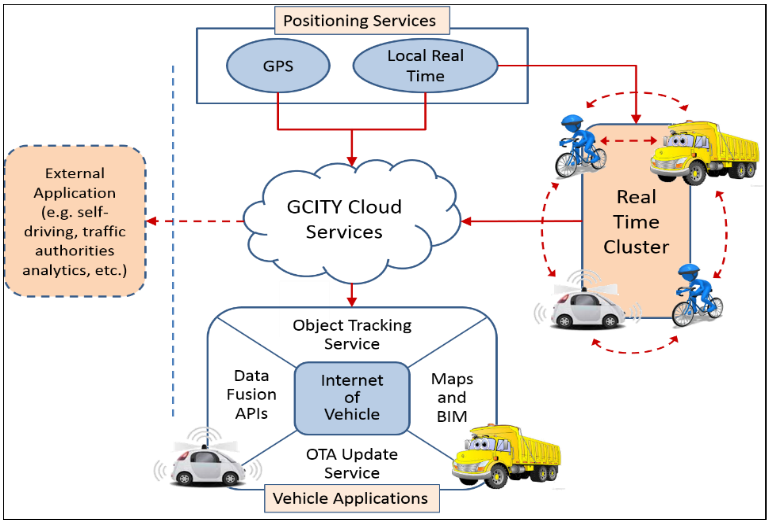
A Concept Study:

GIS-based solution for improving cyclists' road safety (GCITY)



Författare: Mohamed El-Makawy, Mustasim Issa, Erik Perjons

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Projekt inom: FFI - Cyklar och andra fordon i säker och smart samverkan för en hållbar framtid - 2017

FFI Fordonsstrategisk Forskning och Innovation

Innehållsförteckning

1 Sammanfattning

Denna rapport presenterar resultaten från en konceptstudie som syftar till att minska sannolikheten för cykelolyckor genom att öka fordonsförarens medvetenhet om omgivande cyklister. Cykelolyckor med fordon är ett stort problem i innerstäderna, särskilt för tunga fordon (t.ex. lastbilar) och i synnerhet på platser där visuella hinder och omfattande blinda fläckar är vanliga. De flesta av dagens lösningar för fordon är beroende av visualisering och sensorbaserad teknik monterad på fordonet, som kameror och sensorsystem. Målet med denna konceptstudie är att undersöka möjligheten att kombinera Geographic Information Systems (GIS), Building Information Modelling (BIM) och Ultra Wide Band (UWB) för att bygga en lösning som kan varna förare och cyklister för kollisioner genom att lägga till rumsliga komponenter av rörliga föremål i stället för att förlita sig enbart på visualisering eller sensorbaserade lösningar. Huvudresultatet från konceptstudien är en övergripande systemarkitektur, kallad GCITY Architecture, som integrerar GIS, BIM och UWB. GCITY Architecture beskrivs på en konceptuell nivå och består av ett antal tjänster grupperade i ett antal moduler, och syftar bland annat till att utnyttja både GPS och ett realtidspositionssystem för att ta emot koordinater från fordon i rörelse. Som del i studien har också ett antal mindre undersökningar genomförts om hur man kan använda sig av GIS, BIM och UWB i den övergripande lösningen. Dessutom har användar- och systemkrav identifierats. Resultaten från denna konceptstudie har varit grunden för en större FFI-ansökan, som lämnades in i juni 2018.

2 Executive summary

This report presents the results of a concept study aiming at reducing the probability of bicycle accidents by increasing the driver's awareness to surrounding cyclists, which is a real problem especially for heavy automotive vehicles (e.g. trucks) and in the inner cities with wide-blind spots and visual obstacles. Most of automotive solutions of today are relying on camera visualization, image processing and sensor based technology mounted on the vehicles whether they are cameras or sensor systems. The goal of this concept study is to explore the possibility of combining Geographic Information Systems (GIS), Building Information Modelling (BIM) and Ultra Wide Band (UWB) technology to build a solution that can warn drivers and cyclists for collisions by adding spatial components of moving objects rather than relying solely on visualization or sensor-based solutions. The main result of the concept study is an overall system architecture, called the GCITY Architecture, integrating the GIS, BIM and UWB. The GCITY Architecture is described on a conceptual level including involved services grouped in a number of modules, and aims to make use of both GPS and a Real Time Positioning System for receiving coordinates of moving vehicles. The study has also made a number of minor investigations of how to make use of the different technologies involved: GIS, BIM and UWB. Moreover, user and system requirements have been identified. The results of this concept study have been the base for a larger FFI application, submitted in June 2018.

3 Background

Sweden is one of the best performing European countries in road safety (Swedish Transport Agency, 2017). However, cyclists are among the most injury-hit road user groups, and the numbers have increased in the last few years in some figures. According to the Swedish Transport Analysis (2017), 8% of the traffic fatalities in 2016 were cyclists from which about 68% were involved in automobile collision. The percentage of seriously injured cyclists of total injured persons increased from 45% in 2013 to 49% in 2016.

According to the Swedish Transport Agency (2017), accidents between heavy vehicles and cyclists are a major problem in many Swedish cities. The cause of accidents is often related to that the driver of a heavy vehicle does not detect the cyclist. Several large cities such as London and Copenhagen look at instituting special demands on trucks such as stricter driving time rules but there is no requirements for detecting moving objects in the traffic. However, buses as well as the public transportation in general are encouraged today to develop traffic-safety solutions. In addition to that, the transport policy objective inside the cities is motivated towards increasing the travel by bicycle for more sustainable transports and reducing the environmental impact. We can thus expect more potential conflicts between heavy vehicles and bicycles, thus increasing road safety problems. Thus, the overall goal of the traffic committee of the Swedish Transport Agency was clearly expressed in January 2015 to focus on the safety of cyclists.

The bicycle safety has attracted an increased interest among researchers and industry actors at both national and international levels. These interests were put into projects by the automobile manufacturers to develop systems or solutions for reducing the cyclists and motor vehicle collisions. Examples of these projects are: i) an active system (in Jaguar Land Rover) that alerts car drivers for unseen dangers and hazards. The systems is expected to distinguish between bicycle and motorcycles using a range of “instinctive stimuli” to warn a driver of approaching danger (Jaguar Land Rover, 2017), ii) signaling system (in Mercedes Benz) for cyclists on safe passage zone in front of the car. The system is mainly based on radar sensor that monitors the entire area next to the automobile/truck (Mercedez-Benz, 2016; Daimler, 2016), iii) anti-collision warning system for bicycles in Volvo cars. The car’s brakes is automatically activated when the car and cyclist are in danger of colliding (Volvo, 2016).

At the research level, a record number of participants was achieved in the 3rd International Cycling Safety Conference (ICSC2014) in Gothenburg City, November 2014. The conference highlighted different initiatives by research teams, authorities and industries from 23 different countries. This conference was followed by conferences in Hannover (Germany) and Bologna (Italy) for the years 2015 and 2016 respectively. In additional to that, several research projects are currently ongoing for improving or contributing to the reduction of car-bike collision. Among these projects is the project “Cyclist Collision Avoidance Using Imagery Sensor” (started Sep 2016), which aims at developing reliable and robust algorithms for a car-integrated camera system that can detect bicycle and cyclist. Moreover, a global policy was made in Horizon 2020 agenda for unprotected road users in the call for proposals in 2014, and as a strategic goal for smart cities. (Horizon 2020, 2017).

However, most of automotive solutions are relying on camera visualization, image processing and sensor based technology mounted on the vehicles whether they are cameras or sensor systems. They provide signals or warning voice messages to the car drivers when they come within a proximity of another vehicle.

The problems with these solutions can be summarised as:

- the sensors or cameras cannot “see” the moving objects that are hidden behind other physical obstacles or hinders.
- the sensors and cameras do not “understand” the traffic directions and lanes. Therefore a nearby moving object might not be in a danger mood (if it is on the opposite lane but separated by a physical hinder), however, the sensor or the camera highlights it. This might cause an incorrect focus for the driver.
- the sensors and cameras are weather-dependent (i.e. they do not work efficiently in harsh weather conditions such heavy rain or snow).
- the sensors and cameras are only available to a selection of high end expensive vehicles.

Our suggested solution aims at reducing the probability of accidents between vehicles by using the capabilities of Geographic Information Systems (GIS), Building Information Modelling (BIM) and Real Time Positioning Services (RTPS). By detecting the object in the real-time with no latency and visualizing it on a GIS map or BIM, the user will have awareness and predictive vision that help to make a better decision.

The GIS-based solution is argued to be more comprehensive than other solutions by utilizing the capabilities of GIS and that is shown in two ways. The first way concerns the spatial analyses of temporal data of bicycle accidents. This is of great importance for counter measurements of accidents and detecting different patterns such as spatial flows of bicycles. This will allow for rough estimation of accident risks in certain areas and urban road environment. This information can be stored in the BIM objects to be used for desired analyses. In addition to that, spatial data mining techniques can be processed on geospatial models such as indicator-based assessment model for future development or changes in the city transportation network. The second category concerning the spatial real-time representation of traffic, transportation and environmental objects that are shown on car drivers' screens with selective warning messages. This will also be used to warn the cyclists for moving cars through certain devices on the bicycles.

4 Purpose, research questions and method

The GCITY project had its purpose set to research the capabilities of integrating Geographic Information Systems (GIS), Building Information Modelling (BIM) and the Ultra Wide Band (UWB) technology for enhancing the traffic safety and reduce the probability of vehicle-cycle collisions. It further aims at gradually contributing to an improved ability to jointly identify research and development activities that contribute to increased traffic safety and safety of cyclists in the heavily traffic crowded cities.

The research question was: How can the moving objects be detected in the real-time with no latency and visualized on a GIS map and BIM to improve awareness and predictive vision of drivers and cyclists for making a better decision?

The project was a concept study. The research method applied was design science research (DSR). DSR can be defined as the scientific study and creation of artefacts as they are developed and used by people with the goal of solving practical problems of general interest (Johannesson and Perjons, 2012). Artefact is an object made by humans with the intention that it be used to achieve a business objective. Example of artefacts are IT systems, business and IT architectures, methods and models. The main result of this project was the artefact designed on a concept level: GCITY Architecture. In DSR project, the design and development of the artefact is the main activity, but important is also to define the practical problem to be addressed by the artefact as well as the requirements on the artefact, which have also been done in this project. DSR also require an evaluation of the designed artefact. The evaluation carried out in this concept study was only a lightweight evaluation, in form of informed argument (Hevner et al, 2004) presented by the designers arguing that the GCITY Architecture fulfilled the requirements and addressed the practical problem.

5 Goal

The goal of the concept study was to explore the possibility of combining Geographic Information Systems (GIS), Building Information Modelling (BIM) and Ultra Wide Band (UWB) technology to build a solution that can warn drivers and cyclists for collisions by adding spatial components of moving objects rather than relying solely on visualization or sensor-based solutions.

6 Result och goal fulfillment

6.1 Results

The results of the concept study can be categorised in three parts. The first part consist of the results from investigations of the technologies GIS, BIM and UWB. The second part consist of the development of user and system requirements and the overall system architecture, called the GCITY Architecture, integrating the three technologies. This GCITY Architecture is considered as the starting point for the third part, which is a project application that has been submitted to FFI in June, 2018.

Part 1: Result from investigating the technologies: GIS, BIM and UWB

GIS investigation. Through ESRI we have investigated how different map technologies can be used in different applications and business solutions. Moreover, we have also attended education in GIS systems, provided by ESRI. The investigation shows that GIS has a high potential to be integrated with BIM and local positioning system. In addition to different mapping technologies and functionalities in GIS, this integration is found to be facilitated through the concepts of GIS Network Analyst. The Network Analyst is a module that represents smart components of the traffic network that can be used for modelling streets, intersections, directions and flow of the moving objects. When we started working in this project, we aimed to increase the knowledge about the technologies GIS and BIM, so that project participants could use it to learn more about general or technical information.

BIM investigation: An important investigation regarding BIM technologies was to understand how BIM technology can be integrated into mobile and web browsers. A workshop was carried out to implement an extension of openBIM called BIMserver. On top of BIMserver we successfully rendered BIM objects in web browsers, the importance of this was to test the ability to convert the BIM files (IFC) to series of instructions that other platforms can understand. We used a IFC4 model which a designer draw on a certain 3D software. We then exported the 3D design to IFC file, and then applied a converter to convert the IFC instructions into Javascript (Web programming language used in almost every website). This proved the ability to integrate BIM into other platforms for rendering (viewing). Figure 1 shows a sample BIMobject being rendered in a web environment.

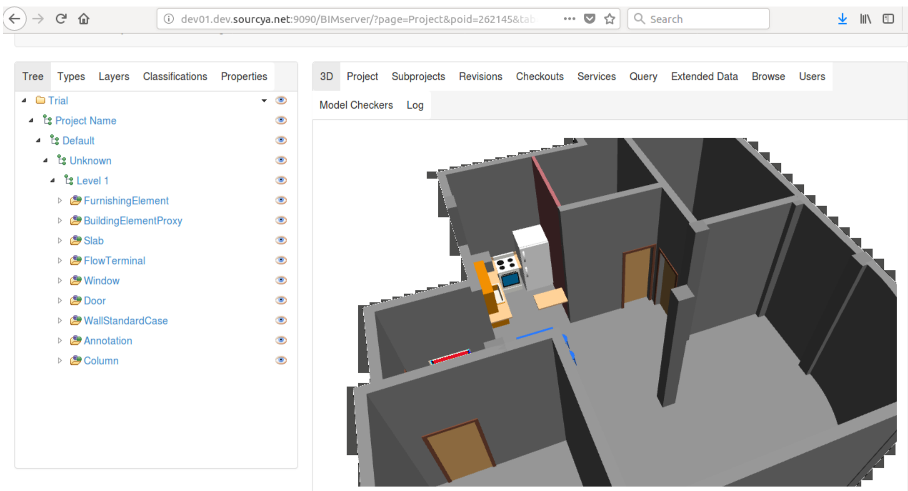

Figure 1: Screenshot for BIMserver rendering BIMobject in a desktop web browser

UWB investigation. The project also focused on the local positioning technologies and searched for the best method to achieve more accuracy especially in real time environment which require a technology with relatively high update frequency. A comparative investigation of different technologies has been carried out, including technologies such as Mobile Positioning System, wifi beacons, UWB, LTE 4G and 5G. As part of this investigation, GCITY participants have met leading 5G experts and developers at Ericsson. Following the investigation on UWB and 5G, it has been decided to consider the local positioning system based on the GIS and BIM as a part of indoor navigation concept however in an outdoor environment.

Part 2: Suggested solution: Requirements and GCITY Architecture

GCITY Requirements Analysis. User and system requirements have been developed. User requirements are the base for presenting different scenarios using the GCITY solution to show the benefit of the solution. System requirements have been used for developing the GCITY Architecture.

GCITY Architecture Design. The main contribution of the concept study is the design of the GCITY Architecture, see Figure 2. Below, the GCITY Architecture is briefly described. A detailed description is provided in Appendix 1.

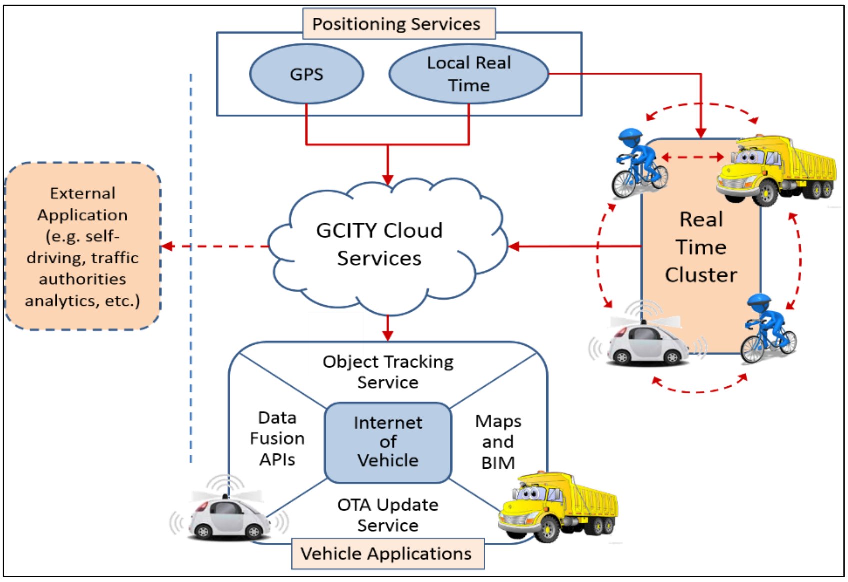

Figure 2: The GCITY Architecture

The GCITY Architecture consists of three main modules. They are: positioning services, vehicle applications and real time cluster. In addition to that, these three modules will communicate and be updated through a GCITY cloud service module.

GCITY depends on the coordinates that comes from GPS or real time positioning systems (RTPS) which will be visualized on GIS map and BIM to give detailed schematic of roads. GPS data will be sent to cloud services which update the map or the model iteratively on the vehicle application to warn the driver before reaching a target crowded traffic area (e.g. intersections).

Data from the RTPS will be sent to a real time (RT) cluster, attached in a specific location around a target traffic area or intersection. This cluster connects with the vehicles app/device or the bicycle device, and by using intelligent transportation systems such as Internet of Vehicle (IoV) would make the decision for safer driving.

Data generated from positioning systems will be saved into a relational database to make an approximate use of it in statistics, analyses, metrics, etc. that can be used in the research body by universities, governmental authorities, or institutions.

Part 3: A New Project application

A new project application was sent in to FFI in June, 2018. The main applicant of the GCITY project is the department of Computer and Systems Sciences, DSV, Stockholm University. In the project application two DSV researchers were included in the project application: Professor Theo Kanter and Docent Rahim Rahimi, both experts in network technology and Internet of Things. There are five other key partners in the project consortium. These are: ESRI Sverige AB (responsible for the GIS part), Tidma AB (responsible for non-GIS development and cloud platforms), Urban ICT Arena (responsible for testing bed and facilitation of different technologies and evaluation) and Stockholm Stad & Nacka Municipality (providing plans, statistics, BIM, and acting as reference partners). The timeframe for the proposed project is 2019-01-01 – 2021-12-31.

6.2 Goal fulfilment

In this section we discuss how the result of the concept study contributes to the goals of FFI.

FFI goal: Increasing the Swedish capacity for research and innovation, thereby ensuring competitiveness and jobs in the field of vehicle industry.

The concept study is a first step towards a solution, and if this solution is successfully developed based on the GCITY Architecture it could increase the Swedish capacity of research and innovation in the vehicle industry, especially since GIS is a main component in systems for self-driving cars. GCITY is built to enable developers to build applications on top of the platform, combining currently used technologies with hybrid positioning systems. This will make it possible to implement new solutions for vehicle security and self-driving cars.

FFI goal: Promoting the participation of small and medium-sized companies
In the concept study, this goal is not fulfilled, but in the new application, a small company is part of the project consortium.

FFI goal: Promoting cross-industrial cooperation
In the concept study, this goal is not fulfilled, but the GIS architecture and a future solution based on the GCITY Architecture could encourage different industrial parties to re-utilize the solution in new ways. One important reason for this possibility is that the GCITY Architecture integrate many different technologies, such as GIS, BIM and UWB, and the architecture can trigger experts in the different technologies txo see further possibilities using the integration.

FFI goal: Promoting cooperation between industry, universities and higher education institutions.
In the concept study, industry (ESRI) and university (Stockholm University) has collaborated and identified areas for further collaboration.

FFI goal: Describe how the project contributes to one or more of the sub-programme objectives stated in the description of each respective sub-programme
The concept study contribute to "Bicycles and Vehicles Secure Cooperation" since it is a first step towards a solution that provides automotive vehicle drivers with the much needed visibility

and awareness to cyclists while warning the cyclists to nearby vehicles. A future solution based on the GCITY Architecture could also prevent a possible collision contributing to “Road safety and automated vehicles” research in an attempt to achieve zero vision in Sweden. Moreover, a future solution based on the GCITY Architecture have the ability to monitor vehicle routes and traffic pattern and thereby build a more “Effective and connected transport system” which would enable us to accurately predict and prevent traffic congestions as well as suggesting the most efficient route leading to a more efficient and sustainable use of time, vehicles and infrastructure.

7 Dissemination och publication

7.1 Knowledge and result dissemination

Hur har/planeras projektresultatet att användas och spridas?	Markera med X	Kommentar
Öka kunskapen inom området		
Föras vidare till andra avancerade tekniska utvecklingsprojekt	X	A new project application has been sent in to FFI
Föras vidare till produktutvecklingsprojekt		
Introduceras på marknaden		
Användas i utredningar/regelverk/ tillståndsärenden/ politiska beslut		

Urban ICT Arena Summit 2017. The GCITY project was part of the exhibition at Urban ICT Arena Summit 2017, Dec 15, at Ericsson Studio. The GCITY project was exclusively selected together with 10 other projects in the exhibition. In total, 60 projects, 40 partners and more than 20 start-ups participated in the Summit. The GCITY project was also presented in a Summit presentation by Professor Theo Kanter, Stockholm University.

7.2 Publications

No research publication has been submitted. However, the project participants are currently working on two publications:

Publication 1: “GIS and BIM hybrid solutions: based on GCITY concept study”
This publication focuses on the integration between GIS and BIM technologies and how to achieve wide utilization in automotive related real-time applications. The paper also highlight other usages for this hybrid like self-driving solutions, transportation navigation in blind spots like tunnels and more use cases in vehicles security and navigation.

Publication 2: “GCITY Architecture v0.1.0”
This publication explains the structure of the architecture, and how technologies are implemented as services. It will also describe the data structure of the whole solution, and the relations between the data models involved.

8 Conclusion and further research

The goal of the concept study was to explore the possibility of combining Geographic Information Systems (GIS), Building Information Modeling (BIM) and Ultra Wide Band (UWB) technology to build a solution that can warn drivers and cyclists for collisions by adding spatial components of moving objects rather than relying solely on visualization or sensor-based solutions.

The main result of the concept study was the conceptual model of an overall system architecture, called the GCITY Architecture. The GCITY Architecture integrate the GIS, BIM and UWB.

The study has also made a number of minor investigations of how to make use of the different technologies involved: GIS, BIM and UWB. Moreover, user and system requirements have been identified. The results of this concept study have been the base for a larger FFI application, submitted in June 2018.

Further research is to develop a complete system solution and evaluate it. This can be done in three overall steps. First, start by investigating and testing the GIS and BIM efficiency in positioning the moving objects (i.e. cars and bicycles) and a model will be constructed for the whole system and solution. Second, implement a prototype of the system and simulate it in a working environment for demonstrating how cars and bikes can be positioned in streets and how the warning systems will work. In addition to that, a warning method for bikers need to be discussed through an intended survey with end users, and a warning device can be then designed. Third, a complete system will be tested in the cars with equipped bikes in selected streets.

9 Participating organisations and contact persons

Organisation	Contact person
Stockholm University	Erik Perjons (perjons@dsv.su.se)
ESRI Sweden	Göran Pettersson (goran.pettersson@esri.se)
Kista Sceince City/Urban ICT Arena	Petra Dalunde (petra.dalunde@kista.com)
Svenska Cykelsällskapet	Lars Brynolf (kansli@svenska-cykelsallskapet.se)
KTH-ITRL (inge budget, endast rådgivande)	Anna Pernestål Brended (pernestal@kth.se)

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Appendix 1. The GCITY Architecture

The GCITY Architecture will have three main modules. They are: positioning services, vehicle applications and real time cluster. In addition to that, these three modules will communicate and be updated through a GCITY cloud service module, see Figure 2.

GCITY depends on the coordinates that comes from GPS or real time positioning systems (RTPS) which will be visualized on GIS map and BIM to give detailed schematic of roads. GPS data will be sent to cloud services which update the map or the model iteratively on the vehicle application to warn the driver before reaching a target crowded traffic area (e.g. intersections).

Data from the RTPS will be sent to RT cluster, attached in a specific location around a target traffic area or intersection. This cluster connects with the vehicles app/device or the bicycle device, and by using intelligent transportation systems such as Internet of Vehicle (IoV) would make the decision for safer driving.

Data generated from positioning systems will be saved into a relational database to make an approximate use of it in statistics, analyses, metrics, etc. that can be used in the research body by the university, governmental authorities, or institutions.

Positioning Services Module

In the Position Service Module, the main sources of getting the coordinates of objects will be handled. This is applied by using GPS in the open areas that don't require high accuracy, and RT positioning systems APIs in the critical areas which don't allow latency. There are a number of technologies in the RT positioning will be studied and tested such as LTE, MPS, UWB, Beacons, etc. Despite the technology used, longitude and latitude will be exported to RT cluster attached around a traffic intersection in order to save it into relational database and resend it to the vehicle app/device or the bicycle device.

GCITY Cloud Services Module

In the Cloud Services Module, there will different services that facilitate the communication and the updates among the other modules and applications:

- *GIS/BIM services.* In the GCITY solution, Geospatial information system (GIS) and building information modelling (BIM) services allow the positioning and visualization of the moving objects. In GIS, GeoDesign term is used to refer to a scenario-based planning process that applies decision making to spatial problems in the context of local and regional features and characteristics. BIM will help, with an integration with GIS, to focus on the construction details of buildings, roads, and street objects in 2D as well as 3D.

Network analyst is used deeply in our solution, as rules and constrains are applied to GIS / BIM layers on roads, intersections and directions. Network analyst tools and relations are used also such as buffer, intersection, etc.

- *Application Update.* GCITY cloud services provide peripheral application updates that used in locating the objects and visualized moving objects in real time into map layer or BIM model. Application update connects with vehicle application through OTA standard for transmission and reception of application related information in a wireless communication systems.
- *External APIs Access.* GCITY cloud services also provide an external APIs access that allow statistics, analyses, reporting, metrics, or any process to enable the university, government, or any research parties to get use of the data saved in the database and integrate more effective solutions or develop the current solution.
- *Relational Database.* GCITY solution provides a relational database to save the data delivered from the positioning systems, so that it could be used in the access of external APIs. Relational database mainly consists of vehicle ID, longitude, latitude, time and date.

Real Time Cluster Module

The Real Time Cluster Module will be used as a communication platform between the moving objects as well as a peer-to-peer tier between vehicles and bicycles.

- *Key-value pair ledger.* The X, Y, Z coordinates which are taken from the positioning system, mainly RT positioning systems, will be exported and saved in the RT cluster to save this data in RAM and transmit it to vehicle apps/device and bicycle devices.
- *RT APIs.* Real Time APIs provide communication between objects in real time communications. Google API is an example of the RT APIs, that allow geocoding and geolocation and the new data is instantly pushed. Esri's mapping API is also an example of the RT API, ESRI's API provide the most powerful mapping visualization, analysis and tools in the real time services. ESRI's API Tracking Server also enables logging and archival of real-time data using the Feature Logger Data Link.
- *RT positioning services.* Real Time positioning service provides instantly update to the moving objects coordinates in real time, and export data to vehicle applications in a specific format or as a longitude and latitude.

Vehicle Applications Module

The Vehicle Application Module includes the needed applications for a vehicle to act upon the designed GCITY functions in avoiding collisions among vehicles and bicycles.

- *GIS / BIM visualization.* This will be a user friendly interface to visualize GIS maps and BIM. While objects move in the real-time, positioning system obtains the coordinates and vehicle app update the map layer or the BIM model according to the obtained position.
- *OTA update services.* OTA update services provide a continuous update through transmitting and reception of the application related in a wireless communication system.
- *Object tracking services.* GCITY vehicle application provide visualization to the moving objects on the road, by drawing a pinpoint on the map or the BIM model. Updated coordinates of the real objects that move on the road are delivered to the vehicle app from GCITY cloud services and also with communication with RT cluster.
- *Internet of vehicles.* IoV technology refers to dynamic mobile communication systems that communicate between vehicles and public networks using V2V (vehicle-to-vehicle), V2R (vehicle-to-road), V2H (vehicle-to-human) and V2S (vehicle-to-sensor) interactions. It enables information sharing and the gathering of information on vehicles, roads and their surrounds. Moreover, it features the processing, computing, sharing and secure release of information onto information platforms. Based on this data, the

system can effectively guide and supervise vehicles, and provide abundant multimedia and mobile Internet application services.

- *Data Fusion APIs.* GCITY solution depends on data fusion to bring sources and information together in an initiative way to make the best use of the big data technology. Data fusion approaches on near-raw sensor data (low-level) and on pre-processed measuring points (high-level). GCITY also model sensor phenomena, road traffic scenarios, data fusion paradigms and signal processing algorithms and investigate the impact of combining sensor data on different levels of abstraction on the performance of the multi-sensor system by means of discrete event simulation.