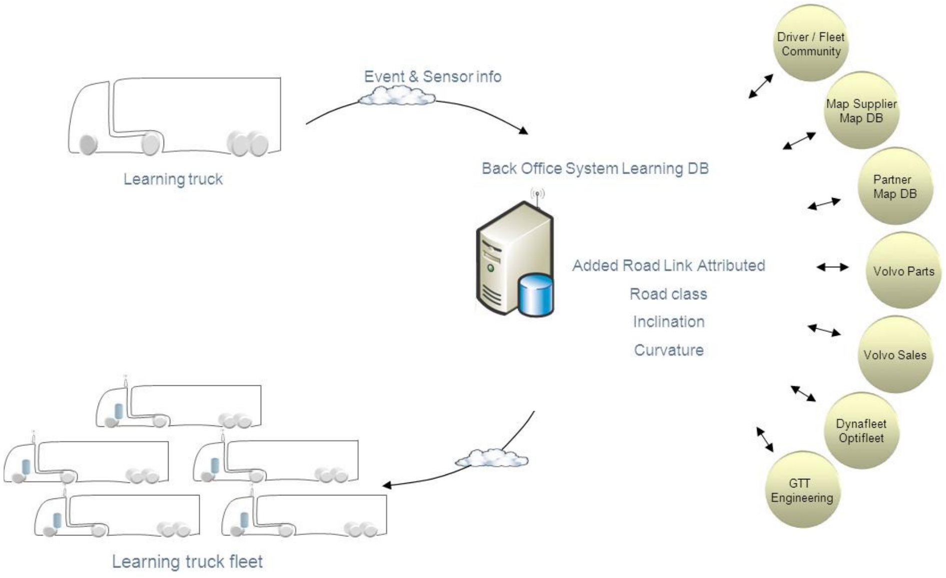
FFI Learning Fleet Technical Report



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FFI Effektiva och uppkopplade transportsystem)

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Innehållsförteckning

1 Sammanfattning

Kartinformation har använts i fordons navigationssystem sedan många år och har därefter också introduserats som stöd för komfort-, körstöd- och drivlineoptimering. De nya användningsområdena har ställt nya krav på kartdatan och inom bara några år förutsås högre nivåer av autonom körning att kräva ännu högre krav på detaljrikedom, pålitlighet och uppdatering. Detta kan naturligtvis också komma existerande kartanvändande tjänster och funktionerna i fordonen till godo i form av stöd för ökad effektivitet.

Ett koncept för att på ett kostnadseffektivt sätt uppnå stöd för allt detta hos kartdata, skulle kunna vara att skapa verktyg som kan samla in, aggregera, förvara och distribuera kartrelaterad sensor- och händelsedata på generiskt sätt. Verktygen och processerna behöver vara flexibla för att nya attribut och representationer skall kunna läggas till.

Avsikten med Learning Fleet -projektet är därför att validera rimligheten hos ett sådant koncept genom att implementera och testa prototyparkitektur och några exempelapplikationer som använder datan samlad från fordonsflottan.

Målet är att utveckla arkitektur för dataflöde och dataförvaring baserat på kravsättning från användarfunktionerna i fordonet och tjänster på Back Office System (BOS). Eftersom projektet vill täcka krav från en bred grupp av användningsområden i kravspecifikationen valdes några exempelapplikationer inom navigation, bränsleeffektivitet (drivlineoptimering), aktiv säkerhet och hantering av fordonflotta.

Tack vare en iterativ process genom ett antal olika projektaktiviteter som specifikation av användningsfall, funktionsspecifikationer, kravspecifikationer, implementation, test och validering, nåddes slutligen målet på tillräcklig funktionalitet för att kunna styrka rimligheten i konceptet.

Ett par av de ursprungligen tilltänkta användarfunktionerna implementerades dock aldrig eftersom de kunde identifieras i andra nyuppstartade aktiviteter med överlappande eller närliggande forskningsområde. Learning Fleet projektet har då anpassat sina aktivititer för att i slutändan uppnå maximalt utbyte av aktiviteterna. Exempelvis har Learning Fleet inriktat sig på att utveckla en bra bas för en kooperativ Hazard Warning FFI projektet BADA (Big Automotive Data Analytics) där flera fordonstillverkare delar data, snarare än att utveckla en enkel funktion inom Learning Fleet –projektet. På samma sätt har arbetsuppgiften ”Fordonsstatistik och –konfiguration” överlåtits till andra aktiviteter där analys av stora mängder data står i fokus.

Test och analys av de implementerade prototyparkitekturerna och exempelfunktionerna indikerar att Learning Fleet –konceptet har potential att bära de funktioner som adresserats i kravsättningen, men det finns fler indikationer i samma riktning. Flera nyligen startatade aktiviteter som SENSORIS[i] och Autodrive Open Forum[iv] visar att användande av data från fordonsflottor bedöms vara en av de mest lovande lösningarna för att snabbt och kostnadseffektivt kunna fylla digitala kartor med vägattribut och hålla dem uppdaterade.

Men att påvisa potentialen och rimligheten konceptet är bara starten. Under arbetet med implementation och test identifierades flera möjligheter till förbättringar och ideer om nya funktioner men också nya frågor att besvara. Exempelvis finnar man i flera av de mest värdebringande potentiella tjänsterna, att det är delande av fordonsflottans data till affärspartners, ibland i tredje led, som höjer värdet av tjänsten för alla inblandade, men det är inte helt klart hur långt ett undertecknande av fordonsflottans ägare och förare räcker för att göra datahanteringen laglig. Djupare analyser av de lagliga aspekterna är nödvändiga och pågående i projektet FFI BADA[ii] men är också föremål för diskusioner mellan europeiska länder eftersom en gemensam lagsättning och tillämpning möjligör mer effektiva tjänster.

2 Executive summary

Map data was introduced in automotive industry many years ago, mainly for support of navigation functionalities. As the utilization of map data in the vehicles spread in to comfort-, driver assistance- and power train optimization, requirements on map data changed. Today, higher degrees of autonomous driving are foreseen to within the next few years require high definition map data content with high integrity and up-to-dateness, which of course also will increase performance of the more traditional map data users in the vehicles and at service providers.

A potentially cost efficient concept for accomplishing this, is creation of versatile tools for collecting, aggregating, storing and sharing map related sensor- and event data in a generic way.

The Learning Fleet project therefore aimed to validate the feasibility of this concept through testing of implemented prototype architectures and sample functionalities utilizing the collected fleet data.

The aim has been to develop the data flow and data storage architecture based on user requirements from the applications and business models. In order to cover requirements from a wide range of functions areas in the requirement specification, applications were picked in fields like navigation, fuel efficiency, active safety and fleet management.

During the different project process sequences from use case scenarios, functional specification, requirement specifications, implementation, test and validation, iterative loops in the end yielded the targeted performance. However, a couple of the originally planned functionalities were cut from the project scope. Since the project start several activities in overlapping and adjacent research topics has been identified and the Learning Fleet project has adjusted its work and scope in order to gain maximum end result. For instance, rather than implementing a very simple hazard warning function, a more solid base has been in provided for an more efficient OEM brand cooperative hazard warning implementation the FFI BADA[ii] (Big Automotive Data Analytics) project. In the same way, the planned implementation of a statistics- and configuration tool was left to activities specialized on big data.

Not only has the analysis of test results and learnings during the project pointed in favor or the concept of learning fleets. Other recently started activities like SENSORIS[i] and the Autodrive Open Forum[iv] indicates that harvesting map related data from fleet vehicles are seen as one of the most promising solutions for fast and efficient population of road attributes in maps and keeping them up to date.

Proving the concept feasible is only the start. During implementation and testing several improvement possibilities, ideas for new functionalities as well as new questions to answer were identified. For example, in many of the more advantageous business models, it is the sharing of collected data, sometimes also to third parties, which makes big gain in value for all involved parties, but it is not clear how far the fleet owners and drivers written consent will cover this use case. Deeper investigations on the legal issues are needed and ongoing in for example the FFI BADA project, but is also a matter for discussion among European countries since a common legislation and practice would allow more efficient services.

3 Background

In an ever more dense traffic environment with requirements on “green”, “just-in-time” deliveries and slim operation margins, it is increasingly important for fleet operators to use optimisation tools which take in account information about the trucks, the road network and what is happening on it.

Classic fleet management systems, navigation systems, vehicle diagnostic systems, eco driving systems and ADAS (Advanced Driver Assistance System) are examples of frequently used tools.

Digital map data has been used in vehicles even before GPS receivers became commercially available. After traditional navigation maps and ADAS maps, high definition maps with dynamic content are about to enter the automotive scene. The drivers for introduction of these maps are needs from autonomous driving functions but also from improved ADAS-, powertrain optimization and navigation functionalities. Maps needs to have new features like individual lane representations, high accuracy and they need to stay updated.

An efficient way of populating these maps with content is to collect geo-referenced data from fleet vehicles. Such data also enables new services such as cooperative hazard warning when collected to back office.

4 Motivation (Syfte, frågeställningar och metod)

As mentioned above, a large potential for gain in mobility, fuel efficiency and safety is offered by the use of digital map data in the vehicle systems and services. Consequently, today navigation systems, map based fuel saving speed control systems, and warning systems are offered by manufacturers of commercial vehicles. To increase performance of these systems and the support of back office services, completeness and quality of data need improvements.

The road network is ever changing and even though map updates are issued more and more frequently, any changes in road network must be must be collected on the field by the map vendors before it can be represented in an update of the map. A smart way of shortening this time is to have the map users automatically- and manually detect and report deviations to the mapmaker. In the FeedMAP[iii] project this concept was tried on a handful of deviation types. In contrast to other concepts like Google Maps and TomTom Mapshare where a user community shares data, the FeedMAP concept incorporates the map vendors quality procedures and guaranties which are important, especially for ADAS maps if they are to support safety- and fuel efficiency applications. However, there is more information related to a position in the road network that can be valuable for map makers, navigation suppliers, truck designers and providers of Local Based Services (LBS). A FeedMAP-like service must incorporate or co-exist with information flow of already existing services on a communication link of a commercial vehicle. Analogously, one cornerstone of increased versatility of the data harvested from vehicle fleets is indexation in time and to road link position. Once the data can be put in a physical context or connected to an event, the number of ways it can be used is multiplied:

- Route- and speed adaptation to dynamic road attributes can save time, fuel and human lives by using “live” data reported from the fleet. A traffic prognosis, based on real time data and extrapolated by using historic patterns data can be used for longer routes.
- Traditional map data is not always up to date or complete, and dynamic data is not always available from authorities or suppliers, or it lacks good geo-referencing. Learning fleet data is then an alternative or complement.
- Active safety systems, which are rapidly increasing in penetration grade, can improve current features and introduce new ones by using static and dynamic map data in combination with “experienced” data from vehicle sensors. Both longitudinal and lateral functions can benefit.
- Several systems and solutions would benefit from enhanced vehicle data , e.g. maintenance (uptime) and driver coaching

To accomplish this, versatile tools for collecting, aggregating, storing and sharing map related data in a generic way are needed. *Figure 1* illustrates the proposed Learning Fleet concept where geo-referenced event- and sensor data is collected from fleet vehicles. The data is then aggregated in back office map databases and utilized in different services. Finally, map updates and service data are distributed to the fleet vehicles.

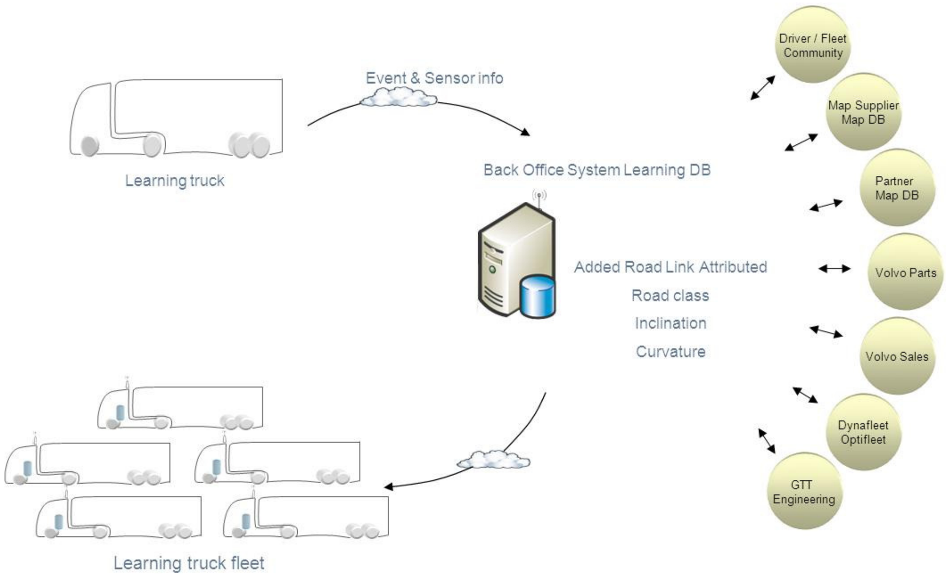


Figure 1: Learning Fleet concept

5 Objectives (Mål)

The main objective was to validate the feasibility of the Learning Fleet concept through testing of an implemented prototype architectures and sample functionalities utilizing the collected fleet data
The aim has been to develop the data flow and data storage architecture based on user requirements from the applications and business models. In order to cover requirements from a wide range of functions areas in the requirement specification, applications were picked in fields like navigation, fuel efficiency, active safety and fleet management.
To accomplish this, a number of activity areas are identified:

- Efficient data infrastructure architecture
- Applications (use case descriptions and requirement specifications)
- Business cases
- Visualisation

These areas are natural boundaries for the work packages described below. Finally, tests for validation of the application- and architecture functionalities are performed for proving the feasibility the Learning Fleet concept.

6 Project realization, Validation and Results (Resultat och måluppfyllelse)

The project is built upon the following work packages;

1. Learning Fleet & Data Architecture and requirements.
2. Development of applications using learning fleet data.
3. Services and Business models.
4. Visualisation.

In this section the reader will find descriptions of implementations, reasoning and considerations. Validation and results are found in the end of the section.

6.1 WP1, Learning Fleet & Data Architecture and requirements

Figure 2 below shows an initial architecture image, including external sources and users, database functionalities and vehicle platform functions.

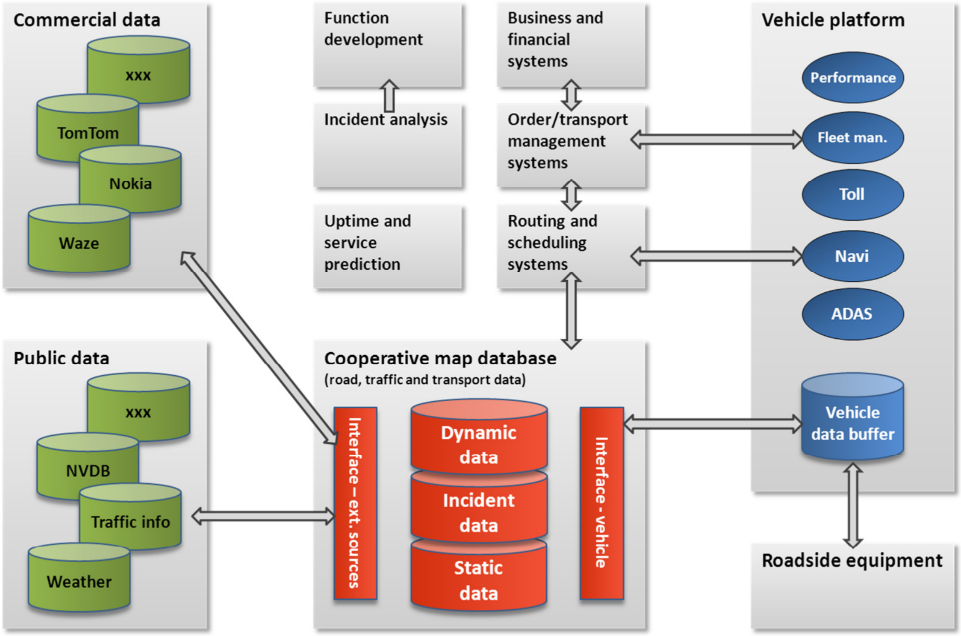


Figure 2: *The learning fleet architecture, centered around the cooperative map database*

The sub components of the work package, detailed below, have been identified as:

1. Map database
2. External data consumers and sources
3. On board client
4. Simulation of fleet and database tests

Both project partners Triona and Volvo implemented their own architectures for on- an off board functionalities in order to allow use of suitable previously developed architecture components as base. When developing the new components, attention has also been paid to parallel and upcoming projects to ensure that the components in their turn can be used as base for future development.

A key to collaboration is to be able to exchange relevant map database content. In this project, the exchange mostly concerns highly dynamic map attributes which can be geo-referenced in a map database using Open LR and distributed in DATEX2[iv]. This approach allows different topology representations and sources to be shared between partners. In the FFI BADA project a similar has been selected.

6.1.1 Triona implementation

Trionas part of the project has been to manage dynamic data to and from Volvo's servers and indirect vehicles and process data. Another important aspect has been to use Trionas past experiences to tie events collected or generated by vehicles to an existing road network (Nationell VägDataBas, NVDB) and to specific routes. This can help to find out about events, conditions and obstacles on the planned route for the vehicle. By being able to act on information received, and for example choose another route, greater efficiency and security can be achieved.

Being able to manage the data of infrastructure, traffic and vehicles from different sources can provide an important added value as supplemental data can help to make a better analysis of the situation on the road.

In order to better analyse how the data flow could look like and be managed a pilot application has been developed by Triona that handles data from multiple sources, linking it to the road network and uploads routes and deliver / presents relevant data for users. Data that is managed here is both static data on the infrastructure and dynamic data that may affect traffic on the selected route. A more detailed description of the pilot is in WP2 Task 2.1

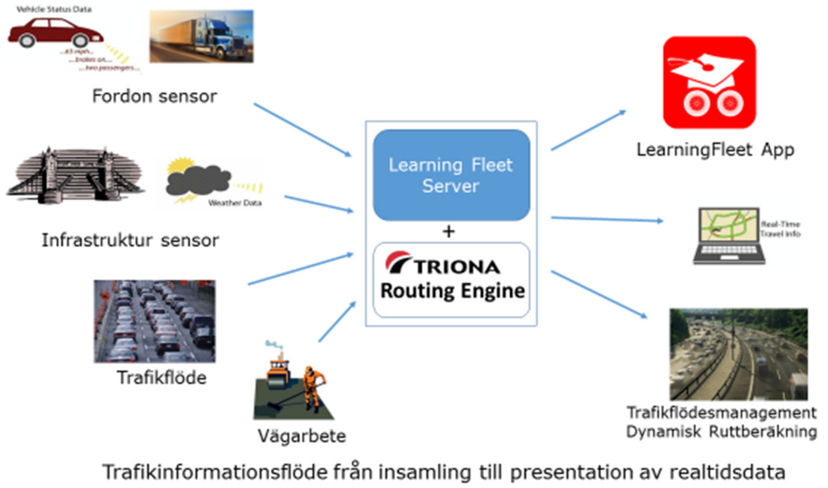


Figure 3: Traffic information flow from collect flow to presentation of real time data

6.1.2 Volvo implementation

Architecture

The cooperative e-Horizon system uses vehicle sensor data from several vehicles to generate a road map database on a BOS (Back-office system) server. Relevant parts of the generated map database are then downloaded to vehicles in subsets, based on their individual positions. The data can be used for vehicle functions that benefit from preview data describing the road ahead, for example the I-See functionality which optimize fuel consumption in undulating terrain in Volvo trucks.

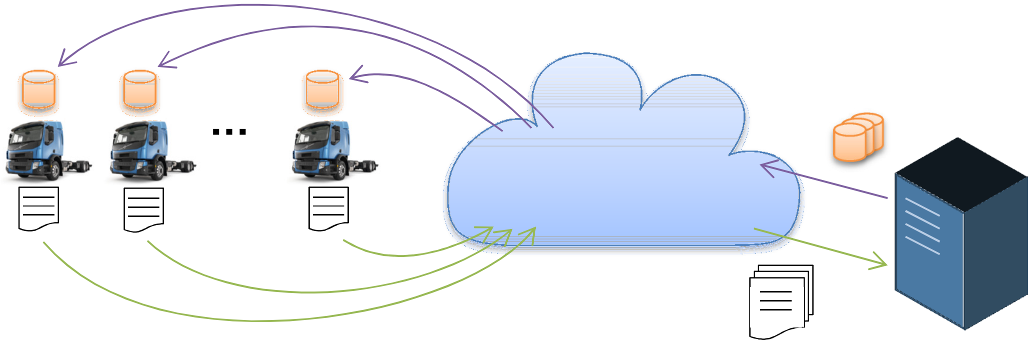


Figure 4: System overall view

The system concept comprises a fleet of vehicles (1 or more) equipped with telematics gateways (TGW), and one BOS server with functionality for map generation, map data storage, and map distribution. Each vehicle in the fleet gathers position data using a GPS receiver and sensors data. These data build a vehicle trace and this trace is uploaded to the BOS via the TGW. The general system architecture is depicted below:

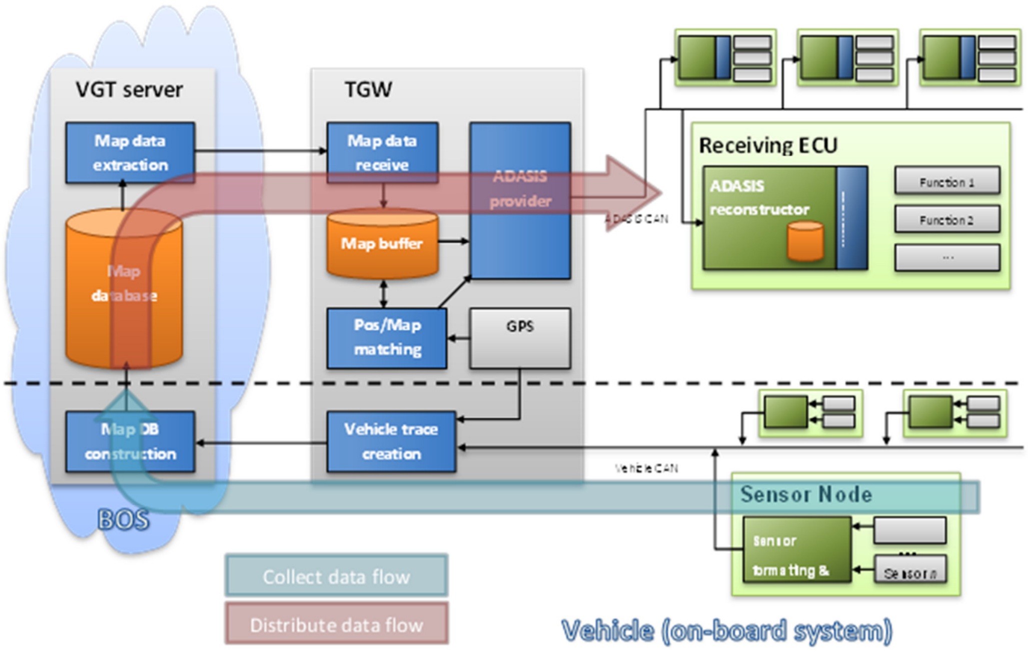


Figure 5: Volvo system architecture for cooperative e-Horizon

A collect flow starts in the fleet vehicles when relevant sensor data are provided by sensor nodes. These nodes are basically ECUs managing one or several sensors and connected to the vehicle CAN networks. Filtering and formatting of the sensor data for reduction of amount of data or improve accuracy (for instance noise filtering) is preferably done in the sensor node where vast amounts for raw data is available. The GPS module is part of the TGW.

The distribute flow utilizes the ADASIS protocol[v] for sharing e-Horizon data to the receiving ECU blocks, completing the loop of data in the system.

Road network topology and geometry

The map on the BOS as well as the on-board map buffer uses certain entities to organize the data in a network structure. The map is built up from **road sections**. Road sections are connected to each other using **road connections**. Each road section has only one direction, so for a bi-directional road, there will be two different road sections, one for each direction. At the end of the road section, there may be one or more road connections and at the start of the road section there may be one or several parent connections. To each road section, **road attributes** can be connected. Several connected road sections can form a **road path** which is the base structure in the above mentioned ADASISv2 protocol for distributing map data to vehicle functions via a CAN bus.

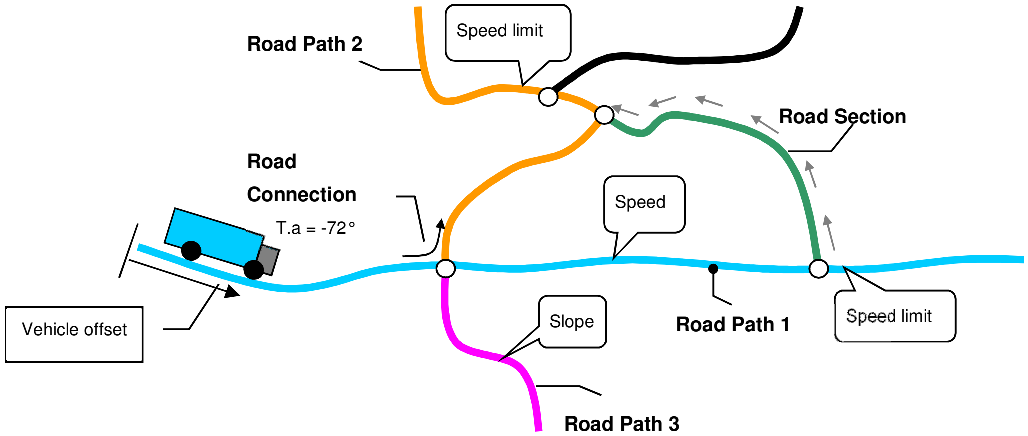


Figure 6: The road paths are colored, and may contain several road sections

In the following sections, entities used to define the road network are described in details. For entities that are stored in database, the name of the corresponding table in DB is written in brackets in the section title.

Trace to road section map matching and sub-traces splitting

In BOS, the first processing steps are to receive a vehicle trace data and map matched it to one or several road sections in the map database. Thereafter sub traces are built from the result of this map matching. Each sub-trace is then considered independently when updating the map data base with the trace data. *Figure 7* shows an example of map matching result of a new trace (in purple) on a map database containing 3 road sections (numbered #1, #2 and #3).

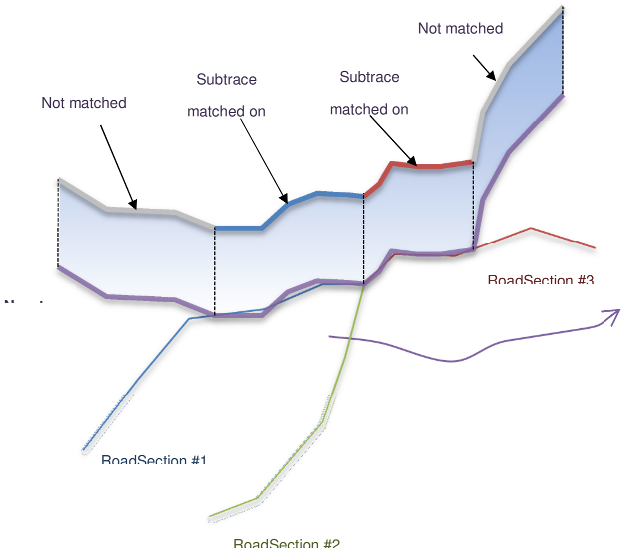


Figure 7: Example of map matching result

Road section geometry building and merging from several traces

If traces cannot be map matched to any existing road section, a new road section can be built from vehicle traces received by the BOS. Traces might be issued by several vehicles or they can be issued by the same vehicle but at different occasions. A given trace can also be the source for several road sections.

Figure 8 below illustrates an example where several traces are forwarded from fleet vehicles to the BOS. When the first trace is received on the BOS, a new road section is built from it since no match can be found in the road database. As a second trace covering the same road is received on the BOS, it is matched to the road and the merging process starts.

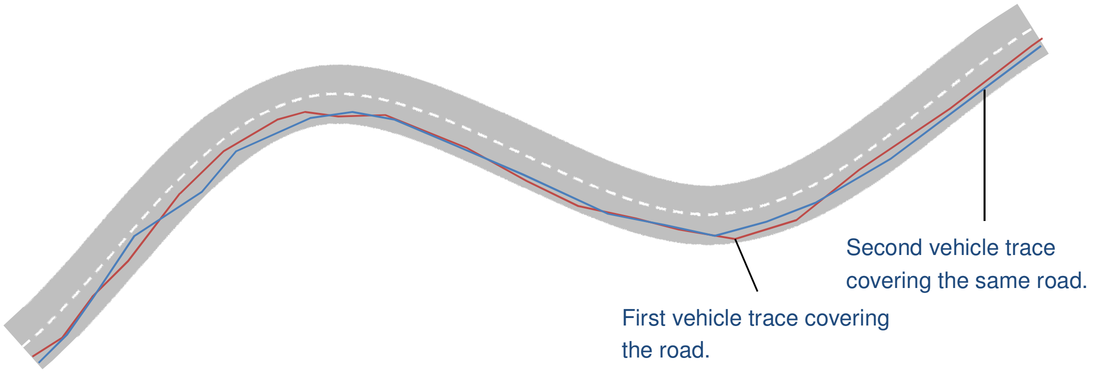


Figure 8: Merging trace geometry representations

When merging the different geometry traces, their shape points are weighted differently in accordance to various factors as GPS precision indicators, dead reckoning history and sensor parameters.

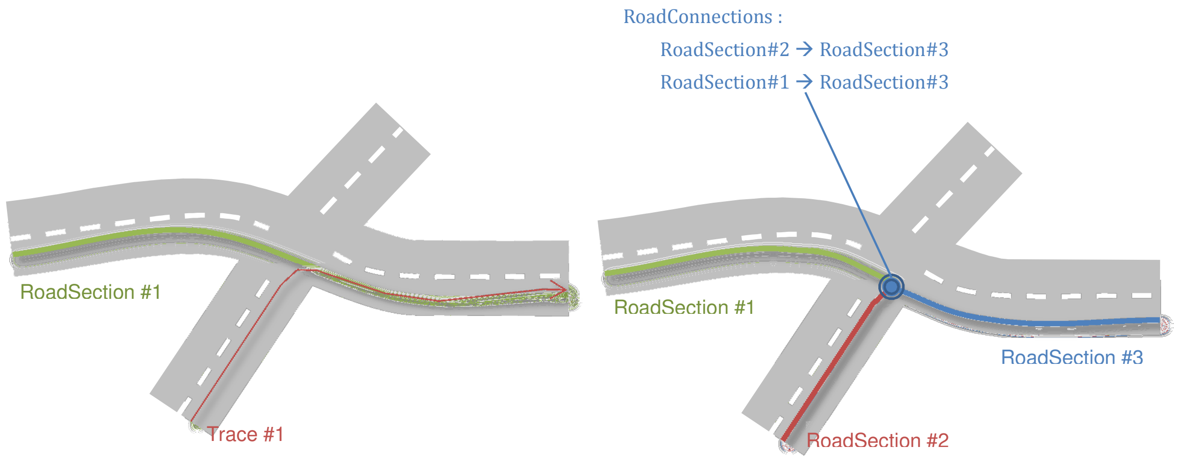
When creating the merged road section, a combined weight is calculated and stored for the updated road section. This combined weight is used when merging further traces.

Road connection building (network topology)

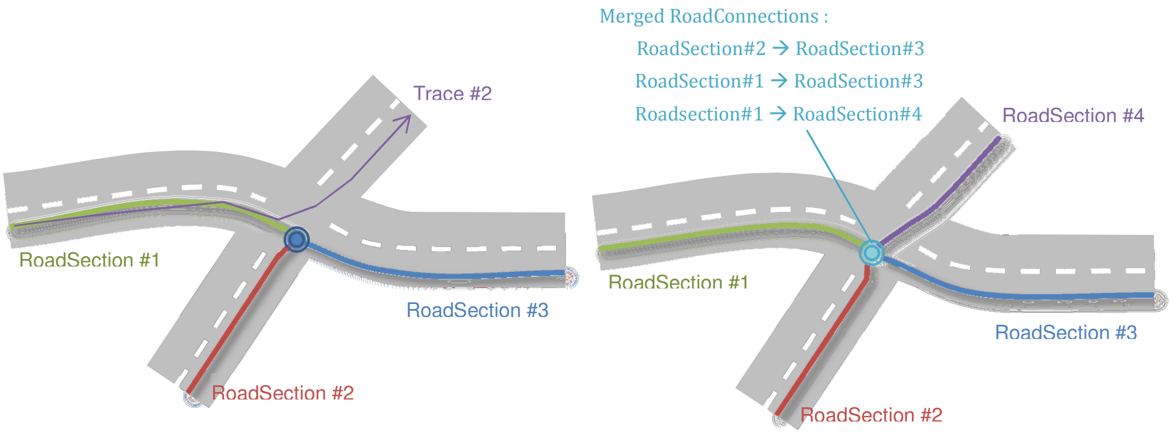
When a trace contains parts that are matched to an existing road section and other parts that are not, it is representative of intersections. It could be a fork from existing road section to a new road section or new road section joining an existing one.

In both cases, the existing road section shall be split at the intersection point and a road connection must be created.

An example of road connection creation is described below. Road section #1 exists in the Map DB while the vehicle runs trace #1 (joins on road section #1). Road section#2 can now be created from trace#1 and road section#1 is split in to #1 and #2 by a new road connection



In a second example the vehicle runs trace #2 , coming from road section #1 and forking to a road not yet existing in the map database. This event yields a creation of a new road section #4 and a new position of the road connection.



This way changes in the road network topology is captured and reflected in with new road segments in the corresponding database representation as the fleet vehicles travels roads.

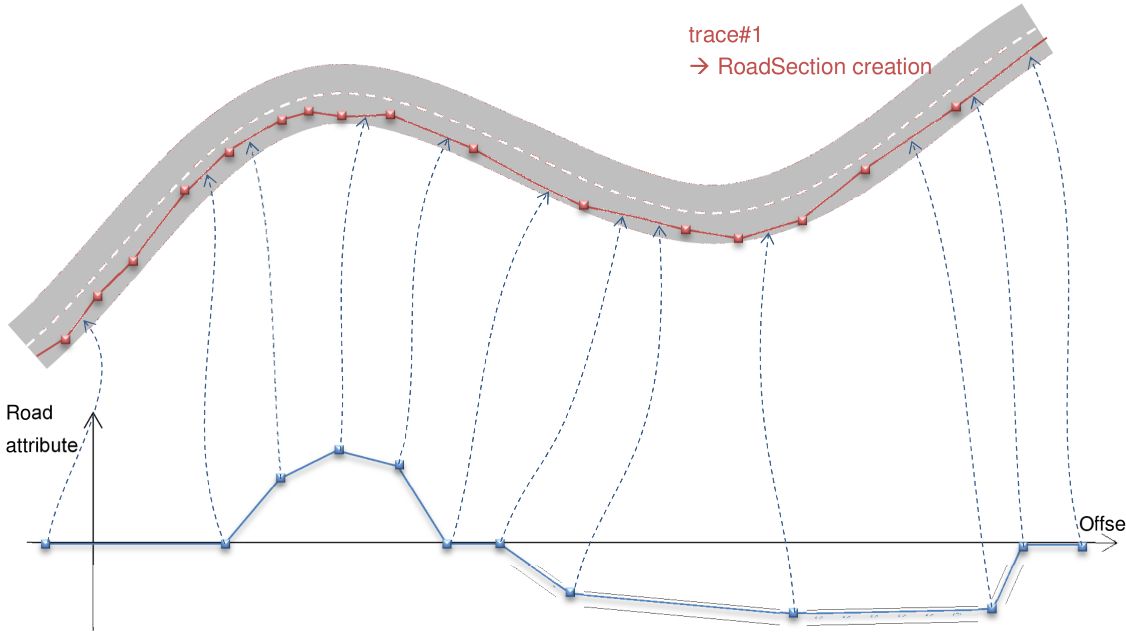
To avoid unnecessary storage, communication and calculation costs the fleet vehicle OBS must first compare the information already available for the road section, before storing and uploading road geometry traces in a “deviation report” to BOS.

OBS can also be instructed by BOS to always report specific data from certain road sections during given conditions in order to quickly produce a basis for confirming or rejecting a suspected deviation on a road section. This “spotlight”-functionality has been described previously for example in the documentation from the FeedMAP project.

Road attributes

Creation and merging of sensor data is linked with an existing road section. Sensor data (non GNSS data) alone are not enough for initiating the creation of a road section. Sensor data are always linked with GPS data within a vehicle trace. Sensor data are sometimes combined into road attributes.

Let’s consider a road on which several traces are forwarded from the vehicles to the BOS. When the **first trace** (trace#1) is received on the BOS, a new road section is built from it and road attributes are calculated from sensor data and mapped on the newly created road section.



The road attribute profile is considered reduced to the minimal amount of data with acceptable quality. As a result, locations of road attributes are not necessarily the same as road shape points. Locations of attributes are identified by an offset from the start of the road section.

As next vehicle sensor data traces are reported to BOS they can be merged with data of the previous trace(s) in a weighting process analogous with the geometry representations describe previously or according to other logical sequences. The choices of methods are of course dependent on the nature of the sensor data and for example binary or highly dynamic attributes needs to be handled differently compared to road geometry.

Road data transfer

Higher dynamics of a road attribute in general requires faster collect- and distribution flow, in order to preserve the value of the road attribute data. This means that capturing, transfer and aggregation of data might need to be handled differently and balance between cost and speed for data transfer might need to be weighted differently. For example large chunks of static data might be transferred via WLAN when it's available while accident- and traffic flow data needs to be transferred immediately. Push- and pull mechanisms also need to be tailored according to the intended use of the data.

In the Learning Fleet implementation by Volvo, only mobile communication between OBS and BOS was implemented for simplicity and budget reasons. Another limitation of the implementation is found in a restriction to only static road attribute data as a result of a coordinative distribution of dynamic attributes to the on-going FFI BADA project. Consequently, those functionalities and corresponding parts of the architecture will be reported within FFI BADA.

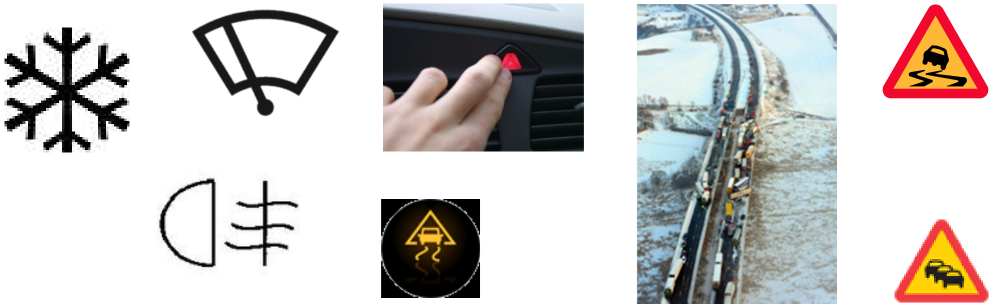
Even if the parts of the Volvo architecture designed specifically for dynamic data are reported elsewhere, there is intent to achieve the overall architecture and functional support depicted in ***Figure 2*** within the combined project activities, and to create a base for fleet data exchange between project partners Triona and Volvo, the design work of the exchange interface and transfer formats was carried out in cooperation with the early BADA activities.

For instance, the import- and export services of Triona's and Volvos' back office are using Datex II [vi] for information exchange and Open LR[vii] for geo referencing between different map topologies.

Support for highly dynamic data from vehicle-to-vehicle (V2V) or vehicle-to-infrastructure can potentially also be integrated in to the architecture but as for the other dynamic data types, such activities are left to explore in other research projects like FFI BADA.

6.2 WP2, Applications using learning fleet data

Based on the architectures described in the WP1 section above, a number of applications utilising the harvested vehicle fleet road data have been implemented by the project partners.
These can be regarded as a few selected samples of beneficiaries of learning fleet data.
During the implementation and testing activities, these functionalities also helped to update and verify the requirement specification and functionality of the generic architecture described in WP1, Learning Fleet & Data Architecture and requirements.



6.2.1 Task 2.1 Dynamic safe and fuel-efficient navigation and driving support

This section describes the navigation- and driving support application developed by Triona.

To support the development of fleet and vehicle optimization systems in a resource-effective manner, the data flow from different sources needs to be handled in an efficient and generic manner. Another important issue is how the access to real-time data about traffic environment must look like. How can parties in the transport market benefit from each other's collected data to create a safer and more efficient traffic?

To analyze the opportunities and needs regarding the use of dynamic data, both internally at Volvo, but also with other stakeholders, the project has worked with a pilot application. The pilot application has taken into account the static data on the infrastructure to create an added value for the user.

The purpose of the pilot is to work with the requirements of such a system to collect and analyze real-time data from traffic and make it available for other applications in the form of events and to support dynamic navigation. The goal for this pilot application is that the system is to show the capabilities of dynamic data in applications of this type and also validate the requirements on data obtained from traffic.

Results from the pilot application is basic functionality for managing real-time data that can then be distributed via products and services, as well as a prototype of a security portal, which is developed in collaboration with external parties.

The pilot project is divided into the following parts:

- Triona Routing and Avståndstjänsten med Route Cache (Server)
- Learning Fleet (Server)
- Mobile App (Android)
- Event generator (Application for internal events for test purpose)
- External data (Collect and work with external data to generate dynamic events.)

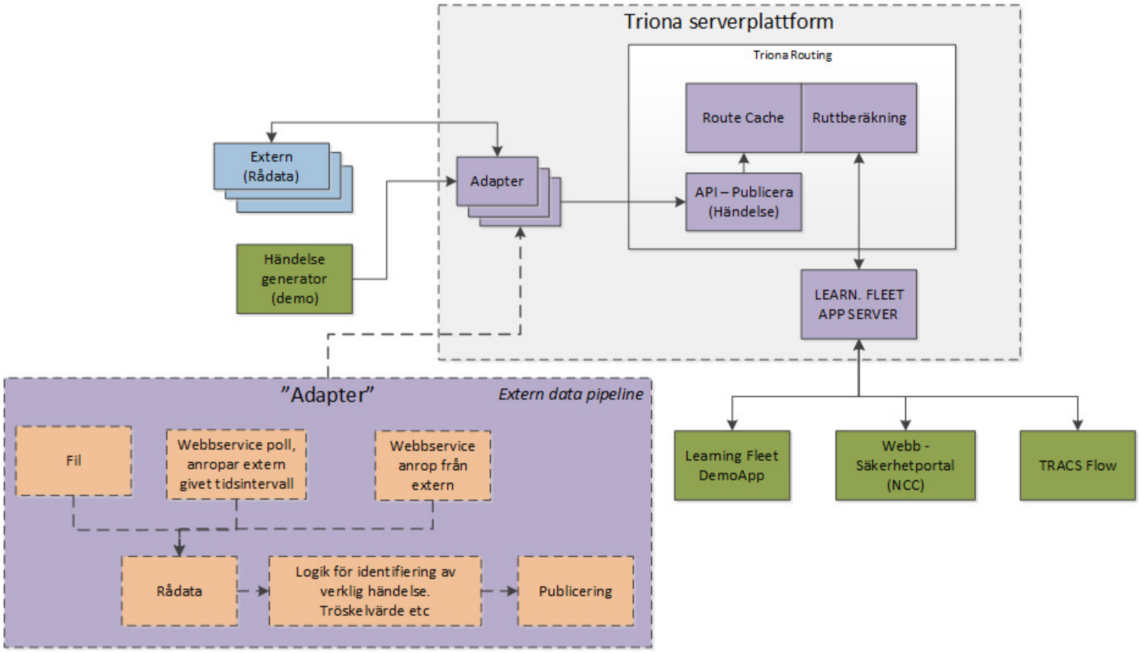


Figure 9: Triona system architecture

The system contains the following functions:

- In the demonstration, data is read into the system via two adaptors, adapter for Trafikverket's traffic information-API and via the Event Generator for manual entry of simulated events. Here you can connect to data from various sources and, for example, get data from Volvo and in the same time deliver back events from other players.
- Events are stored in the event cache in Learning Fleet Server.
- A mobile app (CORDOVA) has functions to create routes based on addresses or points in the map. Via points can be used. Addresses are produced from OpenStreetMap and routes are calculated from the NVDB (National road databank).
- The routes are stored in the route cache in Learning Fleet Server. In this step it also takes in account static data on road sections, such as restrictions on height, weight, etc.
- The mobile app is fed by events that occur along the current route.
- It is possible to select an event, recalculate the route and thus avoiding the road segments where the selected event occurred.

To make the concept useful for different parts, standards in data handling have been used.
Datex II is used for information exchange and Open LR for geo referencing between different map topologies.
In the work with the pilot application Triona have made a decoder to tie positions presented in the Open LR data format to the Swedish national road database (NVDB). By doing that, routing and other features around the road network are possible to use.

By collecting data via adaptors it is possible to get data from different sources in various formats and adjust the data to fit in the pilot. Each source can have its own adaptor.

The pilot shows that by collecting data from vehicles companies can reuse this information both to its own vehicle fleet and at the same time take advantage of the vehicle collectives aggregated data. Along with data on the infrastructure, this can provide a significant added value in safety and efficiency. An important element highlighted in the pilot is validation of collected data. How should the system and users react to information about, for example, a truck that switched on the hazard warning lights? Is this an accident, an obstacle or not. As more data comes in from the same location by several vehicles with hazard warning lights, information about traffic jams etc from road manager the picture may become clearer. For an effective system value limits and analyzes needs to be thought through carefully.

6.2.2 Task 2.2 Longitudinal- and lateral control applications

One of the first longitudinal vehicle control applications using map data were first launched in the mid-2000s for example by BMW in their 5-series (E6x) cars. At the time no ADAS classified maps were offered by map suppliers but with navigation maps only, it was possible to improve ACC by refining “resume-to-set-speed” acceleration in accordance to the road class and limiting at highway ramps under certain conditions.
Since then, ADAS classified maps with information on slope, curvature, speed limit etc, has made it possible to improve safety as well as fuel efficiency and comfort.
The fuel saving I-See functionality found in Volvo trucks is based on an alternative or complementary solution to ADAS maps from commercial map suppliers. As the Volvo truck is driving it automatically stores representations of slopes where fuel consumption could be reduced by longitudinal control or gear selection strategies. The slope representations are then shared with BOS by means of the TGW. BOS aggregates slope representations and distributes to trucks who are heading towards for them unknown slopes.

1. Before the uphills: taking off.
When I-See knows an uphill is coming, it lets the speed increase, approaching the upper speed limit, to gain momentum. The truck stays longer in a higher gear.
2. On the uphills: keeping from downshifting.
When climbing, I-See uses its stored knowledge to avoid unnecessary downshifts towards the top. You approach the crest smoothly without wasting fuel in a lower gear at the top of the climb.
3. On the crests: staying calm.
When approaching a downhill, I-See keeps the truck from accelerating unnecessarily.
4. Before the downhill: rolling on.
Just before the slope, the driveline temporarily disengages, allowing the truck to roll. This saves energy and minimises the need for braking.
5. On the downhills: braking in time.
I-See knows when the slope ends. Thus, when gaining speed downhill, it can apply the engine brake gently in time – rather than abruptly at the end – to prepare for the upcoming topography.
6. In the hollows: some extra momentum.
When a downhill is followed by an immediate uphill, I-See really comes to its own. It lets the truck roll, gaining speed and momentum to climb uphill with less effort.

Figure 10: I-See funtion for improved fuel efficiency

- See more at: http://www.volvotrucks.com/trucks/uk-market/en-gb/trucks/volvo-fh-series/key-features/Pages/i-see.aspx#sthash.fhpdMNrn.dpuf

With the Learning Fleet concept architecture it should be possible to support more detailed and accurate slope representations from the trucks and to cluster and aggregate different slope representation as described in section **Road attributes** above.
According to simulations, the improved accuracy of the slope representation potentially allows at least another 1% reduction of fuel consumption compared to today's I-See according to simulations. Validity of the simulation results are confirmed by test drives on some selected road sections.

Improved road geometry and topology including lane information can also improve safety, fuel efficiency and comfort, since it enables better assessment of vehicle position and prediction of trajectory for the ego vehicle and other vehicles recognised by vehicle sensors.
It will for instance be possible to make earlier assessments of lead vehicle(s) with high confidence, and adopt longitudinal control accordingly. This way the freedom of means for achieving a needed speed change in a fuel efficient, safe and comfortable way can be substantially increased. The gains in fuel efficiency have not been quantified in fleet vehicles within the project. The main factor behind this limitation of scope is that the gains are very much depending on both traffic situation and the road section attributes and it would therefore be very resource- and time consuming to collect the needed data.

Figure 11: Road section topology and lane geometry enable improved target selection for longitudinal and lateral control

Also lateral control can be improved having better perception of the vehicle position in relation to the lane and other road section attributes. This is especially important in situations where lane markers are difficult to track due to adverse light- or weather conditions. Existing functions like lane deviation warning can clearly be improved by access to high accuracy lane information and it is essential for increasing availability of higher degrees of autonomous driving at high speed. This deeply investigated in the FFI VPRP[viii] project and therefore not in focus in this report.

In the original scope hazard warning was included as an example application but due to previously mentioned resource shortage and the start of the FFI BADA project a prototype implementation was transferred to the BADA project. The basic functionality intended for hazard warning was to quickly collect map matched hazard warning activations in vehicles of the fleet to BOS and distribute warning messages to vehicles travelling the concerned road sections. The activations could be manually triggered by the driver or automatically by for instance an emergency brake function.

Figure 12: Hazard warning functions could substantially increase safety especially in difficult light- and weather conditions (example; Tranarpsbron, Jan 15 -2013).

In addition to robustness of ADAS and autonomous driving functionalities, highly dynamic road section attributes like hazard warning, road friction estimations and dynamic speed limits are probably needed for increasing availability of platooning functions on many road sections. This is further explored in research projects like FFI SERET.

6.2.3 Task 2.3 Vehicle statistics & Volvo configuration tool

A study of a statistics- and vehicle configuration tool was part of the original project scope. However, legal issues and limitations of the scope has made it difficult and to some extent excessive to reach the initial ambitions. In the FFI BADA project legal aspects of using fleet vehicle data will be studied and hopefully yield valuable input for any services and tools utilising such data. It is foreseen that the result can have significant impact on the design of a vehicle configuration tool. Hence, implementing such tools using a significant part of the project budget would at this stage produce a risk of the implementation being outdated and of no relevance for proving the Learning Fleet concept.

Instead, it is suggested that a similar study should be started in a suitable context, based on findings from the FFI BADA project.

6.2.4 Task 2.4 Fuel footprint

Our vehicles have sensors that record information while operating and projects such as EuroFOT[ix] collected high amounts of information that was used later off-line due to lack of communication and applications on the road which Learning Fleet project is trying to address. We illustrate possible applications that can benefit from the data collection and communication between vehicles.

One of the factors affecting decision making in operating a fleet of trucks are the costs of operating the vehicles which are mostly the driver and fuel used. It is therefore beneficial to be able to estimate and possibly improve fuel consumption thus enabling the fleet manager to reduce operation costs.

Our focus is then estimating driver performance. By being able to estimate driver performance we can identify driver patterns that lead to a significant change in fuel consumption, either

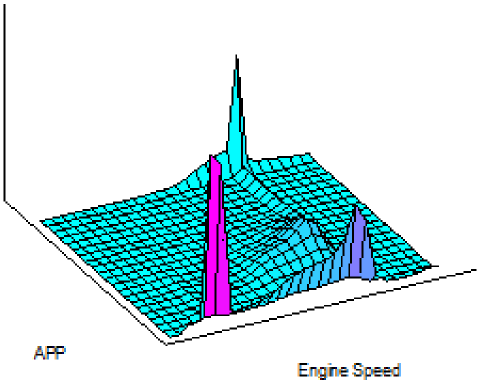


Figure 13: APPES map

positive or negative. Positive changes can be transferred to other drivers using off-line driver coaching or on-line application that make use of V2V (vehicle to vehicle) communication. Negative changes can be corrected through feedback given to the driver. The fleet manager having access to this kind of data can also make better decision when pairing drivers, vehicle and routes to maximize the fleets' performance.

Figure 1 represents how we view driver behavior with a different representation. This new representation can capture specific behaviors that experienced drivers are familiar with, such as coasting, full throttle. We refer to this representation as APPES map and we use its features in order to better understand how moving on this map relates to driver performance and fuel consumption. The benefits of this representation are that the knowledge we extract from it can easily be transferred to the desired recipients and can also be understood by the relevant people. APPES is formed using two distinct sources of data that contain information we want to process. Firstly it contains information about how the vehicle is operated in the form of "engine speed" and secondly it provides us with driver intention in the form of "accelerator pedal" which is one of the important ways that tells us how a driver operates a vehicle. Together the two signals create a correlated picture of how the driver and vehicle interact with each other and the environment.

When looking at driver performance, current approaches are considering raw numbers to determine efficiency, such as recorded fuel consumption, average speed, and so on.

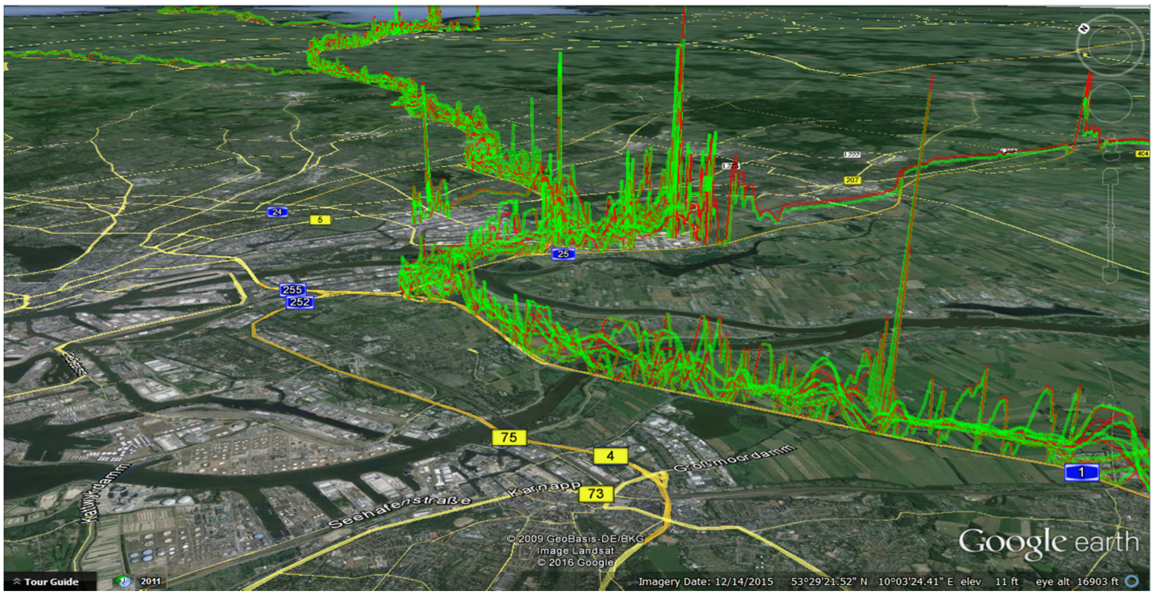


Figure 14: Broad view of fuel consumption for selected number of trips

These numbers are however caused also by factors outside driver's control and demotivate drivers in driving efficiently because, for example, high load leads to high fuel consumption and low load to low fuel consumption and no matter how well or bad a driver does, the gap between those two cannot be bridged.

We therefore, propose a method for reducing the influence of outside factors when calculating driver performance, by means of normalizing fuel consumption which could potentially also lead to identifying situations where performance of drivers is different from the norm, either good or bad. For this method we define "FUNO" as "Fuel Under Normal Operation" as the normalization factor. FUNO is data driven and contains information such as current environment conditions and vehicle characteristics which facilitates comparison of drivers operating different types of vehicles.

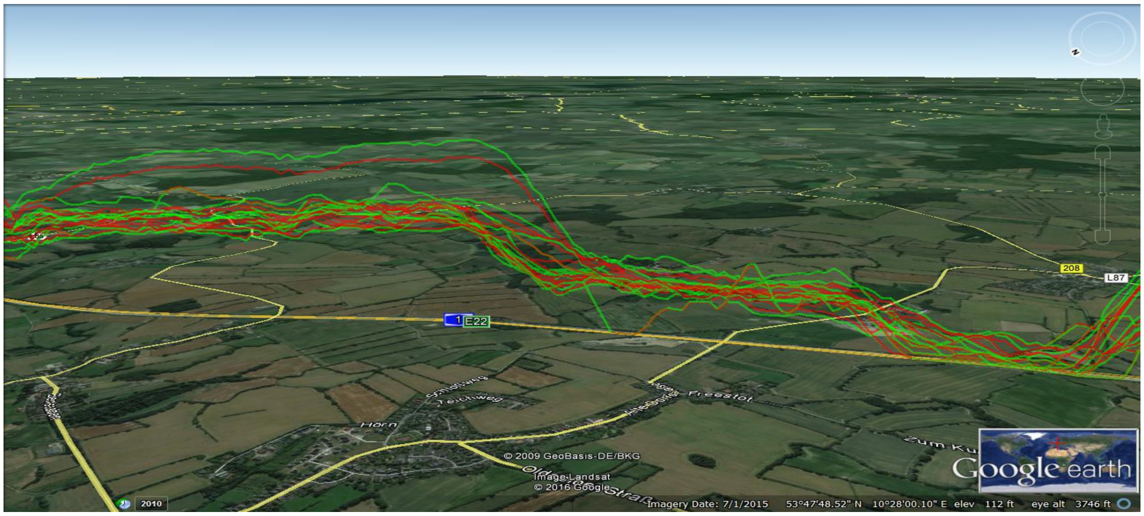


Figure 15: Bird view of absolute- and normalized fuel consumption.

Figure 15 illustrates a bird-eye view of part of the data available in EuroFOT data, which we use for this test case. In green, we have the fuel consumption in absolute number, one green line representing one recorded trip. In red we have normalized fuel consumption which enables us to make a better comparison between drivers as it is weight independent.

In figure 3 we have a closer look at how the normalized fuel consumption is compared to the recorded fuel consumption. Conceptually, if the drivers are doing the same thing on the same road with the same vehicle their normalized fuel consumption will be similar. However a number of factors are unknown which leads to higher differences in the normalized fuel consumption.

Looking onwards, we can think of extracting driver patterns and associating them with various indicators, such as fuel consumption, known environment conditions. By quantifying the impact of each driving pattern we can build up a knowledge library that can be used to coach future drivers, improve existing automated driving systems, such as Adaptive Cruise Control (ACC).

6.3 WP3, Service & business model investigation

This work package aimed to develop service concepts and business models for learning fleet services and evaluate the gaps necessary to make the concepts a reality in terms of customer desirability, technical feasibility and organizational readiness for all stakeholders in the future value chain of the service.

The work package consisted of three main tasks:

1. Explore existing business models & services for 1) logged and 2) real-time commercial vehicle data.
2. Conceptualize Business model and service offering for Learning fleet data
3. Evaluate service concepts

The results from these three tasks are presented below.

Legal aspects on ownership of data

Any provider of services or business models utilising data harvested from fleet vehicles must take legal aspects and ownership of data in to account. The basis is that the vehicle owner and the driver own any positional data generated in the vehicle and any use by others of that data outside the vehicle in any service needs a clear and prior written consent.

This is the case with most of the current services offered in today’s fleet management systems and driver working time support, where for instance the drivers working-, driving- and resting times are saved and aggregated.

In many of the more advantageous business models, it is the sharing of data, sometimes also to third parties, which makes big gain in value for all involved parties. Figure 16 below illustrates how data collected from connected fleet vehicles can be shared and aggregated.

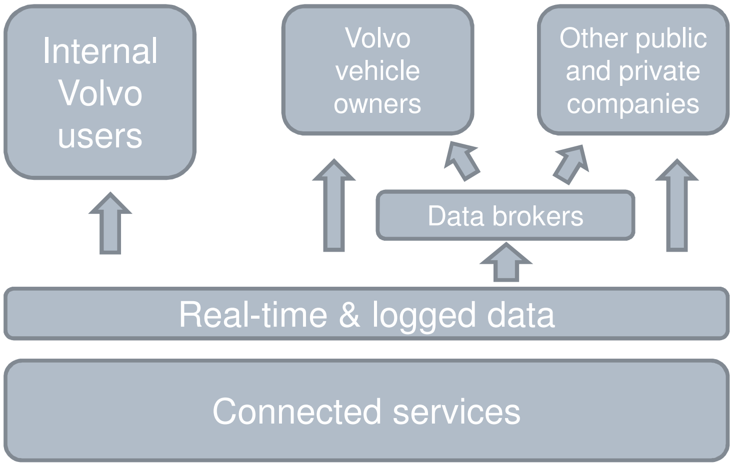


Figure 16: Flow of data collected from fleet vehicles through connected services.

Since data which indicates a position or a specific way of use of the vehicle can be considered as "personal", the written consent is needed but perhaps not always enough, even after anonymization in some cases. The terms under which data can be used may also vary from country to country. The obvious advantages of sharing data harvested from fleet vehicles or derived therefrom have caused an increasing interest and concern for the legal aspects of data ownership on international level. For instance, several countries including the European Data Protection Supervisor are discussing "Open data in the transport area" with a goal to find a common understanding and terms of use among the nations in order to enable value creating services.
In the previously mentioned FFI BADA project a separate work package is dedicated to investigate legal aspects on ownership of vehicle fleet data and the consequences for different services based on such data.

Service offerings ideas

Exploration and conceptualization were done through co-creation workshops with people from different organizations involved in the Learning fleet project.
A quantity of ideas on how to create services and business with the Learning fleet data was generated. Additional interviews were done with some of the participants to explore the ideas further. Below, some of the generated ideas of service offerings based on the Learning fleet data are presented without further details:
Learning fleet data as…

- Tracking and manoeuvring-assistance, for e.g. reverse assistance
- Part of autonomous production system (off-road), for e.g. avoiding collisions
- Part of logistics system, for e.g. providing ETA and re-routing (avoid traffic jams)
- Provider of precise positioning and vehicle load information, for e.g. emergency and rescue operations
- Means of measuring road way conditions, for e.g. pro-active planning of road maintenance

Business model of Learning fleet service to Swedish transport administration

For the conceptualization of business models, the business model canvas as presented by Osterwalder and Pigneur[x]. See *Figure 17* below.

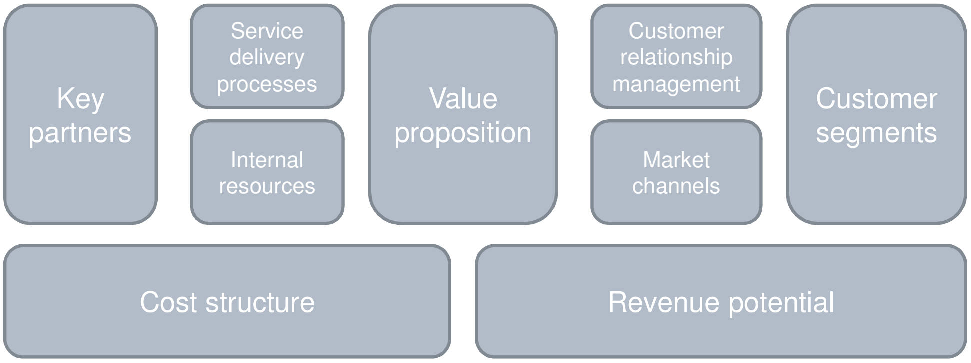


Figure 17: Business model canvas

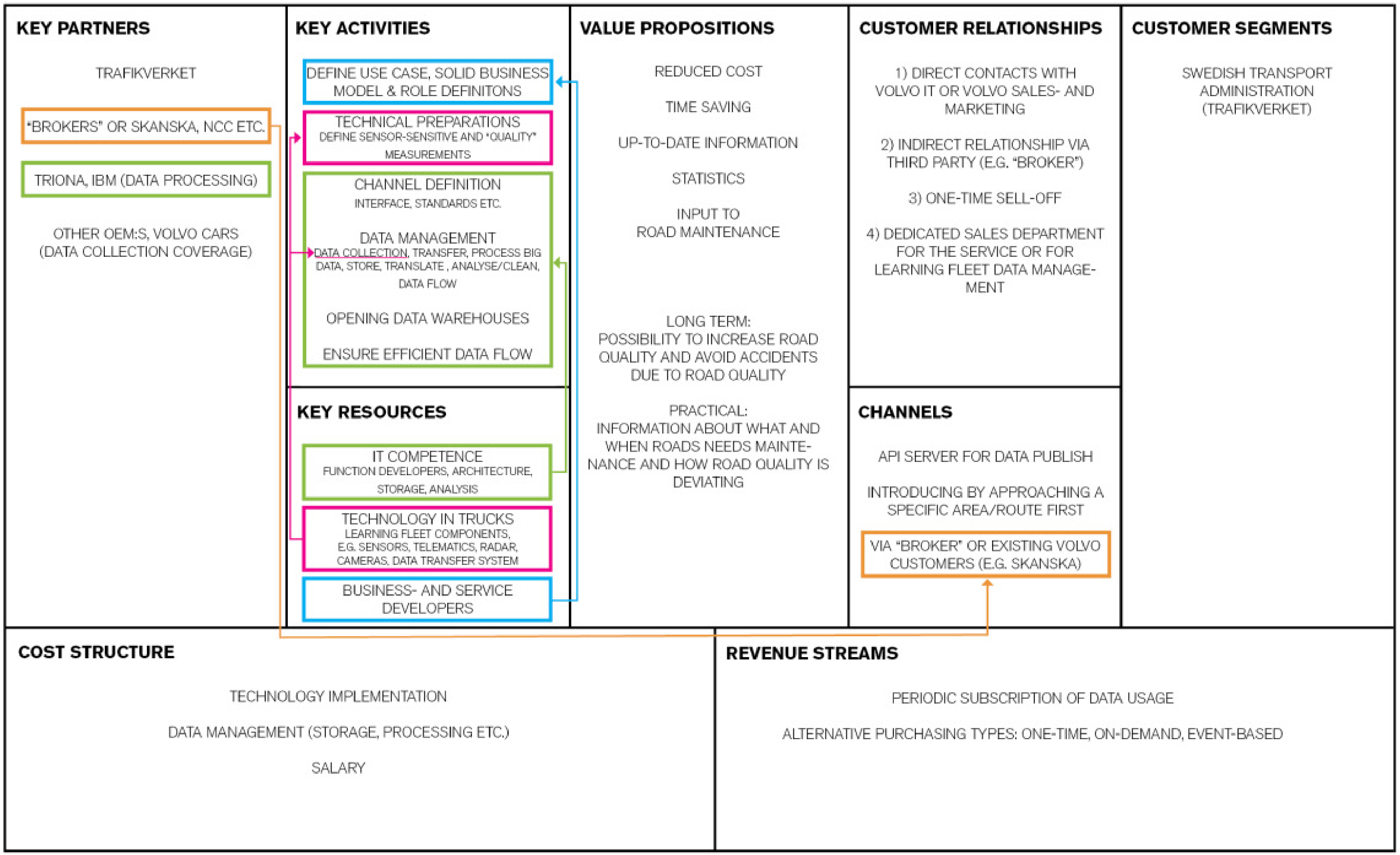
When using the canvas to explore and conceptualize new service offerings and design business models, the focus was on the value proposition (central block of the canvas) to potential customers of the Learning fleet data services.

In this work package, simple business models were created during the workshop for each of the service offering ideas. But a more detailed business model was specifically created for the service offering of using Learning fleet data as means of measuring road way conditions, as this idea was considered most interesting. It's important to mention that all business models were co-created by different partners in the project and not by a single person.
The chosen service offering idea can provide information about road way conditions and road quality by continuously measuring the road surface of larger geographical areas. By collecting data about the road conditions and quality from the many learning trucks on road, this data can then be translated into useful information.
The use of this could for example be:
- Pro-active planning of road maintenance for authorities
- Trend analysis for future road development (by logging type and speed of wear & tear)
- Follow-up of road construction quality

The overall benefits are the instant access to data and reduced manual data collection activities for the customer. And the customer could be Swedish transport administration (Trafikverket), constructions companies and perhaps even insurance companies.
For the business modelling, the main customer considered was the Swedish transport administration (Trafikverket). Today, Trafikverket spend time and money on collecting this kind of information by themselves in order to plan their road maintenance work. If Learning fleet provides this service, it would be of great value for Trafikverket. In other words, up-to-date information about the roads would propose a value of reduced cost and time saved in these kinds of activities for Trafikverket. By providing statistics regarding the road quality and condition, Trafikverkat could use the information to improve road maintenance planning and prediction. In a long-term perspective, this service would contribute to reduced risks of accidents caused by lack of road maintenance.
The co-created business model can be found in *Figure 18*

BUSINESS MODEL CANVAS

GENERATED DURING WORKSHOP 15TH OF MAY 2014



KEY PARTNERS

TRAFIKVERKET

“BROKERS” OR SKANSKA, NCC ETC.

TRIONA, IBM (DATA PROCESSING)

OTHER OEM:S, VOLVO CARS
(DATA COLLECTION COVERAGE)

KEY ACTIVITIES

DEFINE USE CASE, SOLID BUSINESS MODEL & ROLE DEFINITONS

TECHNICAL PREPARATIONS
DEFINE SENSOR-SENSITIVE AND “QUALITY” MEASUREMENTS

CHANNEL DEFINITION
INTERFACE, STANDARDS ETC.

DATA MANAGEMENT
DATA COLLECTION, TRANSFER, PROCESS BIG DATA, STORE, TRANSLATE , ANALYSE/CLEAN, DATA FLOW

OPENING DATA WAREHOUSES

ENSURE EFFICIENT DATA FLOW

KEY RESOURCES

IT COMPETENCE
FUNCTION DEVELOPERS, ARCHITECTURE, STORAGE, ANALYSIS

TECHNOLOGY IN TRUCKS
LEARNING FLEET COMPONENTS, E.G. SENSORS, TELEMATICS, RADAR, CAMERAS, DATA TRANSFER SYSTEM

BUSINESS- AND SERVICE DEVELOPERS

VALUE PROPOSITIONS

REDUCED COST

TIME SAVING

UP-TO-DATE INFORMATION

STATISTICS

INPUT TO
ROAD MAINTENANCE

LONG TERM:
POSSIBILITY TO INCREASE ROAD QUALITY AND AVOID ACCIDENTS DUE TO ROAD QUALITY

PRACTICAL:
INFORMATION ABOUT WHAT AND WHEN ROADS NEEDS MAINTENANCE AND HOW ROAD QUALITY IS DEVIATING

CUSTOMER RELATIONSHIPS

1) DIRECT CONTACTS WITH VOLVO IT OR VOLVO SALES- AND MARKETING

2) INDIRECT RELATIONSHIP VIA THIRD PARTY (E.G. “BROKER”)

3) ONE-TIME SELL-OFF

4) DEDICATED SALES DEPARTMENT FOR THE SERVICE OR FOR LEARNING FLEET DATA MANAGEMENT

CHANNELS

API SERVER FOR DATA PUBLISH

INTRODUCING BY APPROACHING A SPECIFIC AREA/ROUTE FIRST

VIA “BROKER” OR EXISTING VOLVO CUSTOMERS (E.G. SKANSKA)

CUSTOMER SEGMENTS

SWEDISH TRANSPORT ADMINISTRATION (TRAFIKVERKET)

COST STRUCTURE

TECHNOLOGY IMPLEMENTATION

DATA MANAGEMENT (STORAGE, PROCESSING ETC.)

SALARY

REVENUE STREAMS

PERIODIC SUBSCRIPTION OF DATA USAGE

ALTERNATIVE PURCHASING TYPES: ONE-TIME, ON-DEMAND, EVENT-BASED

Figure 18: Business model of service offering to Trafikverket

Further development suggestions

The service offering using Learning fleet data to provide information about road way conditions and road quality for the Swedish transport administration (Trafikverket) is certainly an interesting idea. Because the Learning fleet data would, in the long term, contribute to safety on road ways if they are kept maintained in time.

The business model presented here is certainly only a conceptual business model and the gap to make it a reality could be identified by considering the fulfillment of the three aspects of customer desirability, technical feasibility and organizational readiness.

The technical feasibility does not seem to be the main issue since the Learning fleet is technologically feasible. From an organizational point of view, this service offering might imply a new way of working, but would most likely not change the organizational structure. The customer desirability, however, needs to be confirmed.

A suggestion is to further investigate the service offering idea as well as its business potential together with the stated potential customer, Trafikverket. The focus would be to confirm customer desirability, test the technical feasibility and organizational readiness. Moreover, the results would be to further detail the business model and find a way of working and cooperating with Trafikverket to ensure safety on road ways.

6.4 WP4: Visualisation

The initial purpose of this work package was to connect the result from the work packages above into holistic visualisation platform, so that system status and benefits can be more easily verified.

As the project work started, one of the first tasks were to build a visualisation tool which could allow better understanding of road geometry traces and compiled representations of road sections and connections. After evaluating different approaches, Open StreetMap and Google Earth was used for displaying satellite imagery backgrounds geographically referenced to collected and generated map content. An example is illustrated in *Figure 19* below.

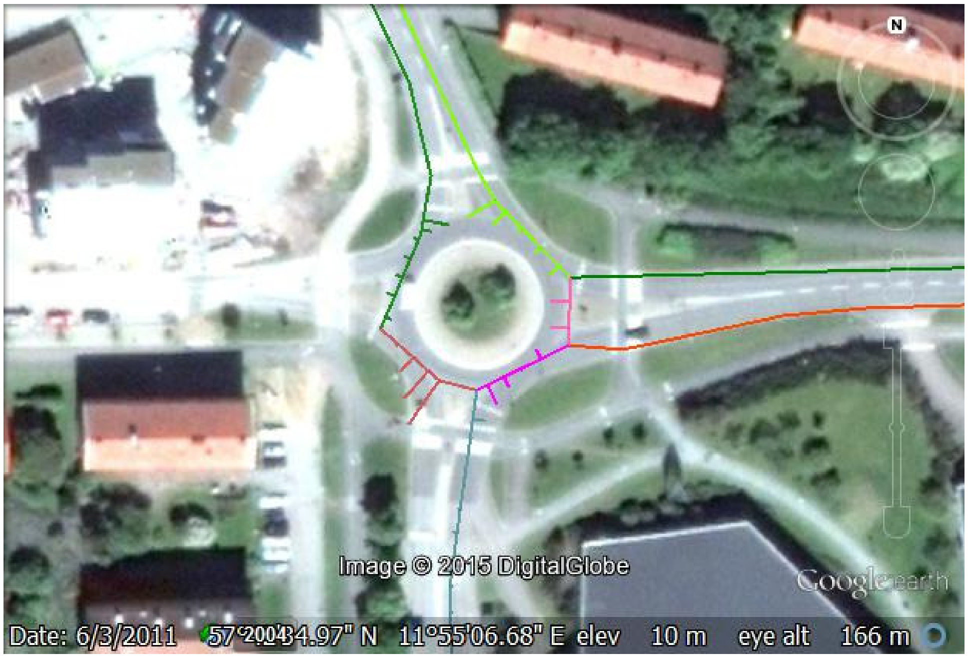


Figure 19: Road sections and connections compiled from traces of a few vehicle passages through a roundabout displayed on Google Earth satellite imagery background. Curvature is indicated by length of the normal (bar perpendicular to curve).

Figure 20 in next section illustrates an example of activity where the Open StreetMap tool was utilised for visual trace representation.

These visualisation tools also gave visual guidance and confirmation for the manual parts of the test procedures described in next section.

The original plan for the visualization platform also included functions for displaying positions and status of individual fleet vehicles but since the fleet to large extent was replaced with simulations, this function became obsolete.

6.5 Validation and results

This section describes procedures and results of the test activities performed on selected components of the implemented systems for validation of feasibility of the Learning Fleet concept.

Testing is therefore concentrated to function areas where key features of the concept are found. Consequently, focus is put on the novel and challenging implementations in the architecture like capturing and aggregating representations of road section geometry and attributes as well as the road network topology.

Geometry and attribute representation

As described in the architecture section, capturing trace geometry representation and attributes starts in the vehicle (OBS) but the in the current concept implementation the aggregation and refinement of data is done in back office services (BOS), where also road network topology is derived. Test and validation activities are below described analogously in corresponding sub sections.

OBS

As previously described in the architecture section, the OBS captures road geometry traces and slope data when driving and uploads the information to BOS. These operations are in their basic functionality straight forward and are therefore not subject of extensive testing.

Plots of a trace report with extracted slope- and altitude information collected from an OBS is illustrated in *Figure 20* below.

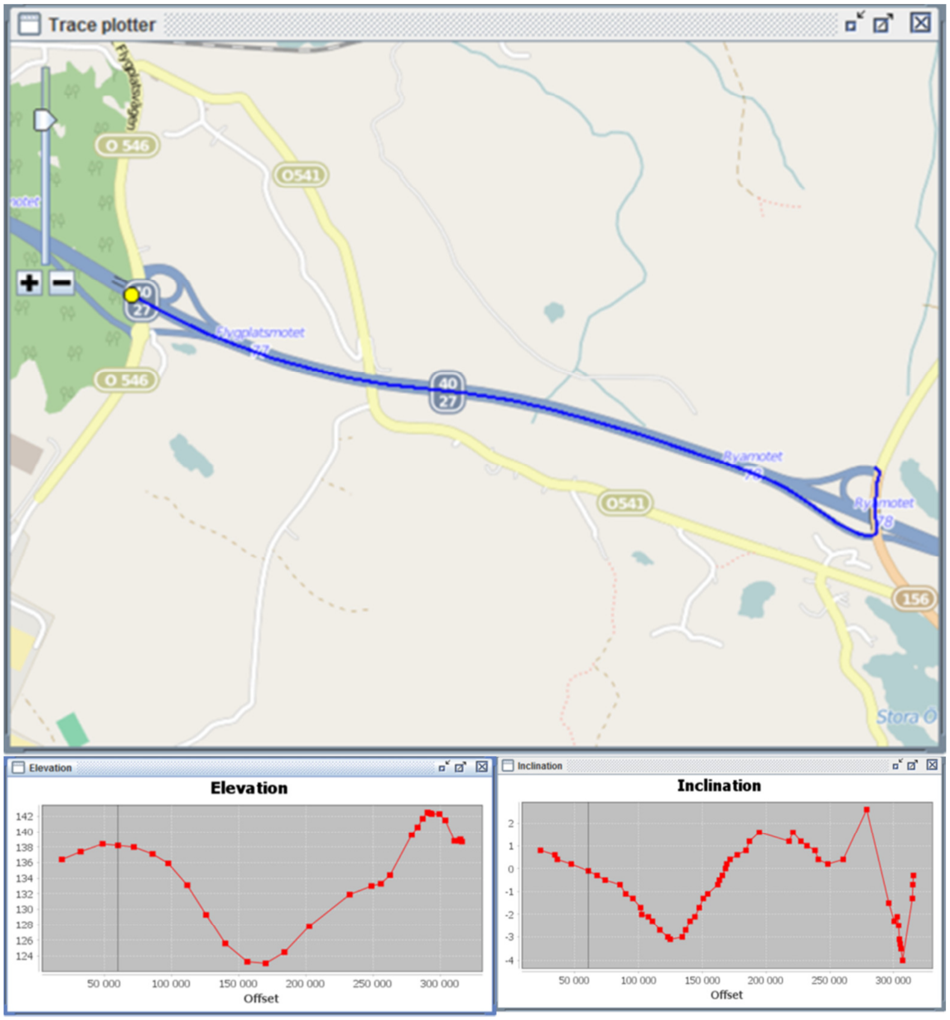


Figure 20: Harvested elevation and inclination data for a set of driven road sections. The vehicle trace is visualized using the Open StreetMap tool.

In order to simulate a significantly larger amount of collected reports, random distributions of offset-, scale- and gain factors were introduced and applied on the reports. The introduced errors should correspond to the variety measurement deviations originating from factors like individual sensors, temperatures differences, weather conditions, GPS satellite positions and driving characteristics which will appear in large a fleet of vehicles driving the same road section at different times.

After a vehicle trace is captured, a transport service of the TGW is utilized for transfer of the data to BOS. These transport mechanisms requires some implementation work but since they were not foreseen to be technically challenging or in any way essential for proving the Learning Fleet concept feasibility they are not completely automated. Instead, some manual input sequences were used. The result of the tests done indicates that the chosen approach will work also for a fully automated transport mechanism but depending on the road section attributes to be transported, some new features of the TGW transport services would probably be suitable. For instance, highly dynamic information like hazard warning data would need close to real-time transport response which is not always available in the currently used data transport service. This will be addressed in the FFI BADA project. Other examples are separation of is a cost efficient distribution vast volumes of non-time critical information and BOS initiated control of data collection and transfer for faster confirmation or rejection of potential changes on a road section or geographical area.

BOS

In the BOS representations from the same road section are identified and clustered. Several representations are then aggregated in to a best estimation as described in the architecture section. Depending on the nature of the attribute, different data reduction settings are applied when generating the attribute representation.

The algorithms for executing above mentioned operations are considered as important part of the Learning Fleet concept and are therefore subject for more extensive testing. A set of test methods are combined to accomplish this:

Automated tests

- Request data
- Receive response
- Validate response
- Test is run every time code is changed.
- No release of build if tests fail.

Manual operation

- Used as a client to inject traces and request generated data for every test scenario.
- Instead of validation of response, the data is written to disk as files of suitable format.
- Triggered by command

Generation and aggregation of slope representations has as a selected example attribute been undergoing the most amount of testing even if other continuous road attributes as curvature, vehicle speed and fuel consumption also can be derived in the same way.

Below, *Figure 21* illustrates altitude information referenced to data from Google Earth, after being transported through the Learning Fleet architecture from truck sensors to BOS map database.

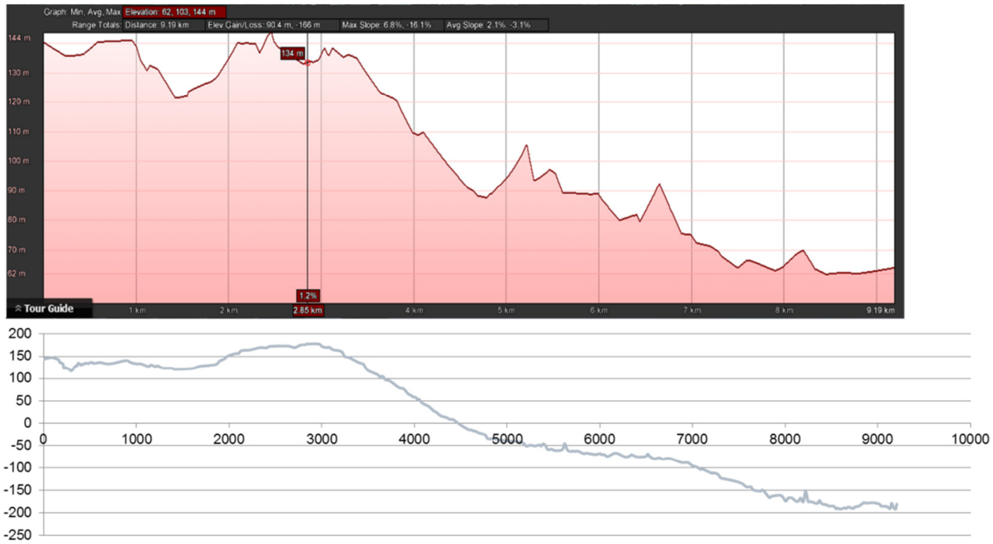


Figure 21: Improved slope and altitude information compared to Google Maps.

The map slope tests comprised validation of the systems capability to handle a number of different slope sequence combinations:

- Up-Down-Up
- Down-up-down
- Constant slope uphill
- Constant slope downhill
- Hard acceleration and retardation
- Different scales of different slopes
- Different slopes with connections

In an iterative process, the test procedures and tested algorithms were improved until the targeted functional performance was achieved. Even if proof of support for the Learning Fleet concept is now demonstrated, any corresponding production functionality must be substantially more refined and tested with a much larger set of measurement data where factors like sensor errors, driving style and environment are combined in different ways.

These attribute data representation operations can be applied and are in the future essential for system solutions based on road network topologies from commercial map databases, as well as solutions where the harvested data is used as base for the road network topology. The later approach is used in Learning Fleet and the results of the test and verification activities can be found below.

Topology representation

In the Learning Fleet project it was decided to explore the possibility to generate the road network topology in the map from harvested vehicle trace data, as described in the architecture section above. Test and validation of the road section geometry and other linear attributes are described above but for the road sections to form a map network topology, the connectivity between the road sections is needed.

The capability to correctly generate connectivity is very important for most users of the map information. Should the connectivity be missing or wrongly implemented, it would not only fail to support a number of functions it could also induce risks for potentially dangerous malfunctions in for example highly automated driving. The functions utilizing the map data must therefore be adjust to level of trust in the map data to the level of integrity of the map. The integrity of the map in turn very much linked to testing of the different map entities where connectivity is one of the most important.

A limitation in the term connectivity for map topologies generated from vehicle trace data is that legal restrictions on travelling cannot be guaranteed as for the commercial maps. The connectivity can indicate that it’s physically possible to travel from one road section to another but it cannot guarantee that it’s legal to do so. Even if traffic sign recognition cameras are getting more common in the vehicles, it is foreseen as difficult to reach a satisfactory trust level within the near future. Commercial map data offer better support for functions needing information on legal right to access a road section, for example navigation.

In *Figure 22* below, it is detected how several vehicle traces first are used for generating road sections initially only connected to other road sections from the same trace, but then clustered in to one “intersection” connection where certain lane connections and driving directions are combined.

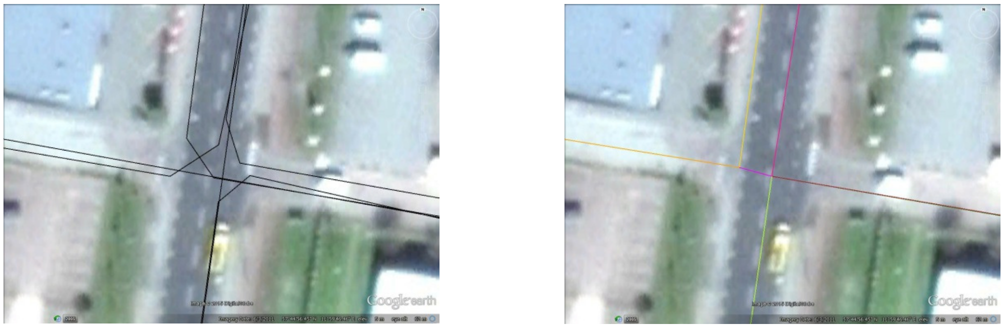


Figure 22: Trace representations from vehicle pass-troughs in the intersection and the resulting intersection topology

Some road section connectivity and topology test scenarios were selected for more substantial test activities:

- Straight road
- Four way crossing
- Highway
- Multiple lanes
- Drive through a fly over bridge
- Roundabout
- T-junction
- Drive through a city centre in high raised building environment
- Parkinglot

Recognizing the type of connectivity is important but the classification of the connection in the database must also be edited correctly when new road section attributes indicating a new connectivity is retrieved by the road connection building software.
As for the road attribute representation test described previously, both manual and automated test sequences were applied.
The test method itself, to perform tests ”off-line” from already collected vehicle traces, enabled re-running component tests in BOS, turned out to be efficient in generating results and input for updates of the different software components.
Much in the same way as for the road section attribute representations there was an efficient iterative process in the end resulting in a satisfactory quality level indicating support of the concept.

7 Transfer and publications (Spridning och publicering)

7.1 Transer of knowledge and results (Kunskaps- och resultatspridning)

Hur har/planeras projektresultatet att användas och spridas?	Markera med X	Kommentar
Öka kunskapen inom området	X	Mainly withinpartner organisations but also requirment input for standardisation initiatives like SENSORIS.
Föras vidare till andra avancerade tekniska utvecklingsprojekt	X	FFI BADA and potentially other not yet proposed projects.
Föras vidare till produktutvecklingsprojekt		
Introduceras på marknaden		
Användas i utredningar/regelverk/ tillståndsärenden/ politiska beslut	X	Potential input to discussion on data integrity. To be further investigated in FFI BADA.

The project has had informal collaboration links to other research projects and relevant forum activities. The main purpose is to secure knowledge transfer of project results and identifying needs from future user functionalities and to influence future standardisation activities.

As the FFI Big Automotive Data Analytics (BADA) project was started, overlaps in project interests and scope were identified. The major overlap was found in investigation of legal issues of using harvested fleet vehicle data on which FFI BADA has a dedicated work package and implementation of dynamic hazard warning. In the later overlap FFI BADA has the advantage of sharing hazard data between different BADA partner databases and fleets.

Volvo Technology aims base its FFI BADA implementation on the architecture derived in the FFI Learning Fleet project adding the support for dynamic data in collect- and distribution services as well as the BOS database.

In addition to research projects, the project partners has also observed and participated in other initiatives and activities, for instance the Autodrive Open Forum which aims to coordinate, align and possibly standardize ongoing activities in the ADASIS-, NDS[xi]- and SENSORIS forums.

The SENSORIS forum initiated by HERE Maps, targets a standard for collecting event- and map attribute related measurement data from fleet vehicles to BOS and map makers. This is just one of the many upstarted activities during the last year on harvesting and utilising geo-referenced measurement data for fleet vehicles for different purposes. Some are, like the FFI VPRP project targeting landmarks for robust high accuracy vehicle positioning needed by future ADAS- and autonomous driving functions. Data collection from fleet vehicles is often mentioned as a potential solution for populating and updating maps with such attributes.

During creation of the business case canvas mentioned in the WP3 section it was recognised that contractors and partners of Trafikverket also would benefit from collected fleet vehicle data. Discussions on this topic have been held with future potential project partners like NCC.

7.2 Publications (Publikationer)

No publications produced from this project other than this technical report, except for presentations at Vinnovas project collaboration meetings.

8 Conclustion and recommendations (Slutsatser och fortsatt forskning)

When reviewing the results and deliverables produces from the Learning Fleet project activities it can be concluded that the main goal has been achieved; to have validated the feasibility of the Learning Fleet concept through testing of implemented prototype architectures and sample functionalities utilizing the collected fleet data.

Since the project start several activities in overlapping and adjacent research topics has been identified and the Learning Fleet project has adjusted its work and scope in order to gain maximum end result. For instance, rather than implementing a very simple hazard warning function, a more solid base has been in provided for more an efficient OEM brand cooperative hazard warning implementation the FFI BADA project.

Other recently started activities like SENSORIS and the Autodrive Open Forum indicates that harvesting map related data from fleet vehicles is seen as one of the most promising solutions for fast and efficient population of road attributes in maps and keeping them up to date. This is especially important for new ADAS functionalities and higher degrees of autonomous driving which currently is pushing development.

Proving the concept feasible is only the start. During implementation and testing several improvement possibilities, ideas for new functionalities as well as new questions to answer were identified. For example, in many of the more advantageous business models, it is the sharing of collected data, sometimes also to third parties, which makes big gain in value for all involved parties, but it is not clear how far the fleet owners and drivers written consent will cover this use case. Deeper investigations on the legal issues are needed and ongoing in for example the FFI BADA project.

Technologies for collection, aggregation and distribution of map related vehicle data must be further developed, tested and refined for gaining the needed maturity. Initiatives like SENSORIS and Autodrive Open Forum can help to accelerate this process.by aligning methods to collect, store and distribute fleet vehicle map data. And that is needed since the number of connected vehicles are accelerating and their data is shared through cooperative map data services, creating a need for standards or at least collaboration and alignment of the way these date entities are defined, transported and stored. This is a probably a prerequisite for being able to efficiently benefit from the collected information.

One example where a common understanding would ease is the lifetime definition of dynamic map attributes. How shall, for example, the valid lifetime of a hazard warning be defined? Is there a preset lifetime which expires if the warning is not sent? Or should there be an active closing from the reporting service? Or should both alternatives be possible? Discussions and in the end, agreements, on such topics are needed. The discussions should be facilitated in joint activities like FFI BADA and other previously mentioned initiatives.

Another need for further investigation is how road authorities map databases and services are best utilized in this context. For instance Trafikverkets NationalVägDataBas[xii] (NVDB), could be used for sharing vehicle fleet data with contractors NCC and road users for increased road safety and more efficient road maintenance.

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