Appendix 3 – Proposed system architecture for personal navigation to autonomous vehicles

The prestudy "Automatisation for increased accessibility?" examined and identified a number of key areas in which autonomous vehicle services could be designed to provide increased accessibility for partially sighted or blind users. Two principles were identified - areas where autonomous vehicles can reduce existing obstacles and areas where obstacles that could potentially be introduced by autonomous vehicles can be mitigated. In both cases utilising the principle of "design for all" can result in both creating services that are usable by more people with disabilities and improved services for users across all categories.

A key potential obstacle that was identified was the issue of removing the human driver from the service. In today's services, the driver is a key factor in accessibility, providing information to passengers either when asked or in the form of announcements and in the case of taxi or service journeys, often helping to locate the passenger and guide them to or from the vehicle. In many service journeys, the driver takes the role of guide for the passenger, helping them to reach their final destination.

Within this project, we have examined how vibro-tactile devices could be used to help guide users to and from a vehicle and examined how a prototype app-based service to guide passengers to the correct vehicle at a busy bus stop could deliver user benefits. But what data needs to be made available in order to make such services a reality and how could those services communicate and share data in order to provide the required level of service?

This study has examined and proposed a preliminary service architecture that can guide the way forward in making such services a reality. The project partners have collaborated in examining the requirements and potential solution for a service architecture. Norconsult and researchers from Rise have examined the solution in more detail based upon Norconsults experience within navigation based upon road network data and upon Rise's experience in Autonomous vehicle systems. Both have contributed knowledge from open data systems and implementation.

Problem definition
The system must provide a data interface that contains information that can be used to provide navigation instructions for a journey from the user's identified position to the position of the chosen vehicle. The instructions must be capable of being used in multiple devices with different means of displaying or presenting the instructions. The integrity of the user and the vehicle must be preserved. At a minimum the system must be able to understand the road network for the vehicle and the user and guide the user on a safe route to the vehicle, but provision could be made for future improvements where vehicle sensor data could provide real-time information regarding potential obstacles in the user's path.

System-of-systems approach
In order to provide the required functionality to meet the problem definition, data from multiple systems will need to be combined. The separate systems could potentially be combined in multiple ways and within the possibilities of this study the project group has in many cases chosen to identify families of services rather than specific services. In some cases, known services have been identified as examples of how such a service could be designed.

Using this system-of-systems approach leads to design of services where the results of combining multiple systems can provide greater value than the individual systems themselves. There are a number of potential challenges with combining these systems as proposed and this study does not intend to address those - identifying solutions could be a part of a potential study to implement a prototype solution.

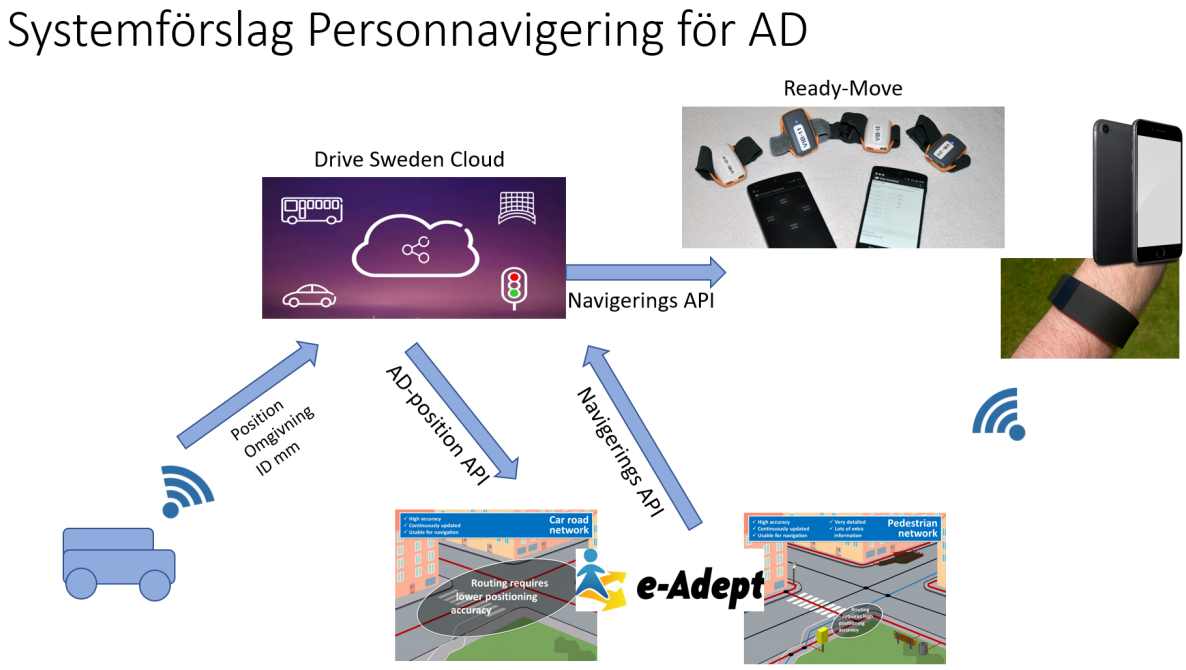

Figure 1. Early system sketch

System components

The proposed system would comprise the following functional components:

- Vehicle positioning
- Person positioning
- Road and footpath network
- Navigation motor
- Integration platform
- Navigation API
- End-user devices

Vehicle positioning

Real-time positioning of vehicles is a prerequisite for navigation to a chosen vehicle. The positioning data needs to be accurate to a level of around 1m or less in order to be usable for navigation on foot.

There is a wide variety of solutions available for vehicle positioning with varying degrees of openness in the provided data. Several public transport providers make real-time positioning data available through APIs as open data. On the other end of the spectrum are private vehicle services where user integrity means that data is not available publicly.

Challenges and possibilities
There are multiple different data formats which would need to be made available in an integration platform in order to be useful for navigation.
User integrity would require that where positioning data is not publicly available that a system is implemented which can authorise access to a specific vehicles positioning data for a specific user. This would be similar to systems implemented by taxi companies or by on-demand journey services such as Uber.

API for real-time public transport vehicle positioning
https://www.trafiklab.se/api/gtfs-regional-realtime
https://www.trafiklab.se/api/oxyfi-realtidspositionering

PubTrans
https://www.hogia.se/transport/public-transport-system/solutions

Positioning of vehicles in service and demand responsive journeys
https://www.planit.se/?pg=1445667

Service for for positioning within fleet management
https://rio.cloud/se/marketplace/produkt/geo

Analysis of value provided by real-time public transport mapping services
https://www.k2centrum.se/realtidskartor-i-kollektivtrafiken

Person positioning
Positioning for the user in the system would be made available through a GPS-enabled app.

Challenges and possibilities
User integrity would require that information used for positioning is made available on demand and for the purpose of aiding user navigation. Data preserved for service logging or analysis could be anonymised to protect integrity.

GPS data alone is not precise enough to be reliable in all situations for person navigation. If positioning is inaccurate it can lead to issues ranging from inaccurate navigation to serious issues regarding personal safety. There are multiple methods that can be used to improve reliability. Norconsult Astando have in their project E-Adept established and tested methods to use multiple sources of positioning data such as accelerometers and regular way-point matching in order to increase positioning data reliability. In the future this could be combined with imaging from vehicle sensors to provide further accuracy.

Road and footpath network
The availability of detailed network geodata mapping both vehicle roads and foot-traffic roads (pavements and paths) is increasing in Sweden. Stockholm and Göteborg for instance both have well defined vehicle and foot networks which are available both in their local road databases (LV) and through the National Road Database (NVDB). This data is an enabler for planning reliable navigation between person and vehicle.

Challenges and possibilities

There are many places where this level of data is not available, especially regarding mapping of footpaths. In such places, alternative methods of mapping would be required. Alternatives include usage of for example Open Streetmap or Google Maps.

Navigation motor
A navigation motor receives a starting position and a destination position and builds a route description based upon a suitable algorithm.

Challenges and possibilities
Different route planners are specialised for different types of navigation. There are a number of open source or API-based route planners available that can guide a user over a journey using footpaths, such as Google maps or Open streetmap. However in order to provide finely detailed navigation over the final metres of a journey a more specialised route planner will be required.

Norconsult have in 2010 developed a solution - E-Adept - which used GPS-units then available and feature-phones to help users with visual impairments or blindness to navigate. The routing module in E-Adept solved several of the issues with more exact positioning and navigation on the footpath network. Development of E-Adept was discontinued, but the algorithms and code remain and can be further developed to provide a detailed routing algorithm for foot-based journeys over the final metres and to utilise modern smartphone capabilities.

Road network information contains limited information about obstacles in the street environment. In a well mapped system, some information about street furniture, flower planters etc will be available. An advantage of a future system would be if it can in real time identify further obstacles and help users navigate around these.

A number of methods can also be used to provide extra details to a routing algorithm - various crowd-sourcing projects have focused on mapping street infrastructure. Volunteered Geographic Information (VGI) https://www.mdpi.com/2220-9964/9/6/341 has been trialled by Mapillary and Open Street Map to provide user generated data about obstacles in the street.

http://locationscience.ua.edu/People/Curtin/CrowdsourcingPenultimate.pdf

These methods could be augmented by data gathered from Autonomous vehicles sensor networks to map in real-time details of the surrounding area, such as stationary obstacles within the area around the parked vehicle and add these to the data used in the routing algorithm.

Integration platform
An integration platform is required to combine multiple data sources in a system-of-systems solutions that will allow for time efficient queries combining the data from the separate system components. A platform will need to be able to either host a copy of the required data sources, or provide a caching mechanism that will make available suitable amounts of data upon demand. The combined result of the separate systems will need to be combined in a single API query and response. This should preferably be hosted on the same platform.

The Ericsson Drive Sweden cloud is a possible platform that could be used for this integration.

Challenges and possibilities
In certain cases, such as vehicle positioning, there may be a need to integrate multiple services that can provide data upon demand. These data sources are likely to have differing structures, but contain similar types of data which the integration platform will need to be able to present in a unified structure. INtegration of each separate data source will therefore require coding to translate necessary data to a standardised format.

Navigation API and end-user devices
The navigation API will provide a simple unified format for navigation queries and results, combining data from the multiple services in the integration platform in a single standardised format. In the API a query will be sent in specifying an authorised user's position and creating a connection with the appropriate vehicle (either a public transport journey or an autonomous vehicle). The vehicle's position will then be temporarily made available in the integration platform for navigation purposes. The Navigation motor will then use these two positions to calculate navigation instructions for the journey. These will be returned as the query result.

Challenges and possibilities
The unique challenge with providing navigation to autonomous vehicles for users with different needs lies in the design of the Navigation API. The navigation instructions need to be designed to provide instructions which can be presented in multiple formats for use in multiple devices. A user who is partially-sighted or blind will have different needs from a user who has cognitive difficulties or a user with a physical disability. Instructions that are intended for listening may for instance include richer information regarding directions than instructions that are intended to guide a user of a haptic, vibro-tactile stimulation device.

To ensure the design of the navigation API can be used in multiple devices it is recommended that a service design study be performed to identify which information would be possible to provide and how it can be standardised to fill the requirements of different users of different devices.

Updated system architecture diagram
The diagram below shows the updated system architecture resulting from the work in this project.

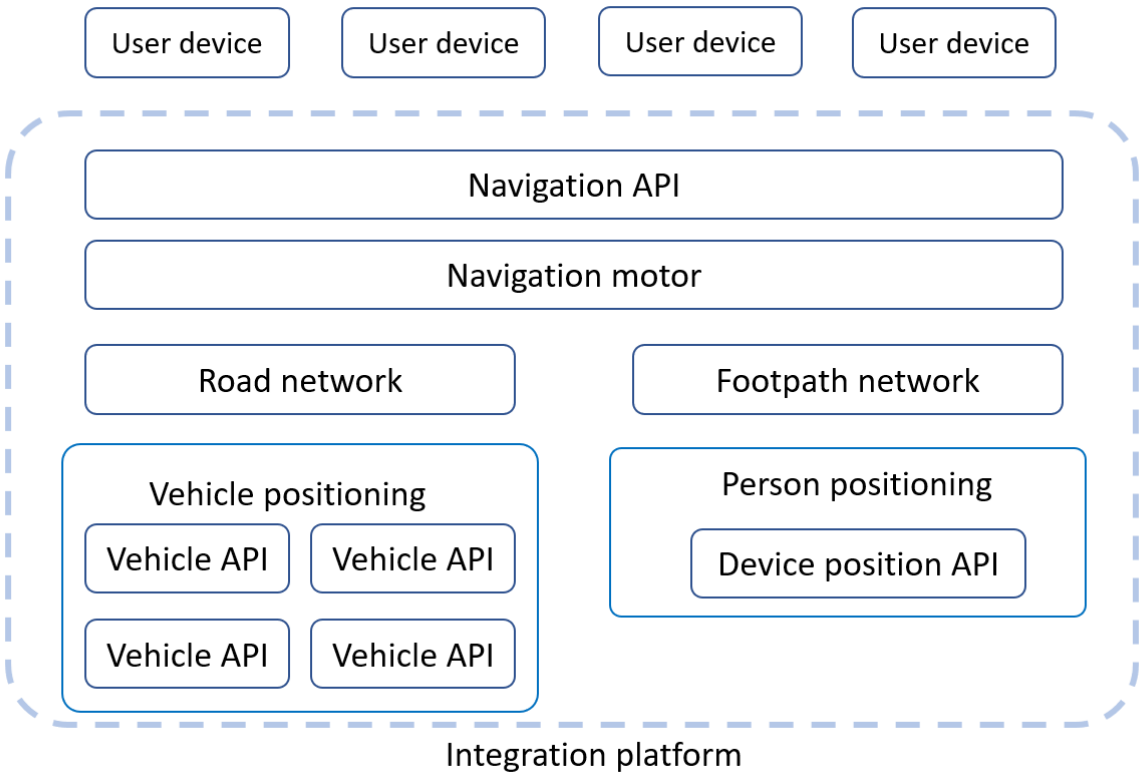

Figure 2. Updated system architecture diagram