Real Time Truck Tracking Mass Haul Android Application for Construction Collaboration Cloud

Master's Thesis
Department of Built Environment
School of Engineering
Aalto University

Espoo, 01 May 2016

Muhammad Hassan
Master of Science in Technology

Supervisor: Professor Kirsi Virrantaus
Advisor: M.Sc Teemu Kivimäki

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author	Muhammad Hassan
Title of thesis	Real Time Truck Tracking Mass Haul Android Application for Construction Collaboration Cloud
Degree programme	Degree Programme in Geomatics
Major	Geoinformation Technology
Code	IA3002
Thesis supervisor	Professor Kirsi Virrantaus
Thesis advisor	Teemu Kivimäki
Date	01.05.2016
Number of pages	6+41
Language	English

Abstract

This thesis provides an over view of previously designed real time tracking solutions that are normally used in fleet management. These solutions normally consist of different hardware modules controlled by a micro-controller. The purpose of this thesis is to introduce real time vehicle tracking using Android smartphone devices and importance of tracking in construction site dump trucks. Furthermore, the importance of using the information in to BIM (building information model) systems for construction site managers, field surveyors, site designers. A test solution is implemented and tested to record the feasibility of the proposed solution and track the issues that this could solve.

Previously designed tracking solutions are hard to setup in the cloud infrastructure, those are more time consuming and error prone, as the hardware is involved so installing and configuring requires time and money. It is very hard to use in- formation captured by those solutions with existing BIM systems for cost and volume estimations. The data need to be exported in different formats and need correction and cleaning before using in other systems. While solution proposed here introduces mobile application that could be installed on any smartphone that supports Android platform. Mass haul is an important factor in cost estimation for construction projects. We have used that information gathered from our proposed solution to be used in coordination with other features in BIM system to calculate the volume and cost estimation and work site efficiency.

This thesis also changed the manual logbook method of transferring working hours to site managers to automatically sending all the information using the cloud infrastructure. Construction site managers would be able see all the information about the trucks like number of hours worked between two dates, kind of material transported by dumpers, total time and distance travelled for each task (each load and unload).

Keywords BIM, Android, Smartphones, Construction Collaboration Cloud, Mass Haul, Volume calculation, Real Time Tracking

Preface

This thesis report formally concludes the results gathered by thesis work done at Infrakit Oy; a cloud based collaboration service provider company for construction sites. This thesis was practically deployed and test in different customers sites. One of the test site is in Bergum Netherlands and the other test site is in Stockholm, Sweden. Many people at both the construction sites have helped in making this project a success and I am unable to name all of them but I am very thankful to every person on the construction sites who have used this application and helped me in achieving the end results we aimed for.

First I would like to thank the supervisor of the thesis, Professor Kirsi Virrantaus for her inputs on the thesis work, organizing the thesis paper and guiding on each step in writing and research work. After that, I would like to thank the co-supervisor of the thesis, Teemu Kivimäki, CEO Infrakit Oy, for offering this thesis position, helping and supporting me in visiting customer sites for gathering research questions, performing user group studies and on all phases from requirement engineering till implementation, deployment and troubleshooting of proposed beta version of the project.Without his help and keen interest I would not be possible to complete this thesis on time both in research and implementation phases. I would also like to thank Matti Mykkänen, CTO Infrakit Oy, for helping me on technical grounds and offering his technical support in successful implementation and testing. Also I would like to thank Pipsa Aro, marketing manager at Infrakit, for singing songs in the office and cheering us up. Finally I would like to thank my parents for their prayers and motivation that helped me in pursuing my educational as well as professional goals throughout my life.

Lets just hope that our research and technical advancement could help in making other's life more easy and meaningful.

Espoo, 01.5.2016

Muhammad Hassan

Contents

Abbreviations

CEO	Chief Executive Officer
CTO	Chief Technology Officer
GPS	Global Positioning System
GIS	Geographical Information System
BIM	Building Information Modeling
ACE	Architecture, Construction and Engineering
USB	Universal Serial Bus
HDD	Hard Disk Drives
GLONASS	Global Navigation Satellite System
GPRS	General Packet Radio Service
3G	Third generation of mobile telecommunications technology
4G	Fourth generation of mobile telecommunications technology
UTC	Coordinated Universal Time
GSM	Global system for mobile communication
HAL	Hardware Abstraction Layer
OS	Operating System
SMS	Short Message Service
HTTP	Hyper Text Transfer Protocol
CSV	Comma Separated Values

1 Introduction

1.1 Background and motivation

As the technology advances, it induces a huge effect in every other field that is associated with it. Fields like bioinformatics, geo-informatics, electrical engineering and last but not the least civil engineering has embraced the advancement to streamline the process and procedures that have been done manually before. As this thesis is presented and implemented in the context of construction and civil engineering, so more emphasizes have been done on explaining the use of technological advancement in construction industry.

Building information modeling

Here the concept of BIM comes into existence. BIM (Building information modeling) is used to improve the project delivery for construction projects and information sharing between the stakeholders throughout the entire life cycle of the project. BIM tools are used to visualize the design and improved digital collaboration and improve design analysis. These tools are used for the digital management of the physical properties of the places using different kind of industry standard design files. These files can be imported and exported in different files formats and thus collaboration between different tools that are used to implement the BIM becomes handy. Figure 1 shows the key benefits of using BIM process for managing construction projects.

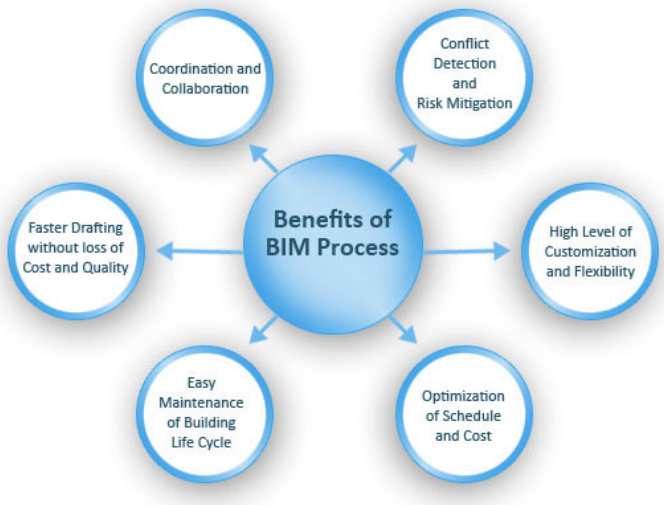

Figure 1: Key benefits of using BIM http://www.bluentcad.com/services/images/benefits-of-bim.jpg

BIM plays an important role in the modern construction paradigms. It gives a complete and transparent picture of the project progress. Progress of the infrastructure projects now could be monitored in nearly real time. All the stakeholders get the clear progress of the project and hence it saves time and money. A modern

BIM software facilitates different stakeholders who are involved in any phase of the project. Infrakit a cloud base software solution provider to construction companies has explained in details about the different stake holders involved in such project [4].

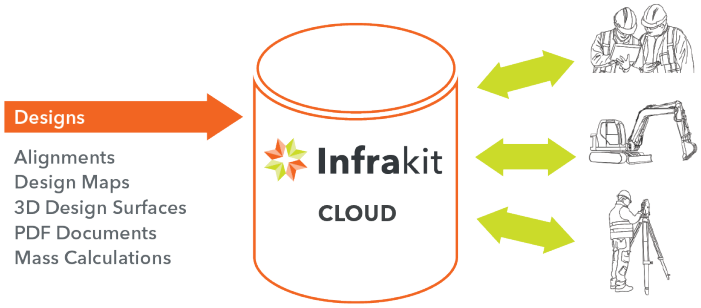

Figure 2: BIM and file sharing between stakeholders and onsite machinery .[4]

In a typical BIM based project management, there are mainly four major roles or stakeholders that uses the service for managing construction projects. Those stakeholders are namely the construction company, the project owner, the design engineer and last but not least the project consultant.

In construction industry, the typical process and procedures mostly relies on paper based solution. All the design are printed on paper and this flow of information between the designers, project managers, field supervisors is manual. This introduces a huge error on the construction level and time delays in completing the project because of lack of information on proper time. As the project delays, it costs more. After identification of such problems many companies has introduced different infra construction based services to manage and handle all the information. Won Suk Jang [21], in one of his papers, explains the importance of tracking in construction site. Tracking on construction sites could be of many types for example tracking materials, inventory, equipment The best management solution is the one which tracks all that information and provides it in real time to the project owner to make timely decision. Thus management systems has very importance in tracking all this information in identifying and recording the optimal use of equipment, information about the material that is being transported to the construction site and off of the construction site, tracking the inventory to reduce the project cost and meet deadlines. In his paper, he further explains that research is always going on identifying how technology could be used to better track the construction phases. Current phases of construction still relays on old legacy systems which causes errors and delays in getting the construction progress.

"The ineffectiveness, reported to be 4% to 6% of labor cost related to manual operation of the reporting, recording and transferring field data in current tracking systems are still an important issues in large construction projects", he explains. In another research he explains that 58% of the work hours are ineffectively used. This ineffectively is could be because of waiting for further instructions from surveyor,

lack of updated information about the project and using paper based design on construction sites. As the thesis is proposed by Infrakit Oy, one of the best construction based collaboration providing service has done research on how digitization could help on saving costs. Research with one clients Destia Oy, a Finnish contractor of road maintenance, roadworks, railways and other infrastructure construction, who has been using Infra services from Infrakit Oy since last 5 years have shown that you could save up to 20% of the construction cost by adopting a BIM (Building Information Modeling) system like Infrakit, being a leading BIM service is one of the leading service provider in road construction that could save huge costs on construction sites. In exploring the different problems at construction sites it came to notice that not only tracking just inventory and equipment but also tracking the vehicles like excavators, dump trucks and other construction machine is very important.

By tracking all the information from vehicles that are being used for mass movement on construction site has a huge impact on project cost and scheduling for contractors and sub-contractors. Furthermore, this information is used in calculating the volumes for designs and effective use of machinery on construction site. It is proved practically how tracking vehicles on construction site help in identifying the project progress and effective use of equipment using Infrakit office application. In a research with one of company De Boer Burgum, from Netherlands, a company providing services as subcontractors to construction site with machinery like dump site trucks and excavators, it was identified that is always difficult for them to track the performance of trucks when they are working on a construction site. Also it is difficult for them to get real time truck location and loads and unload place of the tasks they do on regular basis is also not know. All the information like total mass moved on-site or off-site is transferred manually to office using papers and based on that information they make a bill for the construction companies they have been working as subcontractor. This lack of information, like mass moved by every truck, total fuel consumption is not in real time, so it is always difficult for them to make a bill for the construction company. Also this information, like the mass moved on-site and off-site is also important for Infrakit service as well to make more advance project scheduling and management tool; so this project was proposed to offer De Boer Burgum a software solution that would solve the problem they face.

Cloud computing

As impressed by the technological advancement the previously BIM based tools needed to be installed on the physical machines in the offices requiring a lot of physical computing power. This is because the design files that stores the design information of the construction project usually too big and complex and need special algorithms to parse those file and visualize them, so with the introduction of cloud computing these problem of having high computing client ends have been compromised with more powerful server infrastructure in the clouds. Cloud computing is not that old concept, but within last decade became the de facto for many high end computing

application.Cloud computing is basically a practice of using network of remote servers hosted on the internet for storing, processing and managing the data instead of having local servers in-house as shown in figure 3.

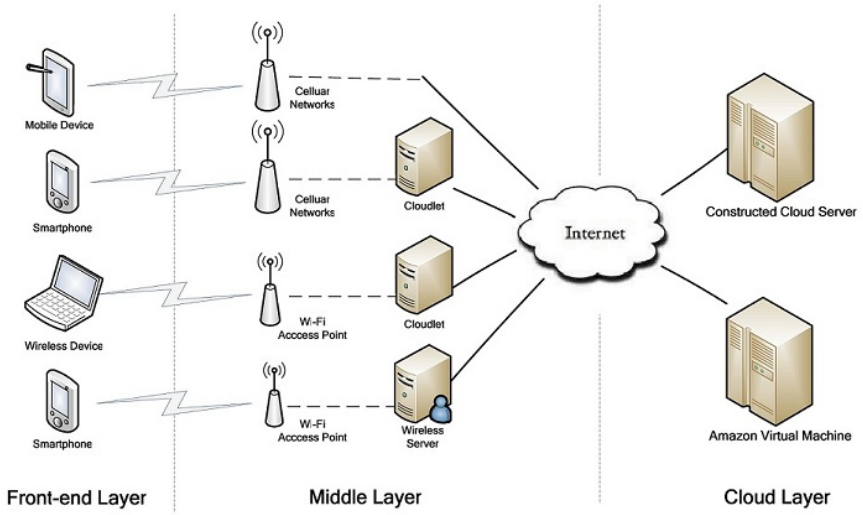

Figure 3: Cloud Computing Architecture [2]

Cloud computing is also called on-demand computing because the resources are allocated on request and once the need for high end computing ends, resources are freed. This practice have great potential for saving budgets as compared to traditional hosting or local server that requires more money and resource person for managing and keeping everything up and running all the times. All the management and maintenance have become the headache of the service providers and users are free to allocate resources whenever they need it. Also this is web based solution so all the design files and collaboration is possible anywhere anytime using an internet and a web browser. Cloud computing is explained in detail in the literature review section.

1.2 The aim of the thesis

The aim of this master's thesis is to describe the importance of BIM, construction site dump trucks tracking and how we can achieve the real time tracking using latest mobile based cloud computing solution. Identifying the problems with the already design solutions and comparing it with proposed solution. This thesis also provides an overview of how information from mass haul could be used in other parts of the project to complete the full picture and make decision making and vehicle management easy and effective. All of those problems are identified on construction sites regarding mass haul and a solution is proposed, designed, implemented and tested on the real construction site. User's feedbacks were collected in testing phase and the feasibility is assessed based on those feedbacks. The solution consist of an Android based smartphone application and web based interface on the Infrakit web

server where project owner could easily track the performance and mass movement from trucks on-site or off-site with real time tracking using Google maps

1.3 Structure of the study

This thesis is divided into following six parts. The first part explains the motivation and background. Second part of this document summarizes the literature review. Different types of tracking solution have been described after reading several research papers. The importance of BIM is analyzed in the context of different research results. Benefits of smart phone based and cloud computing based solution are also explained in detail. Third part of this document explains the research methods and design that are used while doing requirements engineering, implantation and actual field testing of the proposed solution. This section also explains about the architecture of the proposed solution with different use cases of both mobile and web based solution. Fourth section consist of the results that have been achieved and the analysis of few days of data that is logged by the trucks using smart phone application implemented. Fifth section consists of the conclusion that have been drawn from the use feedbacks and recorded logged data from the field dump trucks. Different analyses methods have been used in the conclusion to show what are the other ways this data could be useful. Also how this data; logged by the trucks on web server, could be integrated with BIM to get the more useful results. Section six consists of further improvement in the proposed solution based on the uses feedbacks

2 Literature review

This section summarizes literature that explains BIM, importance and usability of BIM and collaboration in construction, tracking and the use of smartphones for real time tracking system and benefits of integrating material transportation vehicles with BIM software. This section is sub divided into subsections. Section 2.1 explains the BIM and importance of BIM for construction projects. Section 2.2 discusses real time tracking and tracing system for BIM. In section 2.3, importance for tracking the construction site vehicles and material transportation trucks is discussed. In Section 2.4, explores pros and cons of previously designed tracking solutions for construction sites vehicles. Section 2.5 compares the performance of using in built GPS of smartphones and external GPS device integrated with smartphones. Section 2.6 explains the benefits of using smartphone as a device for real time tracking of moving objects like dump trucks

2.1 BIM and importance of construction collaboration services

As the Tracking of vehicles is an integrated part of BIM (Building information modeling) system in order to get the full information, what is happening on the construction site, what kind of material is being transported on the site or off the site? So, before understanding why we need tracking vehicles in construction we first need to understand system in which this module will be added. This section will explain the BIM and its importance. BIM is set of tools that help the architecture, construction and engineering (ACE) industry to perform work in a more controlled, efficient and effective way. BIM is one of the most promising development in the ACE industry [11]. According to Bentley [13], BIM comprises of entire life cycle of the building like design, build and operations and the information is defined and simulated using the integrated tools.

Formally, BIM can be defined as a set of interacting policies, processes and technologies that helps to manage the essential building design and project data in digital format throughout the building's life cycle [14]. Information is accessible in real time through the construction phase in order to achieve objectives and goals and to take timely decisions to cut down the project cost. BIM is new approach that is introduced in design, construction and facility management industry in which the information is stakeholders are facilitated about the progress of work by exchange and interoperability of information in digital format. In most construction companies in the world,typical procedure of information sharing is followed like sharing data manually using hardware device like USB flash drives or HDD (hard disk drives), that causes information gaps, duplication of data, inconsistency of data, waste of time and error propagation. More importantly, the interaction is limited using two dimensions like using the paper on the construction site so introducing geometric dimension as well as time dimension would make the whole process more transparent and less error prone. So, the application of BIM technologies in construction simplifies the

exchange of information and expertise between different actors of decision making phase and of construction and facility management phase.

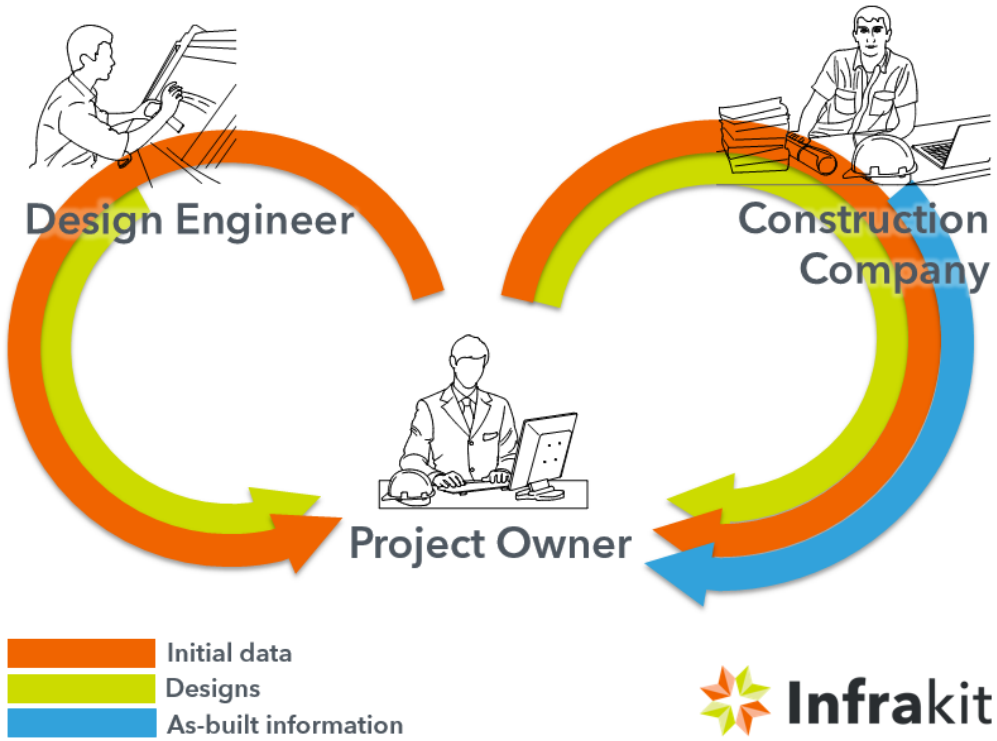

Figure 4: the exchange of information between different stake holders.[1]

BIM allows application to share data in different formats depending on the type of information that is being shared, these formats are The Industry Foundation Classes (IFC) that is free format that means it is not linked to some specific software application, and hence it can be read in a whole range of software application for the exchange of information. Some other ways of exchanging information between the software applications made by the same vendor, like Autodesk (Owner of AutoCAD, Revit and 3ds Max). All of the applications by same software vendor are compatible with each other in order to share information like textures and material easily and to keep everything consistent. Some other formats for data change are dxf, xml, kml etc that can be used to exchange specialized information between different tools.

Building road, rail and earthworks projects using digital designs has been shown to significantly improve efficiency. BIM not only helps in exchanging the information but also provides a whole range of applications that can be used in visualizing and quality control of the whole construction phase using the files shared between the stakeholders. Modern ways of exchanging construction information is usually carried out using a centralized server where all the information resides and could be accessed using a personal computer and a web browser or using a specialized mobile application developed for that particular service. Introduction of mobile technologies in the sharing construction information helps in accessing information

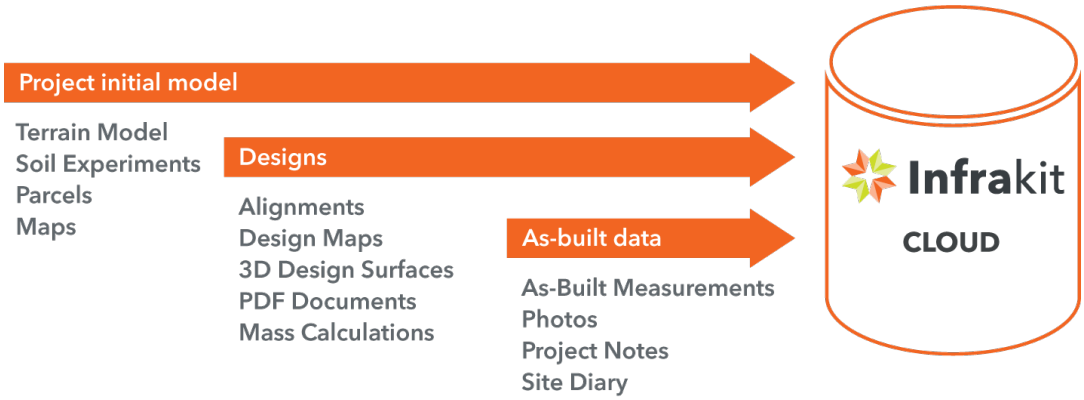

Figure 5: Different types of information shared through BIM collaboration cloud.[3]

in the field using mobile phones or tablets. Thus the transparency is maintained throughout the project's life cycle and information is still available in the maintenance phase. Following figure shows the transition how the information is available with the implementation of BIM.

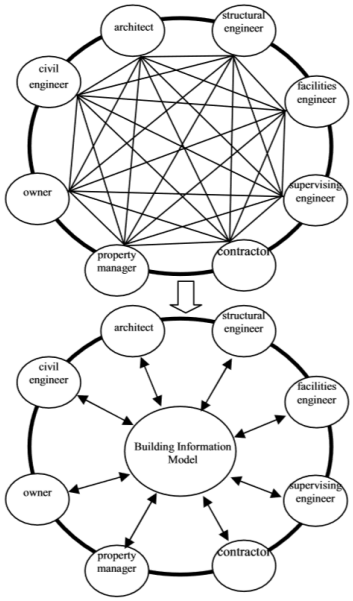

Figure 6: The transition of information sources.[5]

So, the value of BIM in construction has many advantages, weather it is ability to save time using automated procedures, reducing traveling for meeting and onsite visit to get the updated information or saving money, all this because information is available earlier to make cost effective decisions. Over the past 50 years the construction industry had small technological innovation as compared to other

industries. The use of prefabrication, eco-friendly materials and green building design innovations at one side the use of same old procedure and technologies by project teams for construction management on the other side is a notable dilemma. Now, innovation is becoming the need of hour for construction industry, so project managers, contractors and sub-contractor want to use innovation in delivering their work, as a result, we are starting to see the interest of construction management firms willing to invest, in technology vendors for building construction collaboration services, and adopting BIM technologies figure 4 below.

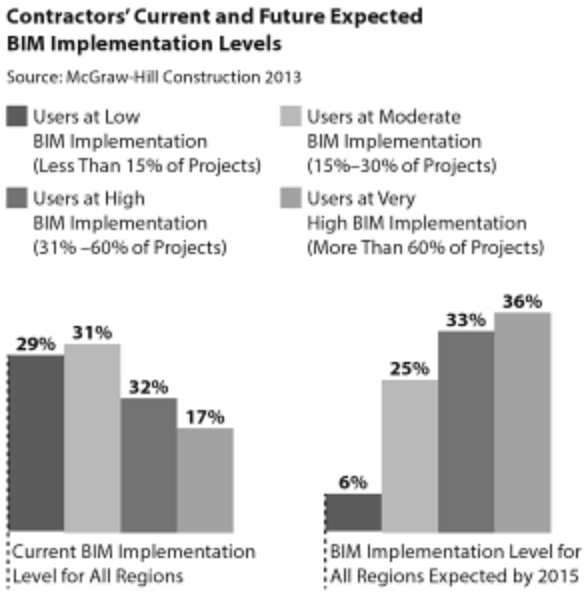

Figure 7: The transition of information sources.[7]

2.2 Cloud computing architectures

Cloud computing used the previously used technologies of web server and virtualization and introduces the concept of on demand computing. Network, computing and storage resources are occupied from a shared pool of resources, consumed as needed and then freed.

After discussing the basic concepts of cloud computing in the introduction of this thesis document, it is necessary to further explain the three basic architectures and all the perks that we get with cloud computing. As by the definition of cloud computing, cloud computing is about on demand resources utilisation, so the biggest benefit of cloud computing is cost efficiency. Mariana et al [12] in his paper about secure cloud computing benefits and risk associated with cloud computing. These benefits include mostly cost efficiency, scalability and flexibility. Figure 8 explains the benefits of cloud computing.

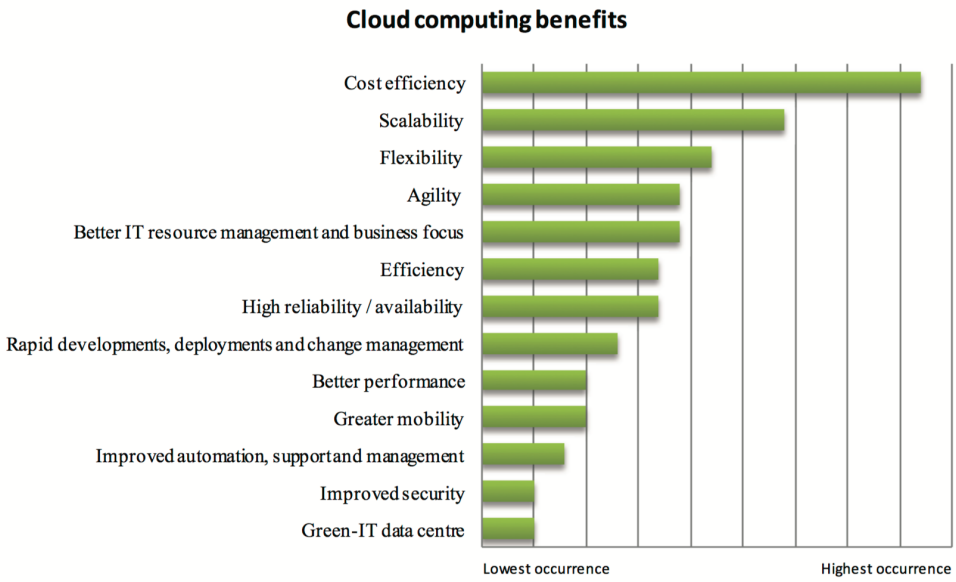

Figure 8: Secure cloud computing [12]

Cloud computing has three basic architectures. SaaS(Software as a Service), PaaS (Platform as a Service) and AaaS (Architecture as a Service). Joel et al [15] in his paper about benefits and challenges of three cloud computing service model explains about the these architectures in detail.

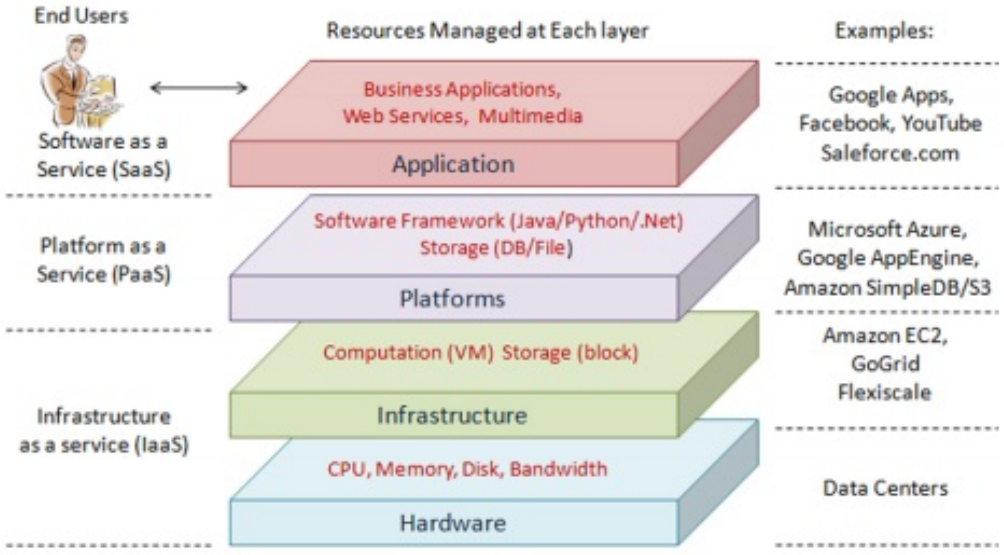

Figure 9: http://cloudcomputingnet.com/wp-content/uploads/2015/05/Cloud-Computing-Architecture-Apps.jpg

SaaS as the name suggests is using the software services that are hosted in cloud and not on the user own's device. This model used pay per use pricing scheme where

different application like gmail, hotmail and Facebook. In this way the limit on end users hardware requirement is lift and the user only needs web browser clients to user the applications any time any where using internet. It saves upfront money and cost efficiency for organisations. In PaaS, the service provider gives access to different APIs, programming languages and development resources with the help of which users can build their own custom applications without installing the development environments. As the application that is built using PaaS has all the features of cloud inherited from the framework so their applications are highly available and and cost effective in resource utilisations using virtualization and on-demand computing technology. IaaS on the other hand is the very basic framework and infrastructure for services that use the servers, storage and virtualization for on demand computing that is provided by the cloud service provider. In IaaS the consumer of the service has to patch up different modules together to make a service. All the management of the resources, checks and validation are in the hands of consumer of the service and not on the service providers and still cost efficient by paying for resources used per hours or so. For truck tracking application and as a whole Infrakit application is concerned IaaS is used to have full control over all the resources and paying for what we have used.

2.3 Tracking and types of Tracking systems

According to book, The Dictionary of Transport and Logistics by David Lowe, Tracking is a process in which different technologies like Global positioning system and electronic communication systems are combined to identify the location of vehicles on earth. This location needs to be real time that means you have active connection to the vehicle for transmitting information or instructions to make better decision or make good use of resources. There is possible to have other technologies instead of GPS like Global Navigation Satellite System (GLONASS), but here we are considering GPS as is the core of implementation platform (Android).

Types of tracking systems

There are two types of tracking systems, namely active and passive tracking systems. The main difference between the two systems is how they transmit and how and when that data is utilized. Passive tracking system usually stores locally within the device information like GPS location, heading, speed and sometimes if necessary events like key on/off door open/close. When this vehicle returns back to the data collection point, this device is removed and all the data is moved to computers for evaluation purposes. In this type of tracking systems it is not possible to get instantaneous data in real time. While active tracking systems uses wireless data transmission technologies like GPRS or SMS based communication channels to transmit the data to online servers where the information is available in nearly real time and then this data is used to make decision on the fly. The data transmitted is normally plotted on digital maps in order to view the location of vehicle. Modern systems consist of both active and passive techniques, when the data transmission mediums (GPS,

SMS, 3G, 4G) are available data is transmitted and when it is not possible to send information to remote servers, the data is stored locally in the device and when it possible to transmit the information the data is transmitted.

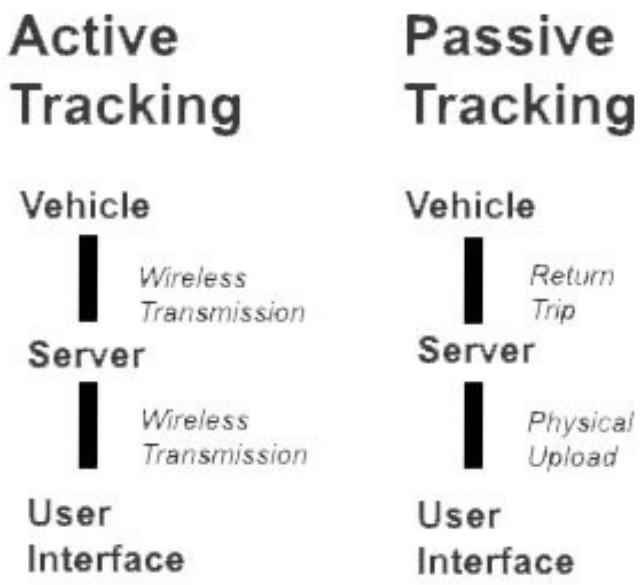

Figure 10: Active vs Passive tracking systems.[8]

2.4 Global Positing System (GPS)

GPS is space-based navigation system that provides the location and time in all weather conditions, anywhere on or near the earth where there is an unobstructed line of sight to four or more satellites. The system provides the critical capabilities to civil military in modern tracking systems, global position system is core factor and whole system depends on it. GPS is fully operational and efficient form of system that is used for optimum positing system. GPS provides precise, incessant, global three-dimensional position and velocity to the users with suitable receiving device. GPS is also used in the configuration of Coordinated Universal Time (UTC) on the receiving devices. The satellite constellation that makes the whole system consists of 24 satellites arrange in 6 orbital planes with 4 satellites per plane. A worldwide ground control center is responsible for monitoring the health and status of the satellites.Configuration information, correcting the orbit, uploading different positing data to satellites are the responsibilities of monitoring station.

For a GPS receiver to work properly and accurately, it must get signals from at least four satellites in order to calculate latitude, longitude and altitude, and then rest of the information could be calculated by these parameters. The position by GPS receiver is calculated by using the triangulation method, it uses three satellites to calculate the position and for the altitude fourth satellite is used. That is why GPS is very accurate in determining the position within meters.

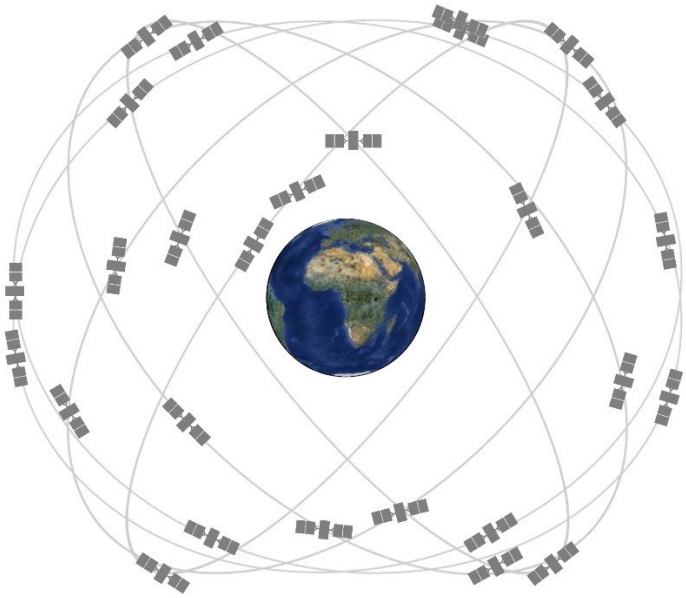

Figure 11: GPS constellation.[9]]

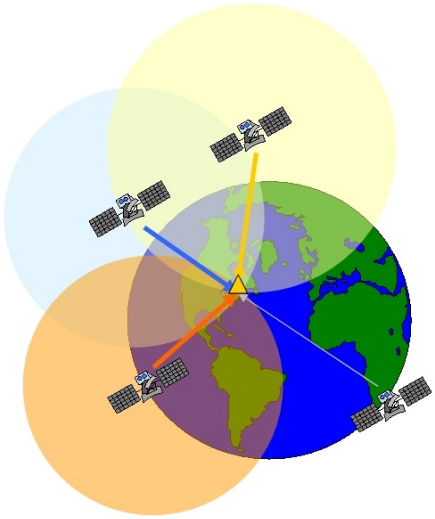

Figure 12: Triangulation http://www.sxbluegps.com/wp-content/uploads/2012/12/gps-triangulation.jpg

2.5 Importance of tracking construction site vehicles

Tracking vehicle is always important in fleet management. People in administration and decision making position need to know about the current status of vehicles in real time to make decisions and meet the customer requirements. As being the main equipment in the construction projects, trucks play an important role in any phase of the project. As this thesis work is done with the collaboration of De Boer Burgum B.V. a company that give services in construction projects. It is very important for them to track in real time which trucks are working on which construction sites and

what is daily progress.

Figure 13: Vehicles working at construction site http://img.directindustry.com/images_di/photo-g/rigid-dump-truck-mining-diesel-21104-3244179.jpg

Volume of construction material like sand, mud, soil, gravel moved off site or on site is very important in project planning. Tracking the volume is important factor in cost estimation and creating the final budget. Trucks are differentiated on the bases of volume they can transport. Trucks are usually used with the excavator and loaders for excavation and soil haul off or delivery (Douglas D. Gransberg et el, 2006:92).

Trucks that are produced within couple of years have very advanced build in machine control system that can give all information about the trucks like current volume loaded, no of tons transferred, number of loads and unloads All this information if used with an existing BIM system would result in time and cost saving decisions. Currently the usage of this information is manual and is not integrated with the BIM systems. In an interview with Cor Lont, Civieltechnisch medewerker at De Boer Burgum B.V. says that, real time location of trucks is also very important for loaders and excavators. Also it is useful to know when the truck is coming back for refill so that the excavator should be free from other tasks and refill the truck.

2.6 Previously designed tracking solutions

GPS based tracking is not new concept. There are many solutions that are already designed that uses the different external hardware modules to make a complete GPS tracking system. These hardware devices are normally used in fleet management system. Also vehicles like ambulances and fire brigade vehicles also uses variations of those device to use as tracking modules. These device normally varies based on the medium of communication to the tracking server and the quality of GPS module used.

The more accurate GPS module is the more precise location we get and accurately we can identify the location of the device on the earth. Following is one of those GPS tracking system where GSM (Global system for mobile communication) based communication system is used to transmit GPS coordinates of the current location. These device as a whole unit are portable and can be attached to anything one wants to track.

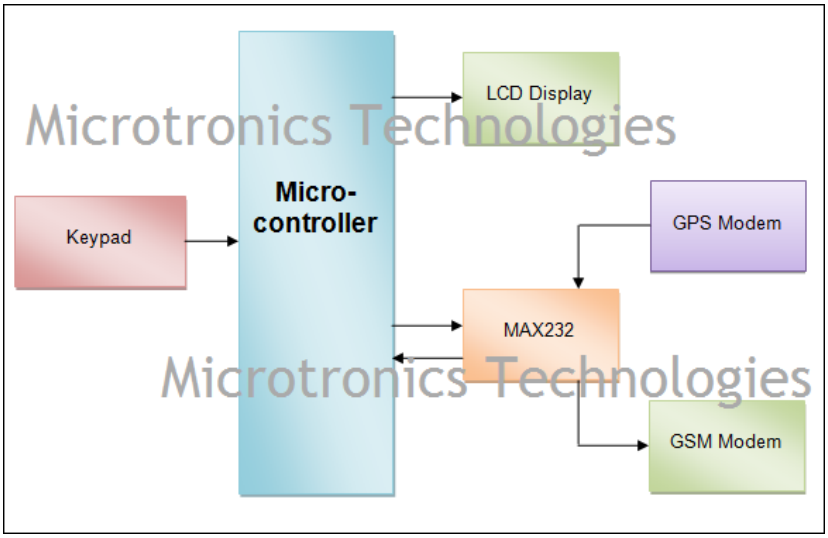

Figure 14: Separate modules and micro-controller based GPS tracking architecture. http://www.projectsof8051.com/circuits/1801-vehicle-tracking-system-using-gps-and-gsm-modem.png

This device consists of Garmin 18-5 HZ GPS receiver with a capability of DGPS (differential GPS) ,PIC16F877A micro-controller unit and SIMCOM 300 GSM modem as shown in figure above. The GPS receiver get the location coordinates from the satellites with a resolution of 5 readings/second in NMEA (National Marine Electronics Association) format which contains different office. There are different algorithms working in the micro-controller that are used to process this NMEA information like latitude, longitude After that micro-controller used serial communication to send this extracted information to the GSM module to SMS. MAX 232 level converter chip is used for voltage level conversion between the micro-controller and the two devices GPS receiver and GSM module.

Tracking center for this information that is sent via SMS is normally implemented in a similar way. This is simply a computer to which a GSM module is attached to receive SMS that contains the location information and other metadata for devices identification and then this information is used with interfaces to google maps program. These maps are embedded in desktop application and that desktop application is usually connected to GSM module.

There is one other variation of tracking system client module that is GPS with GPRS module. In this case GPRS is used as a communication medium by the

micro-controller. The data is sent via GPRS module, GPRS posts data to web based service using HTTP protocol. To save the tracking record history and the current position different type of database application could be used on database servers like MySQL, PostgreSQL and MSSQL A web application is developed where a google map is embedded and all the information of vehicle is requested from the database and shown on the google maps in real time. These web application uses Ajax (asynchronous JavaScript and XML) requests to get latest information periodically. These web application could be accessed anywhere using internet connection using web browser. Following diagram explains a n-tier tracking system.

As we can see from the couple of solutions discussed earlier, these tracking system consists of different hardware modules that come in contact to make whole system. Also it require effort for installation, configuration and troubleshooting. As the number of hardware module increases in a system the possibility of failure also increases but despite the fact, these devices have high precision GPS modules that have very accurate location information for real-time tracking.

2.7 Benefits of using smartphone as a device for real time tracking

As we discussed earlier about the previously designed solutions for GPS based real-time tracking systems, there are many modules that are used to make an integrated system. Considering all the modules important for GPS based tracking, today in the current era, smartphones are also best candidates to be used in the real time tracking system. As with the advancement in the technology, smartphones are getting more and more powerful. Today a smartphone (Android) contains a variety of different hardware sensors and modules like accelerometer, temperature sensor, gravity sensor, gyroscope, magnetic field sensor, orientation sensor, compass, pressure sensor and last but not least GPS receiver. The HAL (hardware abstraction layer) defines a standard interface for hardware vendors to implement so that these modules could be used easily with any smartphone and OS version using those APIs (application programming interfaces). As we are working with android system, the Android system architecture diagram would be helpful in understanding this abstraction provided by Android system to the developer to use those feature of a smartphone for developing any system using those hardware modules. Following is the Android system diagram.

Here in the diagram above we can see the application framework provides all APIs to application developer, while technically these APIs interact with HAL interfaces to use features offered by the underlying hardware module in those smartphones. In addition to all those hardware sensors, all other typical features of a phone like sending SMS, making a call, connecting to the internet, accessing web APIs using HTTP protocol is always there. In addition to all those features, there are still some challenges that needed to be addressed like network availability in the remote areas and battery life however being a portable device with a lot of sensor collections and the available of 3G and 4G based internet connectivity increases smartphone's power

Figure 15: https://source.android.com/devices/images/ape_fwk_all.png

to be on the top of list for developing real-time applications as well.

3 Research methods and questions

3.1 Research approach

One of the important aspect of this thesis is to study the current methods that are being used on construction site for collecting the log information from the trucks and how we can automate the process using a technology and cloud based solutions. To identify the best possible ways to collect the information about the current methods adopted on construction sites and need for a digital solution different research methods have been studied. Based on our case, one of the many research methods is employed to continue with process of gathering user requirements. Before discussing the research methods used, first we could formally define the scientific method that is normally used to draw conclusions and report results. As we can see in the following diagram, the scientific method starts with asking a question about the phenomenon, then using the existing sources we try to find the possible solution and formulate a hypothesis, once we have the hypothesis we could draw the conclusions and report results after conducting a research method.

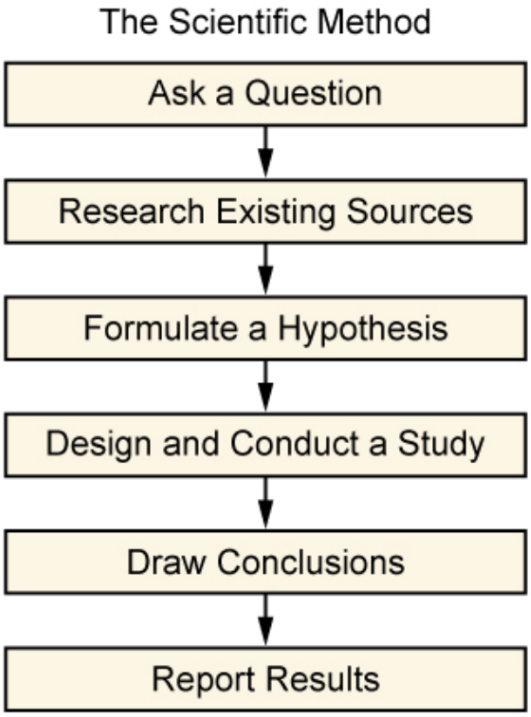

Figure 16: Scientific method identifying and solving a problem https://www.boundless.com/sociology/textbooks/boundless-sociology-textbook/sociological-research-2/the-research-process-26/determining-the-research-design-168-7446/images/the-scientific-method-is-an-essential-tool-in-research

As this thesis is carried out in collaboration with De Boer Burgum B.V, a company in Netherlands that provides services as subcontractors on construction sites with

machines like excavators and dumpers In order to better understand the requirements, we need to employ qualitative methods to get the user requirements, study the previously used methods of collecting log information from trucks and the ways this information that is being used by the company.

In this thesis, to get deeper understanding of need for digital tracking solution for construction site vehicles, different qualitative methods like participant observation, stakeholder interview and focus groups Different user groups have been interviewed and observed like truck drivers, site owner and supervisors to get the information needed to propose a solution and solve the problems that have been reported while gathering log information from trucks by supervisors and truck drivers. Interviews with different stakeholders were the initial steps when the logging problem at construction sites was identified. Importance of digitizing the truck tracking and the use case have been identified in those interviews. Requirement engineering has also been carried out in those meetings. Stakeholders were asked with different questions in the interviews and everything was recorded. Once the interview session was completed all the information was formally written and verified again by the stockholders. Different use cases and requirements have been identified from the user interview have been done after the interview.There are GPS device on the excavators but there are no GPS devices on the trucks working on the field. So, it is impossible to track the trucks, were are they at any particular time, also it is difficult for the trucks for finding routes between working site and dumping site. Also it needed to be tracked which type of material is transported onsite or offsite by trucks. If the site is really big than it is difficult for the trucks for the navigation and finding entry and exit points. Also truck drivers also need to know which excavator they need to go for refill in case of dumping the mass out of the working site. Also the excavator also need to know when the trucks are coming back (distance and estimated time) for the refilling so that they could do some other task. Truck driver give information about their working progress per day by writing working hours on paper and the number of rounds per day, it is difficult to handle the papers and to then digitize the information and save in the computer. Volume for the mass moved is calculated using GPS rover per week manually while some of the trucks have built in weighting system.

In addition to interviews, participant observation and focus group had also been established on the construction site that consist of different truck drivers. All the behaviors have been studied carefully and recorded how they have been doing logging and the use cases for truck drivers have been identified. Those participants were poked with different question about the proposed solution i.e. how they want to see the user interface and how to make it user friendly so that they can still use them while driving around on the construction site without losing their concentration from driving. All the responses were recorded on paper and then formally added to the use cases that have been presented in the results part of this master thesis.

As the research method was detailed and user centric, as the proposed solution would be used on the construction site by different stakeholders so it was important

to formulate the research question while doing interviews, focus group studies and participant observations. In the next section, all the research question that had been identified are presented.

3.2 Research questions

The aim of this master's thesis is to identify the importance of real time tracking of construction site dump trucks and the usability of mass haul information in other parts of BIM solution. Previously designed real time tracking solutions have been studied and a new solution is proposed that solves the problems that is identified on construction site regarding mass haul. Based on the user group studies, previously designed solutions, mass haul information collection methods and literature reviews following research questions have been identified.

3.2.1 How important is dump truck tracking for construction projects?

One of the most important aspect of this thesis was to identify the importance of tracking construction site vehicles in real time. How important it is for the project managers and project owners for project planning. This information was gathered in the interviews with the project owners and supervisors and explained in the motivation of this thesis document. After the realization of importance, we came with the second question stated below.

3.2.2 How the information is collected from dump trucks?

Once the importance of tracking is identified the next question was: what is the information that is important for site project managers and project owners? The answer to this question is the log book that is typically used by truck drivers to log the tasks and then they send this log book or photo of that log using email or any third party messenger. The typical log book entry contains the start time and end time of the task, quantity of material being loaded and the type of material loaded. What other information that they are interested to see was the real time location of the trucks and loading and unloading location of log entry in the log book in the beta version . This lead us to the third question that how we could automate the log entry process so that all the information is captured in addition to the real time tracking of trucks back in the office.

3.2.3 How to automate the process of information collection and how to achieve real time tracking?

Once the information collection needs have been identified, existing solutions were studied. Different papers were also read in order to get the understanding of previously designed solutions. The automation of the process needs a solution that could help in sending log book entries in real time in addition to real time location tracking of the trucks. Previously solutions have specialized hardware and physical installation on the trucks with troubleshooting and configuration needs. We needed to identify

in our research what would be the appropriate solution to achieve all this in addition to maintain the context of the overall project e.g. which logged task was logged by which truck and in which project, what is the path or track of a particular task Next research question was the main proposed infrastructure for the solution provided.

3.2.4 What is the feasible solution that do not need site visit for installation and troubleshooting?

After carefully reading the current research in the area of real time tracking and studying previously designed solutions, it was cleared that previously designed solutions are not good solution in our case because the information should also be incorporated with a BIM system to complete the full picture of the construction site progress. For that custom Android based application was considered as an appropriate solution. First of all it?s free and easy to install from the Google play store so no need for physically installation of the application or any hardware module is required, only Android based devices were needed in that case. Android devices are also cheaper and easily available and has built in GPS, so the proposed solution was happily accepted by the construction site owners, project managers and truck drivers for real time tracking and task logging as they can even test this application on their personal phones. Once the proposed solution was finalized and installed on the Android based smart phones and tested at the real construction sites, there were a lot of questions and modifications that needed to be done to make it usable by truck drivers both visually and technically. All those modifications and suggestions were captured in user group studies on sites and reported in the conclusion of this thesis report. After collecting the information from the truck tracking mobile application on Infrakit servers, now the main questions or the outcome, which is the last research question of this thesis report below.

3.2.5 How to use and analyze the information collected using smart phone application?

This question was one of the important final conclusion of the thesis that how the information could be used. As the information is same as collected manually using log book, so some of the use cases of that information are same, however as we get some additional information that was not possible with the log books like real time tracking, tracks, detailed task information, daily fuel consumption so that could be used in other parts of project planning and decision making for assigning trucks on a particular construction site. This information is discussed in detail in the conclusion of this thesis report; how to use the information and what are the future prospects of using mass haul tracking with the BIM system for better project planning.

4 Results

4.1 System architecture and implemented solution

After completion of qualitative research method, all the information from the interviews and focus groups is formally written and system architecture and technically aspects of the solution have been identified. Proposed solution was to make a real time earth moving dump truck tracking and map based collaboration system using latest mobile cloud computing technologies. As mobile cloud computing is the need of the hour so, testing how we could get most out of these technologies on the construction sites and for dump truck tracking was the initial task in the implementation phase. Following is the high level architecture of the proposed solution that consist of a client server based approach that serves both mobile application at construction site and site owner and site supervisor back at office using Infrakit web application. Web application uses Google maps to show all the vehicles connected to web server using REST API.

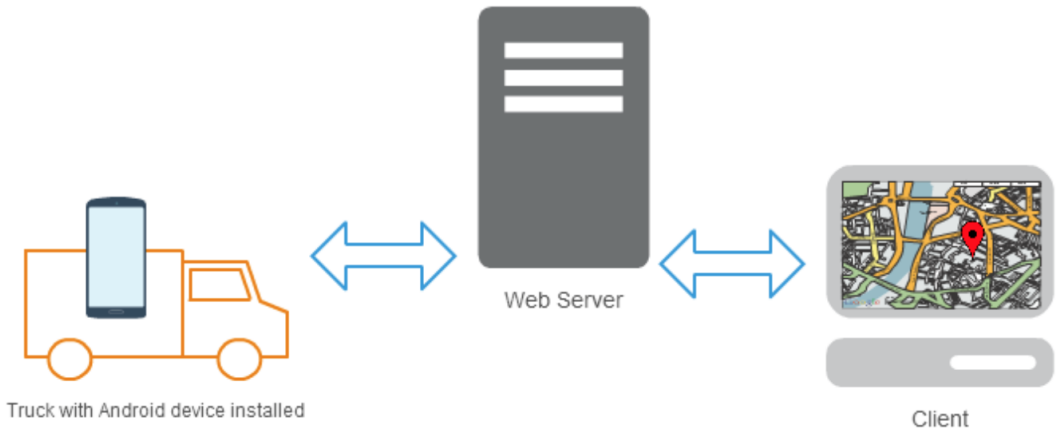

Figure 17: System architecture

As dump truck tracking and working hours per trucks at construction sites is very important to identify the cost estimation for a project. The movement of dump trucks for example on construction sites is also very important for the excavators. Time and resources consumed for taking dump off the construction sites is always of great importance and significance for the construction site manager. This project is proposed to solve a huge list of such problems using the latest mobile cloud computing technologies. Following are the list of problem in more formal way that were identified and finalized for implementation as a part of this master thesis.

Automating manual registers for logging the daily work progress by dump truck drivers. People offsite need to track all the dump trucks working on the project and current status like total moving time, approximate fuel consumption etc on the

project for daily, weekly or monthly reporting. Dump truck drivers need a mechanism for automatic report generation, about the loading and offloading from the site, for the cost calculation and managing assigned tasks

Dump truck drivers are not hi-tech users so optimizing the user interface and making it easy to use. The system is suggested to implement using the Android platform. Each truck would be installed with an Android device with native application installed. The application would use the GPS within the device and send the location to web server for real time tracking. The application would contain option for capturing the loading and unloading of dump and keeping the track. The application would send the statistics like the average distance travelled, quantity of material and kind of material after each unloading to the web server. One of the risk associated with truck tracking application is the battery problem. It is possible that the phone run out of battery or the device is powered off for no reason, built in charger is used with the mobile device so that it does not run out of battery. Other problem could be the availability of internet in that case the data is cached locally inside the device and when the internet is available the data would be synchronized with the web server.

4.2 System use cases

There are several features that have been implemented in order to answer and solve all the problem questions in this thesis. As this application consists of two user ends; front end on the web application and the Android application, so the uses differs for both users but both of them in combination are used to achieve the desired task. On the web application admin is able to add new devices to project with a username and password. Furthermore site admin is able to define different types of material as predefined material list that would be available when the truck driver will login from mobile application. Also site admin is able to assign project to truck user and gives rights to do mass haul activity in any particular project. These list of project will be available to the truck driver and list and they can chose one before doing any mass haul activity. Site admin can also track a vehicle in real time by pressing play button the trucks page on web application, google map will center the map on the vehicle for every new location update.

On the Android mobile application, after login with the same username and password credentials, user is able to select a project in which he or she wants to mass haul. Once the project is selected, the user is redirected to the map screen where user is able to select the volume and the type of material from the predefined list of materials. Also user is able to add any custom material name on the same screen. Once the user has selected the material and volume of the material that is currently loaded in the truck, now user can do load and unload activities. There are different types of information this primarily recorded and then there are secondary information that is derived from that information. For-example, latitude, longitude, volume, material, start time and end time of the task are recorded for each task and

then other information like speed, distance, total mass haul time, total task time, average time and average speed is calculated based on the primary information. This information could be downloaded from the web application in CSV format as show in the figure 27 on page 31.There are many useful visualization that are derived from the information that is collected from mobile devices and presented in the following section. Site admin could generate those visualizations and used them for further decision making or project planning.

4.3 Visualizations and statistics

Data visualization and statistics play an important role in understanding the patterns and information that is hidden deep inside the raw data collected. This information is very important in making timely decisions and understanding the business case. Data visualization is representation of the raw information in some pictorial or graphical format so that it became easily for decision maker to quickly understand and make effective decisions. As discussed in the previous section that different information is collected from mobile devices as primary information and then some secondary information is derived from it. Keeping in mind the importance of mass haul importance for site managers and decision makers, different types of visualization have been produced on the web application in order to give full picture of the story for site admins. Different kinds of graphs have been produced that are described briefly as following.

4.3.1 Heat maps

Heat maps are used in the visualization of latitude and longitude information for last 24 hours for the vehicles. Using heat maps the concentration of the location events are represented by different colors like red to yellow to green describing the most frequent traveling to least travelled paths by the trucks respectively.If a path is followed more than any other path on the site then that path will appear as red differentiating it from the least traveled path. This information is very important for site owners to see where most of the time is spent by the trucks on site. figure 18 shows the heat map for a truck.

4.3.2 Mass haul activity polyline

When a truck driver presses load and unload button on the mobile application start and end time of the task and whole path is also stored on the web server. All the gps position for every 10 meters change in location are recorded and sent to server and saved. Once the task is finished on the server, the whole path is available for visualization and can be drawn as shown in the figure 19.

This polyline is color coded that means time spent for each 10 meters is represented by different colors on map. Green, blue and red color tells us that that 10 meters

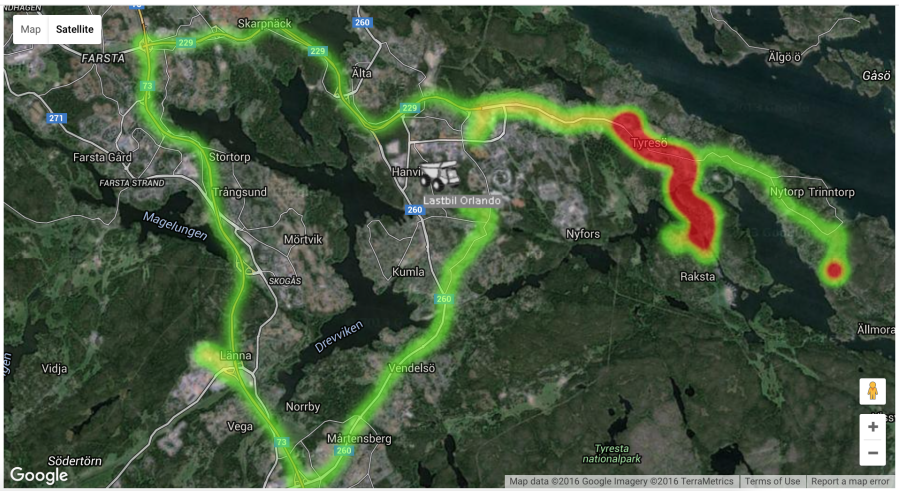

Figure 18: Heat map showing paths followed by a truck in last 24 hours

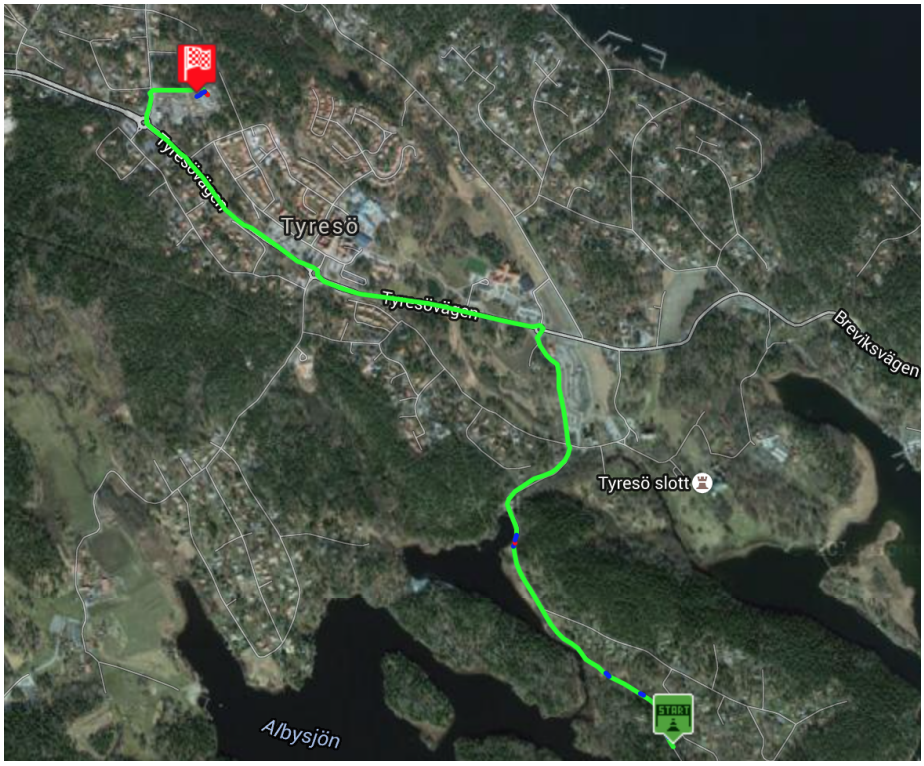

Figure 19: Color coded polyline showing path followed by a truck for a mass haul activity

distance is travelled in less that 3 seconds, more than 3 secs and less than 10 seconds and more than 10 seconds respectively as show in figure 20.

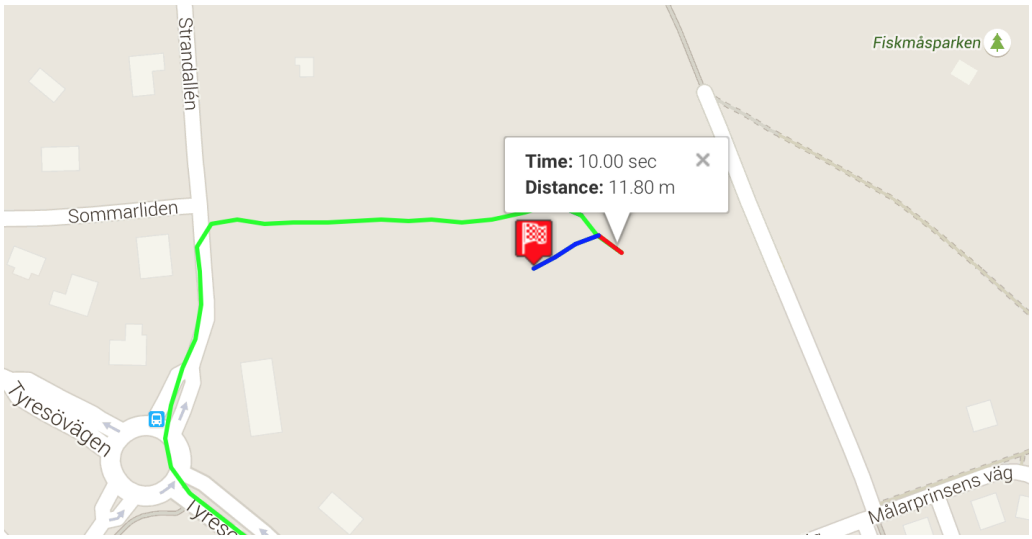

Figure 20: Color coding showing time spent for every 10 meters.

4.3.3 Bar graph for mass haul per vehicle

Bar graph is employed to show the mass haul volume moved by each truck. Volume moved by each truck is represented by vertical bars while the height of the bar represent the total volume moved by that truck from any load to unload location for the current project from the start of the project to till date. Following graph show the bar graph for different trucks on a project. X axis shows the name of the truck along the bar while Y-axis shows the total unit of volumes moved by each truck.

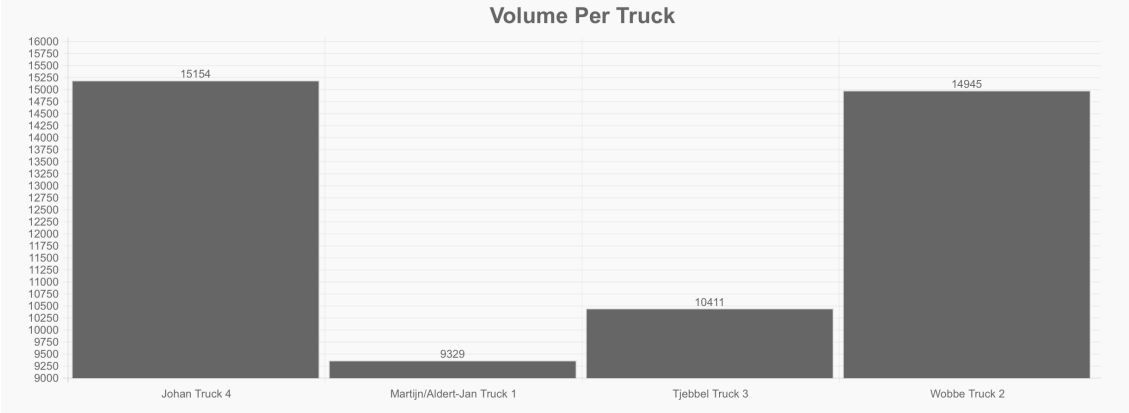

Figure 21: Bar charts showing total volume moved by each truck

4.3.4 Mass haul timeline graph

Another graph that is produced using the information is mass haul timeline graph. Total mass haul per day for the project using all the vehicles is aggregated and plotted against that day using the line chart. Here on the X-axis we have dates from

the start of the mass haul activity in that project till the latest mass haul activity for that project and on the Y-axis volume units are shown. The dates on which there is no mass haul activity like on weekends, those dates are excluded from the graph automatically. Figure 22 shows the mass haul timeline graph.

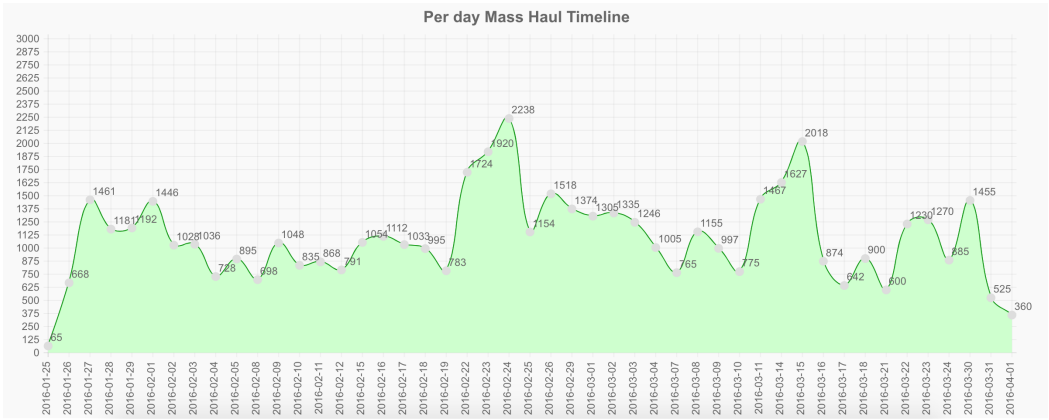

Figure 22: Mass haul timeline per day

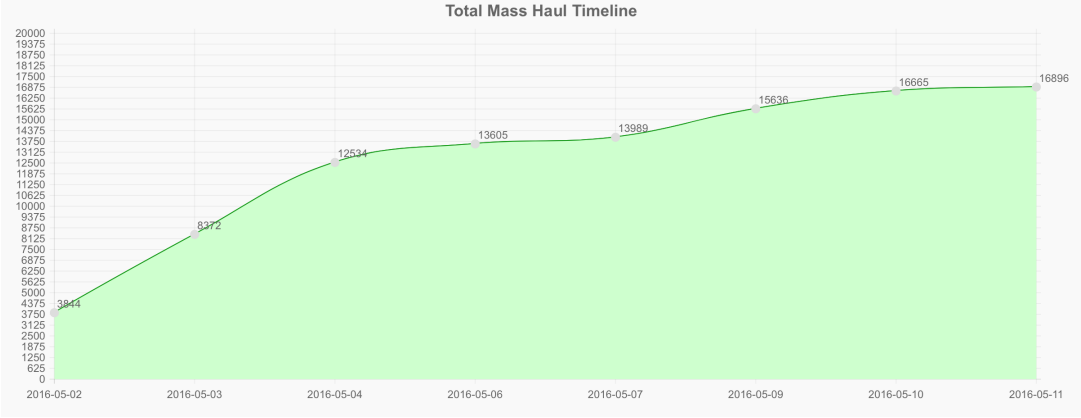

Figure 23: Total Mass haul timeline aggregated all days

4.3.5 Bar graph for volume per material

Another information that is important for the site managers and owners is to see what are different types of material that is mass hauled and what was the volume of that material for the project. So this information is accessed from databases by getting all the unique materials for the project and volume against each material type is aggregated. Figure 22 shows the the volume for all different kinds of material for a project.

Construction site material could be defined in many ways, either site manager can predefine all the list of material that would be available on the site in advance using the truck app web page or the truck driver could define and add the material

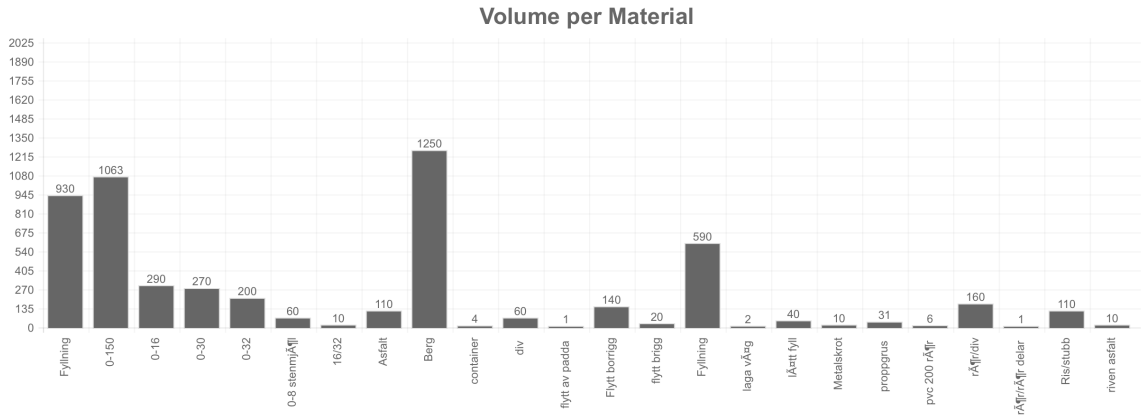

Figure 24: Volume per material

on the mobile phone and then those material will be sent to the web application with each task.

4.3.6 Masshaul Areas

As after testing the implementation, it has been discovered that the application has a limited usability on construction site because of one other reason that it is difficult for truck drivers to use it while driving. Some of the truck drivers are good and comfortable using the application while other feel very difficulty using it. After closely understanding the problem a solution was discussed with site owner to have an automatic load and unload feature that will run in the background when enabled. Figure 26 shows the the load and unload areas defined for the project.Site owner are provided with geo-fence drawing feature on the google map where they can add load and unload area by drawing them on the map using the mouse curser by clicking on the map and then selecting different attributes for that area.

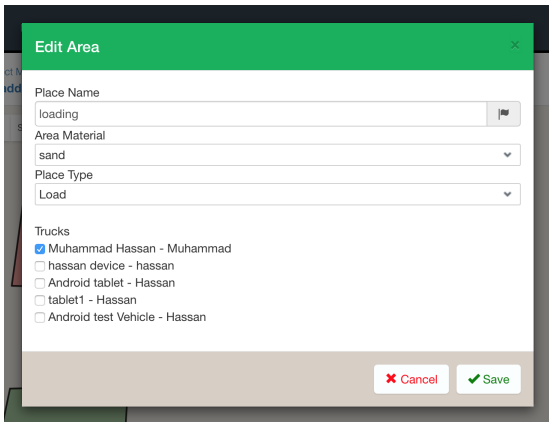

Figure 25: Masshaul area properties

Figure 25 show what properties we can attach to a mass haul area. Mass haul area could be tagged with a name, type of the masshaul area as loading or unloading

area, the material attached to the masshaul area and vehicles that are allowed to used this area for automatic masshauling.

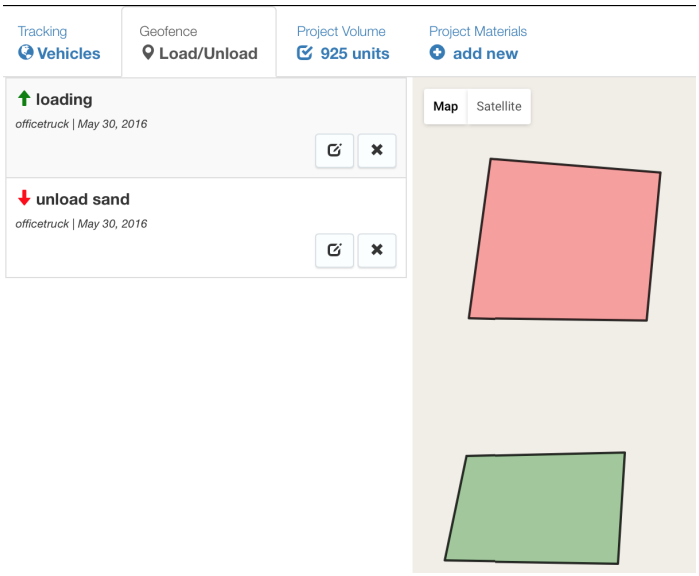

Figure 26: Mass haul areas on map, red as unload and green as load areas

Once the load and unload areas have been creating as assigned to a vehicle then those areas will be automatically downloaded to the mobile device. After downloading the areas there will be an automatic masshauling option in the settings. By default the feature is disabled, but once enabled it will use the loading and unloading area and use the feature point inside polygon to implement the automatic load and unload feature. If the automatic masshauling is enabled then after each location update the application will check if this location is in loading area then it will start the loading if its not already started and once the truck is inside the unloading area and as soon as the application gets location it will poke the unload function if its not already unloaded the task. To make sure that different areas do not overlap it is restricted for each truck to have at most one loading and one unloading area. So that means if one truck has already been assigned in some loading area previously, it will not appear in a new loading area.

5 Conclusion and further research

The aim of this master's thesis is to describe the importance of real time tracking of construction vehicles using mobile cloud computing. One of the main reason of proposing this thesis was to make a solution that is easy to install and requires no troubleshooting and physical access for installation. Furthermore previously designed solution were also studied and the problems were identified.

In this thesis a fully working mobile based tracking solution is developed and the efficiency of mobile based GPS based solution is implemented. We will discuss how real time tracking and mass haul affect the vehicle management at construction site, how important it is for site owners and companies that provide services as subcontractors with their construction vehicles. Also we will discuss what other future improvements and features could be added to the designed solution to make it more robust and usable. All those features were identified after the first testing phase at one of the construction site in Netherlands.Vehicle management and efficiently allocation resources on construction site is really important. The main target of any site owner or a subcontractor is to reduce the waiting time as low as possible and use as minimum number of vehicles as possible to finish a task. Without real time tracking location and status of the mass moving on-site or off-site this is not possible. Site owners need to know how much mass is moved off the site, this is important because this theoretically tells how much work has been done. Also to make a bill for construction vehicles, it is important to know how much mass have been moved on-site and off-site to calculate and estimate total the cost. Not only just the site owners want to check the quantity but also they would like to know where a material was dumped, so that if they need it in future they can easily find it and reuse it in some other projects.One of the challenges that we were expecting was the usability of the proposed solution for the truck drivers. It is always difficult for drivers to use smart phone while driving on construction site. So, one of the core reason for carrying out this research was to check how easily drivers can adopt to this new solution as compared with the manual log book entry. The results were surprisingly different. We were expecting that truck drivers would take more time to feel comfortable with the mobile application and will not use it quite often, but during the implementation and testing phase, all the truck drivers were very interested to adopt this new solution. Everyone started using it within the first hour of on-site training. They were very happy to use this because manual log entry is very tiresome.

The digitization of manual log entries for mass haul has made the job easily for site owners and subcontractors, because now they do not have to manually digitize all the information from papers. All the information is available on Infrakit servers 24/7 and they are able to download this information at any time. Following is the format of file that could be downloaded from the logged tasks.The digitization of manual log entries for mass haul has made the job easily for site owners and subcontractors, because now they do not have to manually digitize all the information from papers. All the information is available on Infrakit servers 24/7 and they are able to download

this information at any time. Following is the format of file that could be downloaded from the logged tasks.

	A	B	C	D	E	F	G	H	I
1	ID	Start	Time	End	Time	Total time	Distance	Material	Volume
2	2	04-12-2015	14:44	04-12-2015	14:50	5.58	2193.0	zand	14.0
3	3	04-12-2015	14:54	04-12-2015	15:01	6.62	940.0	zand	14.0
4	4	04-12-2015	15:08	04-12-2015	15:26	18.20	1802.0	zand	14.0
5	5	04-12-2015	15:30	04-12-2015	15:42	11.50	760.0	zand	14.0
6	6	04-12-2015	15:48	04-12-2015	15:55	6.90	868.0	zand	14.0
7	7	04-12-2015	16:04	04-12-2015	16:11	6.85	983.0	zand	14.0
8	8	07-12-2015	07:41	07-12-2015	07:54	13.28	8191.0	zand	12.0
9	9	07-12-2015	08:00	07-12-2015	08:05	4.85	1741.0	zand	12.0
10	10	07-12-2015	08:09	07-12-2015	08:16	6.28	1821.0	zand	12.0
11	11	07-12-2015	08:19	07-12-2015	08:25	5.47	1767.0	zand	12.0
12	12	07-12-2015	08:29	07-12-2015	08:34	5.72	1828.0	zand	12.0

Figure 27: CSV file downloaded from web application

While doing research and discussing further improvements in the proposed solutions the idea of geo- fencing was tossed from the site supervisors. If we formally describe the geo-fencing, Fernando et el describes it their book Agent Technology for Intelligent Mobile Services and Smart Societies as:

"Geo-fence constitutes a virtual parameter for real-world geographic area. The primary goal of geo- fencing is to track events associated with crossing the boundary of a geo-fence. The service takes as an input current and previous object location coordinates and evaluates them against existing geo-fence".

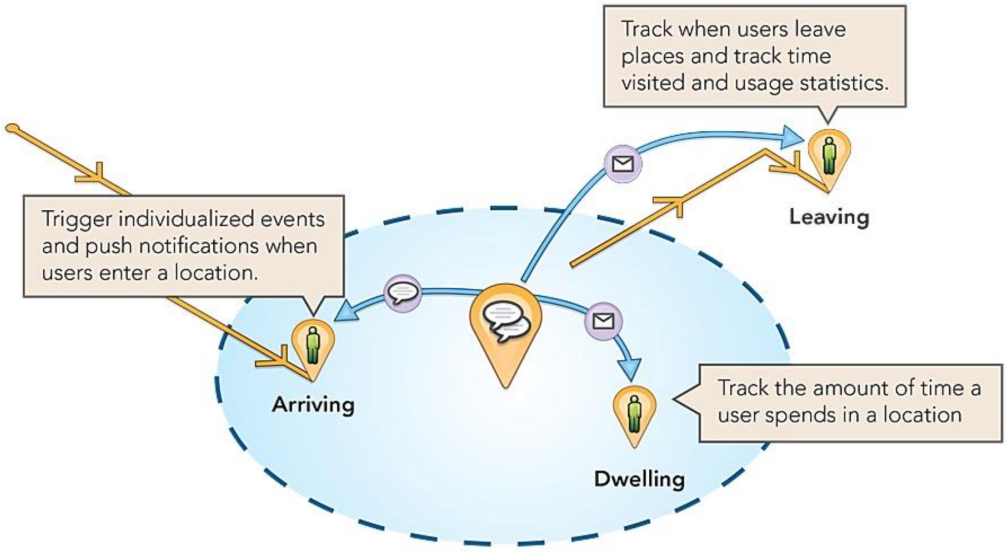

Figure 28: http://www.esri.com/ /media/Images/Content/news/arcnews/winter1213/p3p4-lg.jpg

Geo-fencing is very important concept and is very helpful at construction site. Site is marked and labeled with difference area using web interface and when that

information is available on mobile application for truck drivers it is easily for them to find the dumping areas, pick up areas and getting easy navigation within the mobile application. This is also important for site owners to mark the areas and restrict some area for some vehicles This proposed features will be studies further and feasibility study will be carried out after discussing with different stakeholders.

As this thesis is proposed by Infrakit, a cloud based collaboration platform for infra industry, it is also important with the company's point to view to fully incorporate this information from trucks about mass haul to other modules of this service. As currently the mass or the volume calculation is calculated by service is based on the area. This area is calculated using the design files uploaded to the servers by project owners. Volume and area between different file uploaded is calculated and proposed. Following is a screenshot that is captured form the masses table from one of the Infrakit projects in Netherlands. However, in future, the information from the mass haul will be used in order to verify the volume estimated. This would be useful for quality assurance and comparison between the actual mass moved used trucks and that calculated by the algorithms on Infrakit servers.Finally, as with the boom of big data and analytics, further research could be done in one other direction as proposed by the CEO at Infrakit. The information that is collected at different construction sites can easily end up in thousands of logged entries per day depending on the number of trucks actively working on that project. As the information is very large and could be analyzed and used in decision making and proposing the number of vehicles needed and the time it will take to complete a task at a particular site. So, this information collected now using truck tracking application is not only useful in the current context, but will be useful for doing predictive analytics and assisting site owners in better decision making in long run.

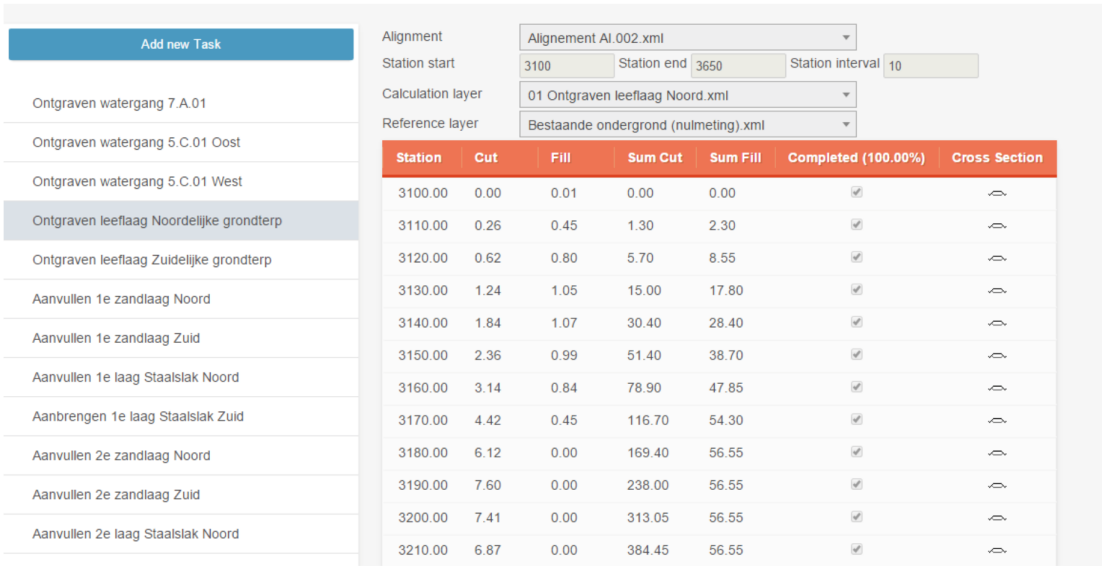

Figure 29: http://www.infrakit.com

Appendix

Use cases for site admin

Following are the list of use cases for Site admin (site owners/ site supervisor) who is responsible for tracking and reports generation.

ID	UC-0
Title	Add vehicle to a project
Description	Admin adds vehicle to a project
Primary Actor	Site admin
Secondary Actor	Truck driver
Preconditions	Site admin is logged into system Truck Driver installed the application on mobile Site admin has machine Id for a particular truck
Main Success Scenario	Site admin selects admin page from settings drop down Site admin selects vehicle page from the list of pages from the top navigation bar Site Admin clicks new vehicle button Site admin fills all the information Site admin selects project for vehicle Site admin saves the vehicle

ID	UC-1
Title	View All vehicles on map
Description	Admin access the system and view all the Vehicles that are connected to web server on Google maps
Primary Actor	Site admin
Preconditions	Site admin is logged into system
Main Success Scenario	Site admin selects project from projects drop down Site admin selects admin page from settings drop down Site admin selects Trucks page from the list of pages from the top navigation bar Site admin presented with all the vehicles in the project on the Google map

ID	UC-2
Title	Zoom to vehicle
Description	Site admin zooms in to the last reported location of a vehicle
Primary Actor	Site admin
Secondary Actor	
Preconditions	UC-1
Main Success Scenario	Site admin selects zoom button from the action menu Site admin see the Google map zoomed to the last know location of vehicle

ID	UC-3
Title	Show truck log
Description	Site admin lists all the logs for a particular truck between two selected dates
Primary Actor	Site admin
Secondary Actor	
Preconditions	UC-1
Main Success Scenario	Site admin click info button Site admin selects a start date and end date Site admin press load button Site admin views the list of logs submitted by a truck driver

ID	UC-4
Title	Show truck log track
Description	Site admin see the track of a log entry on Google maps with load and unload flags
Primary Actor	Site admin
Secondary Actor	
Preconditions	UC-3
Main Success Scenario	Site admin click marker button on the log dialog Site admin view a line showing the start and end of the log entry Site admin click the line to view log information

Use Cases for truck driver

Following are list of use cases for the truck drivers who will use Android truck app on their phones to accomplish following tasks.

ID	UC-0
Title	Login to mobile application
Description	Login using username and password provided by site admin
Primary Actor	Truck driver
Secondary Actor	Site admin
Preconditions	
Main Success Scenario	Truck driver input username and password on the login screen Truck driver press verify button to login Truck driver successfully logged in to mobile application

ID	UC-1
Title	Select Active Project for logging
Description	Truck driver select the active project in which all the logged data would be registered
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-0
Main Success Scenario	Truck driver selects project form list

ID	UC-2
Title	Select Material
Description	Truck driver select material for logging
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-1
Main Success Scenario	Truck driver selects material form list

ID	UC-3
Title	Add new material to the list
Description	Truck driver add a new material to the list
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-1
Main Success Scenario	Truck driver types material name in the textbook Truck driver press retrun button Material is added to the list and selected as active material

ID	UC-4
Title	Select Volume
Description	Truck driver selects volume from list
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-1
Main Success Scenario	Truck driver selects volume form list

ID	UC-5
Title	Start logging task
Description	Truck driver turns on the task logging
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-4, UC-3
Main Success Scenario	Truck driver clicks load button on the tracking screen Task tracking is started

ID	UC-6
Title	Stop logging task
Description	Truck driver turns off the task logging
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-5
Main Success Scenario	Truck driver clicks unload button on the tracking screen Task tracking is stopped

ID	UC-7
Title	Logout
Description	Truck driver turns off the application and submits fuel and total volume at the end of each day
Primary Actor	Truck driver
Secondary Actor	
Preconditions	UC-1
Main Success Scenario	Truck driver clicks settings button from top navigation Truck driver fills total volumes in cubic meter and total fuel in liters for that day Truck driver click logout button,Application is closed and tracking is stopped

References

[1] Different types of information shared through BIM collaboration cloud. http://infrakit.com/wp-content/uploads/2015/05/cylinders_TILAAJALLE_eng.png

[2] Mobile cloud computing architecture http://www4.comp.polyu.edu.hk/~csbxiao/MCCLab/MCCLab_background.htm

[3] Different types of information shared through BIM collaboration cloud. http://infrakit.com/wp-content/uploads/2015/05/cylinders_TILAAJALLE_eng.png

[4] Infrakit for different stakeholders. *https://infrakit.com/en/users/*

[5] Different types of information shared through BIM collaboration cloud. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers By Charles M. Eastman*

[6] The Basics of Cloud Computing by Alexa Huth and James Cebula. *https://www.us-cert.gov/sites/default/files/publications/CloudComputingHuthCebula.pdf*

[7] Expected growth trends of BIM. *BIM and Construction Management: Proven Tools, Methods, and Workflows By Brad Hardin, Dave McCool*

[8] Active vs Passive Tracking systems. http://www.business-software.com/wp-content/uploads/2013/05/active-passive22.jpg

[9] GPS constellation. http://www.gps.gov/multimedia/images/constellation.jpg

[10] GPS Triangulation. *Laura Guerin; Source: CK-12 Foundation; License: CC BY-NC 3.0*

[11] Expected growth trends of BIM. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers By Charles M. Eastman*

[12] Secure Cloud Computing Benefits, Risks and Controls by Mariana Carroll, Alta van der Merwe and Paula Kotze IEEE 6027519

[13] Bentley, "Build as One - BIM is a new way of approaching the design and documentation of building projects", 2006

[14] Rob Howard, Bo-Christer Bjork, "Building information modelling ? Experts? views on standardisation and industry deployment", December 2007

[15] Benefits and challenges of three cloud computing architectures. Joel Gibson et al. IEEE papers arnumber=6412402

[16] Understanding GPS: Principles and Applications, Second Edition by Elliott Kaplan, Christopher Hegarty

[17] Design and implementation of an accurate real time GPS tracking system by Hind Abdalsalam Abdallah Dafallah Electrical and electronic engineering Department. University of Khartoum Sudanese Electricity Transmission Company, SETCO Khartoum, Sudan

[18] Cost Effective GPS-GPRS Based Object Tracking System Proceedings of the International MultiConference of Engineers and Computer Scientists 2009 Vol I IMECS 2009, March 18 -20, 2009, Hong Kong

[19] https://en.wikipedia.org/wiki/Vehicle_tracking_system

[20] http://developer.android.com/guide/topics/sensors/sensors_overview.html

[21] Embedded System for Construction Material Tracking Using Combination of Radio Frequency and Ultrasound Signal

[22] Agent Technology for Intelligent Mobile Services and Smart Societies: Workshop on Collaborative Agents, Research and Development, CARE 2014, and Workshop on Agents, Virtual Societies and Analytics, AVSA 2014, Held as Part of AAMAS 2014, Paris, France, May 5-9, 2014

[23] Cost Effective GPS-GPRS Based Object Tracking System Khondker Shajadul Hasan, Mashiur Rahman, Abul L. Haque, M Abdur Rahman, Tanzil Rahman and M Mahbubur Rasheed

[24] The Solution of Mobile GIS Based on Bluetooth GPS Receiver Fu Xiao-ling, Wang Dian-lai, zhang Meng-meng, Department of Computer North China University of Technology Beijing China

[25] Location tracking in gps using kalman filter through SMS Mohammad Zahaby, Pravesh Gaonjur, and Sahar Farajian Department of Computer Engineering Vishwakarma Institute of Technology, Pune India

[26] A Public Safety Application of GPS-Enabled Smartphones and the Android Operating System John Whipple William Arensman Marian Starr Boler Information Systems Engineering Department Southwest Research Institute P.O. Drawer 28510, San Antonio, Texas

[27] Generating Navigation Capable Maps From User Provided Data with Woodtracker Martin Weigel, Thomas Preuss, Jonas Brustel Brandenburg University of Applied Science Brandenburg an der Havel, Germany

[28] Energy-Efficient Position Tracking in Proactive Location-Based Services for Smartphone Environments Ulrich Bareth, Axel K?upper Deutsche Telekom Laboratories, TU Berlin Service-centric Networking

[29] Android Smartphone: Battery Saving Service Center for IT Advancement International Islamic university Malaysia

[30] Improving the Energy-Efficiency of GPS based Location Sensing Smartphone Applications

[31] Thomas Olutoyin Oshin, Stefan Poslad, Athen Ma School of Electronic Engineering and Computer Science Queen Mary University of London London, England

[32] Initial Test on the Use of GPS and Sensor Data of Modern Smartphones for Vehicle Tracking in Dense High Rise Environments Esmond Mok*, Guenther Retscher** and Chen Wen* * Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

[33] SensTrack: Energy-Efficient Location Tracking With Smartphone Sensors Lei Zhang, Student Member, IEEE, Jiangchuan Liu, Senior Member, IEEE, Hongbo Jiang, Member, IEEE, and Yong Guan, Member, IEEE

[34] Design and implementation of an accurate real time GPS tracking system Hind Abdalsalam Abdallah Dafallah Electrical and electronic engineering Department. University of Khartoum Sudanese Electricity Transmission Company, SETCO Khartoum, Sudan