A B2B case study on intelligent transport systems

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Intelligent Transport Systems (ITS) is a field that concerns the applying of information, communications and control technologies to improve the transport network and its operations. A part of this process is the utilization of vehicle telematics, i.e., the use of in-vehicle devices for the purposes of communication and data transfer.

This thesis focuses on the various aspects of intelligent transport systems. It introduces the main technologies of ITS, the focus points of national research on the area, and also some real-life applications currently either in use or in development. Thought is also given to the business challenges related to product-related services and multi-sector innovations, both of which are prevalent in the field of ITS.

The core of this thesis consists of a practical case study in business-to-business ITS. The case study involves designing and implementing an information system for gathering weighing data wirelessly from wheel loaders. The system was delivered to a Finnish company that does business in, e.g., supplying hardware for heavy-duty vehicles.

Keywords: intelligent transport systems, ITS, vehicle telematics
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1. Introduction

During the past decades the automotive industry has been no stranger to adopting innovative technologies to be integrated into vehicles either directly at the manufacturing phase or via aftermarket add-ons. The driving safety has been improved with proximity sensors, new diagnostics routines have been developed for dealing with malfunctions, and the vehicles’ user interfaces are becoming more sophisticated and are evolving towards a higher degree of multimodality [Gusikhin et al., 2007].

Additionally, one of the defining characteristics of the industry has been technological convergence, which Bernabo et al. [2009] define as “the trend of products once having distinct functionalities coming together to form a single, multi-use product or service”. While at one time the technological focus of attention had been more strictly on improving the driving experience itself, in the course of time the focus has shifted more and more towards developing cross-purpose vehicular solutions to meet the new needs of the customer base.

These points illustrate that for manufacturers and consumers alike it has become natural that vehicles contain advanced and diverse technology, which in turn has provided a favorable environment for third-party vendors to develop and distribute their own vehicle-related innovations.

This thesis focuses on the aspects of the vehicular solutions that are categorized as intelligent transport systems (ITS). The goal of this thesis is to approach the subject from different angles and also from both theoretical and practical standpoints. The theoretical sections cover the technological and business-related aspects of ITS solutions, i.e., what kind of technologies form the foundations of ITS and what challenges are involved from a business point of view. The sections related to practice describe existing ITS solutions and also demonstrate the technical implementation of one ITS application related to business-to-business fleet telematics. By covering the area of ITS from all of these perspectives it is possible to better provide a comprehensive overview of the field.

The structure of this thesis is as follows; Chapter 2 continues where the introduction left off and goes into more detail regarding the research topic. It lays the foundations for the rest of the thesis by describing the research methods used and introducing the business case.

Chapter 3 covers the nature of intelligent transport systems and vehicle telematics, and describes four applications in the field of ITS. It also introduces four Finnish research programmes that have been organized by the Ministry of Transport and Communications. Finally, it discusses the business challenges of
ITS that are related to its multi-sector nature and tendency to consist of product-related services in environments where the amount of uncertainty is high.

Chapter 4 introduces the technologies that form the core of intelligent transport systems, i.e., methods for acquiring positioning information and transferring data wirelessly.

Chapter 5 is dedicated to a case study where a small-scale fleet telematics system was developed to meet the needs of a Finnish company that provides industrial machinery solutions such as weighing-related hardware to be used in wheel loaders. Chapter 6 summarizes and evaluates the work done and provides the conclusions of this thesis.
2. Research methods and the business case

In the background of this thesis there is a hands-on approach to a specific business-to-business vehicle telematics business case. As such, this thesis is largely based on a case study concerning this specific project. This chapter introduces the theoretical background behind a scientific case study, and then continues to describe the nature of the business case.

2.1. On case study methods

Järvinen and Järvinen [2004] define case study as a research method that can focus either on a single or multiple subjects. A case study utilizes questionnaires, interviews, observations and the use of existing material as methods of acquiring information. The authors refer to works by Cunningham [1997] who has introduced four approaches to data gathering in case studies. These include narratives, tabulations, explanations and interpretations.

Cunningham states that narratives are used when summarizing, for example, interviews and meetings, whereas tabulation is a more quantity-based approach for determining how many times a certain event has occurred. An explanatory case study provides accurate, factual information that responds to the questions the researcher has posed. In contrast, an interpretative case study can be “less rigorous and more provocative” when supplying new examples, ideas and approaches.

Reflecting the case study of this thesis in the light of Cunningham’s four methods it can be concluded that tabulation is the only characteristic that did not apply to any extent in the data gathering process. Narratives were used to a very small extent, mainly when recapping the contents of the summary-related phone meeting that took place with the client at the final stages of the project. The main focus of the case study of this thesis was on the explanatory and the interpretative approaches.

Cunningham refers to the explanatory case study method as “illustrating a certain point of view and offering details for the concepts behind them”, which in this case translates to providing one possible implementation of a fleet telematics system and supplying information to justify the design decisions that were made during the process.

However, even though the case study of this thesis has a strong foundation in the explanatory approach, a part of it could also be argued to be interpretative instead of explanatory. The reason for this is that the case study in this thesis does not claim to provide a generalizable solution that could therefore be applied different companies in different contexts within the field of
ITS. Instead it is more, as Cunningham describes it, a “testimony of success of a certain individual or company”.

2.2. The business case

The business case presented in this thesis was related to a real-life commercial application in intelligent transport systems. It involved developing software for a Finnish company that does business in, e.g., supplying different kinds of weighing-related hardware for wheel loader vehicles.

I focused on this project while working at AutoMaint, a research and development centre that operates within HAMK University of Applied Sciences in Valkeakoski, Finland. The role of AutoMaint is to act as a business supporter for the Finnish industry. Its core competences are related to making companies’ production activities more effective with the help of automation, information systems and utilization of business-related know-how. AutoMaint collaborates with both the public and the private sectors and currently employs a staff of approximately 35 persons.

For reasons of confidentiality, in this thesis the developed software is identified by the name ScaleLink. The aim of ScaleLink was to provide a comprehensive information system that would handle the following three high-level tasks:

- to gather weighing data from the wheel loaders of various contractor firms and transfer the data wirelessly to a central server.
- to make the gathered weighing data available online and disseminate it to all relevant user groups.
- to provide the contractors with the option to create different kinds of reports of the received data.

From the perspective of the client, the goal was to achieve an information system that they could add to their product portfolio and sell alongside their existing hardware-based solutions.

2.2.1. The elements of B2B

Since the intention of the client company was to sell ScaleLink to contractor firms, the nature of case was oriented towards the business-to-business (B2B) sector. B2B refers to commerce that takes place between businesses, as opposed to B2C (business-to-customer) where there is always a private individual involved. In either circumstance the commerce can consist of information, goods or services [Hinkelman, 2008].

The B2B market has a number of identifying characteristics that make it differ from the consumer market. In B2B the goal of the purchase is to satisfy
organizational needs instead of individual ones, and the purchase volumes are considerably larger. Consequences of poor purchases can be critical to the operation of the business, and the costs of switching suppliers along the way are larger than in the B2C markets. The promotional tools are based more on interpersonal relationships and tailored selling efforts rather than advertising and mass-marketing [Fill and Fill, 2005].

In many cases the products and services that are offered to the buyers are the same in both B2B and B2C markets. For example, catering services and office equipment are utilized by both sectors. However, in the case of ScaleLink the target group was clearly the business sector since the information system required specific industrial hardware to work.

2.2.2. Perceived benefits and selling points of the system

For the contractor firms to become interested in a new information system it would be required to provide some kind of added value compared to their current way of handling their business. In this case it was evident that the system, once completed, would benefit the purchasing firms. For the contractors the most important feature of the new system was the ability to derive specific pieces of information from the gathered weighing data, e.g., how much sand was loaded at a specific site on a given date, who was operating the vehicle, and to which customer the load was designated. Prior to ScaleLink this information was not readily available.

The old system did have support for printing out a receipt for one weighing or, for example, a summary of one day’s work for a specific wheel loader. However, it was not possible to generate reports based on specific filter criteria or to visualize information that reached a longer time frame. Additionally, the information was not centralized, but instead, all the receipts came from the individual weighing units that were installed in the cabins of the wheel loader vehicles.

This, in turn, led to the need to gather all the needed information from the individual receipts manually, and all calculations had to be done by hand in a separate program, such as Microsoft Excel. This involved an enormous amount of extra work and was also prone to errors if, e.g., some of the individual receipts got misplaced in the process.

In addition to easing the workload of the end-users, the ScaleLink system has also another benefit related to traceability. Since the system acts as an automatic logger of weighing events, it gives the option to easily track back any possible weighing errors – something that was not possible in the old receipt-based system.
Hence, the business case behind the project was rather solid – ScaleLink had the potential to become a product-related service that complements the client company’s existing product portfolio well, and the application area was within the client’s core competences.

Another reason why the business case was very promising was the fact that the system was easy to market to the end-users in the contractor firms. The representative of the client company estimated that approximately 75 per cent of the contractors realized the benefits this type of system would give. Some of them had already requested similar features, and others, in particular those individuals who had to sort out the paper receipts, were relatively easy to convince that a system like ScaleLink would clearly save them considerable time and effort in both short and long-term.
3. Overview of intelligent transport systems

Bunn et al. [2002] define intelligent transport systems as the process of applying information, communications and control technologies to improve the transport network and its operations. Additionally, the authors define vehicle telematics as the use of in-vehicle devices for communication purposes.

These two concepts form the foundations of this thesis. While the terms are quite similar in nature, vehicle telematics can be considered to be the more technology-oriented of them. ITS is a slightly broader concept that has relevant aspects across multiple domains: creating an ITS solution consists of more than just solving the technological issues, and improving the transport network requires, e.g., co-operation with numerous stakeholders from different domains.

3.1. Examples of existing solutions

Along the years numerous companies working on fields ranging from computing to car manufacturing have been working on telematics-driven information systems. The application areas of these systems have included, e.g., tracking of asset management and fuel consumption as well as developing tools for the planning of security, service and maintenance of vehicles [Schwartz, 2003].

Lenfle [2008] classifies vehicle telematics services into two subcategories. The first emphasizes new features that are based on onboard technology. The second considers vehicle telematics to be a platform for enhancing customer relationship management by providing a channel for manufacturer-customer communication. This section introduces a few of the onboard technology-based services that have either already become popular or have a good chance of doing so.

3.1.1. eCall and bCall

eCall, short of emergency call, is a telematics system designed to help improve safety on the road. When a road accident occurs, eCall can automatically send the location of the vehicle and other relevant information to the nearest emergency response centre [Scholliers et al., 2008]. The system also forms a voice connection to the rescue center to make communication possible also in the cases where the accident has made the passengers incapable of movement. An important aspect is the level of standardization that should guarantee that the system will work anywhere in Europe [European Commission, 2009].

eCall is expected to cut down the emergency teams’ response time by 40 to 50 per cent depending on whether the accident happens in urban or rural areas.
Consequently, the system is expected to save 2500 lives each year and help mitigate the severity of tens of thousands of injuries. Faster arrival to the location site is also expected to reduce the time needed to clear the crash site, thus preventing secondary accidents from happening [European Commission, 2009].

bCall, short of breakdown call, works much the same way as eCall, only the contents of the dispatched data are different. The idea of bCall is to alert the nearest support centre in the event where a vehicle is experiencing a technical malfunction on the road [Scholliers et al., 2008].

eCall and bCall have the potential of becoming the so-called killer application of the ITS field, i.e., a new solution that is considered both necessary and desirable and thus makes the platform itself more popular as well. The support from the European Commission helps the technology to become more widely accepted and subsequently to demonstrate the potential of the whole vehicle telematics platform. This process would also help in clearing the way for other telematics applications.

3.1.2. Pay-As-You-Drive insurance system

The trademark Pay-As-You-Drive was introduced by Norwich Union (currently known as Aviva), a British insurance company, and similar concepts have been also developed by a number of other businesses in the field of vehicle insurance. In PAYD a telematics device gathers information about the vehicle’s movements and the driver’s driving habits. These are reflected on the insurance fees, and the car owners can achieve considerable savings when they opt to drive less [Scholliers et al., 2008].

If eCall becomes a widely accepted standard in Europe, it provides a good platform for growth of usage-based insurance systems since the required hardware will already be pre-installed in the vehicles. It has been estimated that the market could expand to up to seven million devices by 2015 if eCall becomes reality [Scholliers et al., 2008]. This will help develop new business models for the industry that are no longer based on fixed monthly or annual fees.

Additionally, a system that encourages people to drive less with their cars can be seen as an improvement from an environmental perspective as well. With the public opinion shifting more and more towards favoring the green values, this has the potential of becoming another advantage when competing on the market.
3.1.3. LoJack theft recovery system

One type of intelligent transport solutions that have become more widely used are the various Stolen Vehicle Recovery (SVR) systems, one of which is LoJack provided by a U.S. based company LoJack Corporation. The concept of the system is not to replace the traditional car alarm itself but rather offer additional features by working in conjunction with the information systems of law enforcement agencies [LoJack, 2007].

Once a vehicle has been reported stolen by the owner the law enforcement computers begin to transmit a radio signal using the radio tower network of LoJack. After the unit in the stolen vehicle receives this signal, it begins to emit a tracking signal of its own. This signal can then be traced by police cars and helicopters that are equipped with LoJack tracking computers.

It has been argued that the features of anti-theft systems could be easily integrated into GPS navigation units, but the separate systems such as LoJack have the advantage of concealment. GPS devices are located on the console of the car whereas LoJack units are hidden in the vehicle chassis in non-standardized locations, making them considerably harder for the thief to detect [Hindo, 2006]. Additionally, GPS requires line of sight to the navigation satellites, whereas a radio signal can also penetrate walls and forest cover [LoJack, 2007].

The reported usage and recovery statistics indicate that the company has more than eight million SVR units installed worldwide, a record of having tracked and recovered 250 000 vehicles and consequently having recovered assets worth five billion U.S. dollars [LoJack, 2007].

While sales-related statistics supplied by a company itself should be taken with a grain of salt, they still demonstrate the business potential that ITS solutions related to vehicle recovery have. The advantage LoJack possesses is that they co-operate with the authorities, which both gives the system a considerable amount of credibility and also clearly improves the system efficiency and rate of recovery.

3.2. R&D by the Ministry of Transport and Communications

Conducting research on intelligent transport systems has sparked interest also at the national level. A point has been made that in countries such as Finland where the population is relatively small and the vehicle volumes are low, the public sector should take on the role of an R&D facilitator in ITS-related matters. Otherwise, it can be difficult for the private enterprises to be able to provide ITS services and the required infrastructures on their own [Roine and Kulmala, 2003].
Finnish Ministry of Transport and Communications (MinTC) has organized four consecutive research and development programmes that have had their main focus on ITS. The programmes have been joint efforts with stakeholders such as the VTT Technical Research Centre of Finland, cities, municipalities, and enterprises working on the field of ITS.

3.2.1. TETRA
The first programme was labelled TETRA (Liikenteen Telematiikan Rakenteiden Kehittämisohjelma, i.e., a programme on developing the structures of vehicle telematics), which ran from 1998 to 2001.

The goals of TETRA were to develop the structures of transport telematics in Finland in order to lay the foundations for producing services on the field in the future. Consequently, the results did not consist so much of new telematics-related services; the focus was mainly on preparing specification documents and increasing communication and understanding between the stakeholders. The main results were reaching the following milestones [Kulmala et al., 2001; MinTC, 2002]:

- Finish the pilot program for DIGIROAD road and street information system.
- Port@net maritime information system covered the sea traffic of whole Finland.
- Standard interfaces were defined for the mediation of traffic-related information.
- A national system architecture on vehicle telematics was produced.

3.2.2. FITS
During 2001-2004 the second programme, FITS (Finnish R&D Programme on ITS Infrastructures and Services), carried on from where TETRA left off. Its aims were to continue increasing Finnish ITS expertise and to develop commercial transport-related services and the required underlying architectures. [Roine and Kulmala, 2003; MinTC, 2004].
Figure 1 shows the eight focus areas of FITS, and according to the final review report the programme achieved concrete results in each of them. The projects within the focus areas were as follows [FITS, 2007]:

- **FITS 1: Prerequisites for services**
  - ITS architectures for freight and maritime transport.
  - The national co-operative ITS forum ITS Finland.
  - The transport data exchange library kalkati.net.
  - Format specifications for Traffic Management Centre data.

- **FITS 2: Impacts, costs and benefits, user requirements**
  - Guidelines for the evaluation of ITS projects and several evaluation studies.

- **FITS 3: Monitoring**
  - The mobile-phone-network-based travel time service.
  - Short-term travel time and traffic status prediction models.

- **FITS 4: Incident management**
  - The automated data transfer system between Emergency Response Centres and Traffic Management Centres.
  - Incident management operations models for road, railway and maritime traffic.

- **FITS 5: Traveler information**
  - The public transport service portal.
  - Public transport passenger information services in many cities.
• **FITS 6: Intelligent control**
  - Advanced traffic signal control systems in many cities.
  - Environmentally friendly pedestrian signals.
  - The realization of forced signal priorities for emergency vehicles.

• **FITS 7: Speed management**
  - The recording vehicle speed adaptation system.

• **FITS 8: Terminal operations**
  - The terminal announcement procedure for PortNet maritime information system.

In addition to the projects mentioned, the results of the programme included service trials and field tests as well as dozens of research, survey and project reports. At the final stages of the programme it was evaluated by experts in the area of transport, and the general consensus was that the development within the programme and the overall level of Finnish ITS was quite good. The criticism was mainly directed towards the unevenness of the results within the focus areas of the programme: while some of the areas produced significant results, the others were found to be lacking in productivity [FITS, 2007].

### 3.2.3. AINO

The successor of FITS was AINO (Ajantasaisen Liikenneinformaation T&K-ohjelma, i.e., R&D Programme on Real-time Transport Information). As the name implies, this programme had quite a focused area on which the research was conducted.

While AINO did contain elements of fundamental research and education, the main focus was on practical uses and pilots of ITS applications. The programme was divided into five subcategories: public transport information, goods transport information, transport network status information, driver support, and service framework. Via these endeavors the formulated goal was to “develop the collection, management and exploitation of real-time information and to create thereby prerequisites for ITS services improving the safety, efficiency and sustainability of the transport system while increasing the well-being of citizens and the competitiveness of Finnish companies” [Broeders and Miles, 2007].

The hierarchy of AINO consisted of individual projects that were assigned to the five sub-programmes. The hierarchy was shaped as follows [Broeders and Miles, 2007], with key projects listed for each sub-programme:
• Public transport information
  o Development and expansion of the tram traffic incident management pilot in the Helsinki metropolitan area.
  o Further development of the passenger information system ELMI.
  o Mobile flexible working to promote the competitiveness of public transport.
  o Rail traffic tracking and incident reporting and information.

• Goods transport information
  o KULTIS – Digitizing of goods transport information.
  o Functional and technical feasibility study for the PortNet 2 maritime information system.

• Transport network status information
  o Feasibility study for traffic control around large metropolitan road works.
  o ONNIMANNI and ONNIMANNI 2 – Real-time modeling and performance monitoring of the urban transport network.
  o ColdSpots development project for accurate road section-specific road surface condition forecasts.
  o A study for the heavy vehicle driver warning and route planning service.

• Driver support
  o In-vehicle warnings about approaching trains at level crossings.
  o The safety and other benefits of the eCall system.
  o Measuring the driving style of a driver and the possible safety impacts.

• Service framework
  o Defining alternatives for the public sector’s objectives in ITS service production.
  o ASKEL – A concrete and economical step towards multimodal transport services in a city.
  o Planning and realization of the eCall test environment.
  o Impact evaluation method of the road surface condition warning service.

As can be seen from the projects within the sub-programmes, AINO contained a vast amount of R&D activity at already quite a practical level.
Worth noting is especially the emphasis on safety issues with, e.g., the projects related to eCall and level crossings.

AINO continued on the footprints of TETRA and FITS in enhancing the communication between Finnish ITS stakeholders. The external auditors acknowledged that AINO had helped in bringing together a strong Finnish ITS community. AINO also succeeded in lifting ITS to the agenda of the relevant partners and made them committed to the cause, which bodes well for the deployment of ITS services in Finland. However, the need for closer interaction among the Finnish stakeholder groups was still identified. The same was also found to apply on international collaboration on the field, regarding exchanging of ITS knowledge and utilizing the findings of projects in other countries [Broeders and Miles, 2007].

3.2.4. ÄLLI

Shortly after AINO concluded in 2007 it was followed by the ÄLLI (Älykäs Liikenne, i.e., Intelligent Transport) programme. It consists of two phases: first, the goal is to lay foundations for the services that are the program focus by streamlining and enhancing the cooperation of the stakeholders in the programme, such as the administrative sector of MinTC and the municipal sector. Second, the focus is on carrying out national pilots with the aim of coming up with viable service products [Mononen et al., 2007].

The high-level goals of ÄLLI are related to the following themes [Mononen et al., 2007]:

- reducing emissions by means of ITS
- improving traffic safety
- promoting efficient use of transport infrastructure
- improving Finnish productivity and efficiency with ITS
- maintaining high quality R&D know-how
- enhancing the functionality of travel services in the every-day life.

The ÄLLI programme is currently still underway. A full report regarding the results will be released after the scheduled completion of the programme later in 2010.

3.3. Business challenges of intelligent transport systems

ITS provides a challenging environment not only from a technological standpoint but also from the business perspective. One of the key issues is that the solutions tend to be product-related services that have a high degree of uncertainty related to the design process. The second issue is that the
innovations are multi-sector in nature, i.e., their influence spans across multiple domains which results in a high number of diverse stakeholders.

3.3.1. Product-related services in an explorative setting

According to Hill [2005] a physical product, i.e., a good, is something tangible that can be transferred between economic units such as individuals or businesses. From an economics perspective one attribute of goods is their scarcity, i.e., their limited availability that is relative to their demand.

In contrast, a service has two main characteristics. Firstly, it causes some type of a change in the condition of a person or a good – with the prior agreement of the person in question or of the economic unit that is the owner of the good. In other words, a service is about performing an activity for the benefit of another economic unit. The key difference between goods and services is that when a service activity is performed, nothing tangible is actually exchanged between the economic units unlike would be the case with goods [Hill, 2005]

ITS solutions are largely based on immaterial services that are tightly integrated into the actual physical products. This phenomenon has a number of terms assigned to it such as product-related services (PRS) [Lenfle and Midler, 2009] or product-service systems (PSS) [Williams, 2006]. All the example applications discussed in Section 3.1 clearly share the characteristics of this – while there is obviously a physical product involved, the actual added value for the end-user comes from the service integrated to the product.

Lenfle and Midler [2009] have researched the field of product-related services and they use intelligent transport systems as an example in demonstrating the related business challenges. An added challenge of ITS is that the solutions in the field tend to be explorative in nature, i.e., they utilize technological innovations, new practices or business models that have not yet been stabilized [Lenfle, 2008].

Lenfle and Midler [2009] followed the development of E/B call (the combined functionality of the eCall and bCall) system within a principal European car manufacturer. The E/B call is considered a typical explorative ITS innovation where breakthroughs are required both related to the product itself and the service integrated to it. The authors identified the following five challenges in the E/B call project:

- Arranging the technical development of the required onboard equipment.
- Designing and developing the information system behind the solution.
• Settling the responsibility issues and other legal aspects that are related to an emergency service.
• Setting up the marketing, sales and service functions and dealing with the fact that the sellers and marketers of the service are different individuals from the ones actually performing the service.
• Designing a solid business model for a service that was considered difficult to sell by many key personnel inside the company.

With these types of aspects present, operating successfully on the ITS field requires broad knowledge from a variety of domains. Law and healthcare are good examples of areas that are outside the core competences of most businesses. Resolving these issues while dealing with the uncertainty and the explorative nature of the projects can prove to be a challenging task for the companies involved.

3.3.2. Stakeholder management in multi-sector innovations

As Lenfle and Midler [2009] noted, the ITS field hosts innovations that span across multiple fields. Bunn et al. [2002] label these as multi-sector innovations and describe them with the following characteristics:
• They affect the political, behavioral, economic, social and technological environments.
• They are related to both the public and the private sector.
• They utilize a mix of both old and new technologies.
• They consist of relationships that reach across sectors in both lateral and vertical directions.

The eCall and bCall applications are good examples of such multi-sector innovations. The research behind them has been a joint effort between private sector companies such as car manufacturers and actors from the public sector such as various municipalities. The solutions involve technological convergence where existing technologies such as on-board vehicle technology and data transfer are brought together via a standardized interface to form new applications. The nature of the service, i.e., improving traffic safety, has the potential to greatly benefit the public good, which makes the application meaningful and interesting also from the political and social points of view.

Due to the cross-sector nature of many ITS applications, they are also characterized by the high number of stakeholders involved. The R&D programmes in Section 3.2 demonstrate this well – they featured relevant stakeholders from research institutes, private businesses, ministries and other
public sector entities. A high number of parties involved makes the stakeholder management another challenging issue for ITS endeavors.

To assist technology companies of the ITS field Bunn et al. [2002] have developed a five-step process for identifying all the relevant stakeholders and thus helping to manage the relationships with them.

The first step involves identifying the key sectors of the multi-sector innovation and then the relevant stakeholders operating in those sectors. The aim is to locate all the stakeholders that have either a direct or an indirect relevance to the firm.

The second step consists of describing the important characteristics that each of the stakeholder groups possesses. Firstly, the scope of the stakeholders should be determined, i.e., whether they operate locally, nationally or perhaps internationally. Secondly, estimations should be made of each stakeholder regarding three attributes: what kind of benefits could be offered to them, what kind of risks they are likely to see in the offer, and what kind of contribution they would be able to make in return.

The third step requires the ITS enterprise to analyze the identified stakeholders based on three specific stakeholder attributes originally introduced by Mitchell et al. [1997]:

- **Power** – does the stakeholder have influence over the organization itself.
- **Legitimacy** – does the stakeholder relationship match socially accepted and expected norms, values and structures.
- **Urgency** – does the stakeholder set time-sensitive and critical requirements on the organization.

The goal is to piece together the positions of the stakeholders by classifying them based on which of these attributes each of them possess. As a result each of the stakeholders’ importance and status in the network can then be evaluated.

The fourth step involves examining the dynamic relationships among the stakeholders. Step three assumed that a stakeholder attributes were either present or not, e.g., a stakeholder either has or does not have legitimacy in the network. However, in reality the situation is more complex than that. The amount of legitimacy a stakeholder possesses is subject to changing along the way, and it is also possible that the classification of a stakeholder changes completely from, for example, possessing no urgency and no power to having both. Understanding the relationship dynamics of the stakeholder network
helps anticipate these types of changes in the environment and thus prepare for the future.

Once the stakeholders have been identified and analyzed, the final step consists of evaluating stakeholder management strategies. Each stakeholder relationship should be considered from the point of view of the business regarding, e.g., standards compliance, privacy concerns and interoperability requirements.

By performing a systematic stakeholder analysis such as this one suggested by Bunn et al. [2002], the complex task of handling the relationships in the multi-sector ITS field becomes considerably more manageable. It provides the means for identifying the key stakeholders of the environment and also for anticipating the inevitable changes in the stakeholder network.
4. The core technologies

While the possibilities of utilizing different kinds of technologies for ITS solutions are limited by practically only the collective imagination of the enterprises involved, there are two core technology areas that are the most important ones in the majority of ITS solutions today. These technologies are related to positioning and wireless transfer of data.

4.1. Positioning with GPS

An essential part of intelligent transport systems is being able to locate specific vehicles and to track their movements. Navigation-based ITS solutions are arguably the most interesting ones from the perspective of an individual consumer. This is demonstrated by the fact that recently the markets for personal navigation devices have nearly doubled each year [Scholliers et al., 2008].

Several positioning systems are either already functional or being developed around the world: Russia has GLONASS, China has Beidou, and Europe has GALILEO. Still, currently the de facto system for accessing position data is via the Global Positioning System (GPS), a system maintained by the United States government. The core principle behind GPS is that the Earth is orbited by 24 satellites which cover the whole surface of the planet. When a GPS receiver connects to three or more of these satellites, the position of the receiver on the Earth’s surface can be calculated using trilateration [Trimble, 2008].

The current dominance of GPS has also raised concerns. Access to position data has become something that is considered a given, and an enormous amount of individuals and businesses worldwide have become dependent on its availability. However, there are no service-level agreements that guarantee the operation of the service, and on top of that the system is maintained by a governmental body [Mannings, 2008]. In this sense the introduction of complementary systems such as GALILEO will increase the reliability of positioning, given that receiver devices that support multiple standards will become more common as well.

GPS was originally developed primarily for military purposes, and so to prevent civilians from getting access to the most accurate location information a technology called Selective Availability (SA) was implemented by the United States Department of Defense. SA effectively meant that the GPS signal was intentionally degraded so that civilian equipment could only achieve an accuracy of approximately 70 meters [Prasad and Ruggieri, 2005]. The disabling
of SA in May 2000 improved the performance of civilian GPS equipment considerably, as can be seen in Figure 2.

![Figure 2: GPS accuracy with and without SA](Prasad and Ruggieri, 2005).

<table>
<thead>
<tr>
<th>Error source</th>
<th>Error in meters with SA</th>
<th>Error in meters without SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective Availability</td>
<td>24.0</td>
<td>0</td>
</tr>
<tr>
<td>Atmospheric delay</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Troposphere</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Ephemeris and clock</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Multipath</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Total User Equivalent Range Error</td>
<td>25.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Avg. Horizontal Dilution of Precision</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Overall horizontal accuracy (m)</td>
<td>75.0</td>
<td>22.5</td>
</tr>
</tbody>
</table>

While the error in meters has decreased to less than a third of what it was when Selective Availability was enabled, Figure 2 shows that a large number of other factors still considerably affect the accuracy of the GPS signal.

Whether this inaccuracy is an issue depends on the application area and purpose of the telematics software in question. When tracking and planning routes from a city to another an error of up to 20 meters may not matter at all. On the other hand, if the goal is, for example, to measure sensor data from a pin-pointed location on the map, a positional error of that magnitude is obviously unacceptable.

Differential GPS (DGPS) was developed to deal with the aforementioned problems in position accuracy. Whereas the traditional positioning approach (often referred to as Standard Positioning Service or SPS) relies on only one receiver, DGPS utilizes the concept of a rover and a reference station.

While the rover moves around, the reference station remains at a place whose coordinates are already known. It calculates the position error between the actual coordinates and the coordinates implied by the GPS signal, and then conveys this information to the rover, which in turn adjusts its own position measurements accordingly [Mosavi, 2006].

If the distance between the rover and the reference station is less than a few hundred kilometers, the GPS signal from the satellite has travelled through similar atmospheric conditions both to the rover and to the base station [Trimble, 2008]. This means that the errors are quite similar in both cases and
thus, error calculations for the rover can be made based on the reference station-related data.

DGPS has thus proven to be quite effective in acquiring accurate position information in civilian applications. In fact, it can be argued that one of the reasons why SA was disabled may have been because its effectiveness was greatly reduced by the DGPS technology anyway. If the true coordinates of a base station were known, also the position of the receiver could be calculated relatively accurately even if SA was used to degrade the GPS signal.

A thing to be considered is that while GPS itself is free to use, the number of DPGS base stations that provide free correction data varies from region to region. In many cases a commercial license is required to access base station data.

4.2. Data transfer methods

Scholliers et al. [2008] estimate that once navigation support has fully established itself as a standard feature in vehicles, the next big market opportunities are likely to be found in the area of providing vehicle owners with dynamic location-based information.

Additionally, the focus in gathering and sharing of information is shifting away from just data related to traffic accidents and roadwork sites. Instead, the dynamic data available to vehicle owners will contain a variety of information that is gathered automatically with sensors and that is more predictive in nature. This type of information could be related to, e.g., the friction of the road or the amount of traffic on a specific road section [Scholliers et al., 2008].

Another focus shift is that vehicles are no longer only at the receiving end of traffic data flow. When suitable wireless data transfer channels are available the sensors that gather information about their environment can be installed just as well in vehicles as in stationary measurement posts. This way vehicles equipped with the proper hardware can actively participate in producing measurement data, and the observation coverage will be vastly improved. Scholliers et al. [2008] note that public transport vehicles and cabs serve this purpose well and that they are already being utilized for data collection in a number of Finnish cities.

4.2.1. One-way information flow with RDS-TMC

A widespread solution for receiving traffic-related data is utilizing the Traffic Message Channel (TMC) system via FM radio’s RDS service. Traditionally, RDS (Radio Data System) is used in particular for automatic tuning of the radio as well as identifying the transmitting radio station [Mannings, 2008]. However, it
can also be utilized to convey simple information about traffic incidents to drivers.

RDS-TMC is widely used especially in Central Europe, and its operating expenses vary from one country to another. In Finland the TMC service is liable to charge and is provided by Destia. For example in Sweden and Belgium it is provided free of charge [Scholliers et al., 2008].

RDS technology does have its benefits: the technology is simple, and the hardware costs for the end-user are very low since virtually all cars come equipped with an FM radio from the factory. Still, it is not a particularly flexible channel to disseminate information to vehicles. Additionally, it can be unreliable due to lack of coverage and interference from external sources [Mannings, 2008].

RDS-TMC is to be followed by the digital TPEG protocol (Transport Protocol Experts Group) that allows the transmission of more diverse information, such as public transport schedules, weather data and news [Scholliers et al., 2008].

4.2.2. Cellular wireless networks and WiMAX

When the amount of gathered traffic information continues to increase the methods of transferring it between vehicles and servers becomes a more and more important factor to consider.

The data transfer capabilities of the GSM system have come a long way since the early days of GPRS. While GPRS provided transfer rates of 115.2 Kbps and its extension, EDGE, pushed the limits to 384 Kbps, the current 3G-based HSDPA technology makes it possible to achieve a theoretical maximum speed of 14.4 Mbps.

The cellular network based solutions are getting competition from, e.g., WiMAX, a broadband technology that is expected to be integrated into all laptop computers in the near future [Scholliers et al., 2008]. The widespread adoption of WiMAX would address some issues and criticism that cellular-based technologies such as HSDPA have received.

The aim of WiMAX is to provide a system that is broadband, mobile and also be built on an IP-based framework [Lee and Choi, 2008]. In this sense WiMAX would be an intermediate form between WLAN and cellular wireless networks. Firstly, it would have longer range than WLAN (10 kilometers provided there is an unrestricted view to the base station [Scholliers et al., 2008]). Secondly, it would provide faster actual downlink speeds and thirdly, the IP-based nature would make it more uniform and better compatible with the Internet world, thus supporting a more diverse set of data services [Lee and Choi, 2008].
One core issue with WiMAX is that even if it were technically superior to currently available solutions, it may not get the chance to gain the needed popularity to become a de facto standard quickly enough. Instead, it may be surpassed by the next generation of cellular wireless technology labeled LTE (Long-term Evolution) that should already be able to achieve theoretical maximum downlink speeds of 100Mb/s [Scholliers et al., 2008].

4.2.3. Vehicle-PDA communication with Bluetooth

Bluetooth is a wireless technology that can be used to connect devices within a short range. Bluetooth consists of interface specifications called profiles that define the protocols and features that support a particular usage model. When two Bluetooth devices conform to these profiles, they can be expected to interoperate with each other even if they have been made by different manufacturers [Muller, 2000].

Development of the profiles is coordinated by the Bluetooth Special Interest Group. Within the consortium there is a specific working group whose focus is on the vehicular applications of Bluetooth. This Car Working Group is developing six vehicle-related profiles for Bluetooth [Scholliers et al., 2008]:

- **Hands-free profile specification**, contains the basic cell phone features, e.g., dialing, answering a call, checking the charge of the battery state via the car controls.
- **Headset profile specification**, contains support for having the in-car systems function as a headset device.
- **Phone book access profile specification**, provides the features for managing the phone book of the device.
- **SIM access profile specification**, provides access to commands related to the device’s SIM card.
- **Message access profile specification**, defines how the device’s inbound messages (e.g., SMS or e-mail) can be managed with the control systems of the vehicle.
- **Off-board navigation profile**, defines the scenarios for transfer of navigation data between the device and the vehicle, e.g., displaying navigation data on the dashboard of vehicle.

It has been estimated that by 2012 a third of new cars sold will have Bluetooth capabilities and at have least some, it not all, of the six profiles available [Scholliers et al., 2008]. Being able to connect a vehicle via Bluetooth to a PDA or cellphone that is equipped with WiMAX or 3G capabilities brings great possibilities for the vehicle to also communicate about its state to the outside world.
5. A case study in B2B intelligent transport systems

This chapter delves deeper into the business case that was briefly introduced in Chapter 3. It introduces a real-life commercial application in business-to-business fleet telematics, here identified as ScaleLink. It was designed for a Finnish company that does business in, e.g., selling different types of weighing-related hardware for wheel loader vehicles.

The final product ended up being a system with five interconnected software units, and the focus of this chapter is primarily on the technological aspects of the implementation. However, thought is also given to different software development approaches and their relation to the project.

5.1. The ScaleLink concept

As discussed in Chapter 3, the goal of ScaleLink was to end up as a comprehensive system for gathering data from collections of vehicles, often referred to as fleets. In this case the fleets consisted of wheel loaders belonging to various contractor firms, and the role of ScaleLink was to disseminate the weighing data to different user groups within these firms. The application was designed to complement the existing hardware that the client company supplied for the wheel loaders.

The aim was to improve the existing system, which did not have the support for storing the weighing data at a centralized location. Instead, it required the contractor firms to process individual paper receipts. Additionally, if there was a need to generate reports or calculations based on the data, it required typing the contents to the receipts to a program such as Microsoft Excel. This made creating reports and overviews quite laborious for the contractor firms involved.
The implementation of ScaleLink did not require changes to the basic principle of the existing system: the scoop of a wheel loader (see Figure 3) is fitted with a set of hydraulics equipment that determines the weight of the load once the scoop is full and gets lifted up. This information is then passed on to a weighing unit (see Figure 4) that is located inside the cabin of the vehicle.

The weighing units have an input system that gives the end-user the possibility to type in information concerning the weighed load, e.g., the material, the customer it was designated to, and who was operating the vehicle. The units contain an internal memory which can be used to save presets regarding, for example, different materials and customers.

With the actual data gathering hardware already in place, the concept of ScaleLink involved developing a solution for transferring this data wirelessly to
a server and making it possible for the end-users within the contractor firms to access and utilize the information in a convenient manner.

5.1.1. The main requirements for the system

The requirements specification for ScaleLink consisted of the following key points:

- **Robust data transfer from the vehicles to the server.** The communication between the vehicles and the central server should be designed so that the GPRS modem can react to a potential loss of Internet connection and process the weighing data accordingly.

- **Support for different types of weighing units.** The client company supplies different weighing unit models from different manufacturers, which means that the incoming data will arrive in a variety of character string formats depending on the unit type. The system should be able to process all these different types of data.

- **Support for detecting and dealing with loss of data.** All the weighing units submit an automatically incrementing number along with the weighing data. These numbers have to be checked to determine if some weighing data has been lost due to, e.g., a hardware malfunction. Additionally, the users should be notified about the loss of data and given the option to input information about a specific weighing to the system manually from a client program.

- **Support for reporting based on gathered data.** There should be extensive reporting support so that the users of the program within the contractor firms can inspect the weighing data of their entire fleet or filter it by a combination of the following parameters:
  - the loader vehicle that carried out the weighing
  - the driver that carried out the weighing
  - the place where the weighing took place, e.g., a specific gravel pit
  - the material that was included in the weighing, such as fine sand or sifted gravel
  - the customer that ordered the weighed load
  - the date of the weighing
  - the time of the weighing, i.e., whether the work was carried out during the morning shift or the evening shift.

Additionally, there should be overviews available of how large quantities of each product have been weighed within a selected time frame. All the reports should be both viewable on the screen and also as printouts.
• **A set of user account and hardware control features.** The administrator of ScaleLink should have control over the users and devices that are allowed to utilize the service. In other words, he is responsible for managing the user accounts, their access rights, and the list of authorized weighing units. Only predetermined weighing unit / GPRS modem unit combinations should be allowed to access the server.

• **Multilingual user interfaces.** Finally, the software that involves the end-users should be available in English, Finnish, Swedish and Norwegian languages and be designed in a way that also facilitates easy addition of new language packs in the future. Since the GPRS modem units do not have a textual or graphical user interface, this requirement concerns only the basic client program.

As can be seen from the requirements list, in this case there was no need for positioning data, which is somewhat rare in a fleet telematics information system. In ScaleLink the focus was on being able to gather information about the weighing process in which the geographical coordinates were not as necessary information as in many other ITS applications.

### 5.1.2. User groups and their access rights

The aim of the system was to cater to the needs of three types of user groups, and this needed to be taken into account when designing each user’s right to access the weighing data. It was important to make sure that the end-user got all the info regarding his own devices, but at the same time you needed to make sure that he could not, for example, access the information that belonged to a competing contractor.

The basic idea is that users can have GPRS devices assigned to them, and they have automatically the rights to view the data that has come from those devices. The identification is done based on each device’s unique IMEI code. However, to facilitate the needs of all users, the following three-tier user hierarchy was formed:

- **Tier 1: Administrator.** An administrator does not have his own devices. However, his account has been granted the rights to access all the weighing data in the system. Additionally, he is the only one who has the authority to add or remove devices and users.

- **Tier 2: Supervisor.** A supervisor account functions much like the basic user account in the sense that a supervisor can have his own devices and access the data originated from them. Additionally, a supervisor can also be given access to data that has originated from devices belonging to a basic user. This is done by either granting him
viewing rights to devices corresponding to a specific IMEI code or to any weighing data that matches a certain keyword, e.g., the location of a specific gravel pit.

- **Tier 3: Basic user.** The basic user only has access to the data originating from devices that have been assigned to him.

![Data access diagram of an example system](image)

**Figure 5:** Data access diagram of an example system where the supervisor has been given the rights to access data from a specific IMEI in addition to his own devices. The administrator has the rights to access data from all users.

With the type of hierarchy presented in Figure 5, the system becomes more flexible since the supervisors can be granted extra access to data on a case-by-case basis. The additional rights are always granted directly by the administrator by using an administrative client program, which is discussed in more detail in Subsection 5.5.4.

### 5.2. Software development models in relation to ScaleLink

Since the ScaleLink project involved building an information system that consists of several interconnected software units, a brief discussion on software development models is also warranted. This section covers the aspects of the waterfall development model, incremental development, agile software development and what kind of role each of them had when designing the ScaleLink system.
5.2.1. The reasoning for rejecting the waterfall model

The waterfall model is regarded as the classical model in system development [Hughes and Cotterell, 2006]. In waterfall approach the beginning of the project contains the planning and design phase of the entire system and is then followed by implementation, testing and installation. The phases of a waterfall are described in more detail in Figure 6.

![Figure 6: Different phases of a standard waterfall model (further developed from Hughes & Cotterell [2006])](image)

The aim of the waterfall approach is to avoid the need to revisit earlier phases of the process once they have been completed. One key critique towards the waterfall model is that in real-world situations there tends to be a varying amount of uncertainty regarding how a system should be implemented [Hughes and Cotterell, 2006]. Depending on the level of uncertainty and the complexity of the system, following the waterfall approach can range from being inconvenient to being impossible. This was also known to be the situation in the case of ScaleLink, and therefore the waterfall model was not really considered to be an option at the beginning of the project.

The software development process of the case study did not follow a formalized or pre-defined development model. The nature of the project was quite incremental, which was reflected on the software development process as well. The process would be best described as a mix of incremental and agile elements.
5.2.2. Analysis of the incremental aspects in ScaleLink

In incremental software development the application is broken down into a suitable number of smaller components which are then developed and delivered sequentially (see Figure 7).

Advantages of the incremental approach over the waterfall model have been analyzed, among others, by Hughes and Cotterell [2006]. The benefits include the following key points:

- **Early increments provide feedback for later increments.** This was the main benefit of using the incremental approach in the case study. It was challenging for both the developer and the client to visualize at the beginning of the project how the final product should exactly
end up. Developing the system piece by piece clearly helped in steering the project towards the right direction.

- **Requirements are less likely to get changed due to shorter implementation/delivery cycles.** This benefit did not become materialized as such. Since the system was tested by end-users already during most of the development phase, there were numerous changes to the requirements throughout the project. On the other hand, it underlines the point why the waterfall approach would not have been a practical choice. With the waterfall model in use the final product most likely would not have met the needs of the end-users: even if the user requirements had been rigorously gathered and defined at the beginning of the project, new ones would have been guaranteed to surface during the testing and operation phases of the system.

- **Users get benefits earlier on in the process.** As the end-users began using the system relatively early on, this was another key benefit. Even though some of the more advanced features related to reporting, user groups and device management were still under development, the core functionality of gathering and saving the weighing data was already available for the users.

- **Management of smaller sub-projects is easier than dealing with one large project.** The contents of each of the increments were not fixed in the incremental delivery plan. The order of doing things was based on rather what feature was the most urgent to the end-users throughout the phases of the project. Even though the system did consist of many smaller components, there were no pre-defined sub-projects, and consequently the management aspect remained largely unaffected.

- **The project can be temporarily abandoned if more urgent work emerges.** In a work environment where there were a varying number of projects ongoing simultaneously, having this option was a clear advantage, even though the need to do so emerged only rarely.

- **Improved job satisfaction via seeing own labor bearing fruit at shorter intervals.** The ongoing feedback from the end-users not only helped to improve the system itself, but it also demonstrated clearly that people do use the system and that they are interested in what is going to happen to it. This helped in maintaining the motivation when working on the project.
Even though the incremental approach has many benefits, it is not entirely without flaws. To offset the list of advantages, Hughes and Cotterell [2006] point out that incremental projects are prone to software breakage, which means the need to modify or fix something that was already done in an earlier increment. This was the single biggest challenge in the project, and dealing with it cost a considerable number of working hours. A more strict requirements specification might have helped in mitigating this problem. However, as discussed before, most of the change requests surfaced from the end-users during the ongoing testing phase of the system and were in that sense rather unpredictable.

5.2.3. Analysis of the agile aspects in ScaleLink

As the agile approach to software development has been gaining popularity in the past decade, a considerable number of new development frameworks and methodologies have surfaced, such as extreme programming, Scrum and feature-driven development.

While these methodologies have their own unique traits, their core ideas also overlap with each other [Koch, 2004]. This overlap is caused by the fact that concrete agile methodologies are based on a more abstract set of agile principles formulated, e.g., in the agile manifesto drafted by Beck et al. [2001].

Considering this difference between agile methodologies and agile principles it can be stated that in ScaleLink no single methodology was applied in its entirety. However, these basic principles laid out in the agile manifesto were all present:

- **Individuals and interactions over processes and tools.** From the developer perspective there were no corporate hierarchies or fixed processes, and the project relied heavily on self-organization and trust.

- **Working software over comprehensive documentation.** Generally, the users are not interested in the produced documents but in the software itself. In ScaleLink the documentation was kept to the bare minimum. The most important documents were the user guide and the design document that outlined the architecture of the system on a general level and described the functionality of each of the software components. Additionally, the source code was commented in attempt to make it as understandable as possible.

- **Customer collaboration over contract negotiation.** Even though customer collaboration means more work and re-working some parts of the software along the way, it is still necessary since only the users can tell what features are really needed in the software. In ScaleLink
the end-users got involved early on in the development process and were thus able to voice their opinions well.

- **Responding to change over following a plan.** There are a variety of aspects that can change throughout a project such as the requirements, the environment, the priorities or even the used hardware. The waterfall model was abandoned for this very reason. It would have been too binding in a situation where the amount of uncertainty related to the project details was quite high.

A point was made by the representative of the client company regarding customer collaboration and responding to change: while the inclusion of the end-users early on in the project is important, it is equally important to maintain a healthy level of critique in the process. The feedback from the users can be immensely useful, but it also tends to contain suggestions that are outside of the application’s main focus area or simply too costly to implement. In this case both the client side and the developer side acted as kind of filters by going through the feedback, evaluating it and deciding if the suggestions were both suitable from a business standpoint and feasible from a technical standpoint.

5.3. **A high-level reference infrastructure**

Millar et al. [2004] introduce a reference infrastructure for a web service driven vehicle telematics information system. In the process they identify four core elements that this kind of system contains:

- display and communications device
- communications network
- network-centric data centre
- the application itself.

At a high level the implementation of ScaleLink is in unison with the authors’ vision of a system infrastructure. However, some differences remain. These differences and the reasoning behind them will be covered next.

5.3.1. **Display and communications device**

Millar et al. [2004] suggest the use of a third-party PDA in each vehicle instead of an device that is integrated into the vehicle itself. Choosing the approach of using an external device for communications was a natural course of action in the case of ScaleLink.

According to the representative of the client company, in this business integrated solutions for this purpose are quite rare. While some are provided by
companies such as Caterpillar, they have never become particularly popular among the users. Additionally, these kind of integrated solutions tend to be restricted to certain wheel loader brands and models, whereas an implementation of a system such as ScaleLink could be installed on basically any type of wheel loader.

However, a PDA is not the only option when choosing a display and communications device. Additional possibilities have been suggested, among others, by Öörni [2006], one of which being the use of a GPRS modem. This approach was chosen also in the case of ScaleLink, which utilizes a Java-programmable GPRS modem unit instead of a conventional PDA. The unit is an A1 TRAX supplied by the Finnish company Aplicom, and its operation is covered in more detail in Subsection 5.5.1.

The benefit of the GPRS modem is that it requires little to no user interaction from the driver of the vehicle who is then free to focus on the actual work. Additionally, the GPRS modem features more extensive I/O connectors than standard PDA units in most cases do.

5.3.2. Communications network
ScaleLink utilizes the GPRS network for the data transfer. This provides an always-on channel for data transmission, assuming that the vehicle is located within the coverage of a GSM network so that the modem unit is able to set up a connection. The data packets sent to the server are very small in size, so the slower uplink speeds caused by the lack of support for HSDPA or even EDGE are not an issue.

Millar et al. [2004] also suggest the use of dual wireless networks, i.e., having the support for connecting both via GPRS and a wireless local area network. In the case of ScaleLink WLAN support is not a feasible option due to the technical limitations of the GPRS modem unit. Also, since the wheel loaders tend to operate at gravel pits and other remote locations, having the option to access WLAN networks when needed would be quite uncommon in practice.

5.3.3. Network-centric data centre
Millar et al. [2004] recommend that all applications interacting with the fleet should be located in a network-centric data centre, as should the data itself. Since ScaleLink operates on a relatively small scale, this was the natural course of action. The only application that communicates directly with the vehicles is the server program that receives weighing data from the GPRS modem units. The data is stored in a database and managed in a way that it is possible for a number of client programs to access it remotely. The structure of the system is covered in more detail in Section 5.5.
5.3.4. The application

Millar et al. [2004] note that with PDA units comes the possibility to run the applications in thick-client mode, i.e., letting the client handle a part of the information processing. While drawing an exact line between what is a thin client and what a thick client is difficult, ScaleLink could be more seen as following the authors’ view and thus using the thick client approach.

In the traditional sense of the term thin clients were simply terminals with very little capabilities of their own. Even though in the ScaleLink system the server handles the majority of the processing, the clients have quite a bit of functionality, ranging from reading I/O’s to maintaining a backlog.

5.4. The choice of hardware

The choice of weighing units to be supported was based on the existing product portfolio of the client. This meant the choices on the hardware side were limited to selecting suitable equipment that would handle the data transmission to the server from each of the weighing units.

![Figure 8: A1 Trax GPRS modem unit. (Image: Aplicom)](image)

Eventually the decision was made to use A1 Trax modems (see Figure 8) supplied by Aplicom. Even though their price is slightly higher than that of some other similar products, they have a number of advantages. The biggest benefit is that they can be programmed with Java ME. The software development kit contains implementations for methods that allow relatively easy access to all of the device I/O’s and also customizable event listeners for the monitoring of incoming data. This makes the unit very versatile and able to serve different kinds of purposes. It was reasoned that the knowledge gained about the unit could be utilized also in the future in developing either an extension of ScaleLink or in a completely new application.

Another major advantage of the unit was that it is capable of handling the loss of GPRS connection and recovering from it without losing any data. This is achieved by saving unsent weighing data to the device’s internal memory. The importance of this was due to the fact that uninterrupted connectivity to GPRS
network cannot be guaranteed at all of the locations where the wheel loaders tend to operate.

Finally, some emphasis was also put on the facts that the company is Finnish and therefore support is generally easier to arrange, and that the company’s focus has been on developing solutions specifically for the purposes of fleet telematics.

5.5. The technical implementation
The programming work related to the system can be divided into three sections: the server-side programming, the client-side programming, and the programming of the Aplicom A1 Trax GPRS modems connected to the weighing units. An overview of the system is shown in Figure 9.

![Figure 9: An overview of the system.](image)

Since the A1 Trax units are programmable with Java ME, the choice of programming language was already predetermined. For the client- and server-
side components of the system the options were more open. The goal was to have the client programs easily deployed into a Windows-based environment, but for the server components there were not any specific criteria to be met, as long as the end result was functional and stable.

Eventually, the choice was settled on C# and ASP.NET, primarily due to the effective development and debugging environment provided by Microsoft Visual Studio 2008, and also due to my personal desire to improve my expertise on the languages. The client company’s server already featured an installation of Microsoft’s Internet Information Services (IIS) that was running as a web server, so the choice was suitable in that sense as well. From the end-user’s perspective the only requirement for using the client programs is the need to have the .NET framework installed on the computer.

5.5.1. The Java program in the GPRS modem

From the perspective of vehicle telematics perhaps the most interesting part of the programming work was the Java code in the GPRS modems. The Aplicom A1 Trax is a compact unit and with its Java ME capabilities and various I/O connectors it could be customized to suit a number of different vehicle telematics applications.

While the Java ME platform inside the modem unit has the features available for doing a variety of data processing operations, most of the needed functionality was consciously transferred to the server side. The decision to keep the Java program in the GPRS modems relatively simple and light-weight had three main reasons supporting it:

• **Limited processing resources.** The modem units have limited CPU power and memory at their disposal, which on its own already justifies delegating a part of the workload to the server.

• **Debugging and troubleshooting.** The unit’s ability to communicate with the end-user is limited to three programmable LED’s in the front panel, and thus it is difficult to notify the user clearly in case something goes wrong during runtime. This makes it extremely important to get rid of software bugs to avoid runtime errors. This was the most important and deciding factor for shifting as much functionality as possible to the server. The server program is based on .NET framework which provides extensive debugging and testing features. Having the majority of the functionality reside on the server made the system more robust and reliable.

• **Speeding up the development process.** Compiling and testing a new build of the server program is a quick task in a desktop environment. In contrast, testing a new build of the Java program in the GPRS
modem takes considerably more time. After building the Java program in Eclipse, the JAR file has to be transferred to the modem either via a serial cable or a wireless update procedure. After this, the unit updates itself and restarts, and only after this you are able to do the actual test. Although at a glance this may not seem like much of a difference, the time does add up rather quickly when testing the program with the real-life hardware configuration and fine-tuning the build in the process. While this was not a crucial factor when deciding to focus the functionalities on the server, the time-saving benefits became more and more evident as the project progressed.

Figure 10: The transfer of data from the perspective of A1 Trax.
The main role of the Java program in the modem unit is to facilitate the flow of information from the weighing units of the wheel loaders to the server (see Figure 10). Once the program starts it begins to listen to the RS-232 serial port of the device and wait for incoming character strings of data. The inbound strings are either sent immediately to the server or saved to the device’s internal memory depending on the device’s connectivity status at the moment.

Since the main functionality of sending a data packet to the server is triggered by an event (i.e., inbound data to the serial port), the program stays idle for the vast majority of the time. The only other times the program is active are when it attempts to send the contents of the backlog to the server and when it is undergoing a software update procedure.

The backlog handling is achieved by using a Timer object that checks the backlog contents every half hour and attempts to send them to the server if necessary. If the transfer is successful the contents of the backlog file get erased, otherwise they remain waiting for the next submission cycle.

The A1 Trax supports Over-the-Air Provisioning (OTAP) which helps manage the devices in case software updates are required during the system life cycle. In OTAP, a standard-formatted SMS message is sent to the modem unit that needs to be updated. The message contains the necessary information for the unit to locate, download, install and run the updated Java program. An example of OTAP messages is shown in Figure 11.

```plaintext
PWD: otapPassword
JADURL: http://updatesserver.com/newJad.jad
APPDIR: a:/work/appdir
HTTPUSER: username
HTTPPWD: password
BEARER: gprs
APNORM: internet.saunalahti
NETUSER: Operator’s APN
NETPWD: Operator’s GPRS username (often not needed)
DNS: Operator’s DNS information (often not needed)
START: install
```

Figure 11: Example of an OTAP message. The left column describes the contents of the SMS message.

The JAR files are located at an OTAP server, which handles the incoming update requests from the A1 Trax units. The protocols allow for setting up a customized server program to handle the software updates, however, since in the case of ScaleLink there was no need for any custom OTAP features, the Apache Tomcat-based standard OTAP server supplied by Aplicom was used.

The server has assignable rule sets to define which device IMEI codes are linked to which software packages. This way the same server can be used to
handle the upgrades of the whole fleet, even if some of the vehicles need to utilize different software configurations.

In order to avoid the need to use a regular cell phone to handle the SMS-based update process, the update commands can be sent using a PC with the help of a GSM modem and update software supplied by Aplicom. In the case of ScaleLink this does not even require acquiring additional hardware since the A1 Trax modem units can be configured to act as GSM modems as well. Therefore having one extra unit that is connected via a serial cable to the computer that performs the updates is enough. The software makes the update process quick, since all necessary SMS update commands can be sent in a batch in one go.

At a general level, being able to upgrade and change the device software on the go without physical access to the modem units greatly improves the maintainability aspect of the system. The units also report back their update status to the OTAP server, so the administrator of the system will know immediately when a unit has completed the updated process or if the update failed.

In practice, the update system seemed to have some bugs with, for example, graphical glitches in the GUI of the update software and with having to restart the Tomcat server each time before sending update commands to the GPRS modems. Also, occasionally the update procedures would not successfully complete for an unknown reason, so multiple SMS commands had to be sent to the GPRS modem units to finish the update process.

### 5.5.2. The server program

The program accepting the connections from the A1 Trax units is essentially a TCP server that is listening to incoming connections to a specific port. In order to prevent unauthorized access, the server only accepts connections from devices whose IMEI code is on the whitelist that is stored in the MySQL database. The IMEI code of the GPRS modem unit works in a similar way as in mobile phones and it provides an unique identifier for each of the connecting devices.

The IMEI whitelist is maintained by the system administrator via an administrative client program (see Subsection 5.5.4). Whenever a new customer begins to use the system, the administrator adds the customer’s devices’ IMEI codes to the database to allow access to the system. Similarly, if a customer ceases to use the system, his ability to use the system can be revoked by simply removing the appropriate device IMEI codes from the database.
Additional measures are taken to verify the integrity of the data. First and foremost the incoming character strings are checked for SQL injections to prevent unauthorized attempts to access the database.

SQL injections are attacks where the attacker tries to manipulate the back-end database queries by submitting malicious input into the system [Andrews and Litchfield, 2003]. In the case of ScaleLink an SQL injection could mean an attacker sending an otherwise legitimate batch of weighing data to the server, but with a parameter containing a string "; DROP TABLE devices;". Without SQL injection precautions in place, this clause would be executed when inserting the weighing data to the database. This could then result in the deletion of all information related to the GPRS modems in the database.

After the inbound character string has been analyzed and deemed secure, the next step is to determine which type of weighing unit it came from. This needs to be done in order to formulate correct SQL insert clauses. All weighing units utilize the Comma-separated Values (CSV) format when presenting the weighing data as a character string, but the order and number of the parameters differ from one unit type to another. Additionally, some weighing unit types send metadata that is considered redundant and thus should not be saved to the database at all.

The weighing units have no way of identifying their type and encasing that information within the character string, so the analysis has to be done server-side based on the parameters containing the actual weighing information. For example, one weighing unit model provides 21 parameters, the last of which is a numeric checksum, whereas another model provides only 12 parameters and no checksum at the end. These kinds of characteristics supply enough information to be able to distinguish the sending weighing units from each other, and thus, be able to formulate the suitable SQL insert clauses.

Each connection from the GPRS modem units is handled in a separate thread, which allows the server to process multiple simultaneous incoming connections as the user base and the amount of devices grow. The connection handling is shown in Figure 12.
5.5.3. The web service

Web services are reusable components that can be published, located and invoked over the Internet using standardized protocols such as SOAP and WSDL [Vidgen et al., 2004]. In ScaleLink the web service component is located on the application server and it is responsible for all the operations that require access to the underlying MySQL database. Requests to complete these operations come from the two client programs and they include the following:

- adding and removing devices
- adding and removing users
- fetching weighing data
• fetching user information
• fetching device information.

The client programs do not need to be granted direct access to the database, but rather they contact the web service via a standard HTTP protocol. This enhances the server-side security, and having the required functionalities available at the server eliminates the need for programming additional DLL components for both the end-user client and the administrative client.

5.5.4. The two client programs

Two client programs were developed for end-user and administrative purposes. Initially the basic version of the client program contained the necessary functionality for the end-users of the system to be able to download weighing data from the server and based on that generate printable reports. Eventually new features were added for checking the received data for missing weighing rows, adding new rows to the database manually, and for deleting existing, erroneously submitted weighing data.

The administrative version of the client program shared the core functions of the basic client, but additionally contained features for the system administrator in order for him to be able to manage end-users’ accounts and devices.

In contrast, there is one feature that the administrative client lacks compared to the basic client, and that is localization for different languages. The UI of the basic client has been translated into English, Swedish and Norwegian to meet the needs of the end-users. The localization was implemented by using resource files, which allows for easy addition of new language packs by creating new resources when needed.

![Figure 13: A sample of a DataGridView component in .NET.](image)
The reports are presented to the users using the DataGridView component of .NET (see Figure 13). Since .NET does not have native support for printing the DataGridView contents and maintaining the layout of the grid, a code library supplied by the open-source community was utilized to provide user-friendly printing support. The rest of the code in the client programs was developed in-house.

All the weighing data that is downloaded from the server is stored locally in XML format. This allows for easy access to the data from the client program itself, and additionally provides a standardized interface that can be utilized by also other programs in the future if necessary. The process of downloading the weighing data is depicted in Figure 14.
6. Conclusions

Intelligent transport systems is a field that has the potential to facilitate development of complex innovations that can be considered to be multi-sector in nature from a number of perspectives. They cross the borders of public and private sectors, and they also span across various business domains. Additionally, they are potentially connected to, e.g., political, behavioral, economic, and technological environments, and this intricateness makes the field particularly challenging. The multi-sector nature of the field also causes the average number of relevant stakeholders in an ITS-related project to be high.

At the moment, the most popular applications in ITS are the various location-related services. GPS combined with wireless data transmission over, for example, cellular wireless networks or WLAN provide building blocks that facilitate developing solutions ranging from simple navigation systems to dynamic location-based information retrieval, which is estimated to be the next popular application area within ITS. It is evident that ITS applications have great potential, and not only from the traditional points of view of business or leisure. The new technologies lay foundations for considerable enhancement in crime prevention and safety by, for example, making emergency response and vehicle theft recovery operations more effective.

The steady growth and good future prospects of the ITS market have sparked interest towards funding related research also at a national level. For example in Finland the Ministry of Transport and Communications has organized related R&D efforts in a focused manner already for the last 12 years. The results have been a combination of theory and practice, providing fundamental research and education, but also pilots, prototypes as well as fully usable applications.

Lenfle [2008] observed uncertainty and challenges in the process of working on an explorative type of project that is making use of specific technical innovations or practices for the first time. These challenges have also the tendency to manifest in the ramp-up phases of product-related services in the field of ITS [Lenfle and Midler 2009].

Also the case study of the ScaleLink system reflected some of these perceived technological challenges, albeit on a smaller scale. The incremental nature of the project was largely due to the uncertainty about the exact shape of the final product. Building the system bit by bit, gaining the required experience and knowledge in the new hardware, and utilizing the comments
from the end-users were essential in steering the project towards the desired end result.

A feedback session was held on May 10th 2010 with the client to reflect on the project and discuss its outcomes. The client was very pleased with the final product. The representative of the client company stated that the most challenging part of the project was the product development process due to the nature of the technology involved. The hardware was new to everyone involved; the developer, the client and also the end-users.

Marketing and selling the product was not considered to be a challenging issue, the reasons being that the core business and consequently the needs of the end-users had already been clearly identified and understood by the client, and a large portion of the end-users were already interested in the features provided by ScaleLink. Thus the business case of the new system had a very solid background.

Now that the capabilities of the hardware are better known and the basic infrastructure for the data gathering is in place, a solid foundation has also been made for adding new features to the system. Potential ideas for further development have already been considered: even though the GPS positioning feature was not considered a necessity at the beginning of the project, it would be possible to, for example, track the movements of the vehicles and utilize geofencing, i.e., defining a virtual perimeter around a specific geographic area and monitoring when vehicles enter it, or to identify different gravel pits automatically based on where the vehicles are located at a given moment.

Preliminary consideration has been put into other features as well. The Aplicom A1 Trax GPRS modem used in the project has inputs that could provide a possibility to connect it with, e.g., a security camera or an RFID tag reader. This would make it possible to develop new features related to surveillance and driver or device identification.

The current status of ScaleLink is promising. Even though the solution is not yet actively marketed, it is already being used in two countries by more than 10 contractor firms in approximately 40 wheel loader vehicles. While there is still room for further development, the system is already in a state where it can be used for the purpose it was originally designed for.

In hindsight it is obvious that at the code level there are many things that would be done differently if the programming work were to be restarted today: with the current knowledge and experience it would be possible to create a more efficient architecture with ease. Also the modularity of the system could be improved to make it more convenient to add new features in the future.
However, the end-users are interested in having a piece of software that can handle the tasks that are required from it. Developers strive towards technical excellence, but especially in software of this size the code-level technical decisions tend not to show themselves to the end-users. The agile manifesto contains the statement “Working software is the primary measure of progress” [Beck et al., 2001], and also in that sense the project can be considered a success.
## Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>APN</td>
<td>Access Point Name</td>
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<tr>
<td>B2B</td>
<td>Business-to-Business</td>
</tr>
<tr>
<td>B2C</td>
<td>Business-to-Customer</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma-Separated Values</td>
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<tr>
<td>(D)GPS</td>
<td>(Differential) Global Positioning System</td>
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<td>DLL</td>
<td>Dynamic-Link Library</td>
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<tr>
<td>DNS</td>
<td>Domain Name Server</td>
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<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>HTTP</td>
<td>Hypertext Transport Protocol</td>
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<tr>
<td>I/O</td>
<td>Input/Output</td>
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<tr>
<td>IMEI</td>
<td>International Mobile Equipment Identity</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transport System</td>
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<tr>
<td>LTE</td>
<td>Long-term Evolution</td>
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<tr>
<td>OTAP</td>
<td>Over-the-Air Provisioning</td>
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<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
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<tr>
<td>RDS</td>
<td>Radio Data System</td>
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<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
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<td>SA</td>
<td>Selective Availability</td>
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<tr>
<td>SOAP</td>
<td>Simple Object Access Protocol</td>
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<td>SPS</td>
<td>Standard Positioning Service</td>
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<tr>
<td>SQL</td>
<td>Structured Query Language</td>
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<tr>
<td>SVR</td>
<td>Stolen Vehicle Recovery</td>
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<tr>
<td>TMC</td>
<td>Traffic Message Channel</td>
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<td>TPEG</td>
<td>Transport Protocol Experts Group</td>
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<tr>
<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<tr>
<td>WSDL</td>
<td>Web Service Definition Language</td>
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<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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References


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