numerous compatible devices available on the market for example from Cal Amp, GenX Mobile, Pointer, Sierra Wireless and GlobalStar. Ford can even provide a factory-fitted telematics hardware installed for pre-ordered Ford vehicle. (Telogis 2012.)

3. SERVICE MODELS

In this chapter three software service models and their benefits and drawbacks are described. Also some financial aspects of each model are presented in order to clarify what is the best option for specific solution from monetary point of view.

3.1. On-premise

In the on-premise approach a company purchases a server and a copy of software or a specific number of licenses to it from a software vendor. Often the company also buys all the other underlying software such as application servers and databases. The company hires the personnel that maintains the servers and software in-house and keeps the system up and running and up-to-date. (Software-as-a-Service Executive Council 2006; Weston & Kaviani 2009; Coupa n.d.)

The set-up and implementation may take long time, even several months. When a new version of software is issued, the company may have to pay a specific fee in order to get the upgrade. While the company can skip or forgo the new version sometimes, if the software gets too out-of-date it may become unsupported in which case the company will have to support and maintain the software itself without help from the software vendor. (Weston & Kaviani 2009; Coupa n.d.)

In many organizations, the information technology (IT) budget is spent in three main areas, software, hardware and professional services. The latest one consists of the people and institutions that ensure the continued operation and availability of the system, including technical support staff, consultants and vendor representatives. In an IT environment based around on-premise software, the majority of the budget is typically spent on hardware and professional services, and minority of the budget is aimed at software. Figure 11 illustrates this distribution. The figure is not based on exact numbers but demonstrates the financial investments to different areas in on-premise model. (Chong & Carraro 2006.)

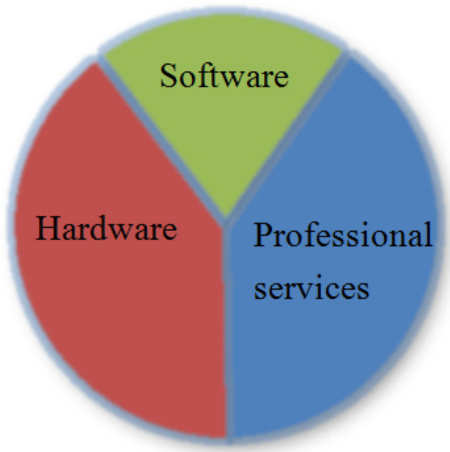

Figure 11 Budget for an on-premise software environment (Chong & Carraro 2006).

There are some cases in which in on-premise solutions could be the best one or could be favored. Especially larger businesses and organizations with highly sensitive data find on-premise solution better for their purposes. If a company wants to maintain full control and ownership of data, on-premise is the most suitable choice. In some cases, it is seen also as advantage that the dedicated IT staff for maintenance and support is in-house. Initial investment is high but it pays off over time. Specifically, if the organization's infrastructure is already in place it may be financially sensible to purchase an application and manage it on own. (Ross 2010; Wong 2010; GFI Software 2010.)

There are some concrete drawbacks presented concerning on-premise model. According to Zhang and Zhan, the main drawback is that the customer typically needs to pay the full price for the product even if only certain functionalities of the software are used. Another drawback in the on-premise model is that the customer needs to constantly update the products whenever a patch or new version is released. This causes additional financial burden as well as technical issues like backward compatibility. Someone also experiences the dependency with the vendor as a problem. It may be difficult to change the vendor in case the customer is disappointed with the product. The customer is fully dependent on the vendor with support issues. The on-premise solution may be challenging also for the vendor as it needs to provide support for several platforms when a new version is released. This ultimately increases the production and distribution costs. Since different pricing can't be used in this model, the vendor charges the same price for every user irrespective to the usage level. For this reason, the user who uses only few features ends up paying more. (Zhang & Zhan 2010.)

3.2. ASP

The Application Service Provider (ASP) concept became popular in the late 1990s with the emergence of the first wave Internet-enabled applications. In the model the provider hosts desktop-type applications from a server farm located at its data center. Users from the customer organizations access these applications via private network or Internet. The concept can be used to nearly any type of application ranging from basic office suites to large enterprise resource planning systems, such as SAP. (Walsh 2003; Strader 2010: 162.)

A typical ASP infrastructure is shown in figure 12. ASPs host applications at the ASP site on servers located in a server farm. A switch allocates the applications to servers according to available capacity so servers are not permanently allocated to a particular ASP customer. ASP applications are single-tenant applications. This means that the server runs only a specific application and only for the end-user group of the single customer. ASPs typically charge the client monthly fee based on the number of users. Charging can also be based on metering of actual usage. (Walsh 2003; Software-as-a-Service Executive Council 2006.)

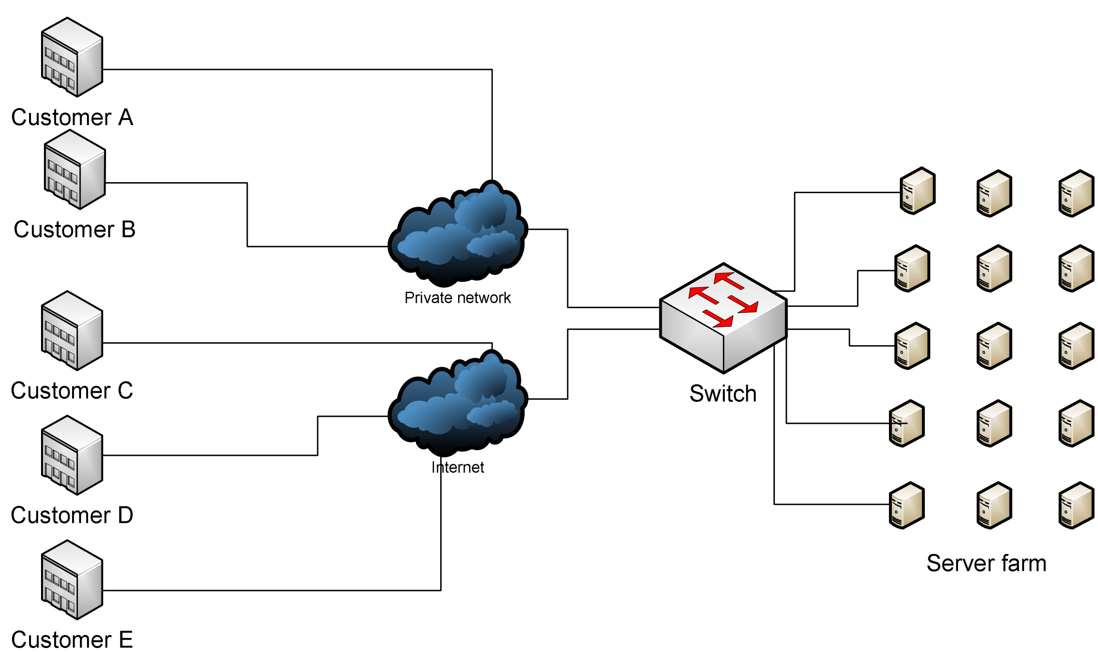

Figure 12 Typical ASP infrastructure (Walsh 2003).

One of the benefits ASP can provide is economies of scale. The ASP can operate a secure, reliable data center at a low cost per user. Especially for small and midsize organizations, the ASP can provide greater levels of reliability and security than it could maintain itself. The ASP achieves this advantage by spreading the costs of its solutions over many customers. The scalability of the applications is often increased when compared to traditional on-premise solutions. ASPs also gain benefit from hiring talented technology experts many small organizations could not afford. The customers of ASP also gain benefits from the relationship in that the ASP keeps it up-to-date on the latest technologies. (Furht, Sheen & Aganovic 2001; Liu 2002; Walsh 2003.)

Although ASP has many benefits, few drawbacks and disadvantages can also be found. The continual payments presume that the monthly fee has to be paid in order to be able to use the ASP service, whereas purchased software is always available when it is once paid and installed. Need to reduce the use of an ASP application may occur for example during financial recession. The second potential drawback is that the company data is not in-house. Mostly this is not a problem, but the reliability of the provider has to be discussed. Possible communication breakdowns are also sometimes causes for concern. Security is also potential threat because the data is stored on external party servers and there are several communication links between the company and the provider. (Wainewright, 2000.)

3.3. SaaS

National Institute of Standards and Technology (NIST) defines Software-as-a-Service (SaaS) as a capability provided to consumer to use the provider’s applications running on a cloud infrastructure. SaaS is one service model of cloud computing. Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources such as networks, servers, storage, applications and services that can be quickly provisioned and released with minimal management effort or service provider interaction. The cloud model consists of five fundamental characteristics, three service models, and four deployment models. The NIST cloud computing definition framework is shown in figure 13. (Williams 2010, 8; NIST 2011.)

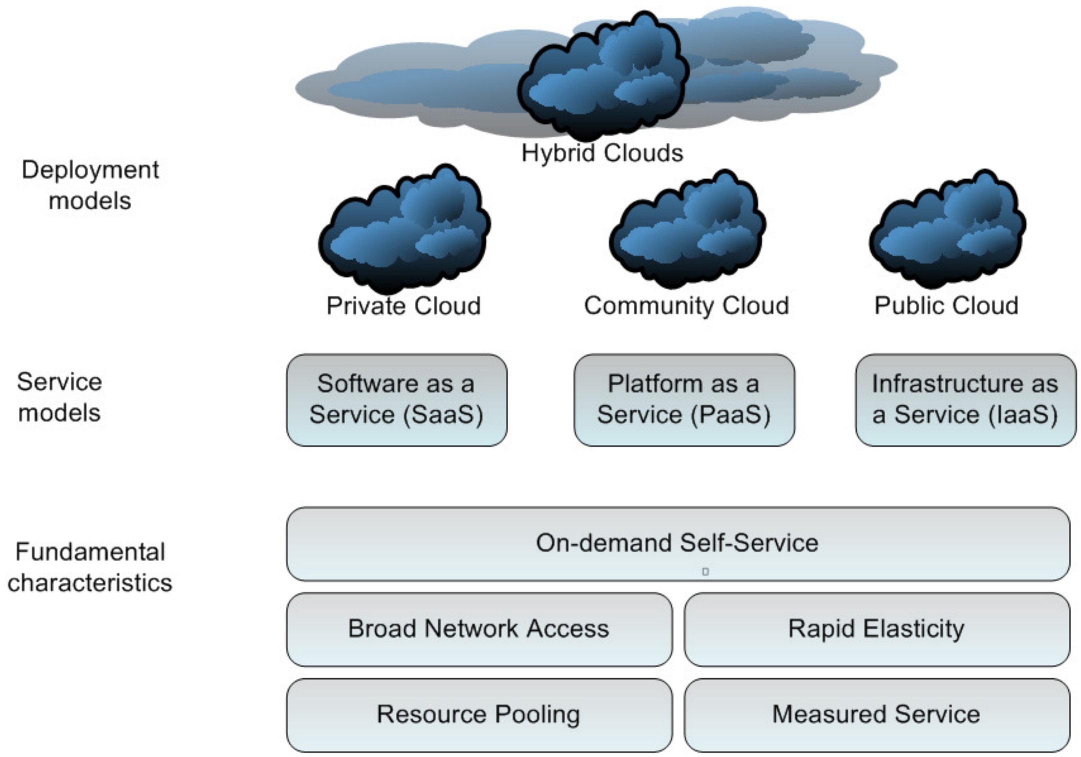

Figure 13 The NIST cloud computing definition framework (Williams 2010, 8).

As seen in the figure, the characteristics are on-demand self-service, broad network access, rapid elasticity, resource pooling and measured service. (Williams 2010, 8; NIST 2011.) On-demand self-service presumes that consumers can log on to a website or use web services to access additional computing resources on demand, whenever they need, without contacting sales representative of support personnel. Broad network access means that services are available over network and accessible using standard mechanisms from any internet-connected device. Rapid elasticity encompasses enabling the computing resources to be rapidly and elastically provisioned or released so that customers can scale their systems up and down at any time according to their changing requirements. Resource pooling enables the customers to share a pool of computing resources with other customers. The resources can be dynamically allocated and hosted anywhere. Measured service presumes the cloud computing providers to automatically monitor and record the resources used by customers or currently assigned to customers. This makes possible the pay-per-use billing model that is fundamental to the cloud computing concept. (Williams 2010, 9-10; NIST 2011.)

The other service models of cloud computing in addition to SaaS are Platform as a Service (PaaS) and Infrastructure as a Service (Iaas). In the PaaS service model the customers are provided with a stable online environment with a programming-language level environment with a set of well-defined APIs to facilitate the interaction between the environment and cloud applications. In the environment customers can easily create, test and deploy web applications using browser-based software development tools. The customer is not allowed to manage or control the underlying cloud infrastructure including network, servers, operating systems or storage, but has control over the deployed applications and probably control settings for the application-hosting environment. (Strader 2010, 160; Williams 2010, 11-14; NIST 2011.)

In the IaaS model the customers are provided with administrative, web-based access to fundamental computing resources, for example, processing power, storage, networks, deployed applications and possibly limited control of selected networking components such as host firewalls. However, the underlying cloud infrastructure is beyond the control of the customer. IaaS systems may contain for example a choice of ready-made virtual machines with pre-installed operating systems such as several versions of Windows, Linux and Solaris. There may also be ability to manually increase or decrease the computing resources assigned to the customer and ability to automatically scale computing resources up and down in response to increases and decreases in application usage. Typically there is also a choice of virtual machines with specific sets of software pre-installed and ability to store copies of particular data in different locations around the world to make downloads of the data as fast as possible. (Williams 2010, 14-15; NIST 2011.)

The deployment models in cloud computing are private cloud, community cloud, public cloud and hybrid cloud. The first one means that the cloud infrastructure is operated solely for an organization. It may be owned, operated and managed by the organization, third-party or some combination of them and it may reside on or off premises. The second model presumes that the cloud infrastructure is shared by multiple organizations and supports a specific community that has shared concerns such as mission, policy, security requirements, and compliance considerations. (Katzan 2010; Williams 2010, 16-17; NIST 2011.)

In the public cloud deployment model the cloud computing services are provided off-premise by third-party providers to the general public and the computing resources are shared with the other customers of the provider. The infrastructure is owned by an organization selling cloud services. In the hybrid cloud model the cloud infrastructure consists of two or more distinct private, community or public cloud infrastructures that remain unique entities, but are bound together by standardized proprietary technology that enables data and application portability. An example of such technology is cloud bursting for load balancing between clouds. (Katzan 2010; NIST 2011.)

In the simplest form SaaS can be defined as a method of delivering a computer program to users using the Internet. The application being used by the customer is hosted using the servers and infrastructure of the service provider. The service may include a single application or a suite of different applications. The applications can be accessed from multitude of different client devices through either a thin client interface, like web browser or a program interface. The SaaS vendor maintains the infrastructure including network, servers, storage, operating systems, or even individual application capabilities. The customer may have access to manage user-specific application configuration settings. An illustrative example of a SaaS solution is shown in figure 14. (Blokdijk 2008, 24; Bhardwaj, Jain & Jain 2010; NIST 2011.)

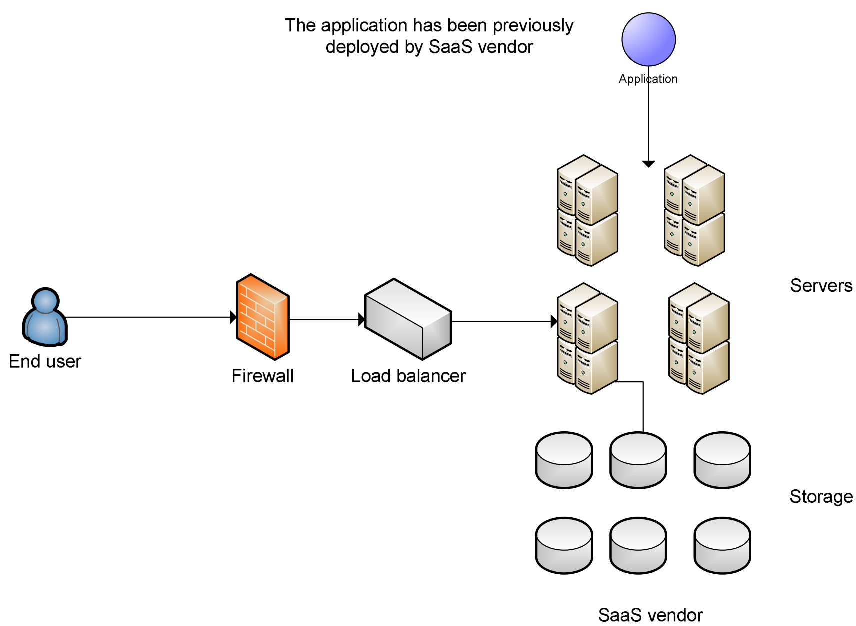

Figure 14 SaaS solution (Bhardwaj et al. 2010).

An essential concept in the SaaS model is multi-tenancy. It means that the physical back-end hardware infrastructure is shared among several different customers but logically is unique for each customer. The architecture of a multi-tenant application enables different companies to share an instance of the application, thereby reducing maintenance work and costs. The application has common logic and unique data elements for several customers on scalable infrastructure resources supported via a cloud platform. (Software-as-a-Service Executive Council 2006; Mendoza 2007, 106; Katzan 2010.)

SaaS solutions are very different from ASP ones. There are three major causes for this. Firstly, ASP applications are traditional single-tenant applications hosted by third party, whereas SaaS application as multi-tenant. Secondly, the ASP applications are hosted by third-parties who typically do not have specific application expertise. The third reason why ASP and SaaS do not equal is that the ASP applications are not written as net-native application. In many cases, the ASP applications were not originally designed for the Internet but were later modified to fit the online market. For this reason, the performance may be poor and application updates are not better than in self-managed on-premise applications. (Software-as-a-Service Executive Council 2006; Blokdijk 2008: 151.)

There are numerous benefits that SaaS model provides. The variable costs are low and they are based on usage instead of upfront fixed cost. Figure 15 illustrates the distribution of company's IT costs to different areas. The available software can be quickly upgraded to the latest releases without the traditional hassles of deployment and installation. Instead of purchasing the software, it is subscribed on monthly or annual fee. SaaS model enables rapid and flawless platform extension, geographic expansion and growth, and worry-free bandwidth. The reliability, performance and efficiency are also improved. Mostly productivity is enhanced and deployment is faster. SaaS solutions also enable access to applications anywhere and anytime. (Blokdijk 2008, 18-19; Clair 2008; Bhardwaj et al. 2010; Williams 2010, 37.)

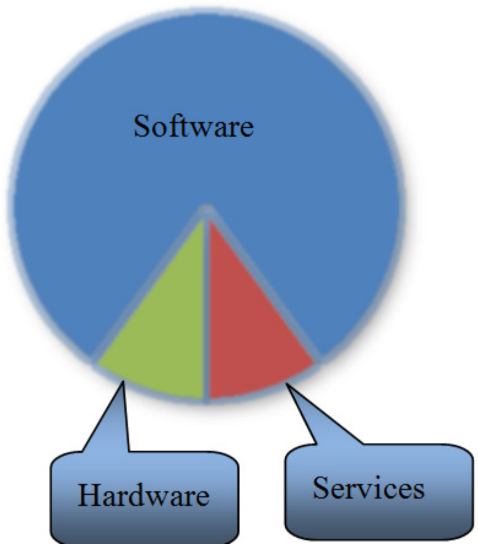

Figure 15 Typical budget for a SaaS environment (Chong & Carraro 2006).

Also some problems and drawbacks of SaaS are presented. Security issues may concern some parties, as third-parties are handling confidential data. Redundancy is also seen as a potential threat considering a situation if the solution provider fails. Over time, as the business grows, the subscription service could be expensive. In some cases, customization and integration with custom systems is probably more difficult that in on-premise solution. Someone may experience it also as a problem that there is no full control over data and processes. (Clair 2008; GFI Software 2010.)

In SaaS model, the various options concerning service monetization for software utilization can be reflected in four categories, which are perpetual license, subscription, transaction based, and ad funded. The first one refers to upfront payment for the service and unlimited access for unlimited time. The second category, as a form of cloud service monetization, can be conceptualized as a time-based perpetual license that is often applied to multiple users. Transaction-based monetization form of pricing allows the provider a means of recouping its upfront infrastructure costs, while permitting the client to benefit from economy-of-scale. This form requires a close association between hosting software and financial billing. The monetization schemes in the last category appear to be the most popular with consumer services. The software service is provided to the client for free, and the sponsor company pays the cost in return for the consumer’s attention. This is so-called freemium model. (Katzan 2010.)

4. METHODS FOR SALES FORECASTING

In this chapter three methods for sales forecasting are presented. They are top-down sales forecasting, bottom-up sales forecasting and synthetic sales forecasting, that is a combination of the former methods.

4.1. Top-down sales forecasting

Top-down sales forecasting also known as break-down sales forecasting is derived directly from analyzes of market potential, from forecasts of market size or individual market segments, and the company's estimates of market share, typically defined in the marketing plan. The calculation is simple, but the marketer needs to understand the subtleties and nuances of the market. The top-down sales forecast can be calculated using equation (Capon & Hulbert 2007, 166; Havaldar 2010, 121):

$$\text{Sales forecast} = \text{forecast market size} \times \text{forecast market share}$$

In figure 16, the development of a top-down forecast is presented. The key steps in the procedure are step 2 and step 3. In step 2, examples of the methods used for forecasting industry sales are Delphi method and regression analysis. Delphi method embodies a questionnaire to which a group of experts responds. A moderator compiles results and formulates a new questionnaire that is submitted to the group. Therefore, there is a learning process for the group as it receives new information and there is no influence of group pressure of dominating individuals. In regression analysis a straight line is fit to past data generally relating the data value to time. The most common fitting technique is least squares. (Chase, Jacobs & Aquilano 2007, 514; Havaldar 2010, 122.)

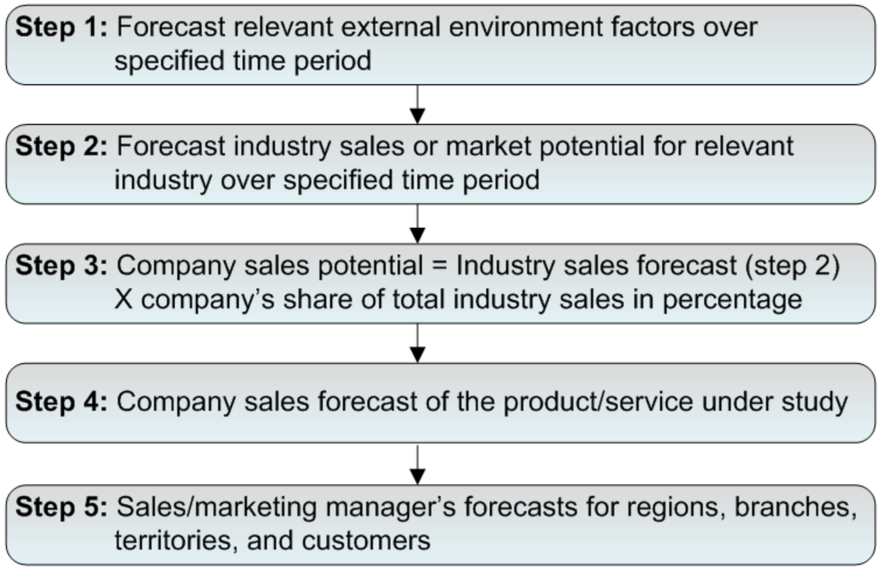

Figure 16 Development of a top-down forecast (Havaldar 2010, 122).

In step 3, in order to estimate the company's share of the total industry sales, a number of factors have to be considered, including the company's current market share, target customers and their perceptions about the company's performance on key factors like quality, service and price in comparison with major competitors, and the company's relationship with most significant competitors. With respect to step 4, the company sales forecast is usually lower than the company sales potential due to insufficient funds, increase in competition, or shortage of raw material. The last step of the procedure is breaking down the company sales forecast to different regions and territories is done based on market potential in different geographical areas. For this purpose, there are methods available such as market build-up method and multiple-factor index method. (Havaldar 2010, 122.) In figure 17, an example of contents in a market share analysis in wind turbine industry is shown. In the analysis, the market share is composed according to region and also by turbine size.

In the market build-up method, the first step is to identify existing and potential business buyers in the geographical territory. The second step is to determine their potential purchases of the product under study. The final step is to add-up the business potential of all the buying companies to obtain a fairly accurate estimate of market potential for the product or service for a specific geographic territory. The approach produces accurate results if there is a list available of all potential buyers and good estimate of what each will buy. In practice, this information is not always easy to gather. (Havaldar 2010, 122; Kotler & Keller 2012, 110-111.)

IV. COMPETITIVE TRENDS IN WIND TURBINE SUPPLY

1. **Wind Turbine Market Share Analysis**
   - Market Share by Region
     - *Europe's Mature Market Structure Consolidates Around Leading Players*
     - *North America Market Suffers Largest Drop across the Key Regions*
     - *Asia Pacific Increasingly Supplied by Local Manufacturing, Indigenous Vendors*
     - *Latin American Market Remains Modestly Contested, but Growing Competition Looms*
     - *Gamesa is Virtually the Only Player in the Africa/Middle East Market*
   - Global Market Share by Turbine Size
     - *Sub-megawatt Segment Dwindling; Some Opportunities in Emerging Markets and Europe*
     - *1.00 MW to 1.49 MW Segment Phases Out as Vendors Move to 2.00 MW and Larger Turbines*
     - *1.50 MW to 1.99 MW the Largest Segment Globally, Driven by Chinese Players*
     - *2.00 MW to 2.49 MW Turbines Core Segment for Multi-Megawatt Players*
     - *Few Players Active in the 2.50 MW to 2.99 MW Segment*
     - *3.00 MW and Larger Turbines Experiencing a Jump in Deliveries*

Figure 17 Example - market share analysis (IHS Emerging Energy Research 2011).

In the multiple-factor index method, in order to estimate market potential for a geographical area, a marketing company first identifies the factors that influence the sales of a product or a service instead of identifying individuals and households as they are very large in number. Generally, there is more than one sales factor that influences sales, for example, population, income and sales of related goods. These factors are given certain weights, corresponding to the degree of sales opportunity. The company might adjust the market potential for additional factors, such as competitors' presence, local promotional costs and seasonal factors. (Havaldar 2010, 122-123; Kotler & Keller 2012, 111.)

4.2. Bottom-up sales forecasting

Bottom-up sales forecasting also known as build-up sales forecasting encompasses the granularity and reality of sales by customer that is not included in the top-down forecasts. Salespeople are in close interaction with the customers and can discuss their needs and requirements for the upcoming period. The company develops the overall forecasts by collecting forecasts from individual salespeople. (Capon & Hulbert 2007, 166; Havaldar 2010, 123.)

In figure 18, the development of bottom-up sales forecast is described. The approach starts so that the company's salespersons estimate or forecast the sales in their respective territories. Salespersons are given guidance by their respective area or brands sales managers on how to get information from the existing and potential customers on the estimated purchases of the company's products for the specified future time period. Each area or branch manager then adds the forecasts received from the salespersons. The manager sends the combined sales forecast figure for each product in units and value to his/her supervisor, who is, regional or zonal sales manager. Each regional or zonal manager adds the sales forecast received from the area or branch managers, and sends the regional or zonal sales forecast to the sales marketing head. The head of sales or marketing repeats the process and presents the proposal of the company's sales forecast to CEO for discussion, modification and approval. (Havaldar 2010, 123.)

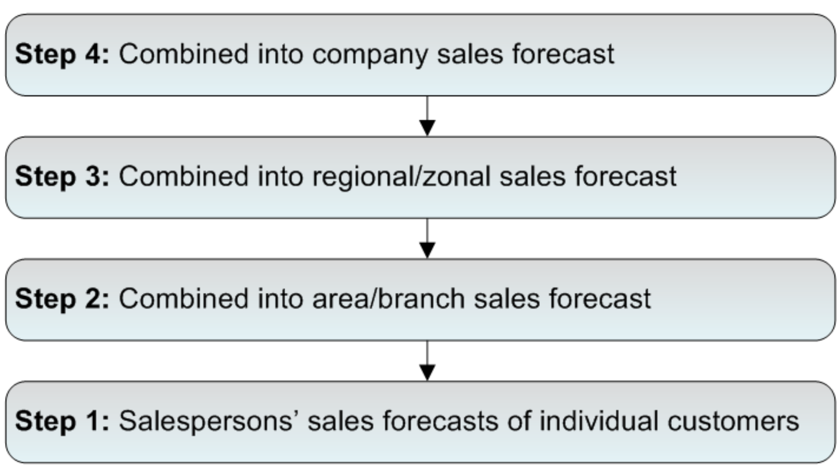

Figure 18 Development of a bottom-up forecast (Havaldar 2010, 123).

4.3. Synthetic sales forecasting

The synthetic sales forecasting is a combination of the best features of top-down and bottom-up forecasting. The top-down forecast comes from the marketing planning process whereas the sales department independently prepares a bottom-up forecast. If the numbers in these forecasts are equal, the forecast is ready. Typically, the top-down sales forecast is higher, and sales managers and salespeople have to re-examine the forecasts customer by customer to see where increases are possible. These revised forecasts are the building blocks for an improved bottom-up sales forecast. Simultaneously, marketing department revises the top-down forecast. Then the revised forecasts are compared and if they are not in agreement, a senior manager usually decides the forecast by an executive decision, and sales management apportions increases to individual salespeople. (Capon & Hulbert 2007, 166.)

5. INVESTMENT DECISION METHODS

In this chapter the investment decision methods used in this study are presented. Most of them are commonly used as it is illustrated in figure 19. Graham and Harvey researched the percentage of 392 CFOs in companies in USA and Canada who always or almost always use a particular technique for evaluating investment projects (Graham & Harvey 2001).

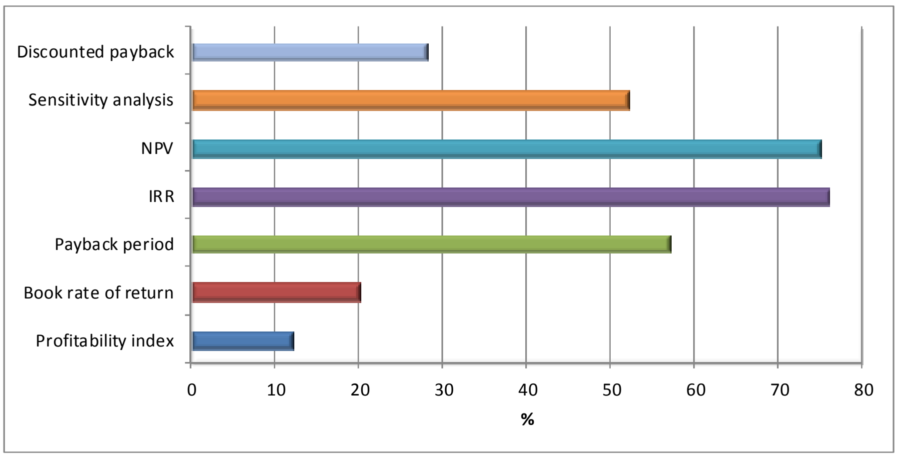

Figure 19 Use of a particular evaluation technique (Graham & Harvey 2001).

5.1. Payback period

A project's or investment's payback period is found by counting the number of years it takes before the cumulative cash flow equals the investment. Payback method does not distinguish among the sources of cash flows, such as from operations, purchase or sale of equipment, or investment or recovery of working capital. The calculation of payback period is simplest when a project has uniform cash flows. It can be calculated using equation:

$$\text{payback period} = \frac{\text{Net initial investment}}{\text{Uniform increase in annual future cash flows}}$$

If the cash flows are not uniform, the equation cannot be used. In that case, the cash flows over successive years are accumulated until the amount of net initial investment is recovered. The payback method highlights liquidity, a factor that often plays a role in capital budgeting decisions. Managers often prefer projects with shorter payback periods (projects that are more liquid) to projects with longer payback periods, if all other factors are equal. Projects with shorter payback periods give an organization more flexibility as funds for other projects become available sooner. (Jain 1981, 457-459; Horngren, Datar & Foster 2007, 731-732; Brealey, Myers & Allen 2011, 133-134.)

Under the payback method, companies choose a cutoff period for a project. The greater the risks of a project are, the shorter the cutoff period is. For example, Japanese companies favor the payback method over other methods and use cutoff periods ranging from three to five years. The payback rule states that projects with a payback period less than the cutoff period are considered acceptable, and those with a payback period that is longer than the cutoff period are rejected. Payback is useful measure, for example, when preliminary screening of many proposals is necessary. It is useful also when interest rates are high and the expected cash flows in later years of a project a highly uncertain. There are three weaknesses in the payback method. Firstly, it ignores the project's costs of capital and the time value of money. Secondly, it ignores cash flows after the payback period. Thirdly, it relies on an ad hoc decision criterion: what is the right number of years to require for the payback period. (Berk & DeMarzo 2011, 164-165; Horngren et al. 2007, 731; Brealey et al. 2011, 133)

In order to get rid of the first weakness, the cash flows can be discounted before computing the payback period. The discount payback rule asks how many years the project has to last in order for it to make sense in terms of net present value. The discounted payback method is not usually used as a strict rejection criterion. Instead it is used simply as a warning signal, whether a proposer of a project is unduly optimistic about the projects ability to generate cash flows into the distant future. (Brealey et al. 2011, 135.)

5.2. ROI

Return on Investment (ROI) is an accounting measure of income divided by accounting measure of investment. It can be calculated using equation:

$$\text{ROI} = \frac{\text{average net income during life}}{\text{gross original investment}}$$

Return on investment is the most popular method to measure performance. There are two reasons behind its popularity. Firstly, it blends all the ingredients of profitability such as revenues, costs, and investment into a single percentage. Secondly, it can be compared with the rate of return on opportunities elsewhere, inside or outside the company. However, like any single performance measure, ROI should be used cautiously and in conjunction with other measures. (Jain 1981, 459; Horngren et al. 2007, 793-794)

ROI is also called accounting rate of return or the accrual accounting rate of return. It can be used, for example, to evaluate the performance of an organization subunit such as division or to evaluate a project. If the computed ROI is higher than the target return on investment such as discount rate or opportunity cost of capital, the project will be accepted. Companies have different approaches in the way how they define income in the numerator and investment in the denominator of the ROI calculation. Some companies use operating income for the enumerator, whereas others prefer to calculate ROI on an after-tax basis and use net income. Some companies use total assets for the denominator but others prefer to focus only on those assets financed by long-term debt and stockholders' equity and use total assets minus current liabilities. The primary advantages of ROI are its simplicity and management's familiarity with it, since it is frequently used in the context of other operational matters. The disadvantage in ROI is that it does not reflect the time value of money, and this compounds when cash flows are uneven. (Jain 1981, 459; Horngren et al. 2007, 793-794)

5.3. NPV

Net present value (NPV) is a way to characterize the value of an investment, and the net present value rule is a method for choosing among alternative investments. The net present value of an investment is the present value of its cash flows minus the present value of its cash outflows. The NPV can be computed using the following procedure. (DeFusco, McLeavey, Pinto, & Runkle 2007, 40-41; Horngren et al. 2007, 727-728.)

1. Identify all cash flows associated with the investment including all inflows and outflows.
2. Determine the appropriate discount rate or opportunity cost for the investment project.
3. Using the discount rate, find the present value of each cash flow. In each flow inflows have a positive sign and increase NPV, whereas outflows have a negative sign and decrease NPV.
4. Sum all present values. The sum of the present values of all cash flows including inflows and outflows is the investment's net present value.
5. Apply the NPV rule. It states that if the investment's NPV is positive, an investor should undertake it. If the NPV is negative, the investor should not undertake it. If an investor has two options for investment but can only invest in one, for example, mutually exclusive projects, the investor should choose the candidate with the higher positive NPV.

The meaning of the NPV rule is that in calculating the NPV of an investment proposal, an estimate of the opportunity cost of capital is used as the discount rate. The opportunity cost of capital is the alternative return that investors forgo in undertaking the investment. When NPV is positive, the investment adds value as it more than covers the opportunity cost of the capital needed to undertake it. Therefore, a company undertaking a positive NPV investment increases shareholders' wealth. An individual investor making a positive NPV investment increases personal wealth, but a negative NPV investment decreases wealth. (DeFusco 2007, 40-41; Brealey et al. 2011, 51-55.)

NPV of a project or can be expressed as the difference between the present value of its benefits and the present value of its costs (see equation 1 below). If positive cash flows are used to represent benefits and negative cash flows to represent costs, and the present value of multiple cash flows is calculated as the sum of present values for individual cash flows, NPV can be shown in form of equation 2 below. (Berk & DeMarzo 2011, 59.)

(1) NPV = PV(Benefits) – PV(Costs)
(2) NPV = PV(All project cash flows)

If the principle is expressed in more mathematical form, it can be shown as equation below (DeFusco 2007, 40).

$$\text{NPV}=\sum_{t=0}^{N}\frac{\text{CF}_\text{T}}{(1+r)^\text{T}}$$

where
CF_T = the expected net cash flow at time t,
N = the investment's projected life and
r = the discount rate or opportunity cost of capital

5.4. IRR

Internal rate of return (IRR) calculates the discount rate at which the present value of expected cash inflows from a project equals the present value of its expected cash outflows. In other words, IRR is the discount rate that makes NPV equal to zero. The rate is called internal because it depends only on the cash flows of the investment and no external data are needed. As a result, the IRR concept can be applied to any investment that can be expressed as a series of cash flows. In addition to NPV rule, IRR rule is another a method for choosing among investment proposals. According to IRR rule, the projects or investments for which the IRR is greater than then opportunity cost of capital, should be accepted. The IRR rule uses the opportunity cost of capital as a hurdle rate, or rate that a project's IRR must exceed for the project to be accepted. If the opportunity cost of capital is equal to the IRR, then the NPV is equal to 0. If the project's opportunity cost is less than the IRR, the NPV is greater than 0, as using a discount rate less than the IRR will make the NPV positive. (DeFusco 2007 et al. 2007, 42-43; Horngren et al. 2007, 728; Berk & DeMarzo 2011, 160; Brealey et al. 2011, 136-137.) In mathematical terms, IRR can be expressed as equation (DeFusco 2007 et al. 2007, 42; Brealey et al. 2011, 136):

$$\text{NPV} \;=\; C_0+\frac{C_1}{1+IRR}+\frac{C_2}{(1+IRR)^2}+\cdots+\frac{C_T}{(1+IRR)^T}=0$$

where
C = C is cash flow at time T

In practice, IRR can be solved in two ways. The first is graphical method and the second is numerical one. Nowadays most spreadsheet applications such as Microsoft Excel have a built-in IRR function. The graphical method is easy to use. It involves selection of few combinations of NPV and discount rate and plotting them on a graph. (Brealey 2011, 136-137.)

It is important to notice that there are some situations, in which the IRR fails. The IRR rule is guaranteed to work for a stand-alone project if all of the project's negative cash flows precede its positive cash flows. If this is not the case, the IRR rule can lead to incorrect decisions. The first pitfall with the IRR is when there are delayed investments. In this case, the benefits of an investment occur before the costs and therefore the NPV is an increasing function of the discount rate. For this reason, the IRR rule fails. The second pitfall is when there are multiple IRRs. These occur if there is a double change in the sign of the cash flow stream. There can be as many internal rates of return as there are changes in the signs of the cash flows. (Brealey et al. 2011, 136; Berk & DeMarzo 2011, 160-163.)

The third pitfall occurs with nonexistent IRR. It is possible that there is initially a positive cash inflow at year 0, after that some negative outflow, and after that again positive inflow. If the positive inflows are large enough compared to outflows and there is large enough initial income, the IRR does not exist at all. The fourth pitfall occurs when there is more than one opportunity cost of capital. The IRR rule tells to accept a project if the IRR is greater than the opportunity cost of capital. In this case, it would be necessary to compute a complex weighted average of these rates to obtain a number comparable to IRR. This means trouble to IRR rule, as it is assumed that there is no difference between short-term and long-term discount rates. (Brealey et al. 2011, 141-142; Berk & DeMarzo 2011, 163.)

When ranking projects according to IRR and NPV the decisions may not be the same always. Firstly, the IRR and NPV rules rank projects differently when the size or scale of the projects differs. The size is measured by the investment needed to undertake the project. Secondly, the timing of the projects' cash flows differs. If the IRR and NPV rules conflict when ranking projects, the directions should be taken from the NPV rule. The reasoning for this is that the NPV represents the expected addition to shareholder wealth from an investment, and the maximization of shareholder wealth is taken to be a basic financial objective of a company. (DeFusco et al. 2007, 45.)

5.5. Break-even analysis

When there is uncertainty regarding the input to a capital budgeting decision, it is often useful to determine the break-even level of that input, which is the level for which the investment has an NPV of zero. In other words, it is assessment how bad the sales can get before the project begins to lose money. This estimation is known as break-even analysis. The break-even point is the quantity of output sold at which total revenues equal total costs. An easy way to determine break-even point is the graph method. Present values of inflows and outflows are calculated in terms of different unit sales and plotted to a graph. The break-even point is where the present value curves of inflows and outflows intersect. This is depicted in figure 20. As it can be seen, the break-even point is slightly less than 100 thousands in terms of sales. (Brealey et al. 2011, 273-275; Horngren et al. 2007, 65; Berk & DeMarzo 2011, 200-201.)

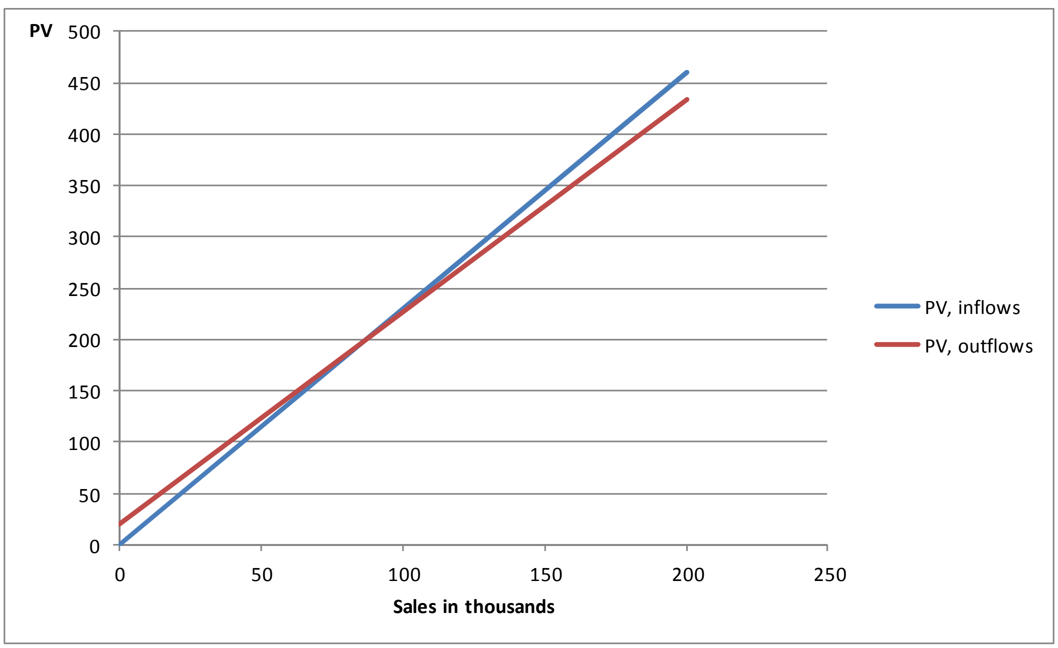

Figure 20 Determining break-even point (Brealey et al. 2011, 275).

6. METHOD

The research approach in this thesis is qualitative as its data originates from only few cases. According to Hollensen and Weathington, Cunningham and Pittenger, quantitative and qualitative research methods can be distinguished by the fact that quantitative techniques involve getting data from a large, representative group of respondents, whereas qualitative research provides a holistic view of a research problem by integrating larger number of variables but asking only a few respondents. Quantitative research is also typically designed to test predetermined hypotheses that are formed based on existing theory (a deductive process), while qualitative research usually functions to develop theory from the data that are collected (an inductive process). (Hollensen 2007, 161-162; Weathington et al. 2010, 526.)

The reasoning behind the selection of the topic of the thesis is the rising interest among businesses towards various M2M systems and their possibilities in a multitude of applications. There is also a need to be able to understand how the project development costs grow along with the scope of system functionality and assess the eligibility of different M2M projects from financial point of view. In order to find solutions to the research questions formulated in the beginning of thesis, a concrete solution to a specific M2M domain is presented. This domain is fleet management and it is aiming for the management of truck fleet. All the fixed and variable costs accrued during the project and during the lifetime of the solution are estimated carefully. In order to assess the potential income, top-down and bottom-up sales forecasts are conducted to find out the potential number of customer companies and also the potential number of users in those companies. To save in the marketing expenditures, the smallest trucking companies are excluded from the group of potential customers. The geographical region in the sales forecast is North America.

Based on the estimated costs, payback time is calculated. Also the eligibility of the project is assessed using ROI, NPV and IRR metrics. In order to figure out the effect of possible fluctuations in different factors in the project and solution costs, sensitivity analysis and Monte Carlo simulation are performed with several variables. To outline the minimum income for the solution in order to keep the project profitable, the break-even analysis is also conducted. This package of different assessment methods and metrics form a decision support system that can be used in evaluation of almost any kind of M2M investment.

7. RESULTS

In this chapter the solution, its functionality and its benefits are presented in more detail. The software service model is also discussed. It is essential to define how the solution is offered to the customers and what kind of financial benefits it creates to the service provider. In order to enable the evaluation the profitability of the solution, the project costs and market size has to be estimated. In the last part, the financial evaluations of the solution are conducted in addition to three other M2M cases.

7.1. The solution

The solution presented in this chapter matches closely with the definition of fleet management system concept defined in chapter 2. The solution consists of two distinct software entities that are central software and site software. An overview of the system is shown in figure 21. The purpose of the software running in central servers is to provide a location-independent web-based management user interface to the system. The role of site software is to collect GPS and other local data and send it to the central. In order to meet the set goals, central software has to provide several features. The main features of central software at high level are shown in table 9.

The central software has multi-tenant architecture. The same instance of the central software is shared between all users. For this reason, the same user interface and data model are provided to all customers without customization. The central infrastructure and software updates are maintained by the service provider. The implementation of the central software is net-native in order to ensure the best possible reliability and performance.

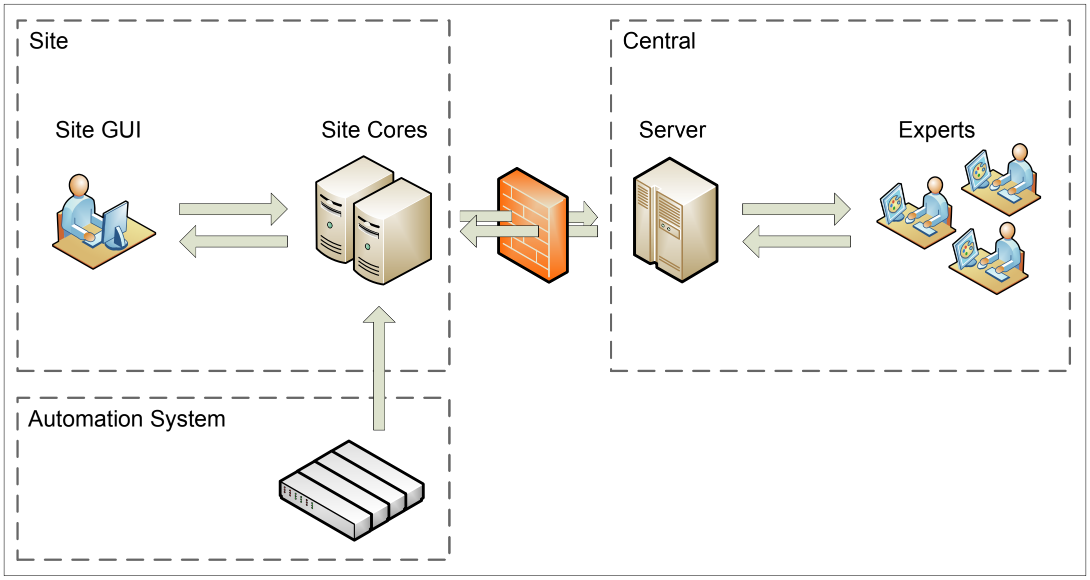

Figure 21 Overview of the system.

Table 9 Central software features.

Feature	**Description**
Fleet management	The user interface provides functionality to manage the fleet at different levels of hierarchy. On the root level of the hierarchy is the customer that may have several fleets. In each fleet there may be arbitrary number of sites and each site might have arbitrary number of assets. Each asset may have a multitude of measurement points such as sensors and digital or analog inputs. The hierarchy presented in short form is Customer.Fleet.Site.Assets.Measurement point.
Vehicle tracking	The solution uses Google maps to view the location and the routes of the vehicles. The map supports zoom in and zoom out functionality and viewing details of the selected vehicle. The details include the status of the vehicle, current speed, latitude, longitude and direction at the minimum.
Reporting	The solution provides a report management user interface. The user can create custom report templates and they can be stored to database and updated later if necessary. The user interface allows managing of constant strings that can be used when creating custom report templates. When generating the report, the output is created in user-specific language.

There are also some limitations on usage of central software. It is not a tool that enables real-time command of any device at site. It is more like a follow-up system which can be used to analyze what is happening or has happened at site and to find out a cause for it.

The site device in this system is a PC with Windows operating system installed. The functionality in the PC is done with specialized application of which features are described in table 10. The application is called Site core. The PC can act as a black box but it can also be managed with a dedicated Site graphical user interface (Site GUI) application. Its features are described in table 11.

Table 10 Main features of Site core.

Feature	**Description**
Data fetching	Reads data from automation system and stores it to the database. The data can be filtered according to configured rules in order to avoid unnecessary storing of same values multiple times.
Data sending to central	Sends filtered data from site database to central at configured intervals.
Providing service to Site GUI	Provides real-time data from automation system and history data from database to site graphical user interface when needed. The application also stores the data to database that are manually added from the user interface.
Multi-core	Can work as a master or slave core. This is required as there may be cases in which several PCs with site application are needed for performance reasons. Sometimes the amount of measurement points to be read may be too much for a single PC and the load has to be divided among several PCs.
Backup of site data	Creates backups of site data at configured periods.

Table 11 Main features of Site GUI.

Feature	**Description**
Login	Login view in the application. Secure user account information access.
User management	Functionality to manage users on site. Users can be added, modified and removed. Different operations are enabled depending on the user rights.
Dashboard	The default view in the user interface. Shows all the alarms, messages and other important information of the site. The view content is configurable.
Assets	Shows the assets and their measurement points of the site hierarchically. A search function is provided in order to find a specific asset or measurement point. The view allows drawing of graphs of selected measurement points in real-time and from history data.
Issues	A view for creating issues or inspecting them. The issues can be created by any site user or received from central. Any number of notes can be added to each issue.
Logbook	A view in which important events from the system are shown and the user can add new events. The viewed events can be filtered according to a variety of criteria.
System update	A view that enables handling of configurations and software updates. New configurations or software updates can be approved or rejected. Reverting to previous configuration or software version is also possible.
Offline Communication	Offline communication view allows the user to upload and download offline packets. This feature is needed when online connection to central is not available.
Status	A view in which detailed status information of the site software is shown.
Multilingual	The language of the user interface and system messages is based on the user settings.

7.2. Service model

In this chapter it is discussed how to create profit with the solution. The software distribution model is first selected with discussion about the reasoning of the decision. As it was defined in the central software specification, the purpose of the central software is to provide a location-independent web-based management user interface to the system. For this reason, on-premise model cannot be used. The central software is specified to be multi-tenant as the purpose is to provide the same instance of the application to several users.

Due to described facts, a cloud computing solution is needed. The cloud computing model provides three service models, SaaS, IaaS and PaaS. The solution cannot be ASP-based as it is specified that the central software is multi-tenant and there are no dedicated servers for different users. ASP solutions are only single-tenant. As the purpose is not to offer a platform with programming languages and APIs for the customer to develop own solutions, PaaS is not a suitable service model in this case. The purpose is neither to provide any interface to fundamental computing resources, such as networks, storage and firewalls. Therefore, IaaS is not the service model for this solution. The only service model of which characteristics match with the defined solution is SaaS.

As the companies using the solution share the same concerns, the most suitable deployment model in this case is community cloud. In other words, all the users have the same kind of need, they want to manage their fleet. Most likely they also share the same level of security requirements and compliance considerations. The private cloud is not suitable model as there is more than one organization using the service. Furthermore, the public model cannot be chosen as there are no common concerns among the users of public cloud. Moreover, the model is not hybrid as there is only one cloud infrastructure in the solution.

In order to start using the solution, the customer and the provider have to make a contract that is valid for a specific period and can be extended whenever needed. This provides the customer with all the typical benefits of SaaS service model such as the maintenance of the infrastructure including network, servers, storage and operating systems. The service provider guarantees that the system is available 99.5 per cent of the time, all year round.

The pricing of the solution is based on the number of user accounts per customer. In other words, a specific fee per user is charged every month. The number of user accounts is defined in the contract, but it can be increased or decreased according to the customer's needs. Billing is based on this number of users agreed irrespective of whether the users have used their accounts. The contract can be terminated by the customer request but the fee of the ongoing month is charged.

7.3. Estimation of the project costs

In this chapter the costs of the project are estimated. The estimations are based on the features described in section 7.1. Each main feature is divided into smaller pieces in order to facilitate understanding of the exact nature of the feature and to make the estimations more accurate.

Before any estimation is conducted, some technical decisions have to be made because they a have significant effect on the pace of the development and total costs. At first, the platform for central software has to be chosen. According to Oracle, J2EE is a platform for enterprise solutions. It enables quick implementation of portable, modular, scalable and secure solutions and easy deployment. (Oracle 2010.) For these reasons, J2EE platform was decided to be used in the implementation.

As the central software is a J2EE enterprise solution, an application server is needed in order to enable execution of the software. According to Flenner, an application server is a software framework in which applications can run. An application server manages global resources, such as database and network connections and naming services. It also provides a secure operating environment. (Flenner 2003, 685.) Oracle WebLogic Server is a popular application server. Oracle states that their WebLogic Server is very fast and reliable, extreme scalable and provides state-of-the-art manageability. (Oracle 2012a.) Oracle's application server was decided to be used in this solution.

The framework for user interface implementation is needed. It was noticed that Vaadin Java framework is suitable for this purpose. It enables the building of modern web applications that look great and perform well. In contrast to JavaScript libraries and solutions based on browser plugins, it features a robust server-side architecture. Vaadin provides also a large collection of user interface components and enables rapid application development. (Vaadin 2011.)

As it is expected that the amount of data handled in central is enormous, a heavyweight database system is needed. Oracle states that their database is very scalable, secure and and provides extreme performance. It is also seen as an ideal platform in cloud systems. (Oracle 2012b.) These reasons were so convincing that Oracle database was the selected option for this solution.

One main feature of central software is reporting. In order to add reporting support, a reporting engine that works in J2EE platform was needed. After evaluating possible engines, JasperReports convinced its suitability for this purpose. According to Sourge-Forge, JasperReports is entirely written in Java and it is able to use data coming from any kind of data source and produce professional-looking documents that can be viewed, printed or exported in several document formats such as HTML, PDF, Excel, OpenOffice and Word. (SourceForge 2012b.)

In order to enable the users to design custom reports, a report designer extension was needed with JasperReports. According to SourceForge, iReport is a free, open source report designer for JasperReports. It supports very sophisticated layouts with diverse contents including charts, images, subreports and so on. The data to reports can be obtained from variety of sources such as JDBC, JavaBeans, XML, Hibernate, CSV and custom sources. The reports can be published in PDF, RTF, XML, XLS, CSV, HTML, XHTML, text, DOCX or OpenOffice formats. (SourceForge 2012a.)

Site core has to be able handle data obtained from a multitude of measurement points in a second and to be able to run in a small portable device such as an embedded PC. Therefore, the performance of site core application is in focus, not forgetting the cost efficiency in the implementation process. Due to these reasons, it was obvious that the solution has to be based on C++ language. It was found that Qt framework is very appealing choice as it has very extensive and well-documented API for implementation of desktop applications. In addition, as it is a cross-platform framework, it leaves an option to later compile the code also for other operating systems such as Linux. Qt offers also advanced APIs for graphical user interface implementation, built-in internationalization and user interface designer application. (Nokia 2012.) The reasons discussed above make the use of Qt practical both in Site core and Site GUI implementation.

The programming language and the platform are not the only issues related to the performance of the site core application. In addition, the data storage has to perform efficiently. When comparing few affordable database engines, it was noticed that SQLite is a very suitable option for Site core purposes. According to SQLite, the database engine is fast, serverless, zero-configuration, self-contained and transactional and public domain. It is also used by many well-known companies such as Adobe, Airbus, Mozilla, General Electric, Google, Microsoft and Skype. (SQLite n.d.) Also performance comparisons between SQLite, MySQL, PostegreSQL and FirebirdSQL convinced suitability of SQLite for this solution (SQLite 2006).

Site core has to fetch data from the automation system that may contain a lot of different devices, which communicate via different buses. In order to avoid disarray in implementation of support for a multitude of buses and devices, a more generic solution is needed. According to OPC Foundation, OPC is an open connectivity via open standards. They fill a need in automation like printer drivers did for Windows operating system. The standards define consistent methods of accessing field data. The methods remain the same regardless of the type and source of data. An OPC server application provides an interface to all the devices in the system. By communicating with the OPC server, any application can fetch data from the automation system in a very generic way. (OPC Foundation 2012.) The decision to use SQLite was even easier as there was a security add-on SQLite Encryption Extension available in the Internet. The add-on enables reading and writing of encrypted database files. It supports RC4, AES-128 and AES-256 encryption algorithms. (Hipp, Wyrick & Company n.d.)

The total costs of the solution are composed of implementation costs, software licenses, server infrastructure costs, installation costs, life cycle costs and warranty costs. The facility costs and electricity costs are excluded from the calculations in this case. The solution implementation is ordered from a subcontractor, so there is no need to pay attention to salaries of the coders or development tools. The only significant implementation-related information is hour price. It is assumed to be 60 €. The assumption of life cycle is twenty years. The license costs are composed mainly of Google Maps as JasperReports and iReport are open source software. According to Schoenemann, the base price of Google Maps is 8 580 € in a year (Schoenemann 2009). It is assumed that the costs remain the same over the system life cycle. In table 12, the different costs accrued during the solution life cycle are shown. See appendix 1 for more details on the project management and software implementation estimations. The length of one work day is assumed to be 7.5 hours.

Table 12 Total costs of the solution.

Item	Price/€
Project management	33 750
Software	
Central software	114 300
Site core	125 100
Site GUI	158 400
Licenses	
Google maps	171 600
Database infrastructure	
Database licenses and support	910 120
Application server costs	
Oracle WebLogic	5 716 200
Life cycle costs	
Support staff costs	1 400 000
Software maintenance costs	28 350
Warranty costs	
Service downtime due to bugs	50 000
Total	8 707 820

The database infrastructure and central application server are purchased as utility computing services. Sahai and Graupner define it as the ability to provide complex computing environments on-demand to IT customers (Sahai & Graupner 2005, 256). Alfresco Software had estimated Oracle database costs to be $59 950. The database was configured for 1000 users. The costs include software licenses and support and processor licenses. (Alfresco Software Inc. 2008.) If roughly calculated, for twenty years the cost would be $1 199 000, that makes 910 120 € using exchange rates on 2^{nd} February 2012.

Crimson Consulting Group had examined the total costs of Oracle WebLogic application server in five years. In the research there were 16 companies involved. The configuration was composed of five servers and each of them had two CPUs. Each CPU had two cores. There were four application server instances per server and four unique applications. The total costs including acquisition and implementation costs, ongoing application deployment and testing costs, vendor support costs, ongoing administration and management costs and ongoing monitoring, diagnostics and tuning costs in five years were $1 882 642. (Crimson Consulting Group 2011.) As the assumed life cycle is twenty years in this case, it makes $7 530 568, which is 5 716 200 € when exchange rate of January 2, 2012 were used.

Jeromin, Balzer, Backes and Huber define life cycle costs as operational and disposal costs in addition to manufacturing costs (Jeromin et al. 2009). In this case, the life cycle costs compose of support staff costs and software maintenance costs during the assumed life cycle. The assumption is that there is one full-time support engineer during the solution's lifetime. His costs are 70 000 € per year with taxes and other expenses. It sums to 1 400 000 € in twenty years. The assumption is that software maintenance takes roughly three months of work during its life cycle. With the assumed hour price of 60 €, it makes 28 350 € if there are 21 work days per month.

It was agreed that the service provider guarantees that the system is available 99.5 per cent of the time, all year round. The same percentage is agreed with the end customers of the solution. Therefore, there is no need to allocate warranty money for service shortcuts due to server or network problems. However, the bugs in the software may cause service breakdowns. For this reason, 50 000 € is allocated to warranty.

7.4. Financial evaluations

In this chapter four different cases on remote management business are presented. The first three cases are practical examples of remote management in order to generalize the topic of this thesis more and the fourth one is related to the solution presented above. Each case contains cost-benefit analysis, evaluation of the eligibility of the investment with several financial metrics, sensitivity analysis and Monte Carlo simulation. Also the break-even analysis is conducted in each case. According to Horngren et al., the cost-benefit analysis is a technique for estimating the monetary costs and benefits of an investment over a particular time period. The approach is the criterion that assists managers in deciding whether, for example, to acquire a new system instead of continuing to use an existing historical system. (Horngren et al. 2007, 11.)

According to Horngren et al. and Brealey et al., sensitivity analysis is a technique that examines how a result will change if the original predicted data are not achieved or if some assumption changes (Horngren et al. 2007, 193; Brealey et al. 2011, 271-272.) As sensitivity analysis allows considering the effect of changing one variable at a time, Monte Carlo simulation is a tool for considering all possible combinations. Therefore it enables to inspect the entire distribution of project outcomes. (Brealey et al. 2011, 277.) The simulations in this thesis are implemented and executed using GNU Octave software. It is a high-level interpreted language, primarily intended for numerical computations. The Octave language is very similar to MATLAB so that most programs are easily portable. (Eaton 2012.) The source codes for the simulations of each case are presented in Appendix 2.

The discount rate used in the financial calculations is higher than bank loans typically have or the return of investment from state securities as there is certain degree of risk in the investments. The right discount rate for a cash flow is the rate of return available in the market on other investments of comparable risk and return (Berk & DeMarzo 2011, 143; Brealey et al. 2011, 35-36). Thereby, in the financial calculations in the cases, the ROI of each company is used as the discount rate.

7.4.1. Remote electricity meter reading system

In this chapter a remote electricity meter reading solution is presented and its financial evaluations are described in an example case. The solution is based on AMR, which is a system that enables to automatically collect and analyze data from devices such as gas, electric or water meters and transfer that data through a network into a backend business system (Motorola 2012). There are two types of AMR system: wire-based and wireless. Examples of the former are PLC and telephone line network. Both of those systems use the existing electric power line and telephone line network to transfer data from each meter to servers in the backend business system. The latter type of AMR system is based on SMS, GPRS and GSM services. An example of such system is shown in figure 22. (Primicanta, Nayan & Avan 2009; Rajaković, Nikolić & Vujasinovic 2009.)

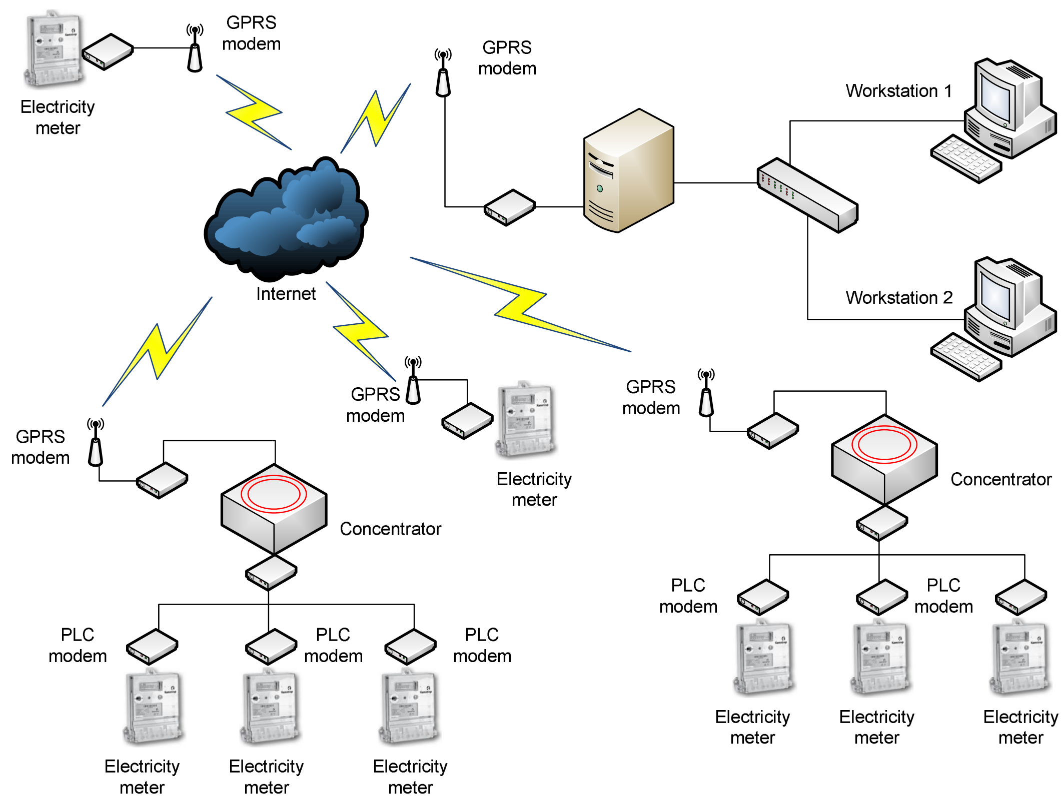

Figure 22 An example of AMR system (Rajaković et al. 2009).

Compared to the conventional method, AMR provides a multitude of benefits and advantages. Probably the most important advantage of remote control and AMR system is reduced operating costs as meter readout crew is no longer needed. Anyone neither has to go to customer's premises to connect or disconnect customers from the power grid, for example, if the customer has not paid his/her electricity bill. AMR practically eliminates miscalculations and misreading of electricity meters and thereby removes the costs caused by human mistakes. AMR also enables reduction of costs due to unpaid electric energy. Some customers are connected to the distribution network and have bypassed their meters or even are connected to distribution grid without meters. This results in electric energy supply without having to pay for it. By using new digital meters all energy leaks can be easily detected and tracked. Remote electricity meter communication, as a kind of control, facilitates in reducing these losses and unauthorized electric energy usage. (Rajaković et al. 2009; Yuan 2011; Motorola 2012.)

AMR system makes it possible to improve the quality of electric energy. The system measures several values such as voltages, currents, harmonics, power factors and voltage and current imbalances. All data are instantly available in distribution center, where it can be analyzed. Based on this analysis, the places within distribution network with lower quality of electric energy can be tracked and crew can be sent there to make the necessary fixes. AMR also helps reducing non-technical losses as it enables locating macro and micro non-technical losses. The sum of all customers' power demand and total technical losses should be equal to total power supplied by one transformer station. If that is not true, micro locating of non-technical losses is necessary. Remote controlled meters can show the location of non-technical losses instantly. (Graabak, Grande, Ikäheimo & Kärkkäinen 2004; Rajakovic et al. 2009; Khalifa, Naik & Nayak 2011.)

AMR provides flexibility of electric energy tariffs as it enables setting up a different tariff for each customer. With that possibility, distribution utility can provide a large variety of tariffs and energy prices which always lead to better load control by avoiding demand peaks which occur during lower tariff periods. The customer may also reduce his energy consumption in high price periods. As the customer's consumption data is instantly available in the distribution center, it can be provided to him/her via a web interface anytime and anywhere. This facilitates the customer to do adjustments on energy usage and save money. One very pleasurable feature in AMR systems is that billing can be based on near real-time consumption, rather than on estimates based on previous or predicted consumption. (Graabak et al. 2004; Primicanta et al. 2009; Rajakovic et al. 2009; Tibbo Technology Inc. 2011.)

After discussing of all those advantages and benefits, it is easy to understand that AMR systems are appealing both for electric energy customer and supplier. In order to proceed to calculation of some financial indicators, the area market potential needs to be estimated first. The assumption is that an electric company in Vaasa, Finland, aims to upgrade the conventional electric energy measurement system to AMR-based one in private households. According to Statistics Finland, there were 29 549 households in Vaasa on 31.12.2010. In addition, there were 1 662 summer cottages in Vaasa at the same date. (Statistics Finland 2011.) These numbers form the total number of 31 211 electricity meters if it is assumed that each location has one meter. This is the absolute upper limit for the area market potential.

In order to find out financial reasoning to upgrade the conventional system to AMR-based one, a cost-benefit analysis is performed. It is based on comparison of investment costs to annual savings achieved by AMR system. Investment costs consist of purchase costs of necessary equipment such as meters and installing costs of the new system. Installing costs are labor costs, vehicle utilization costs during install process and costs caused by undelivered electric energy during the hours when the equipment is being installed to an apartment or cottage. The new AMR system will annually save most of the costs accrued earlier from the conventional system. Those annual savings are composed of at least the factors in the list below.

- No need for electricity meter readout staff.
- No need for staff in charge of plugging and unplugging the customers from the grid.
- No need to use vehicles for meter readout.
- Reduction in manual work. No need to collect, input and analyze the data manually as they are automatically processed.

The cost-benefit analysis presented below is based on the assumption that the new AMR system is implemented by replacing the conventional system with new one on entire distribution grid. The analysis is composed of few steps and the total costs are summed up in the end. After the results from cost-benefit analysis, a sensitivity analysis and Monte Carlo simulation are also conducted in order to see how possible fluctuations of few variables may affect to the payback time.

1. Investment costs of an AMR system

   a) Costs of new equipment

   The equipment that needs to be purchased is the meter and installation material such as cables. It is assumed that a meter costs $c_{meter} = 200$ € and the installation material for each meter costs $c_{material} = 50$ €. The price of one installation can be calculated using formula: $C_{cost/meter} = C_{meter} + C_{material}$

   b) Installation costs of an AMR system

   Installation costs are composed of the time needed for the installation of an AMR meter, other equipment, preparations and transfer of the equipment. It is estimated that it takes two hours to complete an installation. Thereby $t_{inst/meter} = 2$ h. One electrician is needed to conduct the install work so $n_{workers/inst} = 1$. Total cost of one man hour is assumed to be $c_{cost/hr} = 30$ €.

   When all the factors above are summed up a formula that determines the total cost of installation of a meter can be defined:
   $c_{inst/meter} = t_{inst/meter} \times n_{workers/inst} \times c_{cost/hr}$

c) Undelivered electric energy during the installation process

Electricity cannot be used or sold to the customer during the meter installation. It is assumed that a customer is unplugged from the network for two hours so $t_{unplugged} = 2$ h. According to Aldén, an average household in Finland consumes 19 MWh energy a year, if a family with four members live in a new single-family house and electricity is used also for central and water heating (Aldén 2008). This makes 52 kWh per day. Therefore, during the installation about $\frac{52\ kWh}{24} \times t_{unplugged} = 4.3$ kWh cannot be sold to a household.

According to Piironen, an average cottage with base temperature kept over the year, consumes 8 MWh energy in a year (Piironen 2010). This makes 22 kWh per day. Due to this, during the installation 22kWh / 24 × $t_{unplugged}$ = 1.8 kWh cannot be sold to a cottage owner.

The electricity energy price including transfer costs in Vaasa region on 1.9.2011 is 0.092 €/kWh (Vaasan Sähkö 2011). Therefore, costs of undelivered energy per household is 4.3 kWh x 0.092 €/kWh = 0.40 € and 1.8 kWh x 0.092 €/kWh = 0.17 € for cottage owners. If these costs are compared to equipment and installation costs, it can be seen that they have no significance in the total costs. For this reason, they are excluded from the further calculations. The total investment for equipment and installation per meter can be determined with equation:

$$C_{inv/meter} = C_{cost/meter} + C_{inst/meter}$$

2. Investment costs of conventional system for meter reading

a) Equipment costs

In the conventional system an induction meter is used. Each customer has one meter. It is assumed that the price of an induction meter is about $C^2_{cost/meter} = 90$ €.

b) Installation costs

The installation costs per meter in the conventional system can be determined with equation:

$$c^2_{inst/meter} = t_{inst/meter} \times n_{workers/inst} \times c_{cost/hr}$$

The values of the equation parameters are assumed to be the same as in AMR-based system. The total cost for equipment and installation are calculated with equation:

$$c^2_{inv/meter} = c^2_{cost/meter} + c^2_{inst/meter}$$

3. Difference in annual costs between AMR and conventional system

In addition to data center used in AMR system, it is assumed that the only difference in the annual costs between AMR and conventional system is the price of meter maintenance. The AMR system data center is needed to store the collected consumption data. The data center service is acquired from a third-party operator. It is assumed that the data center costs are $c_{dc} = 10\ 000$ € per year.

a) AMR system maintenance costs

Sternau states that there are AMR-based systems still working after 25 years (Sternau 2009). Therefore, it is reasonable to assume that the life cycle of the system is 20 years. It is assumed that the maintenance for an AMR meter is done once in ten years. The maintenance costs of a meter in ten years are assumed to be $C_{maintenance}^{AMR} = 70€$.

b) Conventional system maintenance costs

The assumption for the life cycle of a meter in the conventional system is the same as in AMR one, 20 years. The assumption for the maintenance costs of a conventional induction meter are $C_{maintenance}^{conv} = 50$ €.

As the life cycle of the meters in both systems is assumed to be 20 years, the annual maintenance costs are:

$$C_{maintenance/year}^{AMR} = \frac{C_{maintenance}^{AMR}}{20}$$

$$C_{maintenance/year}^{conv} = \frac{C_{maintenance}^{conv}}{20}$$

The difference in the annual costs is:

$$\Delta C_{maintenance/year} = C_{maintenance/year}^{AMR} - C_{maintenance/year}^{conv}$$

4. Annual operating costs in the conventional system

a) Readout costs of electricity meters

In order to estimate the readout personnel costs, it has to be first estimated how many employees are needed. It is assumed that the meters are read once in three months. As mentioned, there are total $n_c = 31\ 211$ households and cottages in the Vaasa area. If readout of one meter and transition to next location takes 20 minutes, it causes 624 220 minutes that is equal to 10 403 hours of work. If a regular workday length is eight hours, one readout round once in three months requires 1 301

workdays. In order to be able to perform the readout of all the region's meters during three months, it requires
$n_{employees} = \frac{1301}{20\times3} = 21.7 \approx 22$ full-time readout employees if it is calculated with 20 working days per month.

The number of working hours per month is assumed to be $t_{employees} = 150$ h. The total costs of an employee per hour is $c_{employee} = 30$ €/h. Based on this information the annual readout costs in Vaasa area are calculated using equation:
$c_{readout} = (n_{employees} \times t_{employees} \times c_{employee}) \times 12$

b) Field staff costs

The task of field staff is typically plugging and unplugging of customers from distribution grid. The total number of employees in the field staff is assumed to be $n_{field} = 5$. Number of working hours per month is estimated to be $t_{field} = 40$. The total costs of a field employee per hour is $c_{field} = 30$ €/h.

The total costs of field staff in a year are:
$c_{field,tot} = n_{field} \times t_{field} \times c_{field} \times 12$

c) Vehicle costs

It is assumed that the average driving speed with vehicles is 30 km/h including the readout stops and lunch breaks, the meter readers can collect total of
$s_{total} = n_{employees} \times 30 \times 8 \times 20 \times 3$ kilometers during three months.

The official kilometer allowance is used as the value for the cost per kilometer. According to Taxpayers Association of Finland (TAF), it is $c_{km} = 0.45$ €/km in 2012 (TAF 2011). It is assumed that all the vehicle costs, including purchase costs, are in this value. Using data above, the total vehicle costs in a year due to meter readout can be calculated using equation:
$c_{vehicles,readout} = s_{total} \times c_{km} \times 4$

As it was mentioned, there are five field staff employees and they work about $t_{field} = 40$ hours per month with plugging and unplugging the customers from the grid. The assumption is that their average speed $v_{field}^{avg} = 50$ km/h. Then the total vehicle costs of field staff per year is:
$c_{vehicles,field} = n_{field} \times t_{field} \times v_{field}^{avg} \times c_{km} \times 12$

The total vehicle costs are:

$c_{vehicles} = c_{vehicles,readout} + c_{vehicles,field}$

d) Collecting, inputting and analyzing costs

The data collected during the meter readout has to be input, checked and analyzed. It is assumed that there are $n_d = 5$ full-time employees allocated for these tasks. The assumption about their salary costs $c_d = 5\ 000\ €/month$ per each. The total costs per year are:

$c_{d,tot} = 12 \times n_d \times c_d$

The total conventional system costs per year due to meter readout, field staff, vehicle costs and connecting, inputting and analyzing are:

$C_{tot,conv} = c_{readout} + c_{field} + c_{vehicles} + c_{d,tot}$

As a conclusion, almost none of the costs in C_{tot} would occur if a new AMR-based system is installed. For this reason, the calculated costs could be seen as savings:

$C_s = C_{tot,conv}$

5. Return analysis

The total investment to install the AMR system to Vaasa region is:

$C_{tot,AMR} = c_{inv/meter} \times n_c$

As the data from AMR meters to central system is transferred via GPRS link, some data transfer costs occur every month. It is assumed that data transfer cost is 0.5 € per meter a month so $c_{transfer} = 12 \times\ 0.5$ € per meter a year.

The income per year I in the AMR system can be calculated using equation:

$$I = C_s - c_{dc} - n_c \times (C^{AMR}_{maintenance/year} + c_{transfer})$$

C_s is the savings due to establishment of the new system per year,
c_{dc} is the data center costs per year in €,
n_c is the number of customers in Vaasa region,
$C^{AMR}_{maintenance/year}$ is the maintenance cost per AMR meter per year and
$c_{transfer}$ is the data transfer cost per AMR meter per year.

A general formula to calculate payback period is (Horngren et al. 2007, 731):

$$\text{payback period} = \frac{\text{net initial investment}}{\text{Uniform increase in annual future cash flows}}$$

In this case, an equation to determine a simple payback period can be formulated in the following way:

$$\text{payback period} = \frac{C_{tot,AMR}}{I}$$

where

$C_{tot,AMR}$ is the total investment costs for AMR system and

I is the income per year in the AMR system.

When the calculations are performed, the payback period is 5.2 years.

ROI of the investment can be calculated using the equation:

$$\text{ROI} = \frac{I}{C_{tot,AMR}} \times 100\% = 19.4\ \%$$

The ROI of Vaasan Sähkö has been 18.9 % in 2010 (Vaasan Sähkö 2012). If the calculated ROI is compared with that, the investment seems to be slightly eligible.

In addition to ROI, the eligibility of the investment is evaluated also using NPV. Its equation is:

$$\text{NPV} = \sum_{t=0}^{N} \frac{CF_T}{(1+r)^T} = CF_0 + \frac{I}{(1+r)^1} + \frac{I}{(1+r)^2} + \cdots + \frac{I}{(1+r)^{20}}$$

where

CF_T = the expected net cash flow at time t

N = the investment’s projected life

r = the discount rate or opportunity cost of capital = ROI of Vaasan Sähkö 2010.

The result from the NPV calculation is -51 857 €, which is slightly less than 0. Horngren et al. state that only investments with zero or positive NPV are acceptable (Horngren et al. 2007: 727). Thereby the investment is not eligible from NPV point of view.

The third method for evaluating the eligibility of the investment is IRR. Generally, it can be solved from the equation (Brealey et al. 2011, 136):

$$\text{NPV} = C_0 + \frac{C_1}{1+IRR} + \frac{C_2}{(1+IRR)^2} + \cdots + \frac{C_T}{(1+IRR)^T} = 0$$

where
C = C is cash flow at time T

In this AMR case, $C_T = C_s$.

In figure 23, AMR NPV is plotted as function of discount rate. From the figure it can be noticed that NPV is zero when discount rate is about 19 %. This is also the value of IRR. In order to calculate the IRR with Excel, the set of annual cash flows (both inflows and outflows) over the investment life cycle has to be passed to the IRR function. The IRR calculated with Excel is exactly 19 %. According to Brealey et al., the IRR rule states that an investment should be accepted if its IRR is greater than discount rate (Brealey et al. 2011, 137). As the calculated IRR was 19 %, the investment is noticed to be eligible using IRR.

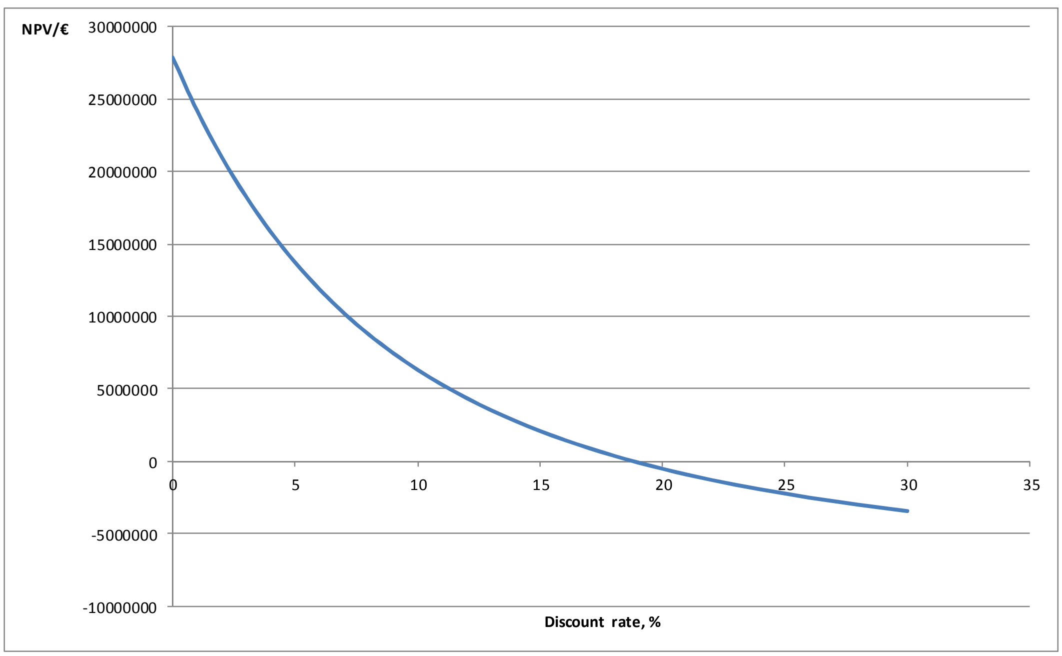

Figure 23 AMR NPV as a function of discount rate.

In order to find the effect of fluctuations in different variables to payback period, sensitivity analysis is conducted with data transfer price, equipment purchase price and maintenance costs of an AMR meter during the system lifetime**.** Each variable is analysed separately. In figure 24, it is shown how the payback time develops as the data transfer cost per month rises and what is the effect with meter prices of 150 €, 200 € and 250 €. As it can be seen in figure 25, a rise in equipment purchase price would cause a dramatic effect on the payback time. On the other hand, if large amount of meters could be purchased at once and some discount is gained, the payback time would shorten significantly. In the figure the effect of installation time per AMR meter is also shown.

In figure 26, the maintenance costs of an AMR meter during the system lifetime with three different conventional meter manual readout times are shown. In the worst case, if there are a lot of problems with AMR meter devices needing field work at the meter and probably purchase of new equipment, the costs could rise even to few hundreds of euros. This could lengthen the payback time significantly, but not as dramatically as a rise in the equipment purchase price. If the manual readout time can be reduced, it has significant effect on the payback time, as AMR-based system does not provide as much savings anymore. Monte Carlo simulation is also performed by using the same variables as in the sensitivity analysis to figure out the entire distribution of payback periods. The values of the variables are changed according to the Normal distribution by using the value that was used in the described basic calculations as midpoint. The results of the Monte Carlo simulation are shown in figure 27. It can be seen that the distribution of the payback periods is very well balanced around the calculated payback period.

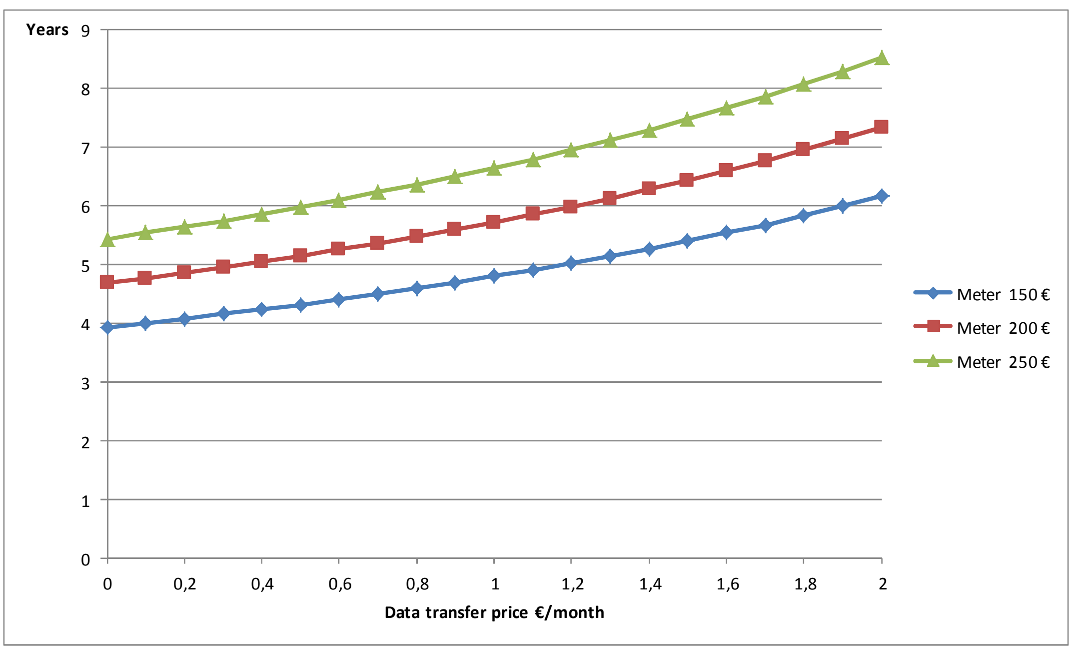

Figure 24 Data transfer cost per month effect on the payback time.

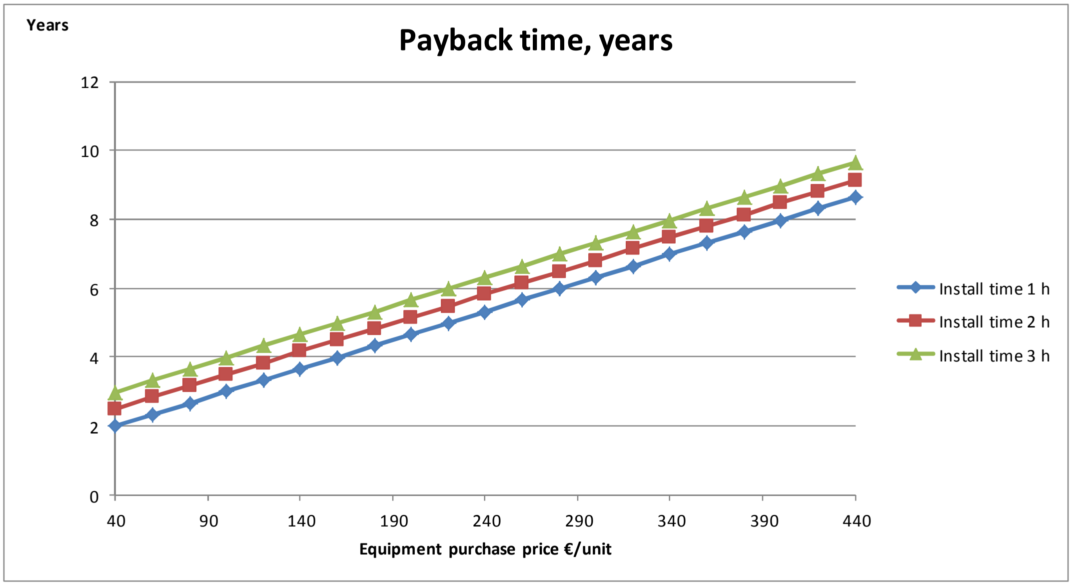

Figure 25 Equipment purchase price effect on the payback time.

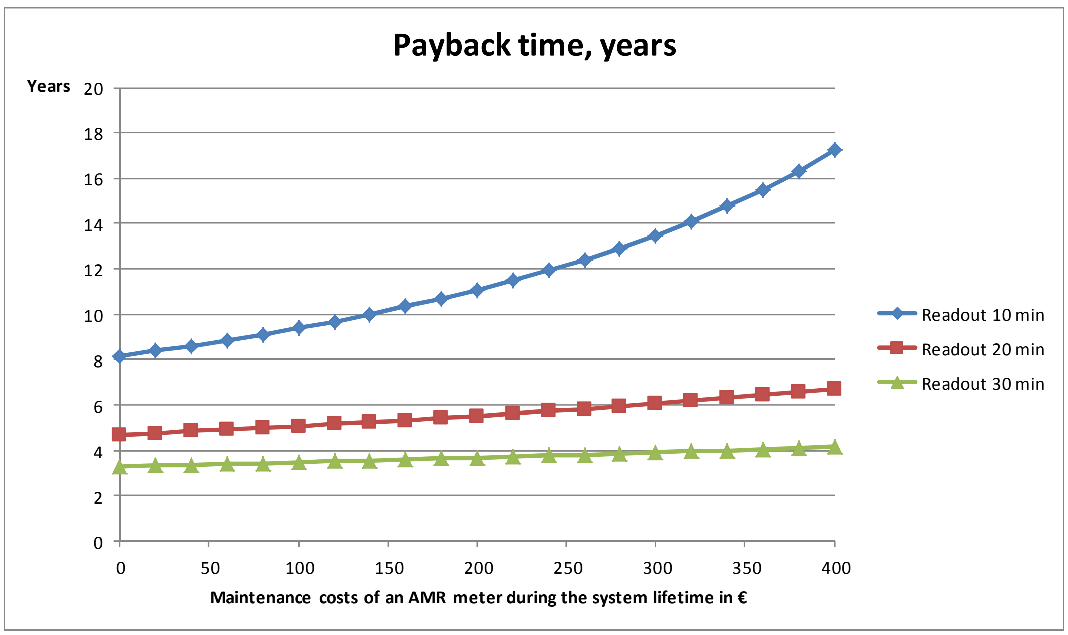

Figure 26 Maintenance cost of an AMR meter effect on the payback time.

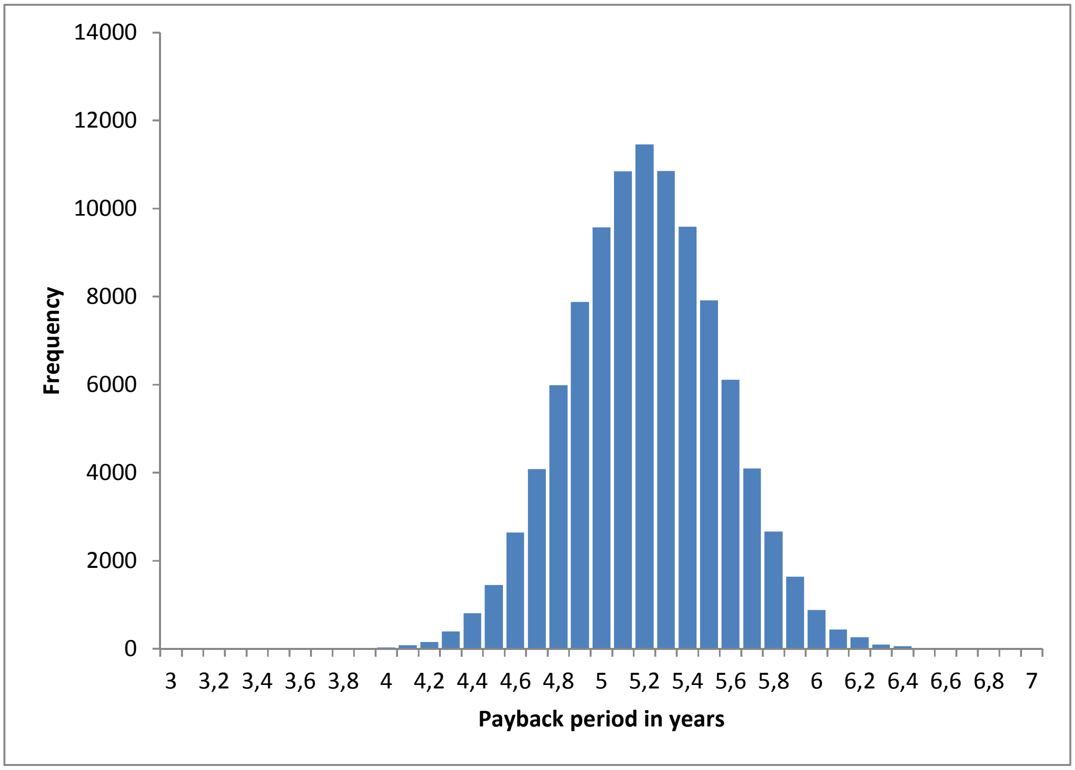

Figure 27 Distribution of the payback periods in the Monte Carlo simulation.

It is also necessary to find out how many AMR meters have to be installed in order to cover the total costs. Therefore, a break-even analysis is conducted. In order to solve the number of meters, the present value of inflows and outflows is calculated under different assumptions about number of meters. The values are shown in table 13. As it can be seen from the table, the NPV is somewhere between 30 000 and 40 000 meters, as the NPV changes from negative to positive within that range. In order to find a more accurate number of meters, the present value curves of inflows and outflows are plotted to a graph. It is shown in figure 28. The intersection point of the present value curves is the point where the number of meters is approximately 31 000.

Table 13 PV of inflows and outflows with different number of meters.

Meters	Savings €	Investment €	Variable costs €	Fixed costs €	PV, inflows €	PV, outflows €	NPV €
0	0	9 675 410	0	10 000	0	9 726 661	-9 726 661
10 000	699 830	9 675 410	95 000	10 000	3 586 689	10 213 544	-6 626 855
20 000	1 399 660	9 675 410	190 000	10 000	7 173 378	10 700 427	-3 527 049
30 000	2 099 491	9 675 410	285 000	10 000	10 760 066	11 187 310	-427 244
40 000	2 799 321	9 675 410	380 000	10 000	14 346 755	11 674 193	2 672 562

The values of the table are based on the following equations:

$\text{Savings} = \frac{C_s}{n_c} \times \text{Meters}$ €,

Investment = $C_{tot,AMR}$ €,

$\text{Variable costs} = (C^{AMR}_{maintenance/year} + c_{transfer}) \times \text{Meters}$ €,

PV, inflows = present value of savings €,

PV, outflows = Investment – sum of present value of variable costs and present value of fixed costs €, and

NPV is the difference between present value of inflows and outflows. The lifetime in the present value calculations is 20 years and the discount rate 18.9 %.

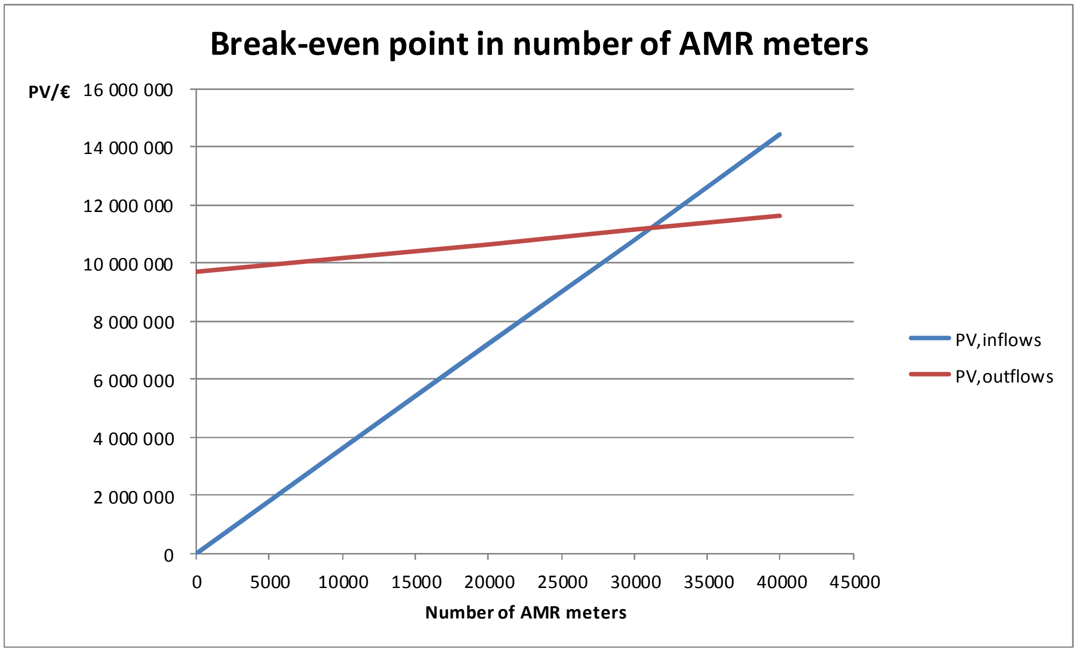

Figure 28 Break-even point in number of AMR meters.

The accurate break-even point b is solved algebraically by using the equations of the lines of present value of inflows and outflows. The equation for the present value of inflows is:

$$y_{PV,inflow} = k_{PV,inflow} \times b$$

where

$$k_{PV,inflow} = \frac{PV_{inflows[3]}}{Meters_{[3]}}$$

The number in square brackets in subscript denotes the row index in certain column in table 13. The first row has index 0.

$$y_{PV,outflow} = k_{PV,outflow} \times b$$

where

$$k_{PV,outflow} = \frac{PV_{outflows[3]} - PV_{outflows[0]}}{Meters_{[3]}}$$

A system of equations is composed of the above equations:

$$\begin{cases} y_{PV,inflow} = k_{PV,inflow} \times b \\ y_{PV,outflow} = k_{PV,outflow} \times b + PV_{outflows[0]} \end{cases}$$

By defining the right hand sides of the equations equal, the following equation can be formed:

$$k_{PV,inflow} \times b = k_{PV,outflow} \times b + PV_{outflows[0]}$$

Thereby, the break-even point b is calculated using equation:

$$b = \frac{PV_{outflows[0]}}{k_{PV,inflow} - k_{PV,outflow}} = 31\ 066 \text{ meters.}$$

7.4.2. Remote water meter reading system

The solution presented in this chapter is also based on AMR. The architecture of the system is mostly similar with the electricity meter reading system presented in the previous case. Basically, there are only two main differences between the systems. First, water consumption is measured instead of electricity. Second, the measuring devices are different.

There are a lot of same benefits with the electricity and water meter reading systems. However, instead of tracking energy leaks, remote water meter reading system enables detecting and tracking of water leaks, for example, if a pipe has been cut or if frozen water has burst it. The basic water measurement system does not analyze the quality of water or measure different properties of water. A water-based system does neither support different tariffs and the water price is typically the same around the day.

In this case, the assumption is that a water company in Vaasa plans to upgrade the conventional water meter system with an AMR-based one. In order to conduct financial calculations, the area market potential has to be assessed. According to Vaasan Vesi, there were n_c = 8 815 billable consumers in Vaasa (Vaasan Vesi 2011a). The assumption is that each location has one water meter so the area market potential is 8 815 meters.

In order to find out financial reasoning to upgrade the conventional water meter system to AMR-based one, a cost-benefit analysis is performed. It is based on comparison of investment costs to annual savings achieved by AMR system. Investment costs consist of purchase costs of necessary equipment such as meters and installing costs of the new system. Installing costs are labor costs, vehicle utilization costs during install process and costs caused by undelivered water during the hours when the equipment is being installed to the customer's premises. The new AMR system will annually save most of the costs accrued earlier from the conventional system. Those annual savings are composed of at least the factors in the list below.

- No need for water meter readout staff.
- No need to use vehicles for meter readout.
- Reduction in manual work. No need to collect, input and analyze the data manually as they are automatically processed.

The cost-benefit analysis presented below is based on the assumption that the new AMR system is implemented by replacing the conventional system with new one on the entire water supply grid. The analysis is composed of few steps and the total costs are summed up in the end. After getting the results from cost-benefit analysis, a sensitivity analysis and Monte Carlo simulation are conducted in order to see how possible fluctuations of few variables may affect to the payback time.

1. Investment costs of an AMR system

   a) Costs of new equipment

   The equipment that needs to be purchased is the meter and installation material such as cables. It is assumed that a meter costs $c_{meter} = 180$ € and the installation material for each meter costs $c_{material} = 70$ €. The price of one installation can be calculated using formula: $C_{cost/meter} = C_{meter} + C_{material}$

   b) Installation costs of an AMR system

   Installation costs are composed of the time needed for the installation of an AMR meter, other equipment, preparations and transfer of the equipment. It is estimated that it takes two hours to complete the installation. Thereby $t_{inst/meter} = 2$ h. One technician is needed to conduct the install work so $n_{workers/inst} = 1$. Total cost of one man hour is assumed to be $c_{cost/hr} = 30$ €. When all the factors above are summed up a formula that determines the total cost of installation of a meter can be defined:
   $c_{inst/meter} = t_{inst/meter} \times n_{workers/inst} \times c_{cost/hr}$

   c) Undelivered water during the installation process

   Water cannot be used or sold to the customer during the meter installation. It is assumed that a customer is unplugged from the network for two hours so $t_{unplugged} =$ 2 h. According to Vaasan Vesi, a person in a household consumes 134 liters of water per day. (Vaasan Vesi 2011a). Therefore, if it is assumed that there are four members in the household, during the installation about

$\frac{134}{24} \times 4 \times t_{unplugged} = 44.7$ liters cannot be sold to a household.

The water price in Vaasa region on 12.1.2012 is 1.25 €/m^3 (Vaasan Vesi 2012). Therefore, costs of undelivered water per household is 44.7 liters x 1.25 €/m^3 / 1000 = 0.056 €. If these costs are compared to equipment and installation costs, it can be seen that they have no significance in the total costs. For this reason, they are excluded from the further calculations.

The total investment for equipment and installation per meter can be determined with equation:

$$C_{inv/meter} = C_{cost/meter} + C_{inst/meter}$$

2. Investment costs of conventional system for meter reading

a) Equipment costs

In the conventional system an induction meter is used. Each customer has one meter. It is assumed that the price of a conventional water meter is about $C^2_{cost/meter} = 80$ €.

b) Installation costs

The installation costs per meter in the conventional system can be determined with equation:

$$c^2_{inst/meter} = t_{inst/meter} \times n_{workers/inst} \times c_{cost/hr}$$

The values of the equation parameters are assumed to be the same as in AMR-based system. The total cost for equipment and installation are calculated with equation:

$$c^2_{inv/meter} = c^2_{cost/meter} + c^2_{inst/meter}$$

3. Difference in annual costs between AMR and conventional system

In addition to data center used in AMR system, it is assumed that the only difference in the annual costs between AMR and conventional system is the price of meter maintenance. The AMR system data center is needed to store the collected consumption data. The data center service is acquired from a third-party operator. It is assumed that the data center costs are $c_{dc} = 8\,000$ € per year.

a) AMR system maintenance costs

Sternau states that there are AMR-based systems still working after 25 years (Sternau 2009). Therefore, it is reasonable to assume that the life cycle of the system is 20 years. It is assumed that the maintenance for an AMR meter is done once in ten years. The maintenance costs of a meter in ten years are assumed to be $C^{AMR}_{maintenance} = 80€$.

b) Conventional system maintenance costs

The assumption for the life cycle of a meter in the conventional system is the same as in AMR one, 20 years. The assumption for the maintenance costs of a conventional water meter are $C^{conv}_{maintenance} = 60\ €$.

As the life cycle of the meters in both systems is assumed to be 20 years, the annual maintenance costs are:

$$C^{AMR}_{maintenance,year} = \frac{C^{AMR}_{maintenance}}{20}$$

$$C^{conv}_{maintenance,year} = \frac{C^{conv}_{maintenance}}{20}$$

The difference in the annual costs is:

$$\Delta C_{maintenance,year} = C^{AMR}_{maintenance,year} - C^{conv}_{maintenance,year}$$

4. Annual operating costs in the conventional system

a) Readout costs of water meters

In order to estimate the readout personnel costs, it has to be first estimated how many employees are needed. It is assumed that the water meters are read once in three months. According to Vaasan Vesi, all single-family house, row house and apartment house customers send the current water meter readings to Vaasan Vesi. The readings of the rest of the customers are obtained by Vaasan Vesi personnel by visiting the location where the meter is and manually taking the readout. (Vaasan Vesi 2011a).

It is assumed that the number of customer of which readout has to be obtained manually is $n_{manual} = 1\,000$. If readout of one meter and transition to next location takes $t_{transition} = 20$ minutes, getting the readout from 1 000 water meters causes 20 000 minutes that is 333.3 hours of work. If a regular workday length is eight hours, one readout round once in three months requires 41.7 workdays. In order to

be able to perform the readout of all the region's meters during three months, it requires
$n_{employees} = \frac{n_{manual} \times t_{transition}}{8 \times 20 \times 3} = 0.7$ readout employees if it is calculated with 20 working days per month.

The number of working hours per month is assumed to be $t_{employees} = 150$ h. The total costs of an employee per hour are $c_{employee} = 30$ €/h. Based on this information the annual readout costs in Vaasa area are calculated using equation:
$c_{readout} = (n_{employees} \times t_{employees} \times c_{employee}) \times 12$

b) Vehicle costs

It is assumed that the average driving speed with vehicles is 30 km/h including the readout stops and lunch breaks, the meter readers can collect total of
$s_{total} = n_{employees} \times 30 \times 8 \times 20 \times 3$ kilometers during three months.

The official kilometer allowance is used as the value for the cost per kilometer. According to Taxpayers Association of Finland (TAF), it is c_{km} = 0.45 €/km in 2012 (TAF 2011). It is assumed that all the vehicle costs, including purchase costs, are in this value. Using data above, the total vehicle costs in a year due to meter readout can be calculated using equation:
$c_{vehicles} = s_{total} \times c_{km} \times 4$

c) Collecting, inputting and analyzing costs

The data collected during the meter readout has to be input, checked and analyzed. It is assumed that there are $n_d = 4$ full-time employees allocated for these tasks. The assumption about their salary costs $c_d = 5\,000$ €/month per each. The total costs per year are:
$c_{d,tot} = 12 \times n_d \times c_d$

The total conventional system costs per year due to meter readout, field staff, vehicle costs and connecting, inputting and analyzing are:
$C_{tot,conv} = c_{readout} + c_{vehicles} + c_{d,tot}$
As a conclusion, almost none of the costs in C_{tot} would occur if a new AMR-based water meter system is installed. For this reason, the calculated costs could be seen as savings:
$C_s = C_{tot,conv}$

5. Return analysis

The total investment to install the AMR water system to Vaasa region is:

$C_{tot,AMR} = c_{inv/meter} \times n_c$

As the data from AMR meters to central system is transferred via GPRS link, some data transfer costs occur every month. It is assumed that data transfer cost is 0.5 € per meter a month so $c_{transfer} = 12 \times\ 0.5$ € per meter a year. The income per year I in the AMR system can be calculated using equation:

$$I = C_s - c_{dc} - n_{manual} \times (C^{AMR}_{maintenance,year} + c_{transfer})$$

C_s is the savings due to establishment of the new system per year,

c_{dc} is the data center costs per year in €,

n_c is the number of customers in Vaasa region of which readout has to be obtained manually,

$C^{AMR}_{maintenance,year}$ is the maintenance cost per AMR meter per year and

$c_{transfer}$ is the data transfer cost per AMR meter per year.

From the general payback equation a simple payback period can be formulated in the following way:

$$\text{payback period} = \frac{C_{tot,AMR}}{I}$$

where

$C_{tot,AMR}$ is the total investment costs for AMR system and

I is the income per year in the AMR system.

When the calculations are performed, the payback period is 13.7 years.

ROI of the investment can be calculated using the equation:

$$ROI = \frac{I}{C_{tot,AMR}} \times 100\% = 10.2\%$$

In this case, the discount rate is calculated by dividing net income by total assets. The net income of Vaasan Vesi in 2010 was 2 578 575.80 € and total assets were 33 322 643.36 € (Vaasan Vesi 2011b). The division produces ROI = 7.7 %. The ROI of AMR-based water meter reading investment is higher than the company’s ROI so the investment is eligible.

In addition to ROI, the eligibility of the investment is evaluated using NPV. The result from the NPV calculation is -730 923 €, that is significantly less than 0. Horngren et al. state that only investments with zero or positive NPV are acceptable (Horngren et al. 2007: 727). Thereby the investment is not eligible from NPV point of view.

The third method for evaluating the eligibility of the investment is IRR. In figure 29, water meter reading system NPV is plotted as function of discount rate. From the figure it can be noticed that NPV is zero when discount rate is about 4 %. This is also the value of IRR. In order to calculate the IRR with Excel, the set of annual cash flows (both inflows and outflows) over the investment life cycle has to be passed to the IRR function. The IRR calculated with Excel is exactly 4 %. According to Brealey et al., the IRR rule states that an investment should be accepted if its IRR is greater than discount rate (Brealey et al. 2011, 137). As the calculated IRR was 4 %, the investment is noticed to be eligible using IRR.

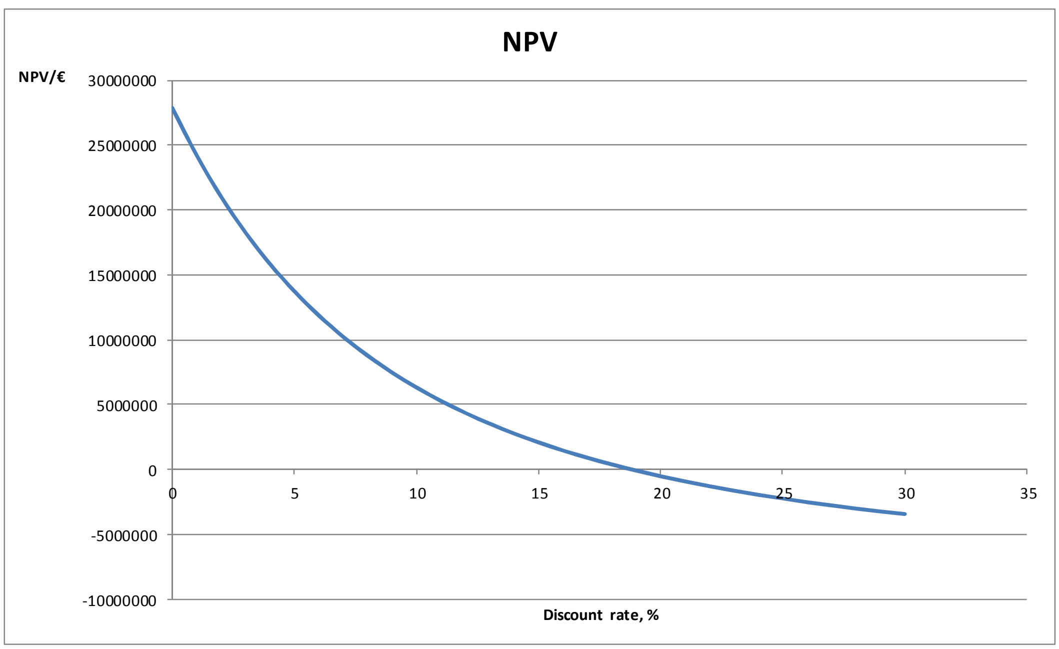

Figure 29 Remote water meter reading system NPV as a function of discount rate.

In order to find the effect of fluctuations in different variables to payback time, sensitivity analysis is conducted with data transfer price, equipment purchase price, maintenance costs of an AMR meter during the system lifetime and number of customers of which readout are obtained manually. Each variable is analysed separately. In figure 30, the effect of data transfer cost per month on the payback time is shown with three different AMR meter purchase prices. As it can be seen, lower costs can keep the payback time tolerable, but when the costs rise above one euro per month, the payback time rises quickly to excessive. In addition, about 1.1 euros per month causes the payback time to exceed the lifetime of the system.

In figure 31, the effect of equipment purchase price on the payback time is shown with three different number of manual readout customers. The price has a strong effect on the payback time. It grows linearly as the price rises. When the price is approximately 320 € per equipment, the payback time exceeds the system lifetime.

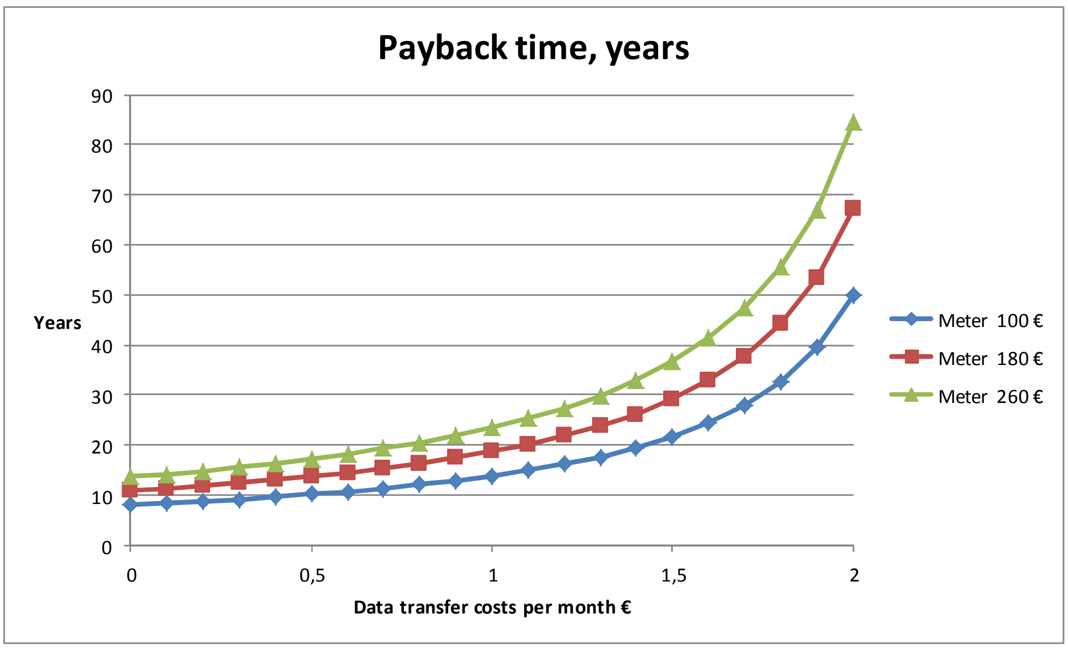

Figure 30 Data transfer cost per month effect on the payback time.

In figure 32, the maintenance costs of AMR water meter during the system lifetime is shown with three different manual readout times. The payback time exceeds the system lifetime in about 320 €. It is quite far from the estimated maintenance costs, that is 80 €. Thereby the maintenance costs are not seen as a big risk. In figure 33 it is presented how dramatic effect the number of consumers of manual readout has on the payback time. The reason for this is that the more there are consumers of manual readout, the bigger the savings are if the systems are upgraded to AMR-based system. Thus the bigger the savings are the quicker the system is paid back. There are three graphs with different lengths of readout in minutes. Monte Carlo simulation is also performed by using the same variables as in the sensitivity analysis to figure out the entire distribution of payback periods. The values of the variables except the number of manually read customers are changed according to the Normal distribution by using the value that was used in the described basic calculations as midpoint. The number of manually read customers is distributed uniformly as its value is unknown and it is based on an assumption. The results of the Monte Carlo simulation are shown in figure 34. It can be seen that the distribution of the payback periods is slightly skewed to the right and the highest number of payback periods occur at year 14 that is more than the calculated payback period.

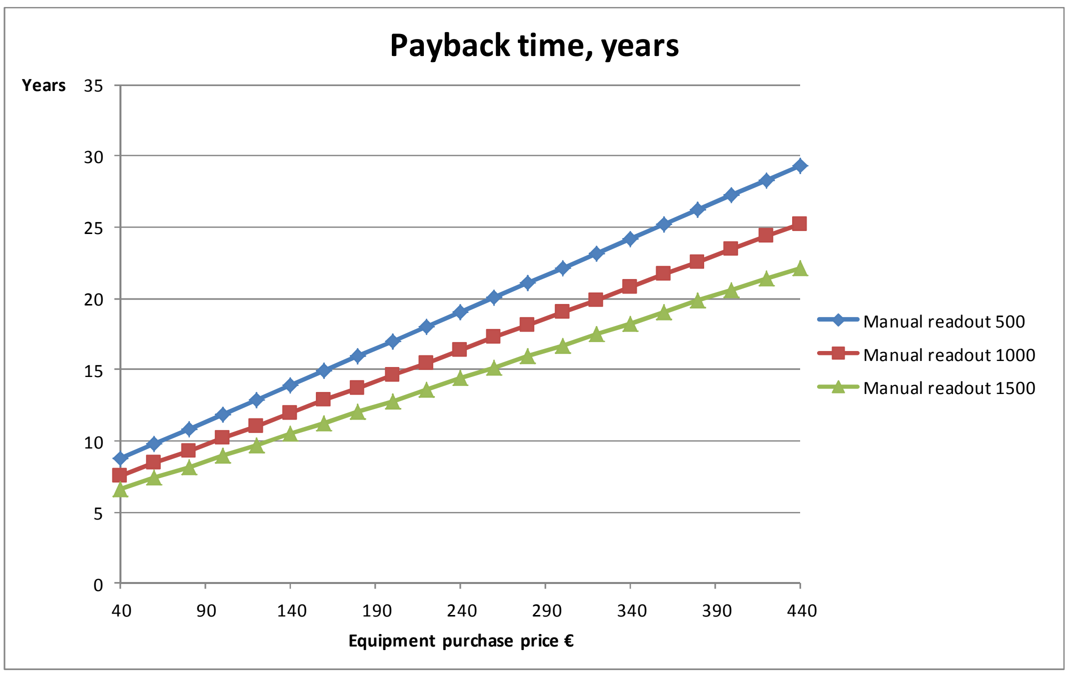

Figure 31 Equipment purchase price effect on the payback time.

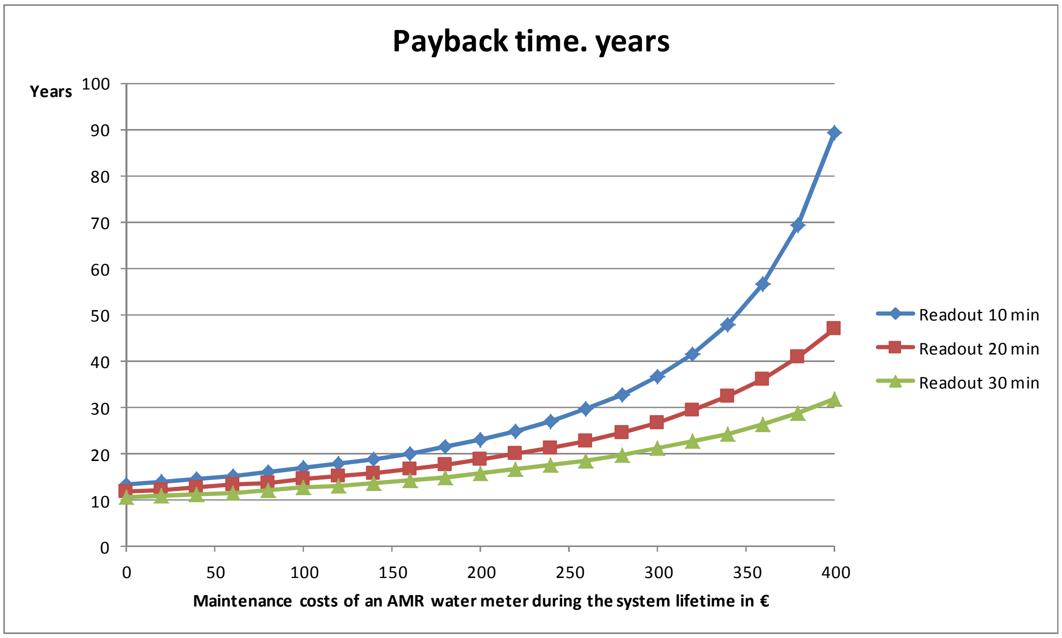

Figure 32 Maintenance costs of an AMR water meter effect on the payback time.

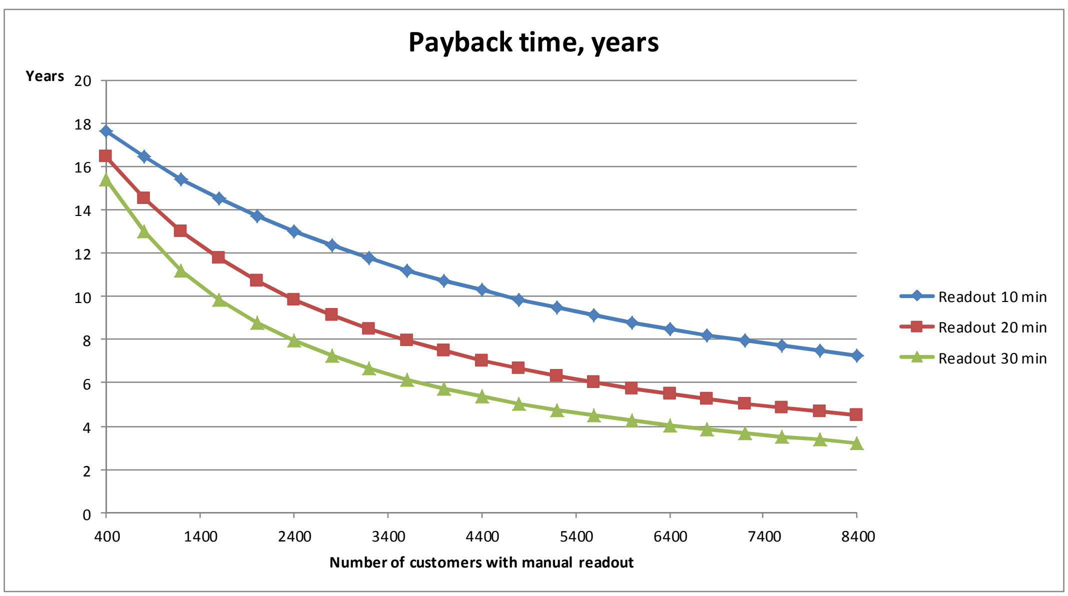

Figure 33 Number of customer with manual readout effect on the payback time.

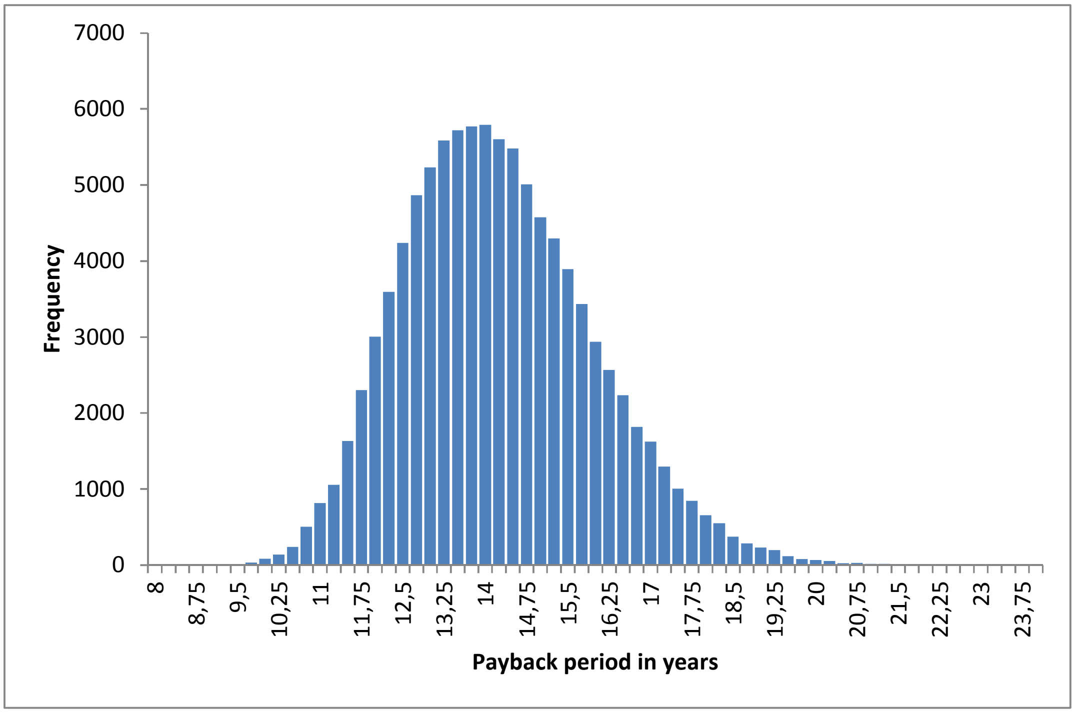

Figure 34 Distribution of the payback periods in the Monte Carlo simulation.

It is also necessary to find out how many AMR meters have to be installed in order to cover the total costs. Therefore, a break-even analysis is conducted. In order to find out the number of meters, the present value of inflows and outflows is calculated under different assumptions about number of meters. The values are shown in table 14. As it can be seen from the table, the NPV is somewhere between 6 000 and 8 000 meters, as the NPV changes from negative to positive within that range. In order to find a more accurate number of meters, the present value curves of inflows and outflows are plotted to a graph. It is shown in figure 35. The intersection point of the present value curves is the point where the number of meters is approximately 7 000.

Table 14 PV of inflows and outflows with different number of meters.

Meters	Savings	Investment €	Variable costs €	Fixed costs €	PV, inflows €	PV, outflows €	NPV €
0	0	2 180 540	0	8 000	0	2 260 870	-2 260 870
2 000	84 020	2 180 540	20 000	8 000	843 672	2 461 695	-1 618 023
4 000	168 041	2 180 540	40 000	8 000	1 687 344	2 662 521	-975 177
6 000	252 061	2 180 540	60 000	8 000	2 531 016	2 863 346	-332 330
8 000	336 082	2 180 540	80 000	8 000	3 374 688	3 064 172	310 517

The values of the table are based on the following equations:

Savings = $\frac{C_s}{n_c} \times$ Meters €,

Investment = $C_{tot,AMR}$ €,

Variable costs = $(C^{AMR}_{maintenance/year} + c_{transfer}) \times$ Meters €,

PV, inflows = present value of savings €,

PV, outflows = Investment – sum of present value of variable costs and present value of fixed costs €, and

NPV is the difference between present value of inflows and outflows. The lifetime in the present value calculations is 20 years and the discount rate 7.7 %.

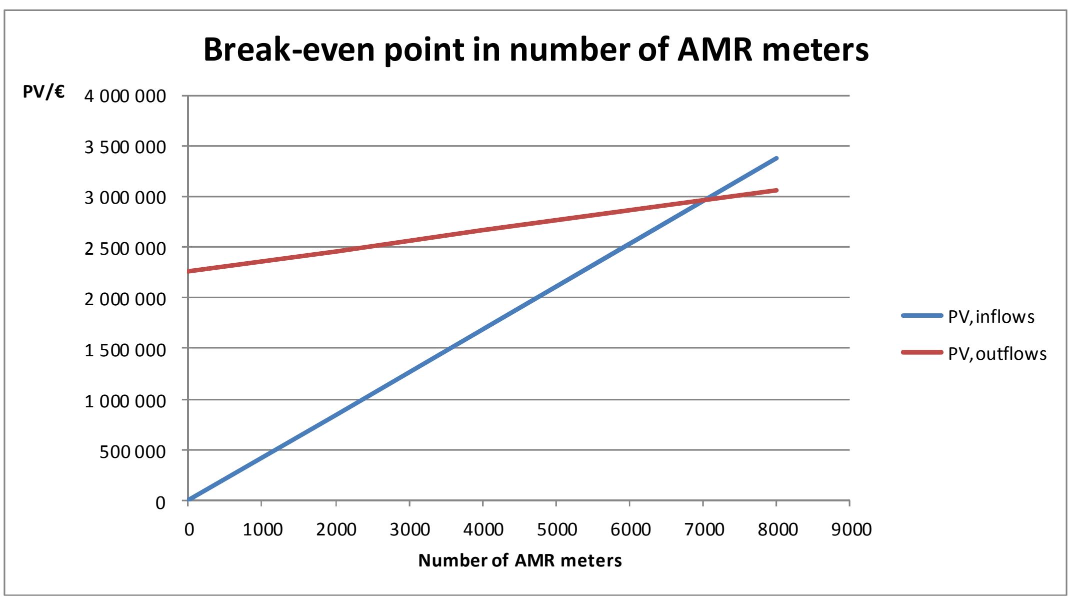

Figure 35 Break-even point in number of AMR meters.

The accurate break-even point b is solved algebraically by using the equations of the lines of present value of inflows and outflows. The equation for the present value of inflows is:

$$y_{PV,inflow} = k_{PV,inflow} \times b$$

where

$$k_{PV,inflow} = \frac{PV_{inflows[3]}}{Meters_{[3]}}$$

The number in square brackets in subscript denotes the row index in certain column in table 14. The first row has index 0.

$$y_{PV,outflow} = k_{PV,outflow} \times b$$

where

$$k_{PV,outflow} = \frac{PV_{outflows[3]} - PV_{outflows[0]}}{Meters_{[3]}}$$

A system of equations is composed of the above equations:

$$\begin{cases} y_{PV,inflow} = k_{PV,inflow} \times b \\ y_{PV,outflow} = k_{PV,outflow} \times b + PV_{outflows[0]} \end{cases}$$

By defining the right hand sides of the equations equal, the following equation can be formed:

$$k_{PV,inflow} \times b = k_{PV,outflow} \times b + PV_{outflows[0]}$$

Thereby, the break-even point b is calculated using equation:

$$b = \frac{PV_{outflows[0]}}{k_{PV,inflow} - k_{PV,outflow}} = 7\ 034 \text{ meters.}$$

7.4.3. Condition-based maintenance system

In this chapter a condition-based maintenance (CBM) system for a wind farm is presented and some financial calculations concerning its payback time and eligibility are conducted. In more detail, the system provides means to remotely diagnose and analyze the status and maintenance needs of a wind farm. In figure 36, Eto, Matsuo, Kurokawa and Fukuda illustrate the architecture of a condition monitoring system for a wind farm. The described solution consists of individual wind turbines of which each is equipped with a wind turbine controller, data logger (remote station server) that collects and distributes the data, remote monitor (remote station), and network for connecting these equipment. In this case, the wind turbine controller is an embedded device controlling the wind turbine blade angle according to wind direction. The device also performs data input process of environmental conditions such as wind direction, wind velocity, and temperature around each wind turbine, and operation conditions, for example, generated power and frequency. It transmits the data of each wind turbine to the data logger and controls start and stop of the wind turbine. (Eto et al. 2003.)

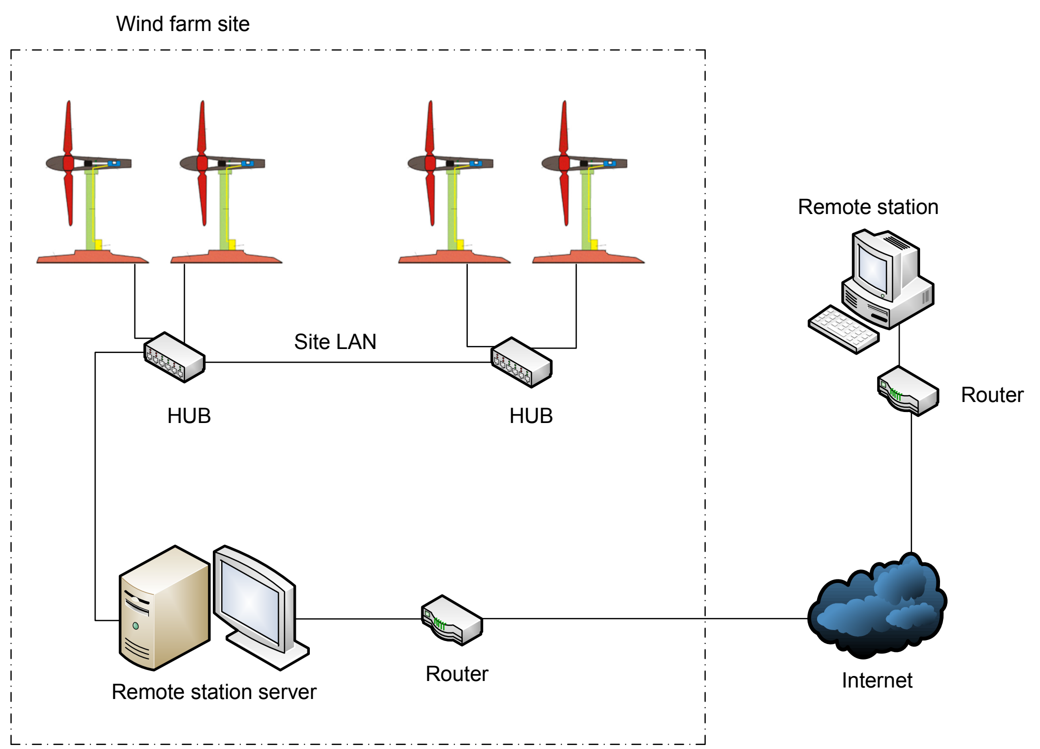

Figure 36 Remote condition monitoring system for a wind farm (Eto et al. 2003).

Generally, the purpose of maintenance is to extend equipment lifetime or at least the mean time to the next failure of which repair may be costly. In addition, it is expected that effective maintenance policies can reduce service interruptions and the many undesirable consequences of such interruptions. Maintenance strongly affects component and system reliability as if too little is done, it may result in an excessive number of costly failures and low system performance and therefore reliability is degraded. On the other hand, if maintenance is done too often, reliability may improve but the cost of maintenance will significantly increase. In a cost-effective scheme, these two expenditures have to be balanced. (Endrenyi, Aboresheid, Allan, Anders, Asgarpoor, Billinton, Chowdhury, Dialynas, Fipper, Fletcher, Grigg, McCalley, Meliopoulos, Mielnik, Nitu, Rau, Reppen, Salvaderi, Schneider, Singh, 2001; Nilsson & Bertling 2007.)

There are different types of maintenance approaches available, such as corrective maintenance, scheduled maintenance and preventive maintenance. In the first approach a component is replaced at a certain age or when it fails. The scheduled maintenance, also known as planned maintenance, presumes that all devices in a given class are replaced at predetermined intervals or when they fail. Scheduled maintenance includes lubrication, tightening bolts, changing filters, calibration and adjustment of sensors and actuators, replacement of consumables such as brake pads and seals, and checking safety equipment. In preventive maintenance practice maintenance is carried out when it is deemed necessary, based on periodic inspections or other means of condition monitoring. Preventive maintenance can be CBM, sometimes also known as predictive maintenance, based on the actual health of the system. In addition to periodic inspections, the health can be determined by analyzing offline measurements, oil samples, SCADA data, or online measurements. Therefore, implementing a CBM strategy is not limited to using online condition monitoring systems. Online condition monitoring is only one of many means to determine the health of a system. Thereby, online and automated condition monitoring is not a synonym for CBM. (Endrenyi et al. 2001; Nilsson & Bertling 2007; Wiggelinkhuizen, Braam, Xiang, Watson, Giebel, Norton, Tipluica, Christensen, Becker & Scheffler 2007; Orosa, Oliveira & Costa 2010; Zhigang & Tongdan 2011.) In this wind farm case, the focus is in condition-based maintenance.

By utilizing condition monitoring information collected from wind turbine components, CBM can be used to reduce the operation and maintenance costs of wind farms. The CBM methods for wind farms deal with wind turbine components separately. In other words, the maintenance decisions can be made on individual components, rather than the whole system. In practice, a wind farm consists of several numerous turbines and each of them has several components including main bearing, gearbox and generator. Therefore, once a maintenance team is sent to the wind farm, it is probably more economical to take the opportunity to maintain several turbines, and when a turbine is stopped for maintenance, it might be more cost-effective to simultaneously maintain multiple components which indicate relatively high risk. (Wiggelinkhuizen et al. 2007; Zhigang & Tongdan 2011.)

CBM approach mainly makes sense if the design life of the component is shorter than that of the entire turbine and if it is clear that wear indeed is the cause of failure. For example, gearbox oil will be replaced several times during the turbine lifetime. CBM can then be applied to determine if the oil needs to be changed after one year instead of half a year that would take place if scheduled maintenance approach was used. CBM approach could then save about halve of the number of oil changes during the turbine lifetime. So called safe life components, for instance, rotor blades, are designed for lifetime longer than turbine lifetime. If such components are replaced during the lifetime, the failure cause is typically not wear but, for example, too high loading, poor manufacturing, or unforeseen conditions. (Wiggelinkhuizen et al. 2007; Zhigang & Tongdan 2011.) There are numerous condition monitoring techniques developed that can be utilized in condition-based monitoring. Verbruggen and Krug, Rasmussen, Bauer, Lemieux, Schram & Ahmann and Wiggelinkhuizen et al. list techniques such as vibration analysis, oil analysis, thermographic analysis of electrical components, physical condition of materials, fiber optic strain measurement of blades, acoustic measurements, electrical effects, process parameters, visual inspection, performance monitoring, time and frequency domain analysis of the electrical power, trending of key component response functions, and self-diagnostic sensors. (Verbruggen 2003; Krug et al. 2004; Wiggelinkhuizen et al. 2007; Yang, Tavner, Crabtree & Wilkinson 2010.)

All those techniques are not currently so applicable and desirable for wind turbines. Some uses of them are presented below with different parts of the turbine. Nacelle contains many of the critical parts of the turbine such as gearbox. It can be monitored using vibration analysis based on different sensors, such as acceleration sensors and displacement sensors. In acoustic emission, higher frequencies are considered, which give an indication of starting defects. Oil analysis is especially of interest when defects are identified. Based on characterization of parts and component data, diagnosis can be approved. This simplifies the repair action. Lubrication oil itself can also be a cause for increasing wear. There is a strong relationship between the size and number of parts and the component life time. Also moist and acidity can strongly reduce the lubrication properties. Safeguarding of the filters, online part counting and moist detection can help keep the oil in an optimal condition. Costs resulting from oil replacement as well as from wear of the components can be reduced by an optimal oil management. (Verbruggen 2003; Krug et al. 2004; Yang et al. 2010; Zhigang & Tongdan 2011.)

Generator and especially its bearing can also be monitored with vibration analysis, similar to the gearbox. Apart from this, the condition of the rotor and stator windings can also be monitored by temperatures. The hydraulic system for pitch adjustment is very critical, except for turbines that have electrical pitch adjustment. Condition monitoring of hydraulic systems is very similar to other applications as intermittent usage is common practice. Yaw system is rather failure prone, but its condition monitoring is difficult due to the intermittent usage. The system is operating a longer period during start-up and re-twisting. (Verbruggen 2003.)

As there are a multitude of possibilities how to utilize condition-based maintenance, a lot of benefits is possible to achieve with these. For example, maintenance can be planned better, the right maintenance can be carried out at the right time and unnecessary replacements can be minimized. In many cases, repairs can be done in conjunction with regular maintenance work. Basically, condition monitoring makes it possible to carry out maintenance and repairs depending on the condition of the turbine. Downtime could be reduced as failures are discovered more easily. Transportation costs to wind farm can also be reduced due to better planning provided by condition monitoring. For example, if one gearbox needs repair, then another gearbox that may fail at a later state could be repaired at the same time. Unexpected plant standstills that cause loss of energy production can be avoided to the largest extent possible. Optimum turbine availability can be guaranteed. (Verbruggen 2003; Krug et al. 2004; Nilsson & Bertling 2007; Yang et al. 2010.)

Based on the benefits discussed above, financial calculations can be conducted on how eligible a CBM solution in a wind farm would be. In this case, it is assumed that Vapo Group builds a new onshore wind farm with eight wind turbines ($n_w = 8$). Vapo Group is a leading supplier and developer of bioenergy in Finland and in the Baltic Sea Region (Vapo Group 2012). At the moment, Vapo Group has eight wind turbines installed in Finland. The calculations are based on the assumption that new wind turbines are built instead of retrofitting the old ones with condition monitoring devices. Typically, the lifetime of the wind farm is designed to be 20 to 30 years (Nilsson & Bertling 2007; Hau 2006, 698). Therefore it is assumed that the lifetime of Vapo wind farm is $lt = 20$ years.

1. Investment costs of CBM system
   a) Costs of equipment

   The equipment that needs to be purchased for one wind turbine are the analysis devices such as oil quality sensors and temperature sensors, wind turbine controller and other material such as cables. According to Fredrik Larsson, managing director on SKF Condition Monitoring Center, price of a condition monitoring system for a wind turbine is 20000 € (Nilsson & Bertling 2007). Therefore, it is assumed that the analysis equipment costs $c_{analysis}$ = 18 000 € since it is assumed that prices go down as the technology develops. The controller costs c_{ctrl} = 300 € and the installation material for each meter costs $c_{material}$ = 500 €. The price of the equipment of one installation can be calculated using equation:

$$C_{inst} = C_{analysis} + C_{ctrl} + C_{material}$$

The equipment costs for the whole wind farm when the number of turbines $n_{turbines}$ = 8, hub price C_{hub} = 200 €, router price C_{router} = 150 €, server price C_{server} = 1 000 € and software $C_{software}$ = 5 000 € can be calculated using equation the equation below. It is assumed that two hubs and two routers are needed.

$$C_{equipment} = n_{turbines} \times C_{inst} + 2 \times C_{hub} + 2 \times C_{router} + C_{server} + C_{software}$$

b) Installation of the equipment

The assumption was that the analysis and controller equipment is mounted only to the new wind turbines as retrofitting is too costly. It is assumed that mounting cost is c_{mnt} = 1 500 € per turbine as the aim is that the mounting is done before the wind turbines are moved to wind farm. Only the cables are connected on-site. Installation of other equipment such as hubs, routers, servers and software is estimated to cost $c_{inst,other}$ = 1 000 €. Therefore, the total installation costs of the equipment for the CBM system is:

$$C_{inst,eq} = n_{turbines} \times C_{mnt} + C_{inst,other}$$

The total investment for equipment and installation of the wind farm can be determined with equation:

$$C_{inv} = C_{equipment} + C_{inst,eq}$$

2. Annual wind farm operations and maintenance costs in conventional system

In the conventional system, the annual maintenance costs are composed of corrective maintenance costs C_{cm} and costs of scheduled maintenance costs C_{sch}. The equation to calculate the total maintenance costs per year is:

$$C_m = C_{cm} + C_{sch}$$

The corrective maintenance costs consist of unscheduled maintenance costs C_{usch} and costs of replacing major components C_{rmc}. The equation to calculate corrective maintenance costs is:

$$C_{cm} = C_{usch} + C_{rmc}$$

The unscheduled maintenance costs are calculated using equation:

$$C_{usch} = C_{man} \times (n_{diag} + n_{maint})$$

where n_{diag} is the number of man hours used for diagnostics of wind turbines and n_{maint} is the number of man hours used for actual maintenance work. It is assumed that there is diagnosis work n_{diag} = 12 hours for and maintenance work n_{maint} = 16 hours for two men per turbine in a year categorized as unscheduled maintenance.

The cost of replacements C_{rmc} is built on the assumption that the gearbox is changed twice (n_{gb} = 2) and the generator is changed once (n_g = 1) during the lifetime of a wind turbine. Two transformers (n_{tr} = 2) and two blades (n_b = 2) are replaced for the whole wind farm during its lifetime. Therefore, the equation to calculate the total cost of replacements over the lifetime:

$$C_{rep} = C_{rgb} + C_{rg} + C_{rtr} + C_{rb}$$

where

C_{rgb} is the cost of replacing gearboxes in the wind farm,

C_{rg} is the cost of replacing generators in the wind farm,

C_{rtr} is the cost of replacing transformers in the wind farm and

C_{rb} is the cost of replacing blades in the wind farm.

The annual replacement costs in the wind farm can be calculated using equation:

$$C_{rep,year} = \frac{n_{gb}}{lt} \times C_{rgb} \times n_w + \frac{n_{rg}}{lt} \times C_{rg} \times n_w + \frac{n_{tr}}{lt} \times C_{rtr} + \frac{n_{rb}}{lt} \times C_{rb}$$

where each cost variable C is calculated using equation:

$$C = n_{man,task} \times C_{man} \times 2 + C_c$$

where $n_{man,task}$ is the number of hours needed to perform the specific task, C_{man} is the price of one hour and C_c is the price of the component. It is assumed that there are always two men doing the replacement. The assumed values for the equation above are:

$n_{man,gb}$ = 8 h, $n_{man,g}$ = 6 h, $n_{man,tr}$ = 7 h and $n_{man,b}$ = 5 h. The component prices are estimated to be gearbox C_{gb} = 300 000 €, generator C_g = 150 000, transformer C_{tr} = 100 000 and blade C_b = 200 000 (Nilsson & Bertling 2007).

Normally, there are two scheduled maintenances per year and typical availability percentage in onshore wind turbines is 97.5 % (Hau 2006; Nilsson & Bertling 2007; Orosa et al. 2010). In this case, it is also assumed that a scheduled maintenance is performed twice a year and the availability percentage $p_{avail,conv}$ = 97.5 % in the conventional system. The scheduled maintenance cost per year is calculated with equation:

$$C_{sch} = 2 \times C_{man} \times n_{sch} \times n_w$$

It is assumed that scheduled maintenance of one wind turbine takes seven hours for two men in a year, so n_{sch} = 7. According to Vapo Group, the annual energy production of its eight wind turbines is about E = 15 000 MWh (Vapo Group 2012). If assumed that without any unavailability time the maximum energy production in a year could be:

$$E_{max} = \frac{E}{p_{avail,conv}} \times 100 \text{ MWh}$$

The electricity energy price including transfer costs on 1st September 2011 is 0.092 €/kWh that is P_e = 92 €/MWh (Vaasan Sähkö 2011). Therefore, the costs of production losses in the conventional system in a year are:

$$C_{pl,conv} = (E_{max} - E) \times P_e$$

The total costs C in the conventional wind farm in a year are:

$$C_{tot,conv} = C_m + C_{pl,conv}$$

3. Annual wind farm operations and maintenance costs with CBM system

As the condition of the wind turbine and the possible cause for a fault is known better when using CBM system, it is assumed that time needed for diagnosis work in the wind farm equipped with CBM system is only 30 per cent of the time compared to conventional system. The diagnosis time cannot be set to zero as the CBM system will not detect all possible problems, and faults may occur also in it. Thereby, the equation to calculate the costs of unscheduled maintenance per year is:

$$C_{usch} = C_{man} \times (0.3 \times n_{diag} + n_{maint})$$

In addition, it is assumed that availability of the wind turbines is 1.3 per cent higher than in the conventional system so $p_{avail,CBM}$ = 98.8 % due to shorter time needed for diagnosis work and better planning which CBM system enables. Due to awareness of the states of the wind turbines provided by the CBM system, the spare parts can be ordered earlier than with the conventional system. This also reduces the turbine downtime. The production losses when CBM system is used are:

$$C_{pl,CBM} = (E_{max} - \frac{p_{avail,CBM}}{100} \times E_{max}) \times P_e = E_{max} \times (1 - \frac{p_{avail,CBM}}{100}) \times P_e$$

The other equations concerning corrective maintenance costs are the same as in the conventional system. The total costs $C_{tot,CBM}$ in the CBM-equipped wind farm in a year are:

$$C_{tot,CBM} = C_m + C_{pl,CBM}$$

4. Return calculation

The difference of the costs between the conventional system and the system equipped with CBM is:

$\Delta C = C_{tot,conv} - C_{tot,CBM}$.

The value of ΔC is the amount of money that the CBM-based system saves per year. Thereby it can be considered as income. However, there are some fixed costs per year as some equipment such as servers will have to be replaced during the system lifetime. Therefore, the income can be calculated using equation $I = \Delta C - C_f$, where C_f = 2 000 €. From the general payback equation a simple payback period can be formulated in the following way:

$$\text{payback period} = \frac{C_{inv}}{I}$$

where

C_{inv} is the total investment of CBM system and

I is the income per year from the wind farm.

When the calculations are performed, it results payback period of 8.6 years.

ROI of the investment can be calculated using the equation:

$$\text{ROI} = \frac{I}{C_{inv}} \times 100\% = 11.6\,\%$$

According to Vapo Group, its ROI in 2010 was 9.5 % (Vapo Group 2011). The calculated ROI is slightly higher than Vapo Group's ROI. Therefore, the investment is eligible. In addition to ROI, the eligibility of the investment is evaluated also using NPV. The result from the NPV calculation is 4 033 €. Horngren et al. state that only investments with zero or positive NPV are acceptable (Horngren et al. 2007: 727). Thereby the investment is eligible also from NPV point of view.

The third method for evaluating the eligibility of the investment is IRR. In figure 37, wind farm CBM system NPV is plotted as function of discount rate. From the figure it can be noticed that NPV is zero when discount rate is about 10 %. This is also the value of IRR. In order to calculate the IRR with Excel, the set of annual cash flows (both inflows and outflows) over the investment life cycle has to be passed to the IRR function. The IRR calculated with Excel is exactly 10 %. According to Brealey et al., the IRR rule states that an investment should be accepted if its IRR is greater than discount rate (Brealey et al. 2011, 137). As the calculated IRR was 10 %, which is higher than Vapo Group's ROI the investment is noticed to be eligible also using IRR.

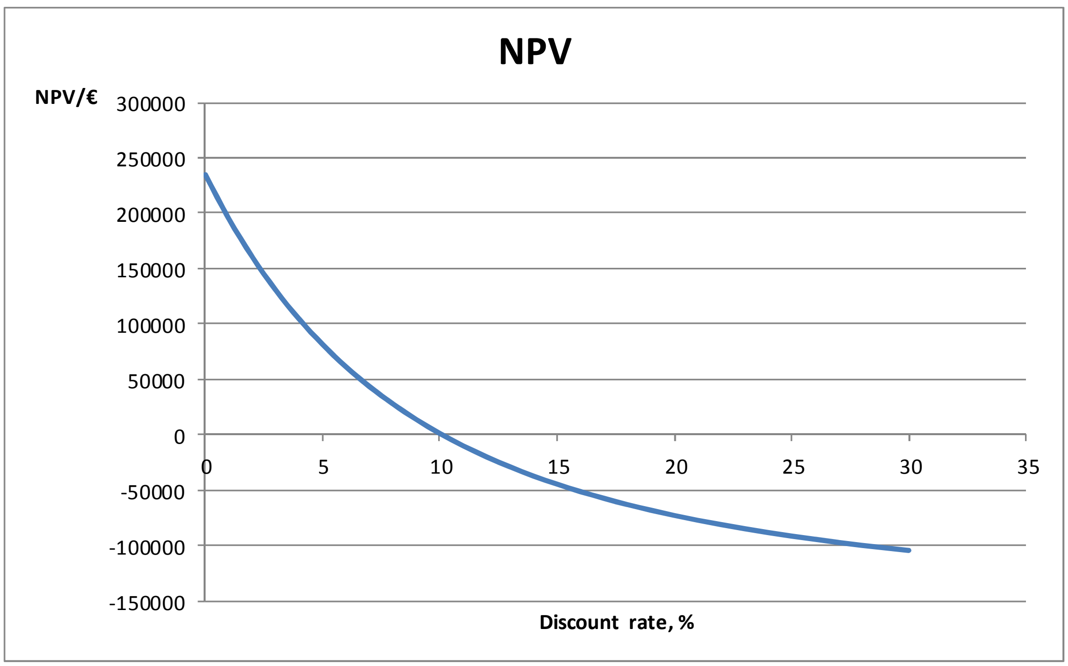

Figure 37 Wind farm CBM system's NPV as a function of discount rate.

In order to assess the extent of variation in different variables may cause to payback time, sensitivity analysis is conducted. The examined variables are price of analysis equipment, diagnosis work amount in CBM system and energy price. Each variable is analysed separately. All the variables are analysed with three different wind farm availability percentages per year. In figure 38, it can be seen how dramatic effect the availability percentage has on the payback time. The analysis equipment price has less significance on the amortization time of the investment than the availability percentage.

In figure 39, the effect of the availability percentage is also obvious. If the availability percentage is close to 97.5, that is the typical value in onshore farms, the payback time exceeds the estimated wind farm lifetime even with the analysis equipment of the lowest price. Therefore it is vital for the investment that higher availability percentage is achieved. The diagnosis time reduction has only a minor role in the payback time. In figure 40, availability percentage is still the crucial factor in the payback time but the rising energy price can shorten it significantly. Monte Carlo simulation is also performed by using the same variables as in the sensitivity analysis to figure out the entire distribution of the payback periods. The values of the variables are changed according to the Normal distribution by using the value that was used in the described basic calculations as midpoint. The results of the Monte Carlo simulation are shown in figure 41. It can be seen that the distribution of the payback periods is very well balanced around the calculated payback period.

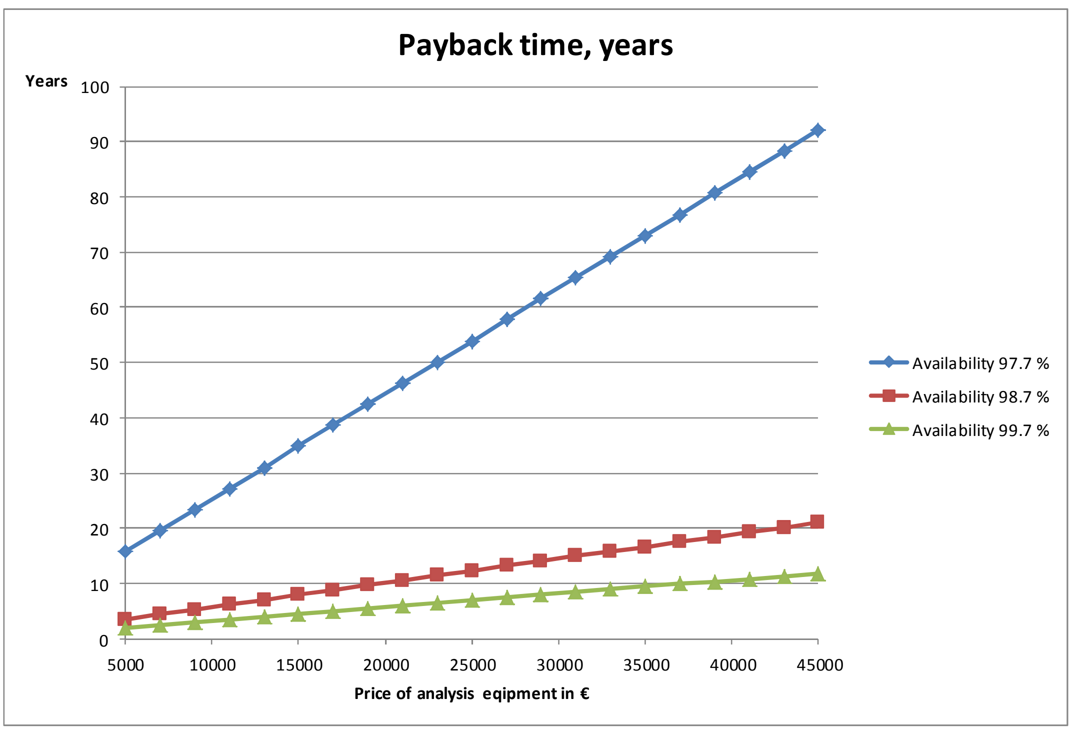

Figure 38 Price of analysis equipment effect on the payback time.

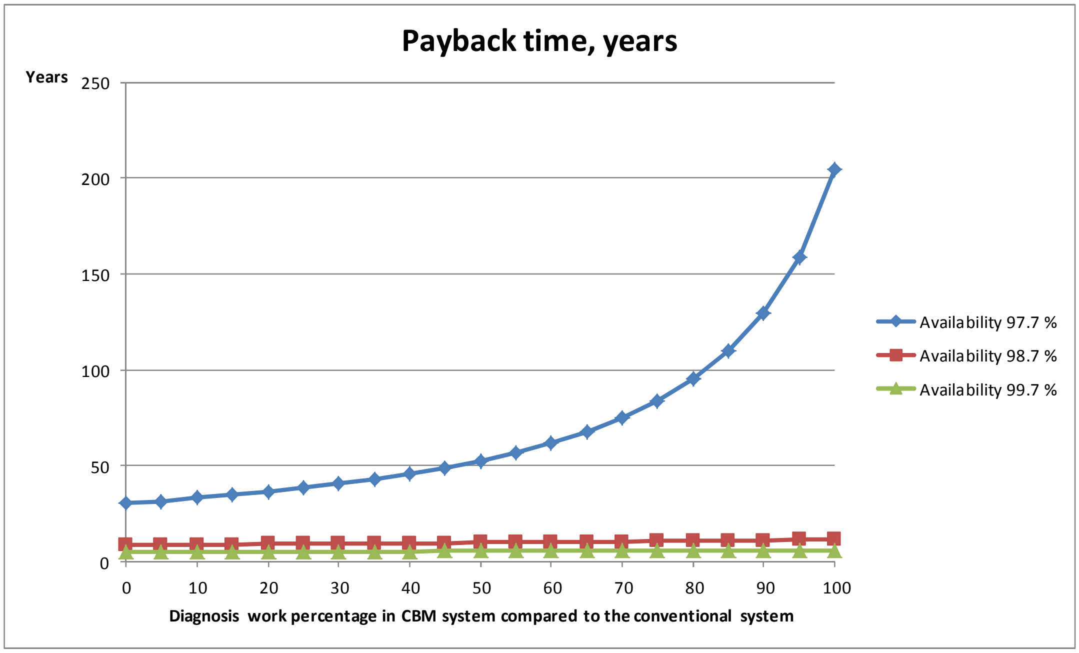

Figure 39 Effect of CBM system diagnosis work amount on the payback time.

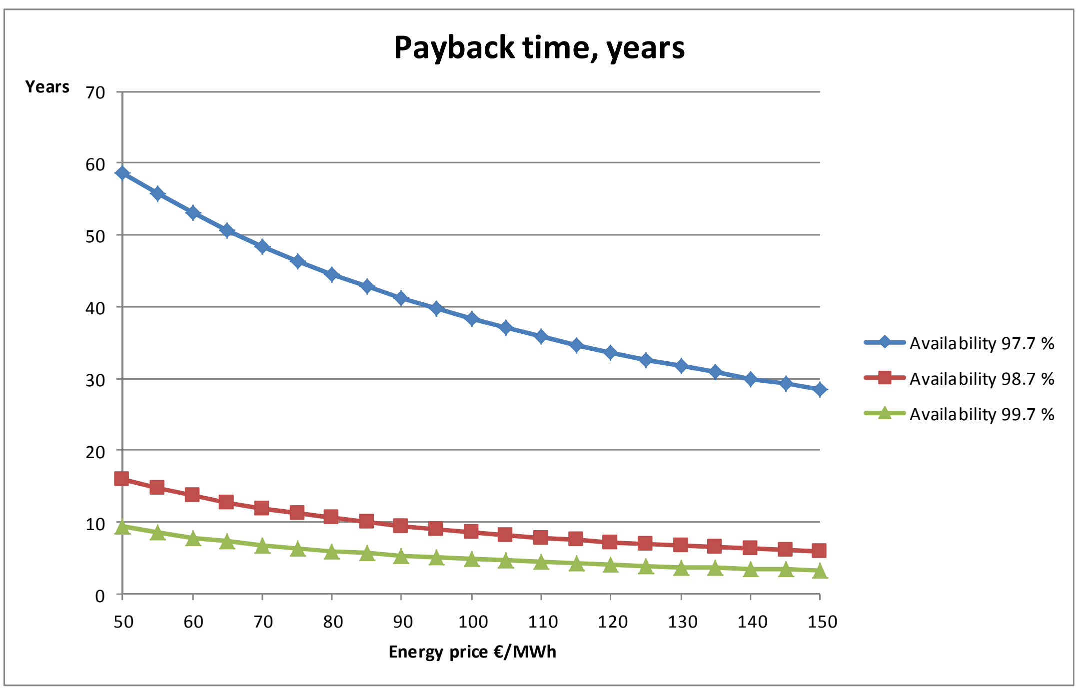

Figure 40 Effect of energy price on the payback time.

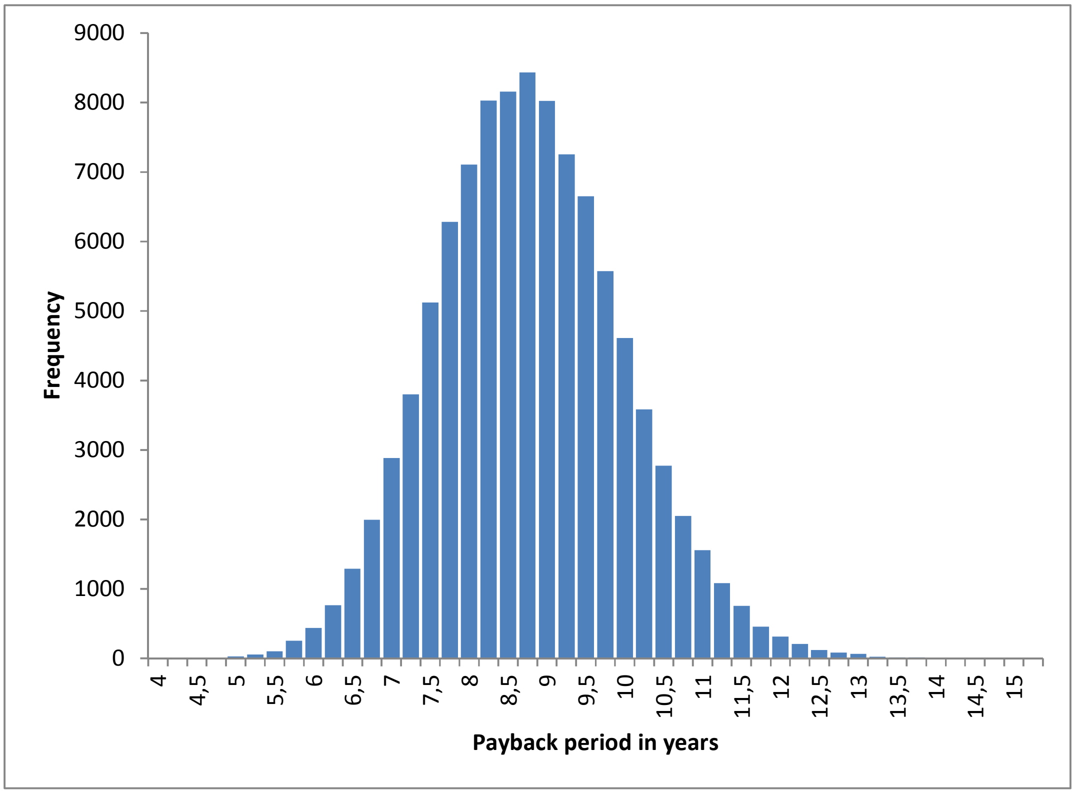

Figure 41 Distribution of the payback periods in the Monte Carlo simulation.

It is also necessary to find out how high the availability percentage has to be in order to cover the total costs. Therefore, a break-even analysis is conducted. In order to find out the percentage, the present value of inflows and outflows is calculated under different assumptions about the availability percentage. The values are shown in table 15. As it can be seen from the table, the NPV is somewhere between 98.7 and 99.7 per cent, as the NPV changes from negative to positive within that range. In order to find a more accurate number of meters, the present value of curves inflows and outflows are plotted to a graph. It is shown in figure 42. The intersection point of the present value curves is the point where the availability percentage is approximately 98.9.

Table 15 PV of inflows and outflows with different availability percentages.

Availability %	Savings €	Investment €	Variable costs €	Fixed costs €	PV, inflows €	PV, outflows €	NPV €
97.7	4 191	170 100	0	2 000	36 933	187 725	-150 792
98.7	18 345	170 100	0	2 000	161 663	187 725	-26 062
99.7	32 498	170 100	0	2 000	286 385	187 725	98 660

The values of the table are based on the following equations:

Savings = ΔC - C_f,

Investment = C_{inv} €,

Variable costs are zero as there are no costs depending on the availability percentage.

PV, inflows = present value of savings €,

PV, outflows = Investment – sum of present value of variable costs and present value of fixed costs €, and

NPV is the difference between present value of inflows and outflows. The lifetime in the present value calculations is 20 years and the discount rate 9.5 %.

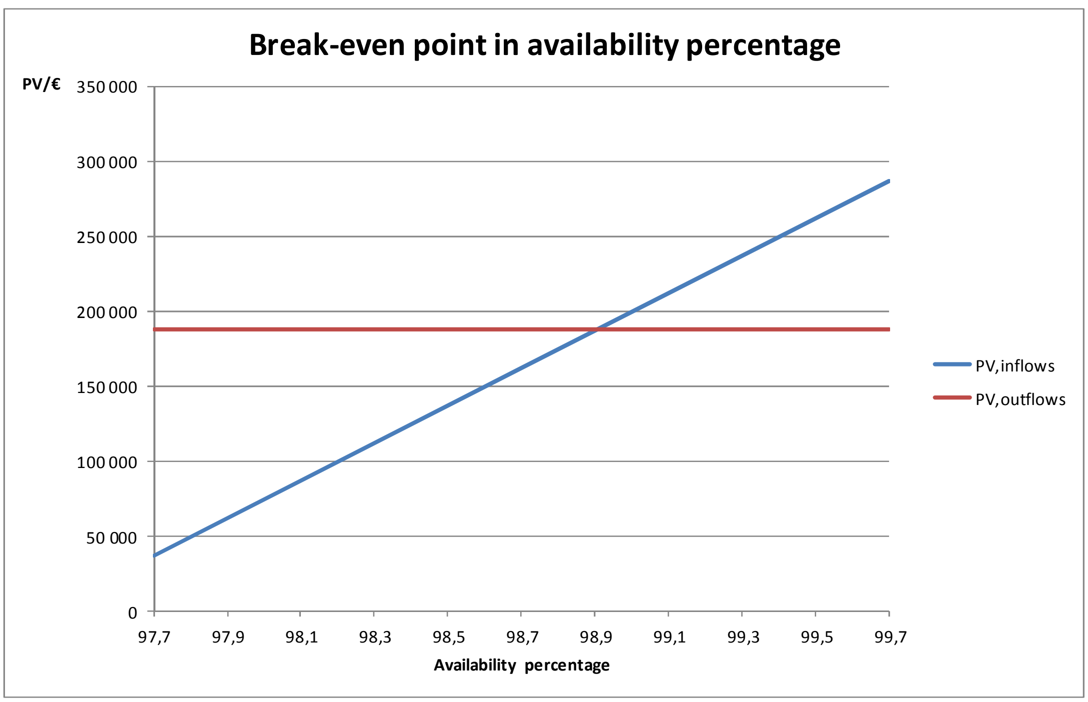

Figure 42 Break-even point in availability percentage.

The accurate break-even point b is solved algebraically by using the equations of the lines of present value of inflows and outflows. The equation for the present value of inflows is:

$$y_{PV,inflow} = k_{PV,inflow} \times b$$

where

$$k_{PV,inflow} = \frac{PV_{inflows[2]} - PV_{inflows[0]}}{Availability\ \%_{[2]} - Availability\ \%_{[0]}}$$

The number in square brackets in subscript denotes the row index in certain column in table 15. The first row has index 0.

$$y_{PV,outflow} = k_{PV,outflow} \times b$$

where

$$k_{PV,outflow} = \frac{PV_{outflows[2]} - PV_{outflows[0]}}{Availability\ \%_{[2]} - Availability\ \%_{[0]}}$$

A system of equations is composed of the above equations:

$$\begin{cases} y_{PV,inflow} = k_{PV,inflow} \times b + PV_{inflows[0]} \\ y_{PV,outflow} = k_{PV,outflow} \times b + PV_{outflows[0]} \end{cases}$$

By defining the right hand sides of the equations equal, the following equation can be formed:

$$k_{PV,inflow} \times b + PV_{inflows[0]} = k_{PV,outflow} \times b + PV_{outflows[0]}$$

Thereby, the break-even point offset b_{offset} is calculated using equation:

$$b_{offset} = \frac{PV_{outflows[0]} - PV_{inflows[0]}}{k_{PV,inflow} - k_{PV,outflow}}$$

and the actual break-even point is calculated by adding the lowest availability percentage used in the analysis to the break-even offset:

$b = b_{offset} + Availability\ \%_{[0]} = 98.9\ \%$

7.4.4. Fleet management

In this chapter the solution presented in this thesis is in focus. First, its benefits are discussed and market potential is assessed. After that, financial calculations concerning the project eligibility are performed. The aim is that the solution provides means to manage a fleet of trucks. Thereby the users of the solution are mostly transportation companies. The solution provides the users with numerous benefits of a fleet management system.

Optimization of fuel costs is more and more important nowadays as fuel price is getting higher and higher. Fleet management system facilitates to save fuel, for example, as it enables finding very easily the closest vehicle to provide transport service from a specific location to another. Fuel saving can be achieved also with better route planning. The routes can be programmed and it can be ensured with the system that the drivers do not deviate from authorized route as the entire movement history can be looked afterwards. The routes and the fuel consumptions can be compared and the driver can be instructed if it turns out that a certain driver causes significantly larger fuel costs than others. The labor costs can be also reduced as the idle time can be minimized by better planning according to the data that the system provides. This also helps verify that drivers have met expected appointments and service calls. The unauthorized vehicle use can be reduced as use of take-home vehicles can be monitored. The system may even lower insurance rates as it can be accurately documented where all vehicles are at all times. With this information, it is possible to reject frivolous property damage claims. (Rodin 1993; Alvarez, Fernandez-Montes, Moreno, Ortega, Gonzalez-Abril & Velasco 2008; iTrak 2012; Telogis 2012)

According to the benefits discussed above, it can be noticed that the system would be useful for all managers involved in transport planning and scheduling, financial managers and also supervisors that have responsibilities in human resource management. Before any financial calculations, the total market potential is assessed. The aim is to outline how many companies there are in North America including the USA and Canada that could potentially use the system and pay for it. It is also assessed how many users there might be in the each potential company.

First, the number of potential companies is forecasted. In this case, it is conducted using top-down approach. As described in figure 16, top-down sales forecast procedure is composed of five steps. The procedure is utilized in five steps below.

1. In the first step the aim is to forecast relevant external environmental factors over specified time period. These are, for example, gas price and competition between trucking companies. If the gas price gets too high, the companies with very low margin may drive to bankruptcy. Competition may also drive smaller companies to difficulties as larger companies may have more cash to keep the transportation costs very low and starve the weaker companies in the market. However, these factors are challenging to estimate in precise number so they are excluded from the estimation.

2. Next the market potential is estimated. According to Truckinfo, there are over 500 000 trucking companies in the USA (Truckinfo 2009). Statistics Canada states that the number of trucking companies in Canada is 56 800 (Statistics Canada 2012). This makes total of 556 800 companies. Any specific method such as Delphi is not used in the estimation.

3. In this step the company sales potential is estimated. In order to calculate it, the market potential from step 2 and the company's share of total industry sales in percentage are needed. In this step, the shares of the competitors are excluded as it is assumed that the presented fleet system can potentially replace the existing systems at customers. Therefore, the sales potential is n_{all} = 556 800 companies.

4. In order to keep the marketing expenditures in tolerable limits, it is decided that the target companies have to be at least of certain size measured in number of trucks. According to Truckinfo, in the USA 82 per cent of the trucking companies operate with six or fewer trucks (Truckinfo 2009). It is assumed that the same ratio applies also with Canadian trucking companies. Therefore, there are:

$$n_{over6} = \frac{100-82}{100} \times n_{all} = 100\,224$$

companies operating with more than six trucks in North America. However, it is realistic to state that all those companies will not acquire the fleet management system in question. The assumption is that share = 10 per cent of them can be the real number. Therefore, the estimate is $n_{top\text{-}down}$ = 10 022 companies.

5. The last step in the top-down approach involves breaking down the company sales forecast to different geographical areas. However, in this study, it is not necessary as the traded solution is software and does not have to be transported to the customer's premises. Thereby, North America is estimated as a whole. The result of the top-down sales forecast conducted here is $n_{top\text{-}down}$ = 10 022 companies.

In order to gain more confidence to the forecast, a bottom-up sales forecast approach is also applied. The aforementioned theoretical framework for the approach is not strictly followed in this assessment as there is no group of salesmen with estimations available. Instead the potential market size is built from the available number of technicians and the time needed to equip one truck with a terminal device.

It is assumed that there are 50 technicians available for mounting the terminal devices to the trucks and it takes four hours to mount a device to a truck. This includes mounting of a small rack for the device into the truck cabin, GPS receiver and cables between the device and engine and GPS receiver. Also travelling time is included in this mounting time. The aim is that a larger number of trucks of same company are handled at the same trip in order to minimize the time needed for travelling and to reduce the travelling costs.

If a normal working day is eight hours, one technician can mount two trucks a day. If a technician works 47 weeks a year, he/she can mount $5 \times 2 \times 47 = 470$ trucks a year. The assumed lifetime of an embedded PC is four years. If a technician equips the trucks with the terminal devices 47 weeks per year for four years, he/she can reach total of $4 \times 470 = 1\ 880$ trucks. With 50 technicians $n_{t,total} = 94\ 000$ trucks can be mounted in four years. It needs to be found out among how many companies these trucks are being shared. As most of the companies are small and operate only with a few trucks, the average number of trucks per company is low. It is stated in TruckInfo, that 96 per cent of the companies operate with less than 28 trucks and 82 per cent operate with six or less trucks (TruckInfo 2009). Therefore, the average is assumed to be $n_t = 10$ trucks per company. The estimated number of companies is:

$$\mathrm{n_c} = \frac{\mathrm{n_{t,total}}}{n_\mathrm{t}} = 9\ 400$$

This is the bottom-up forecast and it is roughly the same as the top-down forecast of 10 022 companies. The total number of the solution users is also assessed. The number is composed of two sources.

1. Companies operating with more than 28 trucks. According to Truckinfo, 96 per cent of the companies operate with 28 or fewer trucks. If it is assumed that the same ratio applies also with Canadian trucking companies, there are:

$$\mathrm{n_{over28}} = \frac{100-96}{100} \times \mathrm{n_{all}} = 22\ 272 \text{ companies.}$$

2. Companies operating with 28 or less trucks excluding also the companies operating with six or less trucks. This number can be calculated using equation:

$$\mathrm{n_{28less}} = \mathrm{n_{over6}} - \mathrm{n_{over28}} = 77\ 952 \text{ companies.}$$

The assumption is that in companies with more than 28 trucks, there are ten persons using the system. This might sound as a big number in companies with approximately 30 trucks but it has to be noticed that in the larger companies there is potentially much higher number of users than ten. This compensates the big number of estimated users in smaller companies. In companies with 28 or less trucks it is assumed that there are three persons using the system. The total number of users weighed with a realistic share can be calculated using equation:

$$\mathrm{n_{users}} = (10 \times \mathrm{n_{over28}} + \ 3 \times \mathrm{n_{28less}}) \times \frac{\mathrm{share}}{100} = 45\ 658$$

This assessment gives an estimate of how large market there is for fleet management solutions specified for trucking companies. However, this estimate is not used in forthcoming calculations, as the financial calculations are conducted from a single trucking company point of view.

It is assumed that Werner Enterprises trucking company in the USA starts to use the described fleet management solution. Its lifetime was defined to be lt = 20 years. The number of trucks in the Werner Enterprises in the end of 2010 was n_{trucks} = 7 275 (Business Wire 2012). As described earlier, the charging of the system use is based on the number of users of the system there are in a month. In order to determine the costs per month, the monthly fee has to be decided. It is assumed that it is C_{month} = 20 € per user per month. In the following a cost-benefit analysis concerning to the whole investment is conducted. The conventional system concept refers to the system without the fleet management solution.

1. Investment costs

   a) Purchase of equipment

   The trucking company has to purchase a terminal device to each truck. It is assumed the price of one device is C_{dev} = 500 €. Thereby, the total equipment purchase costs are:

   $$\mathrm{C_{eq}} = \mathrm{C_{dev}} \times \mathrm{n_{trucks}}$$

   b) Installation costs

   It is estimated that installation of a terminal device into a truck takes four hours so n_{inst} = 4. Price of one man hour is C_{man} = 50 €. Therefore, the installation costs are:

   $$\mathrm{C_{inst}} = \mathrm{n_{inst}} \times \mathrm{C_{man}} \times \mathrm{n_{trucks}}$$

c) Training

In order to enable successful use of the fleet management system, the users have to be provided with some training. It is assumed that each user is provided with two working days of training and each user uses four days on average for his/her own working time to learn to use the system. Therefore, the amount of hours used in training $n_t = 8 \times 6 = 48$. The assumption is that one hour of work costs $c_h = 50$ €. Thereby, the total cost of training per office employee is:

$$C_t = n_t \times c_h$$

The production losses of office employees during the training are excluded in the calculations. According to TruckFLIX, there are total of 1 406 officers, supervisors, administrative and clerical employees at Werner Enterprises (TruckFLIX 2012). It is assumed that almost all supervisors and half of the officers use the fleet management system. The estimated number of users is $n_u = 400$.

In addition, it is estimated that the truck drivers and helpers also need two days on training to use the terminal device installed to the truck. They also use about one day of working time for training on their own. The total driver and helper training time is $n_{t,dh} = 8 \times 3 = 24$ h. According to TruckFLIX, there are total of $n_{dh} = 10\ 003$ drivers and helpers at Werner Enterprises (TruckFLIX 2012). The assumption is that one hour of driver or helper work costs $c_{h,dh} = 40$ €. In addition, as the truck is not on the road during the training, losses are gained from that time. It is assumed that a lost hour costs $c_{lh} = 80$ € for the company. The cost of a driver or helper training can be calculated using equation:

$$C_{t,dh} = n_{t,dh} \times (c_{h,dh} + c_{lh})$$

Therefore, the total training costs in the company are:

$$C_{t,tot} = n_u \times C_t + n_{dh} \times C_{t,dh}$$

The total investment costs are:

$$C_{inv,tot} = C_{eq} + C_{inst} + C_{t,tot}$$

2. The annual fuel costs in the conventional system

In order to calculate the annual fuel costs, few variables have to be found out. According to Business Wire, the average number of miles each Werner Enterprises truck is driven in a month is 9 970 that is $s_{month} = 16\ 042$ kilometers (Business Wire 2012). The fuel consumption of a truck is dependent on the load, speed and other factors. The consumption typically varies between 34-41 liters per 100 km (Natural Resources Canada 2005). Therefore, it is assumed that the average consumption 35 liters per 100 km that is c = 0.35 l/km. The average diesel price per gallon on 27 February 2012 in the USA was $4.051 (Journal of Commerce 2012). That is:

$C_l = \frac{3.07}{3.7854} = 0.811$ €/l using exchange rates on 2nd March 2012.

The total fuel costs of a truck per year can be calculated using equation:

$C_{fuel,conv} = 12 \times s_{month} \times c \times C_l = 54\ 642$ €

3. The annual fuel costs with fleet management solution

As mentioned, the fleet management solution enables finding the closest vehicle more easily, better route planning, driver instructing to drive more economically and reduction of idle time. It has been notified that by using objective data from fleet management system and personalized coaching, a mean diminution on fuel consumption on short-term period can be 13.6 per cent and six per cent on long-term (Delehaye et al. 2007). In order to avoid being too optimistic about reduction on fuel consumption, it is assumed that four per cent in fuel costs per year are saved. Therefore, fuel saving coefficient c_{fs} = 0.04. The equation to calculate the total fuel costs of a truck per year can be calculated using equation:

$C_{fuel,fleet} = 12 \times s_{month} \times (1 - c_{fs}) \times c \times C_l = 51\ 910$ €

4. Annual maintenance costs with fleet management solution

a) Equipment costs

The estimation of the lifetime for the terminal device was lt_{td} = 4 years. Therefore, the terminal device has to be replaced n_{rep} = 5 times during the system lifetime in average. The total equipment maintenance costs during the system lifetime are:

$C_{eq,maintenance} = n_{rep} \times C_{dev}$

b) Maintenance labor costs

The terminal device replacements and other diagnosis work due to coincidental faults in the system in other parts of the system cause some labor costs. The assumption is that the replacement of a terminal device takes $n_{rep,h}$ = 1 hour. It is estimated that each truck needs n_{fmm} = 12 hours of fleet management maintenance related work caused by coincidental faults during the system lifetime. This includes also the cost caused by the replacements of trucks with new ones and the installations of new trucks with the fleet management related devices. The price of one maintenance hour is C_{man} = 50 €. The maintenance labor costs are:

$$C_{l,maintenance} = n_{rep} \times n_{rep,h} \times C_{man} + n_{fmm} \times C_{man}$$

c) Production losses during maintenance

As the truck is not on the road during the maintenance, it causes production losses. It is assumed that a lost hour costs C_{lh} = 80 € for the company. The equation to calculate production losses is:

$$C_{pl} = n_{rep} \times n_{rep,h} \times C_{lh} + n_{fmm} \times C_{lh}$$

The total maintenance costs during the system lifetime per truck are:

$$C_{maintenance} = C_{eq,maintenance} + C_{l,maintenance} + C_{pl}$$

The costs for one year are:

$$C_{maintenance,year} = \frac{C_{maintenance}}{lt}$$

5. Return calculation

The costs due to the use of the fleet management system per year can be calculated using equation:

$$C_{fm} = n_u \times C_{month}$$

The difference between the fuel costs per truck in the conventional system and the fleet management system in a year:

$$\Delta C_{fuel} = C_{fuel,conv} - C_{fuel,fleet}$$

In addition, data transfer from truck terminal device to central causes some costs. It is assumed that the data transfer cost per month is four euros so per year it is C_{dt} = 48 €. Thereby, the income per year is:

$$I = n_{trucks} \times \left(\Delta C_{fuel} - C_{maintenance,year} - C_{dt}\right) - C_{fm}$$

From the general payback equation a simple payback period can be formulated in the following way:

$$\text{payback period} = \frac{C_{inv,tot}}{I}$$

When the calculations are performed, it results payback period of 2.5 years.
ROI of the investment can be calculated using the equation:

$$\text{ROI} = \frac{I}{C_{inv}} \times 100\% = 39.4\ \%$$

In this case, the discount rate is calculated by dividing the net income by total assets. According to Business Wire, the net income of Warner Enterprises in 2010 was $80 039 000 and total assets were $1 151 552 000 (Business Wire 2012). The division produces ROI = 7.0 %.

The ROI of the fleet management investment is greatly higher than the company's ROI. Therefore, the investment to the fleet management system is very eligible. In addition to ROI, the eligibility of the investment is evaluated using NPV. The result from the NPV calculation is 110 726 415 €, that is greatly larger than 0. Horngren et al. state that only investments with zero or positive NPV are acceptable (Horngren et al. 2007: 727). Thereby the investment is very eligible also from NPV point of view.

The third method for evaluating the eligibility of the investment is IRR. In figure 43, fleet management system NPV is plotted as function of discount rate. From the figure it can be noticed that NPV is zero when discount rate is about 42 %. This is also the value of IRR. In order to calculate the IRR with Excel, the set of annual cash flows (both inflows and outflows) over the investment life cycle has to be passed to the IRR function. The IRR calculated with Excel is exactly 39 %. According to Brealey et al., the IRR rule states that an investment should be accepted if its IRR is greater than discount rate (Brealey et al. 2011, 137). As the calculated IRR was 39 %, that is more than ROI of Werner Enterprises, the investment is noticed to be eligible also when using IRR.

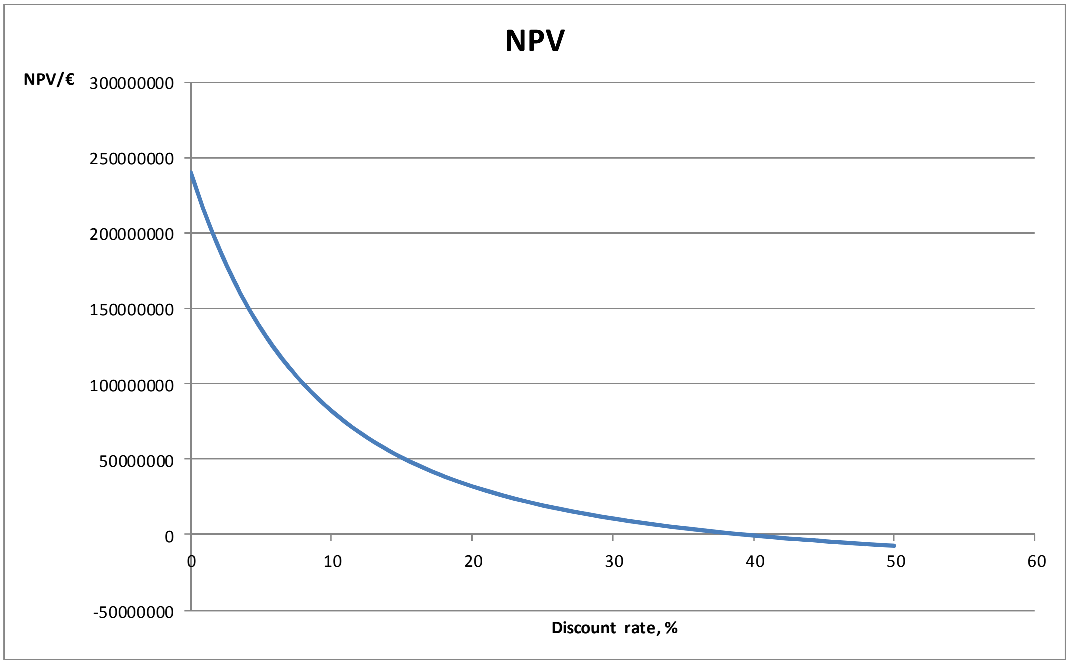

Figure 43 Fleet management system's NPV as a function of discount rate.

In order to assess the effect of fluctuations in different variables on the payback time, sensitivity analysis is conducted with truck kilometers per month, fuel savings per month and fuel consumption per kilometer. Each variable is analysed separately in the following figures. In figure 44, the effect of truck kilometers per month on the payback time is shown with three different assumed fuel saving percentages. As it can be seen, the fuel saving has a dominant effect on the payback time. If the savings are low, the payback time is very long. In that case, the truck kilometers have significant effect on the payback time. On the other hand, if fuel savings are at least few per cent per month its effect on the payback time is lower.

In figure 45, the effect of fuel saving percentage is shown. The same phenomenon as in figure 44 can be seen in this case. The fuel price has a crucial effect on the payback time. As fuel saving increases from one per cent to three per cent, payback time is shortened substantially. When fuel savings are more than three per cent, fuel saving effect is reduced, but still significant. The fuel price does not have that significant effect on the payback time. In figure 46, the effect of fuel consumption on the payback time is shown. In this case it can be noticed again how major factor the fuel saving is. For the investment payback time, fuel saving has a vital role. Fuel consumption has only a minor effect. Monte Carlo simulation is also performed by using the same variables as in the sensitivity analysis to figure out the entire distribution of the payback periods. The values of the variables are changed according to the Normal distribution by using the value that was used in the described basic calculations as midpoint. The results of the Monte Carlo simulation are shown in figure 47. It can be seen that the calculated payback period matches very well with the highest number of the payback periods in the graph. It also indicates that the probability of a longer payback period is very low.

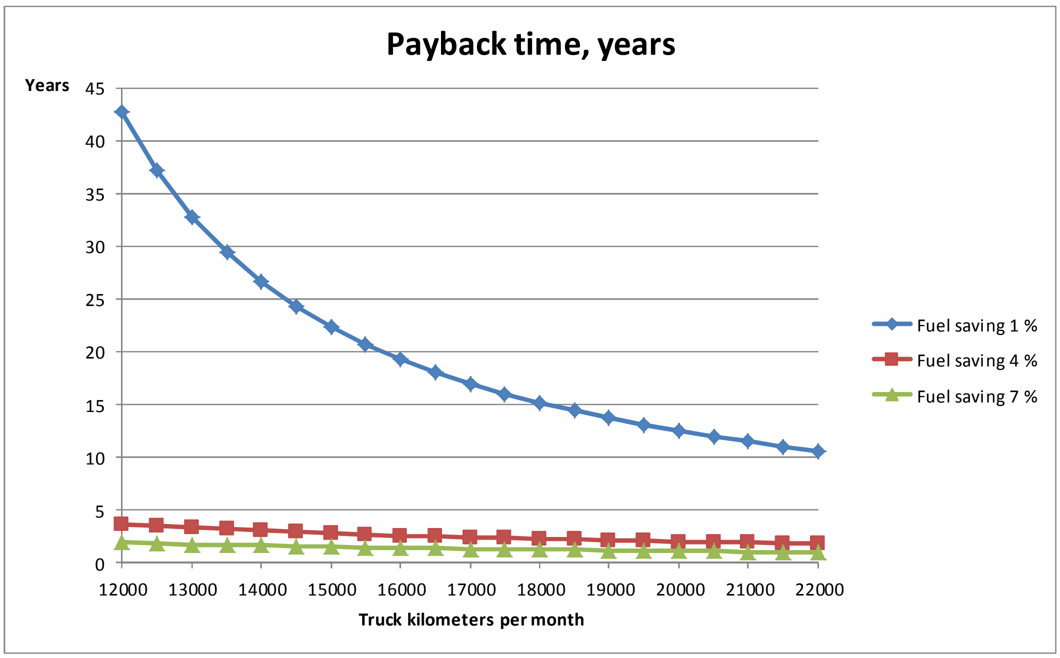

Figure 44 Truck kilometers per month effect on the payback time.

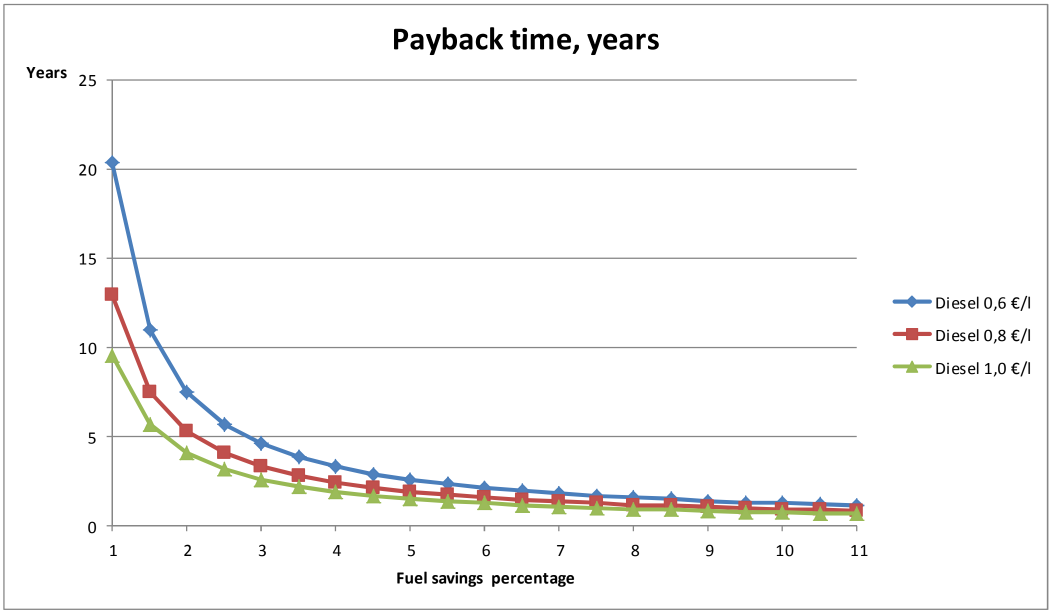

Figure 45 Fuel savings percentage effect on the payback time.

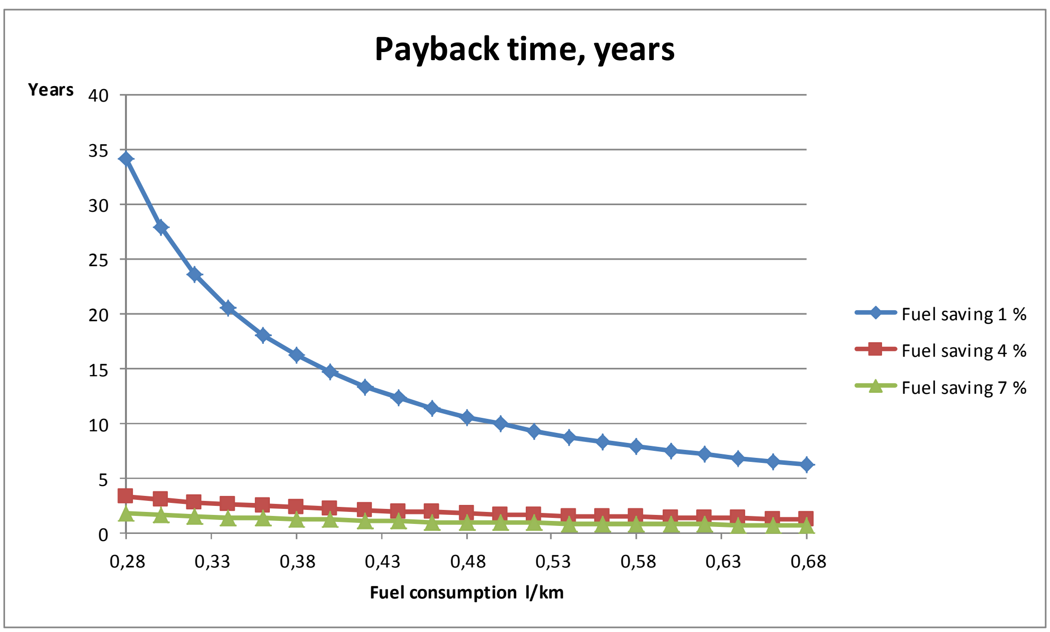

Figure 46 Fuel consumption effect on the payback time.

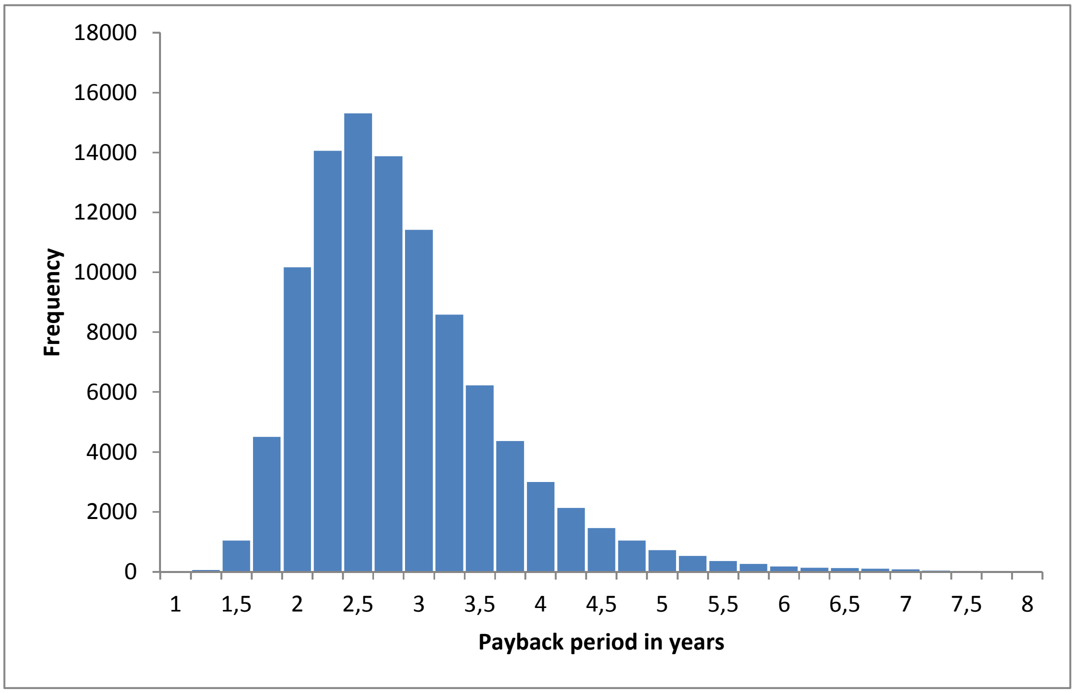

Figure 47 Distribution of the payback periods in the Monte Carlo simulation.

It is also necessary to find out many trucks have to be connected to the fleet management system in order to cover the total costs. Therefore, a break-even analysis is conducted. In order to find out the number of trucks, the present value of inflows and outflows is calculated under different assumptions about number of trucks. The values are shown in table 16. As it can be seen from the table, the NPV is somewhere between 1 000 and 2 000 trucks, as the NPV changes from negative to positive within that range. In order to find a more accurate number of trucks, the present value curves of inflows and outflows are plotted to a graph. It is shown in figure 48. The intersection point of the present value curves is the point where the number of trucks is approximately 1 600.

Table 16 PV of inflows and outflows with different number of trucks.

Trucks	Fuel saving €	Investment €	Variable costs €	Fixed costs €	PV, inflows €	PV, outflows €	NPV €
0	0	30 876 740	0	96 000	0	31 893 765	-31 893 765
1 000	2 185 690	30 876 740	283 500	96 000	23 155 235	34 897 168	-11 741 933
2 000	4 371 381	30 876 740	567 000	96 000	46 310 471	37 900 571	8 409 899
3 000	6 557 071	30 876 740	850 500	96 000	69 465 706	40 903 974	28 561 732

The values of the table are based on the following equations:

Fuel saving $= 12 \times s_{month} \times c \times c_{fs} \times n_{trucks}$ €,

Investment $= C_{inv,tot}$ €,

Variable costs $= \left(12 \times \frac{n_u}{n_{trucks}} \times C_{month} + C_{maintenance,year} + C_{dt}\right) \times \text{Trucks}$ €,

PV, inflows = present value of fuel savings €,

PV, outflows = Investment - present value of variable costs €, and

NPV is the difference between present value of inflows and outflows.

The lifetime in the present value calculations is 20 years and the discount rate 7.0 %.

The accurate break-even point b is solved algebraically by using the equations of the curves of present value of inflows and outflows. The equation for the present value of inflows is:

$$y_{PV,inflow} = k_{PV,inflow} \times b$$

where

$$k_{PV,inflow} = \frac{PV_{inflows[3]} - PV_{inflows[0]}}{\text{Trucks}_{[3]}}$$

The number in square brackets in subscript denotes the row index in certain column in table 16. The first row has index 0.

$$y_{PV,outflow} = k_{PV,outflow} \times b$$

where

$$k_{PV,outflow} = \frac{PV_{outflows[3]} - PV_{outflows[0]}}{\text{Trucks}_{[3]}}$$

A system of equations is composed of the above equations:

$$\begin{cases} y_{PV,inflow} = k_{PV,inflow} \times b \\ y_{PV,outflow} = k_{PV,outflow} \times b + PV_{outflows[0]} \end{cases}$$

By defining the right hand sides of the equations equal, the following equation can be formed:

$$k_{PV,inflow} \times b = k_{PV,outflow} \times b + PV_{outflows[0]}$$

Thereby, the break-even point b is calculated using equation:

$$b = \frac{PV_{outflows[0]}}{k_{PV,inflow} - k_{PV,outflow}} = 1\,583 \text{ trucks}$$

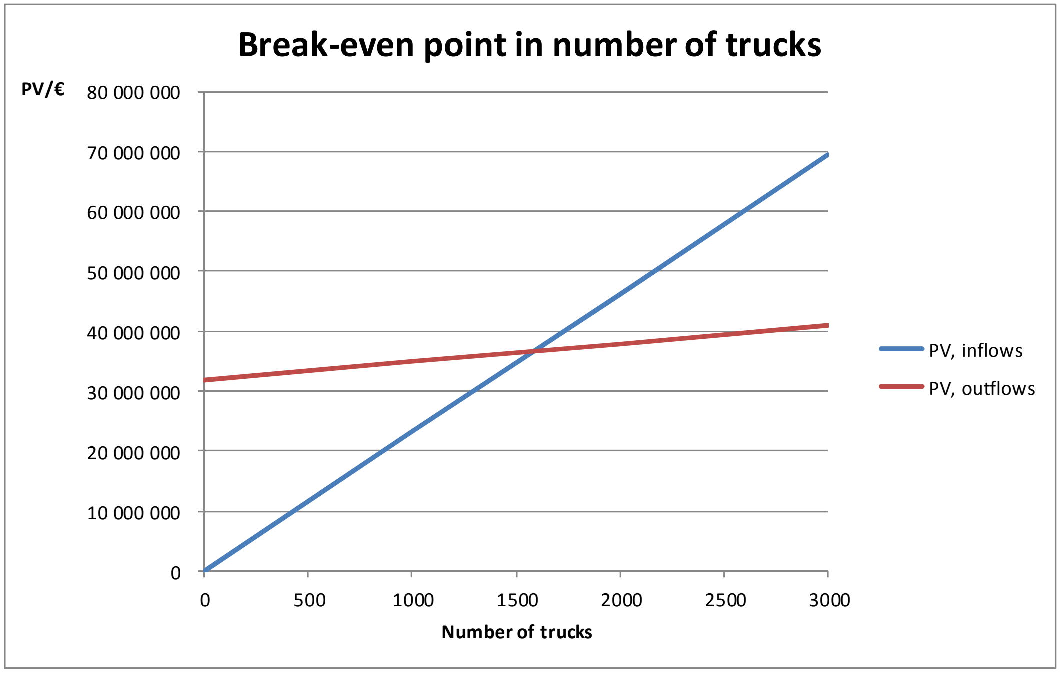

Figure 48 Break-even point in number of trucks.

7.4.5. Summary

In this chapter the common factors of the four presented cases are summed up and analysis is discussed. Table 17 summarizes the most important figures of the presented cases.

Table 17 Summary of the main figures in the cases.

	Remote electricity meter reading system	**Remote water meter reading system**	**CBM**	**Fleet management**
Payback time	5.2 years	13.7 years	8.6 years	2.5 years
ROI	19.4 %	10.2 %	11.6 %	39.4 %
NPV	-51 857 €	-730 923 €	4 033 €	110 726 415 €
IRR	19 %	4 %	10 %	39 %
Discount rate	18.9 %	7.7 %	9.5 %	7.0 %
The significant factors on payback time according to sensitivity analysis.	Equipment and data transfer costs and manual readout time.	Equipment and data transfer costs and manual readout time.	Availability percentage of the wind farm.	Fuel saving percentage and fuel price.
Break-even point	31 066 AMR electricity meters.	7 034 AMR water meters.	Availability percentage 98.9.	1 583 trucks.
Terminal device features	Collects consumption and electricity properties information and sends them to central.	Collects consumption information and sends them to central.	Collects production, status and information on environmental conditions and sends them to central.	Collects fuel consumption, position data etc. and sends them to central.
Central features	Reports, invoicing, user interface for analysis of data.	Reports, invoicing, user interface for analysis of data.	Reports, diagnostics and analysis.	Reports and location of fleet on map.
Terminal device price	200 €	180 €	300 €	500 €

It can be seen from the numbers of remote electricity meter reading system that the payback time is tolerable. As its NPV is negative it indicates that the investment should not be undertaken but IRR indicates the opposite. There are two main reasons for this. Firstly, the discount rate is quite high. This makes it more difficult to gain positive NPV. Secondly, the initial investment to the system due to equipment and installation costs is relatively high. According to DeFusco et al., when making decisions based on NPV and

IRR and if they conflict, IRR should be preferred (DeFusco et al. 2007, 45). From this point of view the investment should be undertaken. As the payback period distribution in the Monte Carlo analysis is very well balanced around the calculated payback period, special risk of a longer payback period cannot be seen. Also for this reason, the investment should be undertaken.

In addition, when considering also other aspects such as environmental issues and the possibility to reduce data transfer costs in future, the investment should be undertaken. Most probably the price per transferred data unit will decrease in conjunction with the development of communication infrastructure. This shortens the payback time and improves NPV values. The conventional solution with manual readout will not be a sustainable option in future due to the growing pressure to reduce greenhouse gases. Private traffic is a major source of carbon dioxide. The more there is manual readout conducted, the more greenhouse gases are released to the atmosphere. Therefore, taking this reasoning into consideration, the remote electricity meter reading investment should be undertaken. The break-even point in terms of installed AMR meters case is very close to the total number of Vaasan Sähkö customers. It means that almost all the conventional electricity meters have to be replaced with AMR ones before the total costs are covered.

In remote water meter reading system the payback time is high. The most significant reason to this is that a large percentage of the meter readouts are conducted by the customers. Therefore, the manual readout staff costs are severely lower than in the remote electricity meter reading system. Even though the discount rate is relatively low, NPV is still strongly negative. However, as it can be seen in the sensitivity analysis, there are certain variables that can have a significant effect on the payback time. In practice, these are also difficult to estimate. For example, the number of manual readout customers is unknown and the time needed for a manual readout is relatively unsure. In case there are many manual readout customers and a readout takes more time than estimated, the payback time may easily halve. Due to this and for the ecological reasons, the investment becomes more appealing. However, as the payback period distribution in the Monte Carlo analysis is slightly skewed to the right and weighed to a longer payback period than the calculated one, the investment should not be undertaken. The break-even point in terms of installed AMR meters is relatively close to the total number of Vaasan Vesi customers. This means that most of the conventional water meters have to be replaced with AMR ones before the total costs are covered.

The payback time in the CBM case is more than a reasonable one. The reason for this long payback time is mainly caused by high equipment costs needed in the CBM solution. Another reason is the relatively low production per wind turbine in a year. According to NPV and IRR the investment should be undertaken. However, the NPV is slightly more than zero even if the discount rate is relatively low. There is a rather big risk that the situation changes so that the investment should not be undertaken, if the decision is based on NPV value. The availability percentage of the wind farm has a major effect on the NPV. It is also a very uncertain factor in spite of the benefits the CBM solution can provide. Minor reduction in availability percentage will turn the investment unprofitable. This is a risk but as there is no evidence why not to undertake the investment and ROI, NPV and IRR indicate acceptance, the investment is worth undertaking. In addition, as the payback period distribution in the Monte Carlo analysis is slightly weighed to the left, it also indicates that the investment should be accepted. The break-even point in terms of availability percentage is very high. It is higher than the assumed percentage that is achievable with the CBM system.

The payback time of the fleet management solution for the trucking company is definitely acceptable. Also ROI, NPV and IRR strongly indicate that the investment should be undertaken. The discount rate is relatively low, but still there is a lot of buffer before the investment becomes worth rejecting. Although there are several uncertain factors such as the number of fleet management system users and the amount of hours needed to train the employees to use it, they have only a minor effect on the payback time. As the sensitivity analysis indicates, fuel saving percentage is the only variable that has a major effect on the payback time. The payback period distribution in the Monte Carlo analysis is well weighed with the calculated payback period and indicates mostly relatively short payback period. Based on these facts, the investment is definitely worth undertaking. The break-even point in terms of number of trucks connected to the fleet management system is very reasonable.

8. CONCLUSIONS

The goal of the thesis was to present and clarify the possible applications for the platform designed in this thesis. In addition, it was realized how little the business impacts of different investments and projects are generally assessed and how challenging it is in many cases. Therefore, a decision support system was also needed in order to provide the means for assessment of business impacts of M2M investments.

As a background for the thesis, an overview of industry standards and applications in M2M was provided. The standards provide a well-defined ground for any solution provider that aims to develop a M2M application. The presented applications point how widely spread M2M-based solutions are nowadays. In addition, investigation of existing fleet management systems was conducted. It was noticed that there are plenty of solutions available. Especially in the USA there are numerous providers, but also a few considerable companies in Europe. Some of them provide turnkey solution from devices to software and even data center services. However, some companies have decided not to design their own hardware, but instead offer support for devices that comply with specific standards.

There are advantages and disadvantages in both options. If a solution provider designs its own hardware, it has all the competence related to the product and allows customization according to customer needs and the availability of a specific device can be guaranteed for a longer period. On the other hand, if the system supports a multitude of standardized devices from numerous manufacturers, it enables the use of widely tested and potentially very mature and stable devices. This may also provide economies of scale opportunities to build the fleet management system with lower costs as the devices are manufactured in larger quantities.

In order to provide a basis for reasoning behind the service model selected for the fleet management solution designed in this thesis, an overview of the most prominent service models was introduced. A brief overview to different methods for sales forecasting was also presented. It was noticed that a top-down approach is easier to apply than a bottom-up approach but it produces less accurate forecasts. In order to ensure a better reliability of the forecast, both methods can be used to assess the same case. If the forecasts deviate greatly, some adjustments should be made to some factors in the forecasts to achieve results that are closer to each other. It was also observed that forecasting involves a lot of assumptions. Therefore, the forecasts are seldom very accurate.

Investment decision methods were also presented shortly. Some of them, for instance payback period and ROI, do not take the time value of money into account. This is significant weakness especially if there are other investment opportunities available for the money or the investment is funded with a loan. However, these methods still can provide an easy and quick indicator whether an investment is eligible.

In the empirical part of the thesis, the presented solution is described on a general level. Some functional and technical aspects are first discussed briefly and the ground for the implementation is defined including high-level architecture and the most important features. Before presenting the estimated project costs, the service model had to be selected. On-premise solution was seen inappropriate as an option as it requires premises, hardware and local support staff. For example, for mid-size and smaller trucking companies this is not an affordable option. In addition, the location-independency criterion is not achievable with an on-premise model. It was noticed that ASP does not support multi-tenancy. Therefore, SaaS was the best option for the service model.

In order to make the fleet management project cost estimation possible, the different development environments, frameworks, programming languages, databases and other implementation-related factors were defined. J2EE platform was decided to be used in the implementation of the central software, WebLogic as the application server, Vaadin as the user interface framework, JasperReports for reporting and Oracle as the database. For the site software, Qt framework was selected for development and SQLite as the database.

In order to provide a deeper understanding from a wider perspective, four practical M2M cases were presented with a detailed cost-benefit analysis and with the use of several investment decision methods. The remote reading system and condition-based maintenance system cases provided additional understanding about the factors that have to be taken into account when creating a decision support system for investing. It was found that the market potential for the fleet management solution is remarkable. In the USA only, the top-down and bottom-up forecasts indicate that there would be more than 40000 users for the solution with a relatively small market share assumption. In these forecasts, the smaller companies with six or less trucks are excluded. They could also provide some additional potential. However, the real potential is waiting on other continents. The use of the system requires only that there is a GSM network infrastructure available in the area where the trucks operate. Moreover, trucking business is only one application for the solution. It could be applied in a multitude of businesses such as shipping, agriculture, forestry and any domain in which vehicles are involved and where location information can be utilized. Regardless of the business, the vehicles share numerous common properties such as fuel consumption, speed, status information and so on.

The presented fleet management solution offers significant financial benefits for any trucking company that uses it efficiently. The benefits are earned from lowering fuel costs that the system enables. In the system, there are several features such as better route planning, fuel consumption comparison between drivers and also idle time minimization, which facilitates to achieve the savings. Even the assumed relatively low saving percentage in fuel costs provided a very appealing payback period of 2.5 years and other metrics proved the investment to be very eligible and profitable for the trucking company. The sensitivity analysis indicated the potential risks concerning the investment. Definitely the most significant factor for the investment profitability is fuel saving. For example, if fuel saving is only one per cent and the average kilometers per truck in a month are slightly lower than average, the payback time can be over 40 years. However, as research proves, there is potential for even larger fuel savings than assumed in this case and thereby a shorter payback time for the investment.

Another potential risk is a combination of low fuel price and low fuel saving. In the worst case, this could raise the payback time close to 45 years. This case will not be very likely as there is rising trend in fuel price. The third risk realizes if the fuel consumption per kilometer decreases significantly from the expected and fuel saving is only close to one per cent. The fuel consumption per truck is likely to decrease during the forthcoming years as there is growing pressure towards environmental issues. The automotive manufacturers are pushed to develop engines consuming less fuel. On the other hand, this risk is not assumable as the effect of the fuel consumption is dramatically decreased when the fuel saving percentage is at least few per cent. For example, with fuel saving of four per cent, the payback time is less than five years even with low fuel consumption.

However, the other three presented cases showed that an investment to a M2M system is not automatically profitable for a company. The remote electricity meter reading and remote water meter reading cases are both ineligible in terms of NPV. The first case is eligible according to IRR result and its payback time is relatively short. In both cases, ROI indicates that the cases are eligible. As ROI does not take the time value of money into account, it is not being accentuated in the decision-making process. As it can be seen, the metrics produce contradictory indication whether an investment should be made. Thereby it is necessary to use several methods instead of staring at a single number. Despite the numerical results, the conventional systems involving a lot of manual labor and use of vehicles will be less-favored. The tightening competition between companies will require the companies to optimize the labor costs and minimize the use of vehicles. Also the trend towards energy-efficient operations reduces the favor of conventional systems. A major driving force in remote reading business is government mandates as they are increasingly requiring use of AMR or AMI systems. This enables economies of scale benefits in meter prices as larger quantities of devices are manufactured. The development of wireless data transfer technologies enables transfer of more and more data with lower costs. Also this favors the deployment of AMR and AMI based systems.

The eligibility of CBM investment is heavily dependent on the wind farm availability percentage. All the financial metrics indicate that the investment should be undertaken, even though the payback period is relatively long. A reason for this contradiction is the discount rate. With few per cent higher discount rate, NPV and IRR would turn the investment totally ineligible. From these points of view, this investment seems risky. However, as the wind energy becomes more and more favored due to its renewability and environment-friendliness, more and more wind turbines and remote monitoring and analysis systems are produced. This enables reduction of prices and facilitates the investments to the wind farm CBM systems.

Some challenges for the use of fleet management solution can be designated. As noticed, the financial investment itself is not significantly large for a trucking company from payback period point of view, but the most likely problems will occur related to the users of the system. For many experienced supervisors it may be difficult to change the working routines they have applied for several years. Some of them may be reluctant to use the new system that may look complicated at the first sight. Few may also experience that they have no time to attend to the training or use their own time to get familiar with the system. These obstacles could be overcome by encouraging to the use of the system and with a good reasoning including the potential to gain some competitive advantage over competitors due to lower fuel costs.

The created decision support system is a comprehensive tool for any manager involved in investment planning. The system contains several methods which can be used to assess the eligibility and profitability of an investment. It was tested with several practical cases from different M2M domains and no large weaknesses were found. The methods are easy to use and the data needed in calculations are relatively easy to collect. For these reasons, it can be stated that the decision support system is successful. However, there is no system that provides the understanding of the application domain. The user of the decision support system still has to be familiar with the most important factors that affect the results that the methods in the system produce.

Some factors concerning to the validity of the results can be designated. For example, when potential market size is assessed, it involves a lot of assumptions. There is no waterproof method to find accurate values to the assumptions. Experience in the application domain helps minimizing the forecast errors. In the four cases presented in the thesis, the aim has been to use preferably more realistic assumptions instead of overly optimistic ones. Many factors are also based on the values from existing real-life cases. In the decision support system, payback period and ROI calculations do not take the time value of money into account and may produce slightly more optimistic values compared to the situation in which the time value of money is taken into account. However, the other methods contain the time value of money in the calculations and thereby make the overall judgment from the decision support system more realistic.

Even though a lot of effort and concentration was put in this thesis, there are still a lot of opportunities left for further research. All the presented cases are based on material from scientific articles, web-pages of numerous companies, books and the writer's own understanding. Much more additional understanding and expertise could be gained by interviewing managers and staff from companies in different M2M domains. The most reliable insights to the prominent factors in different businesses can be obtained only by working several years in the business in practice. In addition, the research could be extended to entirely new area to cover also the eligibility and profitability of service provider investments.

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APPENDICES

Appendix 1. Work estimations for the solution

Table 18 The solution's estimated project management in work days.

Tasks	Estimation in work days
Project management	
Coordination of the work	25
Meetings	30
Other	20
Total	**75**

Table 19 Estimated central software implementation in work days.

Tasks	Estimation in work days
Specifications	
Project plan	3
Requirement specification	8
Technical specification	20
Test specification	10
Test report template	7
Specification meetings	25
User guide	12
Set-up	
Configuring database system	15
Setting up development environment	10
Fleet management	
Main view for fleet management	3
User management view	5
Customer information management	5
Fleet data management	5
Asset data management	4
Measurement point management	6
Configuration management	8
Vehicle tracking	
Main view for vehicle tracking	6
Integrating Google maps to the user interface	5
Handling and viewing detailed vehicle information	4
Reporting	
Management view for reporting	4

Integrating JasperReports to the user interface	5
Integrating iReport to the user interface	4
Testing	
Implementation of unit test code	40
Integration testing	20
System testing	20
Total	**254**

Table 20 Estimated Site core implementation in work days.

Tasks	**Estimation in work days**
Specifications	
Requirement specification	6
Technical specification	18
Test specification	15
Test report template	10
Specification meetings	25
User guide	8
Data fetching	
OPC interface	15
Data filtering	20
Database interface	18
Data sending to central	
Central communication interface	15
Data sending process	5
Database interface	8
Providing service to Site GUI	
Site GUI communication interface	15
Database interface	15
Backup of site data	
Backup process	8
Database interface	7
Testing	
Implementation of unit test code	30
Integration testing	15
System testing	25
Total	**278**

Table 21 Estimated Site GUI implementation in work days.

Tasks	Estimation in work days
Specifications	
Requirement specification	10
Technical specification	20
Test specification	15
Test report template	12
Specification meetings	20
User guide	15
Login	
Login screen	3
Secure user account handling	5
User management	
Management views	5
Database interface	4
Secure storage of user accounts	5
Dashboard	
Dashboard view	3
Management of dashboard content	5
Database interface	3
Assets	
Management view for assets	7
Hierachial view of assets and measurement points	3
Search for assets and measurement points	3
Graph component	40
Database interface	15
Issues	
Management view for issues	5
Communication interface to central	6
Database interface	4
Logbook	
Management view for logbook events	7
Database interface	3
System update	
Management view for system update operations	4
Approve configuration	8
Reject configuration	2
Revert to previous configuration version	8
Approve software update	12
Reject software update	2
Database interface	3

Offline communication	
Management view for offline communication	3
Upload of offline packets	7
Download of offline packets	7
Database interface	4
Status	
Management view for status	3
Internal message handling system	4
Database interface	3
Multilingual	
Enabling multilingual support in the user interface	2
Handling of language files	7
Testing	
Manual user inteface testing	20
Integration testing	20
System testing	15
Total	**352**

Appendix 2. Octave source codes for the Monte Carlo simulations

amr_electricity.m - Monte Carlo simulation for remote electricity meter reading system.

```
#Number of samples in simulation.
samples=100000;
#Total number of meters.
meters=31211;
#Annual readout costs in the conventional system.
creadout=1188000;
#Annual field staff costs in the conventional system.
cfieldtot=72000;
#Annual vehicle costs the conventional system.
cvehicles=624240;
#Annual data handling personnel costs.
cdtot=300000;
#The price of an AMR meter.
Cmeter=200;
#Installation material for an AMR meter.
Cmaterial=50;
#Installation cost for an AMR meter.
Cinstmeter=60;
#Annual data center costs.
cdc=10000;
#System lifetime in years.
lt=20;
#Data transfer costs according to the Normal distribution.
ctransfer=0.5+0.1*randn(1,samples);
#Total investment costs of an AMR meter according to the Normal distribution.
CinvMeter=Cmaterial+Cinstmeter+Cmeter+20*randn(1,samples);
#Maintenance costs of an AMR meter during its lifetime according to the Normal distribution.
CAMRMaintenance=70+10*randn(1,samples);
#Annual maintenance costs of AMR meter per unit.
CAMRMaintenanceYear=CAMRMaintenance/lt;
#Total annual savings.
Cs=creadout+cfieldtot+cvehicles+cdtot;
#Annual income.
I=Cs-cdc-meters*(CAMRMaintenanceYear+12*ctransfer);
#Total investment costs of the AMR system.
CtotAMR=CinvMeter*meters;
#Payback period in years.
payback=CtotAMR./I;
```

amr_water.m – Monte Carlo simulation for remote water meter reading system.

```
#Number of samples in simulation.
samples=100000;
#Number of manually read customers according to uniform distribution.
nmanual=transpose(200+1400*rand(samples,1));
#Total number of customers.
nc=8815;
#AMR meter price according to the Normal distribution.
Cmeter=180+20*randn(1,samples);
#AMR meter purchase price with material costs per unit.
Ccostmeter=Cmeter+70;
#AMR meter installation costs.
cinstmeter=60;
#Annual data center cost.
cdc=8000;
#AMR meter investment costs.
cinvmeter=Ccostmeter+cinstmeter;
#Lifecycle of the system in years.
lifecycle=20;
#Annual vehicle costs due to readout.
cvehiclesreadout=18000;
#Annual data handling costs.
cdtot=240000;
#AMR meter maintenance costs during the system lifetime according to normal distribution.
CAMRmaintenance=80+15*randn(1,samples);
#Annual AMR meter maintenance costs.
CAMRmaintenanceYear=CAMRmaintenance/lifecycle;
#Number of minutes an AMR meter readout takes.
tonereadout=20;
#Number of employees needed to conduct the manual readout.
nemployees=nmanual*tonereadout/60/8/(20*3);
#Number of working hours per employee in a month.
temployees=150;
#Total hour price of a readout employee.
cemployee=30;
#Annual readout costs.
creadout=nemployees*temployees*cemployee*12;
#The annual savings due to use of AMR system.
Cs=creadout+cvehiclesreadout+cdtot;
#Monthly data transfer costs.
ctransfer=0.5+0.1*randn(1,samples);
#Annual income due to the use of AMR system.
I=Cs-cdc-nc*(CAMRmaintenanceYear+12*ctransfer);
#AMR system total investment costs.
CtotAMR=cinvmeter*nc;
#Payback period in years.
payback=CtotAMR./I;
```

cbm.m – Monte Carlo simulation for Condition-based maintenance system.

```
#Number of samples in simulation
samples=100000;
#Number of wind turbines.
nw=8;
#Price of analysis equipment according to the Normal distribution.
canalysis=18000+2500*randn(1,samples);
#Price of an installation equipment including material and controller price.
cinst=canalysis+300+500;
Chub=200;          #Price of a hub.
Crouter=150;       #Price of a router.
Cserver=1000;      #Price of a server.
Csoftware=5000;    #Price of server software.
#The CBM equipment costs for the whole wind farm.
cequipment=nw*cinst+(2*Chub+2*Crouter+Cserver+Csoftware);
#The total installation costs of the CBM system.
cinsteq=nw*1500+1000;
#The total investment of the equipment and installation for the wind farm.
cinv=cequipment+cinsteq;
#Annual replacement costs in the wind farm.
Crepyear=331000;
#Annual scheduled maintenance costs.
Csch=2*50*7*nw;
#Annual unscheduled diagnosis work hours per turbine.
ndiag=12;
#Annual maintenance hours per turbine.
nmaint=16;
#Annual unscheduled maintenance costs in the wind farm.
Cusch=50*(ndiag+nmaint)*nw;
#The annual wind farm energy production in MWh at 97.5 per cent availability rate.
E=15000;
#The annual energy production if availability percentage is 100.
Emax=(E/97.5)*100;
#Energy price in euros according to the Normal distribution.
Pe=92+7*randn(1,samples);
#Annual production loss costs in the conventional system.
Cplconv=(Emax-E).*Pe;
#The assumed availability percentage.
avail=98.8;
#Diagnosis work percentage with CBM system according to the Normal distribution.
diag=30+6*randn(1,samples);
#Annual unscheduled maintenance costs in the CBM system.
CuschCBM=50.*(diag/100*ndiag+nmaint)*nw;
#Annual energy production in MWh when CBM system installed.
ECBM=avail/100*Emax;
#Annual production loss costs with the CBM system.
CplCBM=(Emax-ECBM).*Pe;
#Total annual costs in the conventional system.
Ctotconv=Crepyear+Csch+Cusch+Cplconv;
#Total annual costs in the CBM system.
CtotCBM=CuschCBM+Crepyear+Csch+CplCBM;
#Fixed costs due to replacement of the IT equipment.
fc=2000;
#Annual income due to the use of CBM system.
Iyear=Ctotconv-CtotCBM-fc;
#Payback period in years.
payback=cinv./Iyear;
```

fleet.m – Monte Carlo simulation for Condition-based maintenance system.

```
#Number of samples in simulation.
samples=100000;
#Total number of trucks in the company.
trucks=7275;
#Annual maintenance costs in euros per truck.
maintenanceyear=235.5;
#Fuel price €/l.
fuelprice=0.811;
#Annual data transfer costs per truck.
datatransfer=48;
#Monthly fleet management system costs.
fm=8000;
#Monthly truck kilometers according to the Normal distribution.
km=16042+1500*randn(1,samples);
#Fuel saving percentage according to the Normal distribution.
fuelsaving=4+0.7*randn(1,samples);
#Fuel consumption l/km according to the Normal distribution.
fuelconsumption=0.35+0.04*randn(1,samples);
#Annual fuel costs in the conventional system.
Cfuelconv=12.*km.*fuelconsumption*fuelprice;
#Annual fuel costs when using the fleet management system.
Cfuelfleet=12*(1-fuelsaving/100).*km.*fuelconsumption.*fuelprice;
#Difference in the annual fuel costs between the systems.
deltafuel=Cfuelconv-Cfuelfleet;
#Annual income due to the use of fleet management system.
income=trucks*(deltafuel-maintenanceyear-datatransfer)-fm*12;
#Payback period in years.
payback=34861140./income;
```