Welcome to the Special Edition of Traffic & Roads

Dear ITS World Congress Participant

We are happy to present to you this Special Edition of the Danish magazine, Trafik&Veje – Traffic & Roads. In it, you will find a series of articles on ITS in a Nordic context, and we hope you will be inspired and informed by the way, we embrace ITS in the Nordic countries, from academia to tech-companies to road authorities.

ITS – the Nordic way – is about joining forces in the quest for a safer and more reliable mobility, across many transport modes and across private and public businesses.

We have a strong tradition for bicycling in our cities and for prioritizing innovations that keep all transportation users safe, during commuting. We rely on technology and innovations, but also on the participation to make our cities and transport as efficient and sustainable as possible.

One of the game changers is Mobility-as-a-service that combines new technology – like driverless cars (and metros) – with smart transportation. Better information leads to better planning and use of resources and will ultimately get the commuter from one place to another right on time.

Another giant leap is how big data from surveillance cameras, smart phones and devices are driving improvements in mobility and safety. Real time information and communication enables a more responsive and flexible infrastructure that is more considerate to the given situation and it also enables citizens to plan their journey and choose the right means of transport for the day. This again reduces the need for privately owned cars in cities and opens for smarter sharing of resources and improved utilisation of transport modes.

ITS is a food chain of individual services and technology that combined help improving our quality of life. Together, we can work towards reducing our climatic impact, improving mobility and keeping our cities attractive and safe. Sharing experiences and learning news about ITS is part of this development, and we in the Nordic countries welcome the opportunity to share our ideas and products, and hopefully learn more about your ITS advances as well.

Welcome to the ITS World Congress.
The Nordic ITS organizations, ITS Denmark, ITS Norway, ITS Finland and ITS Sweden, has a long and established cooperation between the countries in the field of digitalization of the transport system.

As the articles show, we are amongst the frontrunners in different areas like Road weather systems, Electric roads and transport system, Road Tolling, Traffic management, Satellite systems, Remote managed Airports, Mobility as a Service, Artificial Intelligence, V2V/V2I, Bicycle Mobility Management and Future Mobility.

I am very proud that we have a very strong cooperation, not only between the countries but also with all the actors like Ministries/Administrations, Cities, Academia, Industry, Consultants and Test and international colleagues.

The ITS community can embrace all this, because our intentions are true and right; to create a safer and smarter society - with better quality of life.

Come and visit us at the Nordic pavilion. During the week will we conduct a series of interesting presentations in the pavilion but also in the sessions that will be held in the session room “Stockholm Nordic Session”.

I wish you all a very inspiring ITS World Conference.
ITS Denmark is an independent membership organization, representing ITS suppliers, authorities and research institutions working with intelligent transport systems and solutions.

ITS Denmark strives to close the gap between research and industry for a stronger synergy and the best possible solutions within ITS. With our expertise we contribute to the expansion of ITS in Denmark. This include information about the benefits that ITS can provide such as traffic safety, economic efficiency, environmental advantages as well as legislative questions in the field of ITS.

The members of ITS Denmark are working with intelligent traffic solutions on different levels in different industries and public organizations. Members benefit from ITS Denmark activities such as seminars, webinars, professional networks and regular news updates.

With the increasing traffic and the rapidly growing traffic problems, the importance of ITS will rise and become a highly beneficial feature. This applies to navigation systems, dynamic traffic information, location-based services, automatic payment systems, intelligent speed adaptation, fleet management or other systems or service features. The potential for ITS is huge - a potential which ITS Denmark tries to create awareness of and support the development of.

Basically, ITS activities consist of land-based traffic, but with time it is the goal that ITS Denmark will work with ITS on several different relations.

ITS Denmark’s main purposes are:

- Supporting research and development in the field of ITS
- Disseminate knowledge about the use of ITS
- Building bridges between research and business
- Coordinate projects
- Work as a network organization that specializes in intelligent traffic solutions.

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The story of ‘MinRejseplan’ – a major step towards MaaS

All delegates at the ITS World Congress will receive a MaaS app, called "MinRejseplan" (MyJourney Planner). This is the story about how it was developed and how we hope it will facilitate a future with better mobility.

Public transport in rural areas

MinRejseplan was launched on 14 May this year as a pilot project in North Denmark Region. The new multi-modal app is based on Rejseplanen’s system, and for the first time in Denmark, it integrates information about both public and private transport.

This means that the residents of North Denmark Region were the first to be offered the opportunity to search for information about travel with all modes of public transport, combined with the private transport services.

Northern Denmark Region is an area with a relatively low population density and only a few larger towns. Only the city of Aalborg that has more than 100,000 residents. Recent developments have shown that it is becoming more difficult to maintain an efficient public transport network in rural areas. NT has therefore built and is managing a vast demand-responsive transport network that deliver over 1.5 million annual journeys.

The latest initiative has been the launch of ‘Plustur’ (Additional Trip), which is a last-mile on-demand concept that connects rural passengers with the main public transport network by minibuses and taxis, at the price of traditional public transport.

Our aim was to develop a travel assistant application, MinRejseplan (MyJourney Planner), that displays the direct, smartest and most economical way to travel door-to-door.

In Denmark, we have a nationwide travel assistant (Rejseplanen) available, that includes public transport services throughout the country. It was therefore essential for us to build on the existing platform as it enabled us to apply existing know-how, utilize customer awareness and better facilitate a subsequent national rollout of My Journey Planner.

My Journey Planner displays a variety of mobility solutions to the users, including traditional public transport solutions like bus and train, as well as private ones like taxi and ridesharing. The solution was part-financed by The Danish Transport, Construction and Housing Authority, an authority under the Danish Ministry of Transport, Building, and Housing.

Through the use of My Journey Planner, the passenger is able to find the best and easiest way to get from A to B, even if the result is a combination of public and privately provided transport. The App features a wide range of easily available information, providing the passenger with the possibility of making both long- and short-term planning decisions.

The ambition has, however, always been to make the solution available nationwide, as there is a need for this in both rural and urban areas. The expressed intention behind the development of for the My Journey Planner App has been to integrate it with the nationwide travel assistant (Rejseplanen).

Figure 1: Content of the new, multi-modal travel itinerary app.
Smart and convenient access promotes public transport

In a hectic daily life, travel choices for busy travellers and commuters are not based solely on preferences and idealism. Choice is also about the availability of the various forms of public transport and the possibility of getting from A to B in a convenient, quick and smart way. It is about providing travellers with a comprehensive overview and access to all traffic information about private and public modes of transport, and allowing them to buy and book their journey anytime and anywhere.

The easier it is for the consumer to follow the growing range of public and private transport options, the better the chance that travellers will choose to combine, for example, bicycle sharing with public transport, and perhaps a taxi or car-pooling for the last section of their journey. International experience shows that the use of public transport increases when it is easier to get to and from the travel hub, which is easier when there are more forms of mobility and transport available. We will be seriously approaching the realisation of MaaS when we can use the same app to pay for a ticket or transport service, and also see the next departure, the price and the cheapest ticket or transport service, and also see the when we can use the same app to pay for a

and several private modes of transport in Copenhagen. The Copenhagen version of MinRejseplan also includes a built-in payment feature.

Conference participants at the World Congress in Copenhagen and all other travellers in Copenhagen can plan a trip through the city that includes the best combination, based on the participant’s own preferences, of public and private transport services, i.e. train, metro, buses, car-pooling, shared car, harbour buses, taxi, shared bicycle and city bikes etc.

The MinRejseplan app displays the next departure and upcoming departures. It shows what the journey will cost and it suggests the fastest and cheapest route, whether you wish to travel here and now, in an hour, or perhaps not until the following day.

A digital ticketing function and payment solution have been incorporated into MinRejseplan, which are valid for public transport in Copenhagen during the congress itself. It is quite easy for other users of MinRejseplan to pay for their trips with a few clicks in the app, as they are sent directly from MinRejseplan to the transport provider’s own app with a payment solution.

The Copenhagen version of the MinRejseplan app is a major step on the digital highway towards a MaaS app, and it is an exciting ‘live demonstration project’ of the future Rejseplanen.

It will be exciting to get feedback from users of the new app during and after the conference, and naturally our goal with MinRejseplan is to implement continuous and constant updates and improvements, where the focus is on the users, and their need for updated and accessible information about all modes of transport. This is the best way to get more people to use public transport, with more environmentally friendly modes of transport, both now and in the future.

Live demonstration of multimodal travel app

The platform for MinRejseplan can easily embrace private modes of transport in other parts of the country, including the metropolitan area. At the ITS World Congress, all the participants will have access to MinRejseplan in a special Copenhagen version, developed specifically for the congress, with information about all public

From North Denmark Region to Copenhagen to all of Denmark

This is the first time MinRejseplan is being rolled out in a large city like Copenhagen, where both the demand and the possibilities for transport are completely different than that in the North Denmark Region. It is encouraging, therefore, that so many transport service providers in Copenhagen wished to be included in the special version of MinRejseplan. Using the experience gathered from pilot projects in two parts of the country, North Denmark Region and the metropolitan area, we will be able to collect and analyse valuable data so that, in the near future, not only the residents of Copenhagen and North Denmark Region but all Danes will be able to search and find their journey using a single app, namely Rejseplanen.

Our long-term ambition is that Rejseplanen’s app will display all the modes of transport and mobility that are available to enable a traveller to get from A to B. This means that in the near future, in addition to bus, train, metro, trams, ferries, car-pooling and taxis, Rejseplanen will also include regional buses, domestic flights, shared cars, shared bicycles, flex-trips, driverless buses etc. for all of Denmark.

Denmark is a digitally well-developed country and the population already has extensive experience of planning their journeys digitally. Rejseplanen is Denmark’s fourth most popular app and has been downloaded over 3.5 million times. With the launch of MinRejseplan in Copenhagen, we have joined the digital elite and are now much closer to being able to offer MaaS to every citizen throughout the country.

Rejseplanen has been downloaded by more than 3.5 million people and more than 1 million journey searches are made through it every day. Today, Rejseplanen is among the four most popular Apps in Denmark and 90 percent of the population is familiar with it. The data provided through Rejseplanen on traditional public transportation is open and used by Google, Citymapper, Apple and more than 500 other companies.

During the last 10-15 years Denmark has been at the forefront of technological development when it comes to digital travel assistants, and as we stand on the brink of providing a nationwide MaaS, the ITS World Congress in Copenhagen provides an important opportunity to launch this technological invention.
Taking video tracking to the next level

In recent years, technological advancements within image recognition and artificial intelligence have changed the way we use video feeds as a reliable source for collecting traffic data. Since 2016, COWI has worked closely with the Czech start-up RCE Systems on the use and further development of the software suite - Data From Sky - for traffic data collection and analysis. Data From Sky has leapfrogged into the traffic realm, offering the most precise and comprehensive traffic data ever on a micro level – just from a simple video feed. In this article, the technological principles behind tracking traffic on videos is described as well as the new uses of such detailed data within ITS and traffic planning.

Hence, traffic data is a cornerstone in ITS. Getting to know everything about traffic is a key driver in developing and optimizing the new solutions that will boost our ability to move people safely and efficiently. In this respect, video tracking has a lot to offer!

Early video tracking systems

Video tracking systems have been around for decades for simple detection, e.g. in signalized intersections (replacing loop detectors) or for simple counting of passing vehicles. Relatively simple algorithms are looking for changes (pixels) in the pictures provided by a video feed. Quite often, a direction is being detected, and sometimes a degree of vehicle classification is carried out in these older systems. However, the data is binary (is a vehicle present at a predefined position or not?), and the systems lack the ability to provide tracking at all as individual vehicles cannot be recognized in different parts of the picture.

Actual tracking systems have the ability to maintain the tracking of individual vehicles over time, which can be used to draw up a line representing the whereabouts of a vehicle during the course of a complete video – given that the vehicle is constantly visible. Unfortunately, the real world turns out to include numerous trees, buildings, other vehicles etc. The result is that the line often is broken and the tracking lost.

Knowing everything about traffic!

Does GPS-positioning, velocity and acceleration values for all vehicles, bicycles and pedestrians 25 times per second compelling? What if we add information on whether the individual motorists are running red lights? And how about automatic identification of near accidents that were just barely avoided?

If you work in the traffic and transport sector, some of this is bound to interest you. Especially if you work with optimizing traffic flows, traffic safety etc. The reason for this is simple: We love data, and the urge for constantly improving our traffic systems by exploiting new data sources is ever present.

Figure 1: A car running a red light.
leading to false data. On top of this, data extracts are still limited, as no true coor-
dinates are present in a regular video feed, making precise calculations of velocity, ac-
celeration, etc. impossible.

Enter image recognition, DNN and parallel computing

Modern video tracking systems take a dif-
ferent approach. Gone are the principles of
searching for pixel changes as well as the
need of line of sight throughout the whole
recording area.

Instead, vehicles, bicycles and pedes-
trians are identified using image recogni-
tion and predictive tracking. Every moving
object is given a unique identifier (GDPR
compliant, mind you!), and on top of that an
actual coordinate system is programmed
into the video. This enables positioning
of vehicles with GPS-coordinates in every
single frame of a video.

From this positioning, numerous out-
puts can be deducted; including velocity,
acceleration (as well as lateral) etc., and the
key gamechanger is that data is de-cou-
pied from the original video, but still linked
to it. This means that when a tracking pro-
cess has been completed, the complete
data extract is available in a separate da-
tabase in which different analyses can be

carried out – and visualized using the origi-
nal video. The advantage is obvious: The
need for new analysis no longer requires
re-analysing the videos again, but can be
completed in the database itself.

There are different approaches to ex-
actly how the specific tracking process is
carried out. In the case of Data From Sky,
the tracking and analysis procedure can be
summarized as follows:

1. Video recording: Mounted camera,
drones etc.
2. Stabilizing and geocoding: Actual ge-
ometry of the filmed location is pro-
grammed into the video metadata.
Lens characteristics etc. are corrected.
3. Tracking of moving objects: individual
IDs are assigned to individual road us-
ers.
4. “Connecting the dots”: Trajectories for
individual IDs are connected through-

![Figure 2: Heatmapping velocities in a Diverging Diamond Interchange.](image2)

![Figure 3: 7.000 cyclists moving through a large signalized intersection.](image3)
out the video. An algorithm smooths out trajectories making sure that small tracking errors will not result in sudden flickering in positioning.

5. Manual quality control → input to DNN (Deep Neural Network) for constantly improving the algorithms.

6. Tracking database: All trajectories are stored in a single database, including information about the video metadata (stabilization etc.).

7. Analysis is carried out using the video as the core of a user interface linked directly to the traffic database.

The technology in this case has been undergoing a huge development over the past two years. Measured on quality, the automatic image recognition is now capable of getting it right about 98% of the time. At the same time, tracking speed has increased significantly. Now, a 4K-resolution video can be tracked at 4 x speed.

These factors make the approach extremely effective in both creating massive volumes of data as well as ensuring very high data quality.

Endless analysis possibilities

Having a complete data package containing all information on all moving objects in a video has significantly raised the bar within traffic analysis. However, the data present is so overwhelming that traditional traffic analysis has to be completely rethought and redesigned to make sense. So, we – the traffic engineers and analysts – are the limiting factor as we tend to think traditionally, e.g. “how can I use data for simple traffic counts?” But a simple traffic count just doesn’t fully exploit the data at hand!

The data is very usable for traditional analysis such as traffic counts, queue assessments and speed measurements (at specific locations) but that is just the start. Exploiting the new data have so far resulted in new types of analysis, e.g.:

- Complete Origin-Destination analysis (through multiple intersections etc.)
- Analysis of velocities.
- Analysis of accelerations, identifying and investigating areas with numerous hard decelerations.
- Gap time analysis, bettering e.g. traffic simulation models.
- Measurement of needed inter-green times and optimizing signal settings accordingly.
- Conflict analysis (Time-To-Collision), pointing out dangerous locations in an intersection.
- Analysis of numbers of motorists running red and yellow lights.
- Analysis of degree of effectiveness in signalized intersections.

Simply put: If you can think it – you can analyse it!

Examples visualized

Figure 1 shows an example of a car caught running a red light – and accelerating while doing so. Hence, it was an intentional act. The analysis in a large intersection in Aarhus, Denmark is made by comparing signal timing information with information on, when each motorist passes the stop line.

Figure 2 shows a heatmap visualizing average velocities throughout a Diverging Diamond Interchange in Odense, Denmark. Data is collected from approximately 7,000 vehicles through a 2-hour period in the afternoon to create this image.

Figure 3 shows a complete overview of cyclists passing through a signalized intersection in Copenhagen, Denmark. A significant number of cyclists choose to (illegally) utilize the pedestrian crossings as means of cutting travel times by not having to stop for a red.

Figure 4 shows an O/D visualization from a large roundabout (Odense). The roundabout is 200 meters in diameter, and without true tracking, it would be impossible to simultaneously keep an eye on all vehicles passing from all directions and accurately map the movements through the roundabout. All in all, this picture generalizes the passing of approximately 9,000 vehicles – and each approach can be filtered for further analysis.

What will the future bring?

The quantity and quality of traffic data being extracted from video using Data From Sky or similar tools is overwhelming, but so far also has limitations. In particular:

- The maximum geographical area that can be monitored is approximately 700x500 meters (at 120 meters of flying altitude using a drone).
- Relatively short videos (no permanent installations).
Post-processing (videos need to be recorded before being processed).

The tracking technology is moving very fast towards real-time embedded tracking. Basically, this will handle two of the current limitations as the need for post-processing as part of the data extraction process will be removed. This, in turn, also means that some of the recording time limitations are also removed, though the full analysis experience suggests that the original videos are needed for carrying out the analysis themselves. As a result, videos need to be available for the whole analysis period, which may pose other challenges (e.g. storage capacity, computational power etc.).

The limited size of the geographical area is mainly linked to restrictions on the recording altitude. In Denmark, drone flight is limited to 120 meters. In some other countries, however, higher flight is allowed, and the tracking algorithms are currently able to track vehicles from an altitude of up to approximately 800 meters, provided that not too many occlusions occur (at this altitude, even clouds can be a challenge!).

The real-time approach, however, has already found its way into exploiting the exact same technology with the aim of detecting free and occupied parking spaces – with a twist! The use of advanced image recognition as well as a DNN means that the parking detection systems based on this approach can classify the parked vehicles – and that they are very robust with regard to handling external factors such as changing lighting conditions, a moving cloud cover, rain and snow. Traditional camera-based parking detection systems simply fail under a wide variety of such conditions due to inadequate handling. An example of such a system is shown in figure 5.

![Figure 5: Real-time parking detection system based on true image recognition and deep neural networking.](image)

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Rasmus Albrink, rsal@cowi.com
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POWERING YOUR 360° SOLUTIONS

COWI is a leading consulting group that creates value for customers, people and society through our 360° approach. We tackle challenges from many vantage points to create coherent solutions for our customers.
New trends in passenger transport services

Over the past few years, private cars and public transport have been challenged by a number of new services, such as GoMore and DriveNow, that offer alternative forms of passenger transport through the Internet and apps. It is difficult to predict how new Internet-based passenger services will evolve, how they will become part of our everyday lives, how they can affect our transportation habits and the physical traffic flows in our society. However, if the use of these services grows very quickly, it can affect the capacity of the road infrastructure and it can bring about challenges as it takes time to expand capacity. At the same time the capacity of the road network in and around the major cities is already challenged today.

Søren Stigel Saugstrup, Adviser Traffic Planning, MOE | Tetraplan
sn@moe.dk

Søren Brønchenburg, Strategic Transport Planner, The Danish Road Directorate
sbr@vd.dk

New internet and app services

In 2015, MOE | Tetraplan and The Danish Road Directorate made a series of analysis of trends in society that potentially affect the use and capacity of the state road network. Trend analysis look at the future and is primarily based on desk research, combining different existing data sources. This article deals with the trend analysis of “Internet-based passenger transport services” and the background for the analysis is that the number of internet services or apps offering “alternative” forms of passenger transport is sharply increasing. Old car share projects are overtaken on the inside by these services. These include GoMore and DriveNow, where you can get lifts on planned trips or use short-time car rental in your local area.

These types of services can affect passenger transport, both across country and in the individual urban areas, and in light of the increasing focus on shared economy, it is expected that the number of these services will increase.

Sharing Economy and Internet of Things

Sharing Economy and Internet of Things are prerequisites for the Internet-based passenger transport services. On the one hand, it is the sharing economy that enables a number of new services in the passenger transport sector. On the other hand, it is the Internet of Things that facilitates and makes these services possible.

Sharing Economy

“How does the sharing economy work in practice - how are things "shared"?\n
- Loan - the neighbour’s hedge trimmer
- Exchange - children’s clothing on a market
- Rent - an apartment in Berlin
- Share - a in the car sharing club

Source: Oxford Dictionaries

Holistic analysis of passenger transport services

In the project, each type of passenger transport service was analysed in the PESTEL + framework, which is an analysis method that uses a number of pre-defined areas in relation to effects and barriers. The areas are:

- Political: e.g. reforms, transfers of resources, etc.
- Economic: e.g. economic conditions, high / low economic cycles, public savings
- Socio-cultural: e.g. changes in users / housing, behaviour, demographic conditions
- Technological: e.g. new technologies, self-service, big data, digitization, social media
- Environmental: e.g. environmental conditions, climate adaptations, etc.
- Legal: e.g. legislation, finance law, EU legislation, TEN-T, etc.
- Spatial: e.g. geographical distribution

What is "shared"?

- Money - Loans for interest
- Cars, Services, Land and Gardens, Apartments - For rent
- Clothes - borrowed or exchanged
- Driving - offered for a fee
- Tools - Loan out for free
- Movies and series - streamed for payment

Who "shares" and why?

It’s about access to the use of things instead of owning them, and especially for more expensive things, such as cars. The sharing economy is growing most among young people and those who live in the big cities. There are some people who choose to "share" from more position-based approaches, such as recycling and environmental considerations. The sharing economy is growing and many people have discovered that they can earn money by renting out their car or home, or that they can save money by renting an item or a service provided by other private individuals.

Internet of Things

"The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data."
Source: Oxford Dictionaries

For the individual, it is the smartphone that provides access to various mobility apps in passenger transport, and via GPS and IoT, the position can be matched with shared bikes and cars and with public transport travel plans for a full transport solution.

Different services and their impacts

The passenger transport services are all linked to IoT and the sharing economy, but they are different in nature, and they use different business models.

Private car sharing services

Private shared car services are companies that offer a service where they connect a private person who wants to rent a car with a private car owner who wants to rent his car out. They compete with commercial car rental companies. One example is GoMore with 71,000 cars in Denmark.

Traffic impact on Danish State Road Network:
Provides more people access to driving = more trips
Fewer people buy their own car as they can easily rent a car = fewer trips on the state road network.
Extension of public transport to last destination = reduces car commuting to the cities.
The pricing makes it unattractive for longer trips e.g. on the state road network.

Commercial car sharing services

Commercial car sharing services are companies that "rent out" their own cars for shorter periods. The car can be picked up and handed back within a limited area. These easily accessible rental cars, which are rented out by the minute, are also called - "drive yourself taxi". One example is Green Mobility with 450 cars in the Copenhagen area.

Traffic impact on Danish State Road Network:

Cheaper and easier to rent a car = more trips on the state road network.
Fewer people buy their own car as they can easily rent a car = fewer trips on the state road network.
More people buy cars, as renting out can co-finance the purchase = more trips on the state road network.
Expects that more trips will be longer trips, also on the state road network.

Car-pooling services

Car-pooling services are companies that offer a service where they connect a car owner who provides a trip - with a passenger who needs transportation on all or part of the route. The lift is offered by car owners on the "Car-pooling app", where interested passengers can book a seat. One example is GoMore with 580,000 members in Denmark

Traffic impact on Danish State Road Network:

Cheaper and easier to rent a car = more trips on the state road network.
Fewer people buy their own car as they can easily rent a car = fewer trips on the state road network.
More people buy cars, as renting out can co-finance the purchase = more trips on the state road network.
Expects that more trips will be longer trips, also on the state road network.

Car-pooling services with "stops" and real-time car-pooling services

The German provider Match Rider has tried to make the Carpooling services more attractive by making "pick up places" on the road network. The reason is that they consider that one of the main barriers to carpooling services is that commuters / drivers do not want to detour and spend extra time in their daily commuting. They have solved this by making virtual "pick up places stops" in the form of geo-coded "points" on the road network.
Traffic impact on Danish State Road Network:
Increased capacity utilization of the cars on the state road network = fewer cars on the state road network.
Cheap car-pooling lifts pull customers from trains = more road trips on the state road network.
The services have many users and many of the trips are long and take place on the state road network.

This means that the commuter / driver does not need to take a detour and use extra time, and that driver and passenger do not have to agree on pick-up and drop-off points prior to the trip.

In real-time car-pooling services, the "match" of a car already driving and a real-time trip request is made in real-time. This makes this type of transport much more flexible than normal interconnection services.

MaaS / Mobility Services
MaaS covers the concept of Mobility as a Service. It is mobility services where you get the entire transport from A to B by combining different modalities through a provider. The providers offer mobility packages that the individual customer can choose between – just like mobile subscriptions. The concept is like a well-developed “Rejseplanen” (The travel plan), where the provider organises booking and payment of the different mobility services used on a combined trip.

Cities are driving fast changes
Today, it is especially car-pooling services (like GoMore) that have many users across the country. But private car sharing services (like GoMore) and commercial car sharing services (like DriveNow) are successful in and around the largest cities where there is a certain concentration of people – it is a prerequisite for the services to work! Therefore, the effect of these services on traffic and capacity on The Danish State Road Network will primarily be on state roads in and around the major cities.

Private car sharing and car-pooling services also include traffic outside the major urban areas, which can affect traffic and capacity on the entire state road network. However, there will be a larger supply of these services in the major cities, and therefore the trips will largely go to or from these cities. Therefore, the overall impact of the various passenger transport services on the state road network, at least in the short term, will primarily relate to the major cities.

In a slightly longer perspective, new car-pooling services with "virtual stops" and "real time matching" can increase the attractiveness of car-pooling services, both for commuters and other shorter trips on the state road network, and MaaS may come into play in the slightly longer term, but it is difficult to assess future impact on traffic and the capacity of the road network outside the major cities.

The development of the analysed passenger transport services is most uncertain and they require increased attention as they can develop rapidly and potentially can create radical shifts in traffic. In relation to the development of traffic on the state road network, car-pooling services and Maas are particularly interesting.

New investments by major automakers show that the market for mobility is changing at the moment and that these services will be more predominant in the future. In December 2016, VW launched their new "car brand" MOIA, which will provide new concepts for car-pooling and mobility in major cities, and Ford acquired the Chariot car-pooling service in San Francisco in the fall of 2016, and invested in the largest bicycle sharing service in the US.

Sources:
[2] Car2go
[4] Drive Now
[8] Lyft
[9] Maas.fi
[12] Oxford Dictionaries, Internet of Things
[16] Ubigo
[17] Wikipedia, Mobility as a Service
Cities need to be resilient and flexible in the face of requirements that increasingly change day by day, while still providing an attractive habitat for both citizens and visitors. The MobiMaestro platform implements dynamic strategies to meet both policy goals and citizens’ expectations. Come visit us at booth E-85.

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New way of sharing data for traffic information

Sharing of data between authorities and private players supports accessibility and is of great benefit to road users. As private players in the traffic information and navigation market are in demand of the knowledge held by the road administrations, the challenge is to find the right model and method of cooperation to benefit all stakeholders.

Internationally, many authorities are struggling with data sharing, either between road administrations or across private and public players. Questions are raised as to how cooperation is to work in practice, what systems and data standards are to be used and how data sharing will become a benefit to all stakeholders. This is also the case in Denmark, and the challenge is to find the right model and method of cooperation.

Recently, the Danish Road Directorate has introduced a new solution for sharing data about the road administrations’ planned roadworks and events.

Data sharing tool
In cooperation with Sweco and a reference group of municipalities, the Danish Road Directorate has implemented a new data sharing tool. The tool makes it easy to provide a common overview and traffic information across road administrations and to share information with private players.

The tool is called OTMAN – O for Overview, T for Traffic information and MAN for management. Once implemented, administrators in the municipalities are able to share data directly with both the Danish Road Directorate, other municipalities and private players through their own road administration system.

Administrations can remain in their current workflow and system while they process applications and permissions for roadworks.

Specifically, the administrator is tasked with:
- providing additional information relevant for the traffic information to the authorities for their processing
- quality assuring and updating the data transferred and transformed into traffic information.

OTMAN has been developed to be compatible with both RoSy and Vejman.dk (Danish asset management software systems). The Danish Road Directorate makes sure that data is transformed into, and communicated as, traffic information. This way, the municipalities can, in a relatively simple way, provide traffic information to their own citizens and other road users driving in the municipality.

Sharing data = shared benefits
Once data has been entered and verified in the individual municipality, it is automatically transformed into traffic information. It can be viewed through the Danish Road Directorate’s traffic information channels (Trafikinfo on web and app). In the Copenhagen Metropolitan Area, the information can also be viewed in the app Trafikken Hovedstaden, which has been developed in cooperation with the City of Copenhagen.

Moreover, data is “set free”, allowing service providers to use data in their services. Today, Google, TomTom and Trafikalarm (traffic alert) receive data from the Danish Road Directorate and transmit it to
their own maps, navigation systems and apps. With the new tool, data entered by the municipalities is also available to road users via the Danish Road Directorate’s partnerships.

Finally, data can also be viewed on the municipality’s own website, either via a special custom regional section of the map on Trafikinfo.dk or, via a data feed to the municipality’s own services.

**Common overview**

The cooperation between the authorities on the exchange of data ensures a common overview of the situation on the roads. This is a benefit to both the Danish Road Directorate and the municipalities.

The Danish Road Directorate can use the overview to create the best possible traffic flow. This could, for instance, be if a road accident occurs and a motorway has to be closed for so long that the police want to divert traffic from the motorway. In such situations, an overview of the municipal roadworks is very useful to ensure that traffic is not diverted to a local road with major roadworks.

Another situation could be a large event where the municipality expects heavy traffic volumes. This knowledge is very useful for the Danish Road Directorate who can then notify road users if queues are to be expected on the motorway when everybody is moving at the same time.

The municipalities can use the overview to quickly inform citizens and road users about roadworks and events. The benefit of sharing knowledge is that the overview is provided both within the municipality and also across municipalities and authorities.

This means that service is provided both to citizens travelling within the individual municipality and to road users driving across municipal boundaries and road networks. Citizens can obtain information and receive notifications about current and future traffic nuisances, allowing them to plan their trip on the roads.

OTMAN helps improve satisfaction, mobility and safety – also for the contractors on the roads, because the road users know that they are there.

**Why is traffic information important?**

Data about roadworks and events will turn into traffic information focusing on the consequences experienced by the individual road user or citizen, like obstacles on the road, closures, delays, etc. It provides the road users with an overview and allows them to make timely decisions on an informed basis.

Traffic information is a highly cost-effective tool to create accessibility. The user surveys conducted by the Danish Road Directorate show that traffic information increasingly make road users change route, mode of transport or time of departure if there are obstacles, intense traffic or other nuisances on the roads.

This creates better accessibility, greater road safety and better handling of accidents across authorities for the benefit of the entire society.

**Incentive of private players**

Through dialogue with different service providers, it has become clear that private players in the traffic information and navigation market really appreciate that road administrations make knowledge available about the traffic situation on the roads. To a large extent, service providers are able to track when the roads are congested, but they do not have the authorities’ knowledge of planned roadworks and events; when and for how long something is going on and what consequences it has for the traffic.

Our experience and dialogue show that if data is transmitted from the road administration in data formats that are internationally known and recognised, then service providers are willing to show such data. It is in their interest to provide the best possible information to those who buy their services. And this is exactly where road administrations and service providers have a common incentive.

However, as a road administration, it is important to reach a wider audience than just those buying a (private) service. And that is why the Danish Road Administration makes the traffic information available free of charge on Trafikinfo.dk and on the Trafikinfo app.
In bad weather, road users seek traffic information on Trafikinfo

Road users want traffic information when it suits them. A recurring result of the Danish Road Directorate’s user surveys is that most road users do not seek information about traffic conditions until they need it – e.g. in case of accidents or bad weather. Consequently, updated and available content is needed when accidents happen or a storm is raging.

Sine Dyreborg, Danish Road Directorate
email: SJL@vd.dk

User Behaviour:
54% use trafikinfo.dk when situations such as accidents or bad weather occurs, 35% use it for their regular trips, whereas 29% use it in connection with their work.
Survey on Trafikinfo.dk, September 2017, by Gallup.

Extreme weather requires more staff
When extreme weather, such as a storm, hits Denmark, the telephone lines are red hot at the Danish Road Directorate’s Traffic Centre and the employees are busy. It also shows on the traffic map on Trafikinfo where warning triangles pop up with details about closed roads, windsocks, dropped goods, accidents and water on the road.

When storm Ingolf raged during the weekend 28-30 October 2017, several bridges were periodically closed as a consequence of heavy storm with hurricane force gusts. Moreover, roads were blocked because of fallen trees and rising sea levels in the inner Danish waters. Under extreme weather conditions, such as Ingolf, additional staff is called in to the Danish Road Directorate’s Traffic Centre to handle the large number of calls. The employees have to coordinate emergency response activities to restore accessibility on the roads, e.g. by removing fallen trees, and ensure that road users are informed of events causing problems on the roads.

Traffic information is communicated across various platforms
During storm Ingolf, the employees at the Traffic Centre provided regular traffic updates via Trafikinfo, which is the Danish Road Directorate’s own service, but also via other services.

Traffic information over the radio is one the most effective ways of getting communication through to the road users. Surveys show that 78% use the radio to receive traffic information, underlining that the day-to-day cooperation with DR P4 Trafik is highly important. DR P4 Trafik broadcasts directly from the Traffic Centre. The goal is to reach drivers as fast as possible, allowing them to change route.

In connection with the raging of storm Ingolf, the Danish Road Directorate also sent out direct broadcasts on TV2 News in connection with the closure of the Storebælt Bridge, with the expected time of closure being one of the key messages. Moreover, we tweeted 24 times on Twitter where our traffic information is shared and distributed by our partners such as the police, the Danish Meteorological Institute and other partners.

As part of our ongoing development of the quality of content, services and co-op-

The Danish Road Directorate’s Traffic Centre is open 24/7 – all year round. We collect information about the traffic situation from a variety of partners – e.g. the police, contractors, DR (the Danish Broadcasting Corporation), municipalities, emergency services and road users. If an accident happens, we support the work of the police and dispatch sign vehicles to the spot to divert traffic. In situations of dropped goods or emergency events affecting traffic, we contact the relevant players to ensure that the traffic situation does not develop into inconvenience for the road users.

Through the Danish Road Directorate’s traffic information service, Trafikinfo, which is available on the web and as app, road users can find current information about traffic conditions affecting accessibility on the roads. During the winter season (1 October – 1 May), the Vintertrafik (Winter Traffic) service is open on the web and app with special information about winter road conditions from the Danish Road Directorate and the municipalities.

Traffic information is also broadcast on the radio in close cooperation with DR P4 Trafik (national radio programme), and is transmitted to car navigation systems and other media such as Google, TomTom and Waze.
Figure 1: Screen from Trafikinfo.dk showing a webcam.

Optimize the mobility in your city thanks to improved traffic insights

FLOWcheck is a powerful web application to analyse historical Floating Car Data up to two years back. It provides you with the means to uncover traffic bottlenecks affecting your area. How accessible is your city? Where is traffic cutting through residential areas? Where does traffic slow down and where do people drive too fast?

Get more information visit: https://www.atki.dk

What is Floating Car Data?
FCD is anonymized localization data collected from devices in vehicles driving on the road, reporting information on their locations, speeds and directions. Together, they give a reliable overview of traffic conditions.
erative relationships, we evaluate our overall traffic information after extreme weather situations. We look into whether we have successfully communicated the relevant information at the right time and through the right channels.

Webcams are popular
For several years, the Danish Road Directorate’s webcams have been some of the most visited content on our traffic information services - probably because the users can actually see the traffic situation for themselves. This is especially the case in extreme weather such as storm, cloud-burst or snow, where user statistics show that visits to our webcams increase significantly across all services. During storm Ingolf, we measured a fivefold increase in visitors to our webcams at trafikinfo.dk compared to a ‘normal’ weather weekend. The Danish Road Directorate has approx. 400 webcams across Denmark.

A unique information services
During the winter season, our winter information service, Vintertrafik, is activated on the web and app. It is de-activated in the summer. The colours on the traffic map illustrate when de-icing/snow clearing has been carried out or whether the roads are slippery, and it is possible to see the winter service level of given roads.

Vintertrafik combines the joint efforts of the Danish Road Directorate and the municipalities, and data is received from almost all municipalities in the country. The on-duty winter supervisors in the municipalities regularly enter current data on slippery roads and latest de-icing/snow clearing in a winter operation system (Vinterman), and those data are distributed directly as traffic information at Vintertrafik on both web and app. This way, the road user can get an overview of conditions for his or her route.

In Aalborg, Vintervagtcentralen (the Winter Watch Centre), ensures that all winter data for the main road network is updated on an ongoing basis. They are in close dialogue with the Danish Meteorological Institute to ensure that the Danish Road Directorate is at the forefront when it comes to timely intervention.

Communicating pre-travel information is important
Socio-economic analyses show that queuing for a long time is very expensive for society. To ensure that road users are able to reach their destination in time, one of our challenges is to make road users check the traffic situation before they leave home so that they can change their time of departure or route.

To make sure that road users have time to respond to the traffic information, we have developed a feature in our services that allows road users to subscribe to traffic information for a particular route or area and receive either push notifications from the app or an e-mail from trafikinfo.dk if anything happens on the route. This may be a decisive factor in making road users change behaviour either by changing route or time of departure – or perhaps even not leaving at all.

This way, current traffic information at the right time and at the right place contributes to ensuring accessibility on the roads.
TWO WAYS TO MAKE TRAFFIC HEALTHIER AND SAFER

PROMOTE CYCLING
Get more people on their bikes and improve health, air quality and congestion with bicycle counters from ITS Teknik, following the example of Denmark, Sweden, Norway, Iceland, Finland, Ireland, Scotland, England, Wales, the Netherlands, Belgium, Luxembourg and Spain.

Bicycle counters from ITS Teknik:
• Robust and vandalism protected
• Elegant and classic design
• Up to six information displays
• High sensor accuracy
• Data can be transmitted via an open interface

REDUCE SPEED AND IMPROVE SAFETY
Lowering average speeds by 5 km/h, speed indicators from ITS Teknik reduce the average speed. Construction cost is low compared to alternatives.

Speed indicators from ITS Teknik:
• DS/EN 12966-approved
• Adjustable and service-friendly
• High operational stability
• Low power consumption (e.g. via solar cells)
• Remote monitoring and counting of traffic volumes

Visit us at stand C1-030 to meet the team and see our products in the flesh.

ITS TEKNIK A/S supplies complete, innovative and cost-effective ITS solutions to a wide range of countries. Bicycle counters and speed indicators are just two examples of a range of products with clear benefits for traffic management, the environment and the urban population.
Smart cities using Sum Zero in transport systems

To achieve the global goals for a sustainable world, launched by the UN in 2015, everyone must do their part. Sum Zero is an approach that ÅF uses to integrate the global goals into the development of sustainable cities. Future transportation that adheres to these goals, will lead to smarter cities by being fossil fuel free, silent, safe, clean, attractive, inclusive and space efficient.

From Vision Zero to Sum Zero
The idea of Sum Zero is based on the Vision Zero approach to road safety. Vision Zero stands for no loss of lives in traffic accidents and strives for a safe transport system overall. Just like Vision Zero is clear about what to achieve in the transport system – no traffic fatalities and severe injuries - the global goals are also clear. The combination of these goals has the same approach as Vision Zero. The Sum Zero approach has been the foundation of a research project that ÅF runs together with representatives from two Swedish cities; Gothenburg and Uppsala and representatives from AstaZero, Cycleurope, Veoneer, Chalmers technical university and the Norwegian Public Roads Administration.

Back-casting; visions realized
The research project investigates methods and tools in planning processes towards a sustainable transport system, regardless of its infrastructure, products or services in the system. Back-casting was used as the planning method, rather than the usual forecast planning methods that is based on existing trends. Physical areas in Gothenburg and Uppsala has been used to practice the ideas through visualization. The visualization has mostly focused on virtual reality (VR) and augmented reality (AR) which allows us to imagine abstract ideas in a time- and cost-efficient way. The work process that has been developed during the research project can be seen below. The global goals have been the starting point and visualization and back-casting have been implemented through an iterative process, where tools such as sustainability ratings, user stories, and simulation are used to reach Sum Zero.

Tools to achieve Sum Zero
The project has focused on the relation between visualization, analyses and simulation and how these tools together can help realize Sum Zero. Through visualization you can experience the potential changes in society and you can challenge your thoughts on what specifics the future sustainable transport system should contain. It helps us see what we need to develop and analyse further. Other advantages with visualization tools are the ability to communicate ideas, which also strengthens the democratization process of urban planning.

Figure 1: Back-casting by Sum Zero (global goals) as the set vision and the iterative process towards its fulfilment. (Image by ÅF).
Other tools used to complement the visualization are ÅF’s own sustainability rating system, user stories, and the analytical tool; Visual City. The sustainability rating measures the different parts of a future transport system, such as a road, bike lane or tram line, and ensures that it fulfils parameters and aspects of Sum Zero. User stories are used to understand the individual’s perspective and Visual City combines the visualization to fact-based analyses. These tools interact with the visualization and together they identify how different services, products and infrastructure affect each other and the surroundings.

Ideas of a future transport system

Different ideas of sustainable mobility have been evaluated by the tools above. Amongst other, freight pods, maintenance pods, mobility-as-a-service and cycling infrastructure have been developed in totally new ways.
Combining approaches is key to success

The overall success has been the combination of Vision Zero and the UN goals, bringing together an immense variety of stakeholders and combining visualization with classical analysis tools and measurement methods.

The research has resulted in a holistic work method towards Sum Zero, as well as a verification of suitable tools that can be used in planning processes. By adding tools to the back-casting method, such as user stories, analytical tools as Visual City and sustainability ratings, different relationships and conflicts between components can be clarified, exemplified and solved. AR and VR can also make it easier to see the effects of new approaches in urban planning and user stories can provide the perspective of individuals, their different needs, behaviours and priorities.

Global Goals are expressed in a way that only allow eradication of the negative aspects of mobility. Therefore, innovation is necessary in several fields, while in traditional planning a structured compromise between benefits and costs would have been sought.

The different ideas of a future sustainable transportation system have been tested and evaluated through the chosen tools. One of the conclusions is that different tools in interaction are needed to achieve the goals. Although, this must be done together with different stakeholders and inhabitants, otherwise we cannot create smarter cities.

One of the main contributions of the project has been to provide a platform for discussion and dialogue with several stakeholders of varying knowledge. During the project, several stakeholders and participants have been involved, both from the private and public sectors. The mix of these participants has added great value.
Figure 6: Maintenance pods: smart autonomous robots which take care of the maintenance of sidewalks and bike lanes to minimize the risk of tripping accidents. (Image by ÅF).

Thank you for believing in us. We are looking forward to providing and supporting the new tolling system at the beautiful Storebælt Bridge.
How to Accelerate Cycling Through ITS and Technology

ITS is traditionally about optimizing traffic flow, reducing the numbers of stops, and increasing speeds for cars. However, in support of the increasing interest of cities around the world to accelerate cycling as transport, cities, along with the ITS and tech industry have developed ITS solutions to optimize flow, reduce the number of stops, and increase safety for people on bicycles. This article will present some of the different solutions implemented in Denmark and make the case that such solutions could be easily implemented elsewhere to achieve common goals.

By Marianne Weinreich, Market Manager, Smart Mobility, Ramboll and Chairman of the Cycling Embassy of Denmark mwein@ramboll.dk

Cycling – the fastest growing mode in cities

On Tuesday, September 18th, 2018, the Cycling Embassy of Denmark is co-hosting a debate at the ITS World Congress with the Dutch Cycling Embassy entitled: “Connected, Cooperative and Sustainable – How Cities Can Accelerate Cycling Through Intelligent Mobility Solutions.”

We feel there is a need for this discussion, since most of the transport sector’s innovation is focused on motorized transportation, even though cycling currently is the fastest growing mode of transport in cities.

The potential for accelerating sustainable, healthy, and congestion-reducing transport such as cycling through ITS and other intelligent solutions is huge. We want to discuss how cities and the private sector can work together to make sure that innovations and new technologies of the future correspond with both public authorities’ and citizens’ needs for mobility, better use of public space, congestion, better quality of life for citizens, better public health, a more vibrant urban life, and reduced noise, emissions, and pollution.

Optimizing flow, speed and safety

Political will to invest in a network of safe cycling infrastructure and planning the city for cycling is the corner stone in creating a city where people ride bikes for transportation. Once you have that, you can accelerate cycling uptake by making it even more attractive to ride, for instance by optimizing corridor flow and speed for cyclists and reducing the number of stops. This technique of easing the experience for drivers has been used with cars for decades but having to stop at an intersection is arguably even more annoying as a cyclist who must give up momentum in braking and subsequently use more energy to get back up to speed. Transfer of this technology, already proven to be effective in car lanes, is easily applied to bicycle lanes.

Riding the green wave

Making sure cyclists don’t have to stop through several intersections is called a green wave. To ride the green wave, some Danish cities have solutions where cyclists are informed with signs which speed they need to ride while others have installed LED lights that cyclists can use to adjust their speed to be in sync with the traffic signals. In the city of Aarhus, RFDI technology is being tested where cyclists carrying a RFDI chip on their bikes can even activate the green signal phase at an upcoming intersection when passing a RFDI detector placed a certain distance in advance.

Siemens has created an app-based system called SiBike that determines the speed and direction of the cyclists via the GPS sensor in their smart phone and activates upcoming green traffic signals.

Supercykelstissekretariatet (The Cycle Superhighway Secretariat) in Greater Copenhagen is testing a countdown system that allows cyclists to see when the signal will turn green and use that information to adapt their speed to the signals.
In the most optimal systems, a cyclist would not have to activate, wear a device, or change her/his behavior, but be automatically detected and the signal dynamically adapt to the actual speed of the cyclist.

When it rains, it’s green

In the city of Odense, cyclists get 20 seconds additional green time when it rains on the cycle superhighway at an intersection between the city center and the university. A combination of a rain sensors and laser detection of cyclists approaching the intersection activates the extended green time during pre-defined conditions. The solution is explained to the cyclists on a small sign at the intersection and a light goes on when they are detected, so they can see that the system is functioning.

ITS can increase safety

At many intersections in Denmark, there are smaller, special traffic signals for cyclists. They can be programmed to give cyclists a leading phase green light to cross the street before the cars get a green signal. By giving cyclists a head start, conflicts with motor vehicles are reduced.

LED studs have been used in Copenhagen to warn right turning truck and lorry drivers about cyclists in the bike lane, thereby mitigating right-turn accidents (where truck drivers have low visibility). The road studs flash in the driver’s side mirror when activated by cyclists crossing on green, raising awareness of the lorry drivers.

In the City of Aarhus, dynamic signs have been installed at an intersection as a pilot test. The signs flash and warn cyclists when there is a large vehicle in the right-turn lane. The system warns the cyclist in contrast to the system described above where the system warns the driver. In any case, such systems must be highly reliable and designed so that road users are not confused in case they fail to function.

**Showing cyclists that they count**

Developing ITS solutions for cycling also means showing cyclists that they are appreciated and welcome in the city. The approach of creating high quality tech solutions for cyclists as a way of encouraging cycling was first tested in Denmark in 1999-2002 during the Odense Cycle City project.

In addition to green waves and LED lane lights, the city and a local ITS company developed the world’s first so-called cyclist counter, which is now implemented in cities all over the world.

In addition to showing cyclists that they count, the device also serves the critical purpose of providing the city with valuable data about cyclists every day. To succeed in the former, it is important that the counting mechanism is installed at a sufficient distance ahead of the counter display so that the cyclist can see her- or himself being counted.

**A geo-fence is a virtual perimeter for a real-world geographic area. A geo-fence could be dynamically generated—as in a radius around a point location, or a geo-fence can be a predefined set of boundaries (such as school zones or neighborhood boundaries). The use of a geo-fence is called geo-fencing (Wikipedia).**

**Cykeldøttæller.**

**Rain sensor in Odense.**
App technology and cycling

Since 2002, when the first cyclist counter was installed in Odense, a technological revolution has taken place and, with the introduction of the smart phone and apps, using technology to accelerate cycling has entered a new era.

Wayfinding apps for cyclists with the possibility to choose the fastest, safest, greenest or even happiest route are available. Tracking and gamification apps, where one can win prizes or collect points to get coffee or discounts at local shops by cycling, are being used to promote cycling and collect data in cities all over the world. App technology has made dock-less bikeshare possible and, subsequently, attempts to solve some problems arising from the increase of dock-less bikeshare systems are being made using technology such as geofencing.

The Cycling Embassy of Denmark is a comprehensive network of cycling professionals from private companies, local authorities and non-governmental organizations, working together to promote cycling and share our know-how and expertise in cycling.

Multimodality

The European Commission has named 2018 the Year of Multimodality. Technology plays a big part in making a multi-modal lifestyle easy. The Cycle Superhighway Secretariat in Copenhagen has worked with the Danish travel planner service Rejseplanen to develop new features that make it easier to combine longer bicycle rides with public transportation. The main purpose is to test different solutions that may reduce the barriers experienced when shifting between public transport and a long bicycle ride. The project focuses on multi-modal journeys where the journey by bicycle is longer than five kilometers (three miles). This typically involves journeys that go beyond the normal bike ride to the nearest bus stop or train station. In Denmark, there has not been a lot of focus on these types of trips, where the commuter wishes to travel further by bike, even though there are other options available.
**Cycle Zooperhighway**
In Egedal, a small Danish town, technology and African animals have been used to motivate local kids to bike to school and wear a helmet; they have created the world’s first cycle zooperhighway. Along the 2.3 km (1.4 mile) school route, nine different animal sculptures have been installed. Lights in the animals can be activated by the children if they have an RFID chip on their bike helmet. The project idea has been developed with the school children and the purpose is to create an incentive to bike to school, create a better school route experience, and make the children feel safer.

**Make it about people**
There is no doubt that technology and ITS will play a big role in planning for and accelerating cycling in the future. At the Cycling Embassy, we are engaged in the debate about autonomous vehicles’ impact on cycling, the potential for cycling as part of MaaS solutions, space optimization through advanced cycle planning tools, data management for bicycle traffic, and more. We are excited about the huge potentials technological development holds. At the same time, we urge that the development of new solutions will focus on how tech can help make cycling more attractive and easier for people and help cities reach their goals for a more safe, sustainable, livable, climate friendly, green, effective and healthy city.

“Connected, cooperative and sustainable – how cities can accelerate cycling through intelligent mobility solutions.” Tuesday, September 18 at 13.30-15.00 at ITS Forum.

(Figure 6) The World’s first cyclist counter in Odense 2002.
Follow the Nordic Stream

This year, the City of Copenhagen, in collaboration with the Network of ITS National Associations, will address the topic – “Cross-border solutions”. The ITS Nordic Network has organized a special Nordic Stream across the different topics, highlighting the ITS Nordic way. You can follow the sessions in room Stockholm.

NS0 CROSS BORDER MOBILITY SOLUTIONS: TOWARDS A SEAMLESS FUTURE. BY THE ITS NATIONALS
Monday 17 September 2018, 13:30–15:00
The roll out of Cooperative ITS services in Europe is accelerating, pushed forward by Industry funding and political engagement on both national and EU level. Crossborder cooperation on European scale and between countries is essential for harmonized and coherent deployment. To maximize the service for the user and to have maximum impact on reduction of traffic jams, pollution and number of accidents. This session will provide hands-on experience of C-ITS deployment in Europe in cross border initiatives. The panel, representatives from different countries will present:
- C-ITS deployment initiatives
- How public and private sectors organize their cross border cooperation across topics such as strategy, policy, procurement, standards and innovation.

The representatives will continue to share experience and knowledge in a Q&A slot. The session will end with the role of the individual ITS Nationals and the Network of ITS National Associations to promote deployment of cross border mobility solutions.

Speakers
Christoffer Karlsson, ITS Sweden, Sweden
Paul Hutton, ITS UK, United Kingdom
Martin Russ, AustriaTech, Austria
Roman Srp, ITS&C Czech & Slovak, Czech Republic
Mihai Niculescu, ITS Romania, Romania

NS1 THE TECHNICAL PLATFORM FOR SEAMLESS TRAVELING
Tuesday 18 September 2018, 09:00–10:30
To get MaaS working – we need IT systems that work seamlessly between all participants form planning to operation. Which technical platform are need for MaaS, what can we offer today? Three speakers from different transport modes provide their views.

Speakers
Pekka Eloranta, Senior consultant, Sitowise, Finland
Niklas Löschner, Technical expert, HaCon, Germany
Matias Mal Dalsgaard, CEO, GoMore, Denmark

NS2 GLOBAL STANDARDIZED REAL-TIME MARITIME INFORMATION SHARING – WHY NOW?
Tuesday 18 September 2018, 13:30–15:00
Stockholm (Nordic Stream)
Maritime companies have traditionally been secretive about their information. Sharing it used to mean that competitors took advantage. Nevertheless, the close collaboration between business partners in all industries is slowly being realized in shipping as well. There are several initiatives around the world and they tend to build partnerships in order strengthen each other. Shipping can leave its position as the black sheep of the logistical chain and become one the most vital parts in coming developments. Moreover, ports will become not only goods hubs but also information hubs.

Speakers
Thomas Christensen, SMART, Korea
Ben van Scherpenzeel, Port of Rotterdam, the Netherlands
Per Setterberg, STM Validation project, Swedish Maritime Administration, Sweden

NS3 HOW CAN SELF-DRIVING FEEDER SERVICES IMPROVE PUBLIC TRANSPORT?
Tuesday 18 September 2018, 15:30–17:00
Stockholm (Nordic Stream)
Most cities are facing a growing urban population and increased need for smart and effective mobility. Largescale introduction of self-driving vehicles represents huge opportunities for individual mobility solutions. However, if such vehicles substitute passenger cars, it represents a potential increase in urban transport and thus reduced mobility for everybody. Transport authorities is challenged towards proving a more attractive and seamless public transport in a door-to-door perspective to obtain mobility for all and help ensure quality of life. Self-driving vehicles should be an integrated transport mean in the overall mobility solutions for communities.

This session will cover deployment of self-driving vehicles as first and last mile services. This mode of transport is still new, and due to lack of suitable regulation, operational standards and business models, it is still to a large extent unproven. The Norwegian SmartFeeder-project will examine these issues and especially pay attention to the relationship between feeder operators and Public Transport Agencies in the Nordic Region.

Speakers
Lone Lervag, SINTEF, Norway
Martina Muegger, PostAuto, Switzerland
Oscar Nissin, Metropolia University of Applied Sciences, Finland
Marieke Martens, TNO, the Netherlands
Espen Strand Henriksen, Kolumbus, Norway

NS4 AUTOMATION AND SAFETY – AT SEA AND ROADS
Tuesday 18 September 2018, 17:15–18:45
As the level of automatisation is increasing in all transport domains, it is expected that transport safety will be enhanced substantially as a result. What are the underlying drivers and concepts for this development – and what are the conditions that need to be in place in the first place? What kind of new safety and risk issues will autonomous transport modes and new technology induce?

Speakers
Javier Yasinikouski, International Maritime Organisation, Spain
Hege Okland, NCE Maritime CleanTech.Norway
Cato Gill Eliassen, Kongsberg Seatex,Norway
Hannu Karvonen, Port of Rotterdam, the Netherlands
Javier Yasnikouski, International Maritime Organisation, Spain

NS5 CAAS – CORRIDOR AS A SERVICE
Wednesday 19 September 2018, 09:00–10:30
Corridor as a Service – CaaS providing. New competitive delivery alternatives for global traders. Cross continental door-to-door delivery transparency to traders. Accurate and fast delivery time with steady driving speed.
If it works in the Arctic Nordics, it will work everywhere. The Nordics are used to operate at extreme conditions, especially at winter time. Our transportation system on roads, rails, see and air works 365 days a year despite the challenging weather conditions, even when it is raining cats, dogs, snow or hail. Alongside with the automatization we will face new kind of challenges and especially the role of data becomes even more crucial. How to ensure a common, cross border data basis for all modes and all circumstances? How to collect data in extreme conditions and to maintain or preferably improve the service level in automated world? A discussion about the automatization of systems, processes and services and ensure cross border transportation system that works safely and securely in all conditions.

Speakers
Harri Santamala, Sensible 4, Finland
Oddgeir Kristiansen, Norwegian mapping authority, Norway
Hamid Zarghampour, Finnish Trasport Administration, Sweden

NS9 5G /6G OPPORTUNITIES AND TELECOM CONNECTIONS WITH C-ITS
Thursday 20 September 2018, 11:00–12:30
Stockholm (Nordic Stream)
Almost all carmakers state that they will provide autonomous vehicles that will be connected to roadside equipment, authorities and other cars. However, a broad agreement supporting the connection of right standards and communication technology is still lacking. Cross-border communication is crucial to successful implementation in the Nordic region. There are two major projects in the Nordic region that highlight the problematic issues; general coverage, fragmented telecom actors and inaccessiveness towards 5G/6G.

Speakers
Knut Evensen, Q-Free ASA, Norway
Stefano Sorrentino, Ericsson, Sweden

NS10 OPEN ECOSYSTEM FOR MOBILITY AS A SERVICE
Thursday 20 September 2018, 13:30–15:00
The Nordics are the most known forerunners in Mobility as a Service. All Nordic countries have some activities in this field and especially in Finland and Sweden MaaS has become a common, cross border data basis for all modes and the user may often use a combination of modes when travelling to her destination. On the other hand, the user may not be aware or care about who the transport authority is that provides the service, but only interested in getting the right and relevant traffic information for her journey. Realising this has been a driving force behind cooperation and creation of joint traffic management services in the Nordic Countries.

Speakers
Merja Penttinen, VTT Technical Research Centre of Finland Ltd., Finland
Jan Wilhelm Tieroll, RWS, the Netherlands
Karolina Hedberg, Swedish Transport Administration / Viati Consultant, Sweden
Arne Lindeberg, Swedish Transport Administration, Sweden

NS8 ARCTIC SNOWHOW AND THE AUTOMATIZATION OF TRANSPORT SYSTEM
Thursday 20 September 2018, 09:00–10:30
The Nordics are used to operate at extreme conditions, especially at winter time. Our transportation system on roads, rails, sea and air works 365 days a year despite the challenging weather conditions, even when it is raining cats, dogs, snow or hail. Alongside with the automatization we will face new kind of challenges and especially the role of data becomes even more crucial. How to ensure a common, cross border data basis for all modes and all circumstances? How to collect data in extreme conditions and to maintain or preferably improve the service level in automated world? A discussion about the automatization of systems, processes and services and ensure cross border transportation system that works safely and securely in all conditions.

Speakers
Sami Sahala, Forum Virium Helsinki, Finland
Göran Smith, Chalmers, Sweden
Endre Angelvik, Ruter, Norway

NS11 BETTER MOBILITY WITH PUBLIC TRANSPORT
Thursday 20 September 2018, 15:30–17:00
Good mobility is an important factor for many people. Public transport plays an important role in providing a good mobility service and liveable cities. In cities and rural areas the needs are different, but the biggest challenge is to provide equally good services under a sustainable model. The session will present different implemented public transport solutions from the Nordic countries.

Speakers
Sini Punta, HSL, Finland
Endre Angelvik, Ruter, Norway
Frode Hvattum, ROUTER AS, Norway
Annette Enemark, Public Transport Movia, Denmark

NS12 NORDIC TEST AREAS AND DEMONSTRATION SITES
Thursday 20 September 2018, 17:15–18:45
The session will provide an overview of how travellers’ needs are collected, analysed and used in the development of traffic information and common communication channels. We foresee that the long tradition of cooperation and exchange of experiences between the Nordic countries will create fruitful discussions during the session.

Speakers
Orjan Tveit, NPRA, Norway
Noora Lähde, Finnish Transport Safety Agency, Finland

NS13 MAAS IN REAL LIFE – THE DELEGATE APP?
Friday 21 September 2018, 09:00–10:30
During the ITS World Congress, all the participants as well as the citizens of Copenhagen will be able to use a new MaaS-app “MinRejseplan” (meaning ‘My Journey Planner’). It is developed by the public sector, and it will display information about all sorts of collective transportation – as well as private transportation such as trains, the metro, buses, carpooling, harbours, taxis, car-sharing, bicycle-sharing, and city bikes. In the session the MaaS app will be presented, and will be compared with MaaS solutions from the other Nordic countries regarding the opportunities for PPP.

Speakers
Marten Rignell, Skånetrafiken, Sweden
Christina Hvid, Rejsesplanen, Denmark
Jonna Pöllänen, MaaS Global Ltd, Finland
Thomas Oster, Nordjylland Trafikselskab – North Denmark Region, Denmark
Susanne Krawack, City of Aarhus, Denmark
Automatic Payment Solutions

When the Storebælt fixed link opened in 1998, it was one of the longest of its type in the world and a feat of engineering. The bridge also brought about technological innovation, most notably BroBizz, a device that collects payment automatically when using the bridge and which ensures rapid passage through the toll station.

By Helle Bech, CEO, BroBizz A/S
hbe@brobizz.com

Ole Lykke Christensen, CEO, BroBizz Operator A/S
olk@brobizz.com

Today, 20 years on, BroBizz continues to gain in popularity. It is now linked to more advanced technological solutions, can be used at many more locations, works outside Denmark’s borders and has acquired competitors. It is no longer the only digital offer for motorists who wish to use automatic payment solutions.

The BroBizz schemes are organised into two business areas within the Sund & Bælt Group – issuer and operator in the BroBizz A/S subsidiary.

The issuer is the company that interfaces with the customer and owns the device, i.e. the unit that registers data when the motorist drives through the toll station. The issuer looks after all customer data and ensures that toll fees are collected.

The operator is the owner of the facility where charges are payable, e.g. the Storebælt fixed link. The operator decides the fees for using the facility and what discounts can be offered. The operator sells and markets the product to the customer.

Since the Sund and Bælt Group comprises both an issuer and operator business, it is firmly established in the Danish market. However, new technologies, more accessible cross-border payment systems and new players in the market mean that competition in terms of payment and charging methods for transport services is now significantly different and tougher than before. The Sund & Bælt and the BroBizz business areas, therefore, have long been focused on creating coherent payment concepts that provide end-users with a clear overview of services and conditions.

At Sund & Bælt, digital opportunities mean that we can deliver added value to our private and business customers. This also means that we have moved into new business areas. Indeed, one would be justified in asking whether we have the ability to cope. The answer is that we are a small organisation, but we have a very large customer base, we have a good brand, we succeed in attracting skilled experts and we are agile. We believe that speed is a decisive factor in the digital development process and we can deliver on that parameter.

Operator upgrades technology

The toll station that the company operates on the Storebælt fixed link has worked impeccably since the bridge’s inauguration and has undergone upgrades and expansions along the way. Next year, however, it will be replaced by a new system that is future-proof, thus enabling it to handle the increased traffic on the link.

The upcoming facility on the Storebælt link will be equipped with state-of-the-art technology and with more express lanes for customers using automatic payment methods. This will eventually enable them to drive through the toll station at speeds of up to 50 km/h. The new system means that we can provide customers with an enhanced service experience, reduce operating costs and ensure fast passage for the increasing number of drivers on the link.

Today, an average of 35,000 vehicles cross the link every day, with a record recently being set at 52,000. However, queues are non-existent, and we want things to continue in this way.

Growth in Denmark and international ambitions

Around one million Danes now have a BroBizz in their vehicle, which they are using increasingly. The technology in today’s BroBizz is the Dedicated Short-Range Communications system (DR-DC), but the company is also prepared for the Global Navigation Satellite System.

By managing both technologies, BroBizz is helping to accomplish the vision of making it easier to travel in Europe. Through the so-called European Electronic Toll Service (EETS) directive, the European Commission has the objective that one and the same electronic transponder, e.g. the BroBizz, should be able to be used on all payment systems in the EU. This will make life easier for road users, who will only need to have one contract with one issuer, e.g. BroBizz A/S. We have yet to get this far, but the implementation of the directive is underpinned by the rapid spread of new digital and payment services. Before long, we expect to see the first regional solutions with BroBizz A/S as a participant.

In practice, BroBizz A/S has long been a major player in regional collaboration. Over ten years ago, BroBizz became part of EasyGo, the first cross-border payment solution in Europe. Behind the initiative was Sund & Bælt, Øresundsbro Konsortiet – the operator of the Øresund Bridge – and the Norwegian and Swedish transport authorities. Austria joined the partnership later on. In other words, the partners were first movers in Europe in a collaboration that means that road users can drive through Scandinavia and across Austria and pay tolls on roads, bridges and tunnels with the same device. In Scandinavia alone, one device can be used at 55 locations, and the sys-
The toll station on the Storebælt link. Some 35,000 vehicles use the facility on a daily basis – and there are no queues, thanks to the automatic payment systems.
Denmark's first autonomous bus in regular operation at University Hospital

During spring and summer 2018, a yellow, autonomous, and very cute minibus (Line 249), has been operating in the nearly 400-meter-long hallway at the University Hospital of Zealand in Køge, south of Copenhagen, as Denmark’s first autonomous bus in regular operation. Though the route is short, the need is there and the test line has been a huge success, carrying over 6,000 passengers in only 65 days of operation, among them many disabled persons. Here are some insights from the first phase of the Autonomous Hospital Bus Project.

Mads Bergendorff, Project Manager, Public Transport Authority Movia
mab@moviatrafik.dk

Jakob Keinicke Sørensen, Head of Projects, Copenhagen Metro
jks@m.dk

Why an autonomous bus in a hospital?
The project partners are testing the autonomous bus technology at two hospitals in the Region of Zealand from 2018 to 2020. A hospital has several unique benefits as a test site:
- An autonomous bus is solving real transport needs for patients with low requirements to travel speed e.g. between departments, from/to the nearest public transport hub, etc. Currently, these transport tasks are carried out either by the region itself, Movia’s flexible service or the hospital staff.
- A steady flow of passengers throughout the day. Suited for the size of vehicle.
- A hospital is a very well-defined trial area where the complexity of the route and traffic can be gradually increased.

The Autonomous Hospital Bus Project consists of three consecutive phases: Phase 1 is an indoor test with one bi-directional bus operated with low speed (3.5 km/h) in SAE level 3 in both route and on-demand mode during 3 months. Test site is University Hospital of Zealand, Køge. This part is not covered by the Danish legislation for autonomous vehicle testing. Phase 2 is a parking shuttle around the hospital of Slagelse. Operating speed is planned up to 23 km/h in SAE level 4. The route length is 2.4 km in low density mixed traffic with both route and on-demand operation. Finally, Phase 3 is a back in Køge with a first/last mile shuttle between the hospital and nearby S-train station. Operating speed is planned up to 23 km/h in SAE level 4. The 1.8 km route is high density mixed traffic with two light-controlled intersections and at a bus terminal by station.

The primary goals of the Autonomous Hospital Bus Project are:
- Conducting autonomous passenger transport on three selected routes, with an increasing complexity,
- Gather knowledge and experience regarding application for authority approval, safety assessment, mobilization, operation, evaluation and other relevant conditions for the further development and dissemination of the technology,
- Testing the technology in different contexts and use cases (the three project phases),

Phase One in figures:
- One Navya Arma bus (bi-directional)
- 4 stops (ramps)
- 375 m route length
- 65 days of operation, 8 hours per day
- 6449 passengers transported, of which 350-wheel chair users and 194 persons with walkers
- 842 km total distance travelled by the bus

The partners in the project
- Movia (Public Transport Authority)
- Copenhagen Metro
- Capital Region of Denmark
- Region of Zealand
- Autonomous Mobility (bus operator)
- Atkins (independent safety assessor)
- University Hospital of Zealand, Køge
- Slagelse Hospital
- Psychiatric Hospital of Slagelse
- Municipalities of Køge and Slagelse
Extracting and disseminating lessons learned for the benefit of municipalities and regions, relevant authorities and other public institutions, operators and suppliers, as well as public transport passengers.

The Autonomous Hospital Bus Project serves as a solution not only to concrete passenger transport needs, but also as a platform for testing, developing and gathering know-how for the autonomous technology.

**Phase One Results – Lessons learned**

Overall, Copenhagen Metro and Public Transport Authority Movia are satisfied with the outcome of the trial so far. At the time when this article is written, evaluation of the first phase (the indoor route at the University Hospital Zealand, Køge) has not yet been completed. However, some important preliminary lessons can already be extracted.

**Operation and bus technology**

The bus navigates the route based on image recognition only, as it is not possible to use the normal GPS localization software indoors. This proved to be a challenge for the bus software and it has required calibration of the bus systems as well as several software updates. During operation, restarts are carried out by the operator on board, see Table 2 with development in the number of software restarts during operation in phase 1. These errors are naturally undesirable as they delay the bus during operation and also require the operator to interfere, which does not harmonize with taking the operator out of the bus in Phase 2 and 3. On the positive side, it has not at any time during phase 1 been necessary to use the emergency brake.

**User survey**

A number of user surveys have been conducted among users and non-users of the bus. Parts of the user survey is coordinated with a number of other Danish test sites for autonomous busses, with the purpose of being able to compare results and enlarge the total knowledge base. The following analyses are planned for the entire project:

1. Standard customer satisfaction analysis that matches the satisfaction analyses conducted on normal bus lines.
2. Anthropological “travel along” analyses. These are carried out by an analyst with special focus on the autonomous bus.
3. In cooperation with the Danish University, RUC, analyses are conducted, focusing on user behaviour on / off and how the bus is used.
4. In cooperation with the Danish University AAU, analyses of the bus’s impact on the urban environment are carried out (only phase 2 and 3).

*Figure 1: First autonomous bus in Denmark, Line 249, indoors at University Hospital of Zealand, Køge. Photo: Copenhagen Metro/Lene Skytte.*
Movia is still in the process of performing these user surveys, but the “travel along” analysis has been conducted by Epinion through interviews in early August 2018. Observations show that users generally feel more mobile and independent when using the autonomous bus, as they can overcome the long walkway without special assistance. None of the respondents show any signs of insecurity by using the autonomous bus. Several people point out that the Copenhagen Metro is also autonomous, so they have no trouble using the bus. Some users stated that they preferred not to use the bus, but this was because they specifically wanted to walk themselves, instead of being transported.

In general, the information to passengers could be improved. It was unclear for several respondents for which type of passengers the bus was allowed. Also, better information about the “on demand” mode was requested. The bus is only running “on demand” out of peak-hours, but the concept of how to order the bus at the bus stop did not come across easily. This will be improved for the next phases. The operator onboard seems to play an important role for passengers seeking information and confidence with the operation mode of the bus.

Test preparation
As the test took place indoor, the new Danish amendment legislation for autonomous vehicles is not applicable. However, the project chose to carry out the preparatory safety work according to the same principles of safety assessment, prescribed by the amendment legislation. In practice, the project’s independent safety assessor, Atkins, submitted an assessment, based on the operator’s project description and a series of performed safety tests during the preparation phase. Prior to the start of the trial, the Hospital senior management approved the application documents.

To structure the safety work, the project decided to organize two risk workshops with the participation of all parties. The route itself was measured, piloted and calibrated with the bus over a period of only two weeks. During this period, technicians from the bus supplier, Navya, the bus operator and the project working group worked intensively on the bus route, ramps, stops, and traffic information for hospital users and employees.

The bus was thoroughly safety tested on the route a few days before the final approval was granted. The test catalogue, prepared by the bus operator in close cooperation with Copenhagen Metro and Movia, consisted of 15 performance tests and safety tests such as tests of brakes, sensors, door locks, location on route, blinkers and head/rear lights, safety equipment and emergency procedures. Thanks to a very close and constructive cooperation between all parties, not least from the hospital’s side, the entire preparation was carried out in just over a month.

Learning Objectives
With technology and software still in early development and testing phases, Movia and Copenhagen Metro have designed the Autonomous Hospital Bus Project to ensure clear progress in the pilot design and to gradually get hands-on experience with bus technology, operation and customer acceptance:

Phase 1
- First-time operating experience with autonomous technology in a protected indoor environment (SAE level 3)
- First customer experiences with the bus (route and on-demand operation) as patient transport

Phase 2
- First operating experience with autonomous operation on public road in mixed traffic
- Real autonomous operation with operator outside the bus (SAE level 4)
- Customer experience with the bus as a parking shuttle for patients, relatives and employees, including on demand

Phase 3
- Operational experience with two autonomous buses in conjunction with other public transport
- Experience with driving on congested roads, in light-controlled intersections and at a bus terminal by station
- Customer experience with the bus as first/last mile shuttle for patients, relatives and employees
We take a seat in your world

Meet us at stand C2-070
Experience the Dynniq Flow in VR
Bicycle counters promote cycling, health and environment in cities

Cyclists are here to stay. And not only in Denmark, which has been on the world map for many years as one of the great cycling nations. Cycling is gaining in popularity all around the world. This is very clear to us here at ITS Teknik, with recent years bringing ever more interest to our bicycle counters, especially abroad, both in Europe and beyond. They offer a very visible signal of the priority now being given to cycling in so many of the world’s cities.

By: Lars Hougaard Jakobsen, Head of Sales, ITS Teknik A/S, Denmark

Bicycle counters lead to sense of community and better infrastructure

A bicycle counter registers the number of cyclists passing by in real time and displays running totals for both the day in question and the year to date. As well as showing the date, time and temperature, the bicycle counter can also provide cyclists with useful information on roadworks, fastest route, time to the city centre, and much, much more.

One good reason for installing bicycle counters in a city is community building. By showing cyclists that they are not alone, the bicycle counters send a signal that cyclists and their efforts to reduce their carbon footprint and look after their health really do matter and is considered a priority.

Data from the counters can provide useful information about cycle flows in the city, which can be used to improve the infrastructure and help local authorities to plan efficient cycle routes, better cycle paths and cycle lanes, signage and information systems, and cycling campaigns.

More cyclists benefit society

There are numerous benefits to promoting cycling in urban areas, not least in terms of health, congestion, and the environment.

As most people know, regular exercise is very important for preventing and treating lifestyle diseases. Physical activity also impacts our mental health, bringing about a sense of well-being and energy. We also know from research that cyclists spend less time off work through illness.

More cyclists also mean less traffic and congestion, making cities safer and easier to get about in. Air pollution from cars and trucks is a vital environmental challenge worldwide. Biking, on the other hand, is an environmentally friendly mode of transport that cuts carbon emissions and contributes to clean and healthy cities.

ITS Teknik is therefore working hard to develop intelligent transportation systems that can increase the number of cyclists and improve the cycling infrastructure to the benefit of society. Travelling by bike should be an attractive option, and installing bicycle counters has been shown to contribute to this.

Ambitious goal for cycling in Scotland

ITS Teknik has supplied 15 bicycle counters to Scotland and another five elsewhere in the British Isles. We have even installed a master data counter in Edinburgh showing the total number of cyclists picked up by all of the different bicycle counters in Scotland.

Scotland is investing heavily in promoting cycling. In 2010, the government published a vision where 10 per cent of all journeys within the country’s borders are by bike. The government therefore decided to help cyclists (and, even more importantly, non-cyclists) see the popularity of this alternative mode of transport by installing bicycle counters. Until then, there were all kinds of traffic management products targeting motorists, but nothing for cyclists.

The first bicycle counters were installed in Scotland in 2014 and have since helped increase awareness among non-cyclists by showing people of all ages that cycling is not a minority activity but an entirely normal and popular form of day-to-day transport.

Scotland chose ITS Teknik partly because our bicycle counters are larger than average and therefore easy to read. They are also more flexible in regards to the information they can display, and well protected against vandalism, which is important in a public setting.

Bicycle counters have motivational effect in Belgium

ITS Teknik has supplied 12 bicycle counters to the Belgian capital, where the conclusion is that they have a motivational effect by showing that cyclists quite literally count in a big city like Brussels.
According to a spokesman for the city’s minister for mobility, Pascal Smet, the counters have a threefold purpose. First, they give cyclists a sense of community. Second, they help make drivers more aware of cyclists. Third, they send a clear signal to motorists stuck in traffic on their commute, reminding them of just how many cyclists enjoyed a faster journey that day.

In the Belgian cities of Ghent and Bruges, data from the bicycle counters is used partly to see whether the existing infrastructure is adequate. For example, data from a counter in Bruges revealed that the number of cyclists had grown to the point where the cycle path was approaching full capacity.

Getting more motorists to see the benefits of cycling

In Denmark, many towns and cities are working on getting even more people to go by bike.

Aalborg, Denmark’s fourth largest city, has installed a number of bicycle counters from ITS Teknik as part of efforts to tackle the perennial problem of rush-hour congestion. By making cycling a priority, and underlining this with high-profile initiatives such as bicycle counters, the city hopes to create an attractive, healthy and safe urban environment with good mobility, untroubled by excessive traffic, noise and pollution.

Figure 1: Bicycle counter in Copenhagen.

Aalborg has also chosen to display how long it takes to cycle into the city centre from the location of the bicycle counter. Here too, the counters are not aimed solely at cyclists. The idea is also to encourage motorists to change their behaviour and swap four wheels for two, by showing them not only that cyclists are a priority but also that they may well get from A to B faster.

Surveys carried out by the city show that both cyclists and motorists are very aware of the counters and regard them as an interesting innovation.

Strong demand abroad

ITS Teknik has already exported bicycle counters to Sweden, Norway, Iceland, Finland, Ireland, Scotland, England, Wales, the Netherlands, Belgium and Luxembourg, with Valencia in Spain planned to join the list in November.

But there are still many countries where bicycle counters are not yet a fixture on city streets. We are therefore delighted here at ITS Teknik to receive so many enquiries from cities around the world interested in using bicycle counters to show that they support cycling and are doing something for cyclists.

Meet Team ITS Teknik at stand C1-030.

Figure 2: Bicycle counter in Scotland.
Big Data and Intelligent Traffic Light Controller for Predictive Traffic Management Services

Traffic congestion is a growing and global problem, impacting the majority of people traveling and goods moving in the urban areas. Cities are challenged to keep the traffic flowing, to reduce pollution and decrease the economic damage, caused by congestion. New technology for traffic light controllers is based on real-time data fusion through a real-time traffic model: Smart Traffic. This has the effect that rather than waiting for queues to start, each vehicle approaching the intersection is detected and predicted. For each vehicle a prediction is made for what time it will arrive at the intersection. With this prediction it is possible to continuously calculate the most efficient schedule, whereby the throughput is significantly increased. Smart Traffic reduces the experienced delay at intersections up to 30%.

Big data powering change

Urban areas in the EU experience a continuing growth in inhabitants. Already, around 60% of Europeans live in these urban areas (cities > 100,000 inhabitants). Due to urbanization this number is expected to rise to 70% or more, while the total number of EU citizens rises as well. This increases pressure on the liveability in cities. Considering mobility alone, more inhabitants means more traffic, more congestion and a higher risk on accidents, resulting in even more congestion. The effect of all this is more pollution, decreased safety, higher cost and reduced liveability. Solving these topics are the main priorities for Smart Mobility.

Big Data is seen as something for the future, but by means of innovations, big data is powering solutions that are deployed today. The urban area is deployed with millions of traffic sensors ranging from induction loops, camera’s, Wi-Fi sniffers, Floating Car Data (FCD), etc. Most of the time these sensors are deployed with a very specific and limited use case. An example is the usage of loop detectors for traffic lights. With the move towards making this type of data available in real time, new opportunities arise.

Smart traffic

Smart Traffic is a new technology to incorporate big data into traffic light control, in order to increase liveability in urban areas.

Figure 1: Architecture Smart Traffic.
Available sensor data are fused into a reliable and complete image of the traffic in the measured network, using a real-time traffic model hosted in a central cloud. Smart Traffic optimizes the control of traffic lights, making use of the real-time traffic model. Various studies show a reduction in experienced delay up to 30%, compared to current state-of-the-art vehicle actuated control.

Smart Traffic consist of multiple modules (see figure 1). The predictive traffic light controller optimizes the control of intersections, making use of the real-time traffic model. A supervisor is used to activate alternative control strategies for the controlled intersections in the network, either automatically or triggered by external systems.

The developed solution is cloud-based, making it possible to fuse data provided by different sources, like induction loops, camera’s, radars and FCD. Furthermore, additional computing power is easily available in the cloud and the costs of on-street hardware can be reduced. Using the cloud-based approach makes Smart Traffic both scalable and affordable.

**Real-time traffic model**

Over the past years, the amount of installed traffic sensors has significantly increased, leading to an increased volume of traffic data. However, the increased amount of data has not always resulted in an increased insight in the traffic flow. Some parts of the road network are over-measured, while other parts are under-measured. On a main urban road induction loops, ANPR camera’s, radars and FCD can be found, while on a minor road only FCD is available.

The objective of the developed real-time traffic model is to make better use of the available sensors, in such way the calculated traffic information has a higher quality compared to the data provided by the individual sensors, and the number of required sensors is lowered.

Traffic sensors can be divided into two categories:
- **Road-side sensors.** Road-side sensors, like induction loops and ANPR camera’s, register the passage of individual vehicles. For each vehicle, the time and location of the detection are collected. A roadside-sensor collects data of all passed vehicles.

Figure 2: Visualisation of expected arrivals (blue bars) and scheduled green phases by the predictive controller (green bars). The objective of the controller is to schedule the green phases minimizing for example the delays experienced by vehicles.
In-car sensors. In-car sensors continuously transmit the current position, heading and speed to a central server. Only a part of the vehicles is equipped with an in-car sensor.

Fusing both sources into a real-time traffic simulation model makes it possible to continuously calculate the position of all vehicles in the measured network. Using this model, not only equipped and connected vehicles can be followed through the network, but there is also an accurate estimation of legacy non-connected vehicles in the network.

The real-traffic model is used to predict the arrivals of individual vehicles at the controlled intersection. For each vehicle not only, the expected arrival time is predicted by the real-time traffic model, but also variables like the expected waiting time, number of stops or emissions.

**Predictive traffic light control**
The real-time traffic simulation model is the foundation of the predictive traffic light controller. Where the current generation of traffic light controllers is vehicle actuated and responds to the presence of vehicles measured by their own induction loops, the predictive traffic light controller responds to the information provided by the real-time traffic model.

Introducing the real-time traffic model to traffic light control, has two main advantages.
1. Vehicle actuated traffic light controllers only know if a loop is occupied or not, and an unknown number of vehicles is queued in front of the intersection. The predictive controller, using the real-time traffic model, knows the number of vehicles waiting and for each vehicle the waiting time, the stops in the queue and the produced emissions.
2. Current state-of-the-art traffic light controllers are responsive to their induction loops. The occupancy of a loop determines if a direction is served or if the green time is extended. Using the real-time traffic model makes the predictive traffic light controller anticipatory to the expected arrivals of vehicles, cyclists or pedestrians.

Using the real-time traffic model, the predictive traffic light controller continuously optimizes the sequence and duration of green phases (figure 2). The controller constantly selects the best set of directions to serve next, together with their optimal green times. An object function is used to weigh alternatives, and select the best one. This makes it possible to prioritize directions or mobilities, e.g. public transportation or cyclists.

**Supervisor**
In real life traffic management, the objective of a controlled intersection in the greater network can vary in different circumstances. During peak hours, for example, some directions can be prioritized over other directions, while in off-peak hours all directions are served equally.

Also, events like congestion, bridge openings or tunnel closures can result in active traffic management and the desire to control intersections differently during the event. Therefore, we introduced the supervisor module which can manipulate the object function of controlled intersections.

This supervisor is either triggered by external systems, like another traffic system (e.g. a bridge or tunnel) or a traffic management system, or by specific traffic circumstances (e.g. congestion or blocking back) measured by the real-time traffic model.

**Use Cases**
Smart Traffic makes it possible to deploy various use cases including the optimisation of traffic lights, prioritisation of specific vehicles and to inform (self-driving) vehicles about the scheduled signal phases.

**Traffic light optimisation**
The core of the use case traffic light optimisation is the real-time traffic model. Upon the projection of individual vehicles, cyclists and pedestrians in the model it is possible to predict the individual vehicular movements. With these predictions, the sequence and duration of green phases of the controlled intersection are continuously adjusted to the actual traffic demand.

Optimisation can be done for a single intersection, but also for a range of intersections. In the last case, each intersection will be controlled solitarily, but due to the supervisor it is possible to align the network in such way that optimal traffic flow is reached.

**Prioritization**
The use case prioritization is intended for policy makers to prioritize the local policy. Examples are trucks that get higher priority in the harbour or bicycles receiving higher priority in urban environments.

In order to prioritize it is key that all vehicle movements at the controlled intersection are correctly assigned to the correct modality. This can be accomplished using sensors which are able to distinguish modalities or by using separate infrastructure for certain modalities (e.g. a bike-lane). With the object function of the controlled intersection it is possible to prioritize one modality over the other.

Prioritization can also be used for public transportation or emergency vehicles. When an emergency vehicle is approaching the intersection, the movement is predicted and scheduled. Due to this, the disruption on the intersection will be limited.

**Information**
The last use case is to inform the driver. This use case is also based on the real-time traffic model. Due to the predicted arrival of vehicles, cyclists and pedestrians, it is possible to share a reliable time-to-green and time-to-red towards the approaching vehicles. By sharing this information in the industry standards SPaT and MAP it is possible to link this information in regular or autonomous vehicles. Along with the SPaT data also the ‘Why Wait’ can be provided, a message that can be shown in case immediate priority is granted to emergency vehicles of public transport (see figure 3).

Using available data, different use cases are possible, ranging from informing the driver with a smartphone app to informing a self-driving vehicle so it can adjust its speed in such a way that no stopping is required.
MOBILITY IS LIVABILITY
WHEN YOU FEEL IN FLOW
ON YOUR URBAN MOVE

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You can experience our work during your everyday commute. When you ride your bicycle to work and hit every green light, or when your transfer between different modes of transportation flows seamlessly.

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Finland as a smart logistics global hub

The transport system as a whole is in a state of transition. Modern technologies enable new options for transportation of people, goods and data. However, logistics is not famous for its innovations, and the logistic sector is often considered as a very traditional and labour force driven business.

Noora Lähde, Trafi
noora.lahde@trafi.fi

Lasse Nykänen, VTT
lasse.nykainen@vtt.fi

Anne Horila, Growth Corridor Finland
anne.horila@hameenlinna.fi

Matti Lankinen, Vediafi
matti.lankinen@vedia.fi

Corridor as a Service (CaaS) looks to achieve disruptive change for logistics. CaaS aims for more efficient and safer multimodal logistics, through digital services and full-scale digitalization of the logistics chain, multimodal goods transport and new innovations in the vehicle, or by implementing infrastructure that focuses on how to serve international business and logistics more effectively. These new value adding services may have an effect on the logistics hierarchy and potentially improve logistics, but also international commerce on a larger scale.

CaaS is developed in Finland in an open ecosystem towards a solution which is beneficial both for the private and public sector. From the public sector it is coordinated by Traffic Lab and from the private sector by Vediafi and VTT, alongside with various organizations from the public sector, private sector and cities.

Part of the CaaS ecosystem organisations in Brussels: Trafi, VTT and Vediafi.

Corridor as a Service Ecosystem

In the ecosystem, different sectors and actors each have their specific role – the public sector focuses on the policy, transport system development and decision making, the research organizations study potential impacts and gives input on how to integrate exploration into business, while the business and the private sector is focusing on creating customer value. The overall targets, such as seamless logistics, cannot be reached alone. Cooperation makes for more efficient results.

Traffic Lab enables Finland to become a hub for innovation ecosystems and smart logistics

While CaaS development is driven by companies, the public sector facilitates it. Traffic Lab Finland, coordinated by Finnish Transport Safety Agency, has been key driver for CaaS development and it has established its role as a link between the private sector and the Finnish transport authorities, by enabling and promoting new innovation trials and open test environments. Please see below the list of open test environments: https://www.trafficlab.fi/testing_zones#!/0

In addition to authorities, cities have also significant role in the CaaS development and in the CaaS ecosystem, the Growth Corridor Finland (collaboration network, comprising 20 cities and municipalities, four ministries, three regional councils, four chambers of commerce and Finnish Entrepreneurs) has been linking CaaS development to the goals of the cities.

Read more:
https://www.trafficlab.fi

International corridors in Corridor as a Service.
Open interfaces as key to a successful ticketing platform

Mobility as a Service has disrupted the transport industry with innovative ways to obtain traveling services, combine personally-owned and public transport and to pay for these services. New services are in high demand as the world’s population is moving into cities and sustainable mobility services are essential to the functioning of metropolitan areas. In addition to optimizing route planning and all the new sharing, ride-hailing and renting services, also flexible payment and ticketing options are needed.

Tuomo Parjanen, PayiQ Ltd.
tuomo.parjanen@payiq.net

PayiQ®

PayiQ’s mission is to develop cloud-based multimodal mobile ticketing and payment solutions for transport operators and event organizers. The company’s solutions provide end users with a way to travel door-to-door, by giving them the freedom to combine various means of transport and services as one transaction, using their mobile phones.

PayiQ’s strengths among the various MaaS solutions are effective fraud prevention, versatile and dynamic ticketing options and limitless OEM possibilities for existing systems. At the core of PayiQ’s solutions are sophisticated fraud prevention algorithms that detect potential risks in real-time, so they can be tracked and prevented. The company’s technology is built to be extremely flexible regarding use cases and payment options. New ticketing options are easy to create and PayiQ also provides combination tickets to different means of transport and even to events. One of the much-used features of PayiQ’s solution is the possibility to top up and load travel cards, completely mobile. The company utilizes Microsoft Azure’s cloud services and it can be integrated to any existing service through its open interfaces, whether for providing ticketing services or payment options.

PayiQ’s customers range from cities’ public transport departments and private transport and MaaS operators to event organizers and sports clubs. PayiQ is answering their various needs by moving towards being a platform that allows the integration of payment facilities to all kinds of mobile services. As a versatile ticketing platform PayiQ supports all common payment methods from operator billing and debit/credit cards to various online wallets. At the same time the company is rapidly expanding internationally. Permanent presence has already been established in Sweden, Russia, Spain and Dubai. Far East and Australia are in the pipeline.

Cooperation and openness are essential for thriving in today’s market. PayiQ cooperates with large and small public and private operators and organizations, as well as with various banks and payment facilitators. PayiQ is also active in various smart city collaborations and a member of Microsoft’s CityNext and co-sell programs.

Figure 1: PayiQ provides a combination of tickets to different transport modes.
From pilot projects to an autonomous world: An operator’s experience

Have you ever tried fitting a triangle into a square shaped hole? It’s not easy. As an operator of autonomous solutions, we often find ourselves in situations similar to that.

Peter Sorgenfrei, CEO, Autonomous Mobility
peso@amobility.dk

AV technology to change the world

Autonomous vehicle technology is not just an improvement of the car. Like the internet, it has the ability to change society in fundamental ways. The development can go down different tracks, but ultimately there’s potential for a revolution.

In a world of full autonomy, traffic accidents will decrease massively. This is something to look forward to - but insurance companies might need to find new markets. And maybe we will have to 3D print organs to supplement donation as fewer people lose their lives on the streets?

Consider city planning and urbanisation: With full autonomy, shared solutions and efficient integration with trains and other mass transit solutions, the number of vehicles in the street will drop by maybe 70, 80, 90 percent or more. No more roadside parking, as vehicles will be orbiting or charging. No traffic jams, as the (few) vehicles are controlled by smart, data-driven fleet management systems.

That will lead to a cityscape with more green spaces or housing. And perhaps a decrease in urbanisation, as people can work or enjoy their free time while being transported door-to-door.

Finally, the technology will increase mobility in society. Persons with disabilities, minors and elderly people will get to drive around, and rides will be cheaper - so more people will drive more miles. This would be a problem for congestion and pollution levels, had we not transitioned to green energy, shared capacity and solid integration with mass transit solutions as well.

Expanding operations

This is why we are so committed to driving change and disseminating the technology. Starting with fairly simple and short-termed pilot projects, we will progress step by step and adjust operations to the learnings we gain in the different use cases.

The pilot projects are testing grounds for on-demand solutions. At the hospital in Køge you can push a button on the bus stop sign that communicates to the bus to pick you up. In time, we will be testing on-demand functionality from passengers’ smartphones, making traditional bus stops redundant. In a few years we should have entire cities mapped digitally, and combined with reliable and high-speed connections, the on-demand functionality will be “everywhere” within these areas.

By that time, we expect to have scaled up our pilot projects to fixed operations on various locations. We will cover larger areas with a flexible, demand-driven service.

A transition fueled by coalitions

The goal is achievable, but we don’t want to do this alone, and we shouldn’t. In each of the pilot projects we undertake, we partner up with a range of stakeholders - e.g. in the AVENUE project where 16 European partners demonstrate full scale autonomous solutions in four cities - but other al-
Political ambition to make Denmark a frontrunner should be followed up by concrete dispositions and action plans: Road and traffic authorities should focus on mobility instead of construction work.

As a green nation with a long history of reliable and shared transportation solutions, paving the road for more autonomous and shared solutions is an obvious move. Denmark needs a new success story like the way we developed wind power. Today we have to make a mark in a world that is increasingly challenged by climate change and congestion in the big cities.

In the transformation we’re about to undergo, stakeholders in transportation are not the only ones to push the development. Urban planners and city developers have deep knowledge and should take part in the discussion. Decision makers in job regulation, education, innovation, business regulation and technology have important roles to play, too, since the societal effects are so fundamental. In this early stage there’s plenty of opportunity to shape the development to support the society we want our kids to grow up in.

Let’s raise the bar - collectively! Transportation can be a positive addition to people’s lives. It can improve quality of life and give people a sense of community. Our ambition is to show it, not tell it, and that’s why transporting passengers in real life situations in the streets matter so much for us. But we need more allies in the pursuit of full autonomy. Hop on one of the shuttle buses from Navya that we are operating at ITS World Congress 2018, or find us at our demo with Local Motors at the conference.

By Bjarne Jørgensen, Executive Director (Asset Management), Sund & Bælt Holding A/S

The new project has been created in a close collaboration between KPMG, CN3, IBM and Sund & Bælt. The partnership takes in experience from two decades in asset management, digital technologies, advanced analysis models, budgeting and digital 3D models for visualising the maintenance of infrastructure projects. This experience is now combined in one concept around one of Denmark’s busiest roads. The project has been made possible with the assistance of the City of Copenhagen and HOFOR, the utilities company of the metropolitan area, which has provided data on the infrastructure surrounding H.C. Andersens Boulevard.

Simply put, the project involves translating the knowledge and the huge amount of data collected from the partners, creating a transparency that can shed light on and create an understanding of what happens to H.C. Andersens Boulevard for the rest of its service life.

Transparency in this case is not just a question of being able to analyse the entire value chain. It is also about understanding how policy decisions can affect the road section, whether it is a transition to new materials, revised maintenance budgets, or other policy priorities of a transport nature. Transparency as such, however, is not worth much if it is not translated into concrete action. Therefore, one of the project’s main challenges is, through intelligent use of data, to maximise the maintenance effect resulting from coherence between senior management’s strategic decisions and the engineers’ work processes.

The partnerships were set up at the beginning of 2018 on the initiative of Sund & Bælt, which, using the latest technology, aims to develop and qualify the maintenance of the company’s own facilities. Pilot Project H.C. Andersens Blvd. Copenhagen will be presented at the ITS World Congress in Copenhagen. Come along and listen to the experts on the stand E-079 or in the theatre hall on Tuesday 18 September from 15:30 to 17:00.

H.C. Andersens Boulevard.
New data-driven projects have to develop effective traffic solutions.
Guide to Nordic activities – Nordic Pavilion

In the great exhibit hall at stand number C3-020, you will find the Nordic Pavilion. This is a 144m2 stand organized by the ITS Nordics – ITS Denmark, ITS Sweden, ITS Norway and ITS Finland.

The Nordic Pavilion is a meeting place that contributes to an increased Nordic collaboration and knowledge transfer within ITS solutions.

Nordic Pavilion is equipped with 9 screens, displaying fragments of what the four Nordic ITS organizations have to offer as well as information about their member organizations. The design of the pavilion expresses the Nordic style in light wooden material and with comfortable settings for “hygge” (coziness).

As the theme of this year’s ITS World Congress is “quality of Life”, the Nordic Pavilion is also trying to provide a “quality of life” framework. It is possible for you to meet as well as relax in a nice lounge area or you can join a casual and fun game of table curling.

Reception

Nordic Pavilion invites all interested delegates to our reception at Wednesday 5.30 pm! We offer our guests an appetizer and cold drinks. We hope you will stop by and greet us.

Auditorium with interesting presentations

The entire booth is built around an auditorium with room for 20 persons. Here we will have a series of interesting presentation from the four Nordic countries. Examples include:

- Test results from the first Danish autonomous bus service. Tuesday 9 AM.
- The new traffic model for Copenhagen. Thursday 12.30

Guide to Nordic activities – Nordic Stream

This year, in cooperation with the ITS Nordic Network, the City of Copenhagen has organized a special Nordic Stream across the different congress topics, highlighting the ITS Nordic Way.

Nordic Stream consists of 14 sessions that cover diverse and interesting topics such as Traffic and Management Services, Innovative Multimodality, Autonomous – Automated – Connected Vehicles, Seamless Travelling and Future MaaS Platform. These are all related to the congress’ main topics:

1. Mobility services – from transport to mobility to livability
2. ITS and the environment
3. Connected, cooperative and automated transport
4. Next generation goods delivery
5. Satellite technology applied to mobility
6. Transport network operations
7. Host topic: Cross-border mobility solutions

You can find the Nordic Stream and detailed information about the sessions page 30-31.

What: Nordic Stream is a series of sessions within the field of ITS, highlighting the ITS Nordic Way.

Where: You can join the Nordic Stream in the room called “Stockholm”

When: The sessions spread out throughout the whole congress week 17th-21st of September.

Extracts from the pool of presentations:

Tuesday 9.00-13.00. “The Technical Platform for Seamless Traveling” – Danish representatives from 3 different transport modes talk about technical platforms for MaaS.

Thursday 15.30-17.00 - “Better Mobility with Public Transport” a session tie presentation from Finland, Norway and Denmark about different solutions for public transportation.

Friday 9.00-10.30 - “MaaS in Real Life - The Delegate APP” - about the new Danish MaaS-APP ”Min Rejseplan”. Presentations and benchmarking with other Nordic solutions.

Learn more about Nordic Stream in the Programme.

All 5 Nordic countries are listed at top ten among the happiest countries in the world. Will you join the happiness at Nordic Pavilion?
Innovative signal control increases intersection capacity

The City of Aarhus and Ramboll want to increase the capacity of one of Aarhus’ most busy intersections by introducing variable stage order and variable inter-green times.

In 2016 the City of Aarhus adopted an overall ITS plan, containing a number of innovative initiatives in order to improve road safety and pass ability, along with improving the driving experience in Aarhus.

One of the initiatives is the implementation of a new principle for signal control in one of the busiest intersections in Aarhus. The signal control has three main principles which differs from the traditional Danish signal control:

1. No upper limit for cycle time
2. No predefined phase sequences
3. Variable inter-green times

The above-mentioned principles for signal control have been tested in two separate initiatives on the same intersection using microsimulation in VISSIM.

**Phase sequence adapts to traffic demand**

Traffic is continuously monitored 0-500 m from the intersection by radar, to register various traffic data, including:
- Distance between vehicles in motion (GAP)
- Vehicle type
- ETA at the stop line (Estimated Time of Arrival)
- Number of vehicles waiting at each stop line
- Waiting time at each stop line (measured for the first car to arrive)
- Number of vehicles in each approach.

From this data the signal controller decides which phase is the most relevant, based on traffic demand. The calculations are based on an array of parameters which can be set individually to customize the control to prioritize e.g. trucks or to reduce the overall number of stops.

With no predefined phase sequence, a phase with low traffic demand can be skipped, while other phases with a high traffic demand each can have a second green time. To ensure green time for signal groups with low traffic demand, waiting time for each signal group is monitored and is included in the calculations with its own adjustable parameter setting.

To adjust parameter settings, Ramboll has simulated the intersection with VISSIM. For this purpose, Ramboll has developed tools for simulation of radar ETA functionality in VISSIM using Visual Basic and VISSIM’s COM Module.

**Variable inter-green times**

Traditional inter-green times are fixed and based on conflict zone measurement and estimated vehicle speeds. While these inter-green times are suitable in most situations, situations occur where time is wasted due to inter-green time when traffic has already left the intersection.

Traffic safety is a key issue when using short inter-green times. And since the choice of shortening inter-green times is based on traffic detection, the reliability of traffic data is critical.

To address this, redundant detection is used together with conservative criteria for in which situations inter-green time shortening can be deployed.

As the initiative to some extent may compromise current Danish road regulations in regards of requirements to minimum green and times, a collaboration with the Danish Road Directorate has been established. They participate in project meetings and the development of the principles.
The criteria for reduced inter-green time is that both the approach which has just ended its green time and the conflict area in the intersection must be clear of traffic. Arguably, the criteria could be set for traffic in approaches for which reduced inter-green time could still be allowed, but this has not been included due to traffic safety considerations.

**In complex signal installations with many phases the inter-green times can constitute up to one third of the time.**

### Simulation results

A VISSIM model was made to simulate the intersection using traditional vehicle actuated signal control. The two initiatives were incorporated in similar VISSIM models and results were compared separately to corresponding results from the initial model with traditional traffic control.

Simulation results show a general improvement of passability and an increase in capacity through the intersection for both initiatives.

Since phases with a low traffic demand can be skipped, some turn movement may have an increased queue length and waiting time. At the same time however, the overall queue lengths are reduced.

In the table below, results are listed for total travel time in the VISSIM model and the total number of stops at the intersection. Both initiatives have a significant effect on the number of stops in the model, while overall travel time in the models is also reduced by both initiatives compared to traditional signal control.

<table>
<thead>
<tr>
<th>Car/van</th>
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<tbody>
<tr>
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<td>Total number of stops</td>
<td>Travel time</td>
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<td>-3%</td>
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### Plan for implementation

The signal control is expected to be installed in the first half of 2019 with the first full scale tests during the following summer. The evaluation is to be carried out in the second half of 2019. At the ITS conference in Copenhagen September 2018, the simulation results are presented.

As part of the evaluation, video and drone recordings have been made at the intersection before implementation and similar recordings will be made after implementation. These recordings will be used to compare capacity and pass ability before and after implementation.

Furthermore, video recordings are used for mapping traffic behavior and as evidence for perceived safety at the intersection. Aalborg University will be mapping and analyzing near misses. Finally, the evaluation is expected to comprise an estimation of the expected road-user gains in the form of reduced waiting time and total number of stops, both in relation to installation investments as well as drawbacks for some traffic flows.

Ramboll is expected to lead the preparation of the overall project evaluation and concurrent supervision, that will ensure that the functionality of the installation complies with the described functionalities.

To see the VISSIM simulation of the future signal control please scan the QR-code.

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**Figure 1:** Drone recording of the intersection is used to analyse the behaviour before implementing the new signal control.

**Figure 2:** VISSIM simulation for the intersection Genvejen/Møllevåben/Sletvej with ETA-radar function.

**Figure 3:** Scan the QR-code to see the simulation.
Nordic ITS Cooperation

ITS Sweden is a national ITS organization that was established in 1999 and today have 32 members. There are around 93 national ITS organizations in the world.

Of priority for ITS Sweden is to support the development of robust systems in the digitalization of the transport system in Sweden and to promote Swedish competitiveness internationally. Important areas for ITS Sweden are the coordination and operation of national plans within ITS or "Digitalization within the transport system".

Our task is to support and coordinate a sound development in the area of digitalization in the transport system (ITS), which includes information and communication technologies for efficient, safe and sustainable transport solutions. The organization works in collaboration with, in particular, the Nordic and Baltic ITS Organizations and the 27 sister organizations in Europe.

ITS Sweden have an important role to play in Sweden. The big thing for Sweden right now is to bring together all actors and create concrete plans. We have been very active here, but we have lost momentum and the Copenhagen Congress will be an important meeting place.

The development of intelligent transport systems is going very fast right now. What’s exciting is not just the technology itself, but also how more demands are put on environment, efficiency, safety and robust systems. Key customer requirements are shared transports, car-sharing, autonomous vehicles and alternative fuels.

Among the members of ITS Sweden are the Swedish automotive industry, consulting companies, several universities, science parks, major cities like the city of Stockholm and the city of Gothenburg, as well as the Skåne region, the Swedish Transport Administration and the Swedish Transport Agency.

Other priority areas for ITS Sweden include connected and collaborative systems, ITS in the planning and investment process, ITS in Cities, energy efficiency, public transport, mobility as a service, intelligent freight transport, city logistics, unprotected road users, urban traffic management, C-ITS, and E-call.

Come and visit us and our members at the Nordic pavilion, stand no C3-020 at the ITS World Congress in Copenhagen.

You can find more information here www.its-sweden.se.
Mobilizing an Urban District with Driverless Busses

Aalborg Municipality has, as the first in Denmark, submitted an official application to the national Road Directorate for the use of driverless busses. The driverless busses are intended to increase mobility with self-driving technology on a pathway in Aalborg East, allowing more people to get around in an easy, safe and sustainable manner. The project is supported by both the local community and by the business network, and has many stakeholders.

Maria Quvang Harck Vestergaard, The City of Aalborg
maria.vestergaard@aalborg.dk

Ditte Bendix Lanng, Aalborg University
dbla@create.aau.dk

Søren Risdal Borg, Aalborg University
srbo@create.aau.dk

An urban district in transformation
Aalborg East is one of the largest and most dynamic suburbs in Aalborg. In a number of ways, the district is characterized by its planning in the 1960s which, according to functionalist principles, created a traffic efficient but also physically and socially sharply divided district where cars and soft road users are separated, and many residential areas appear as isolated enclaves, without strong inter-relationships. During the latest years, the district has undergone a large transformation process with comprehensive housing renovations and new constructions.

Today, most public transport in Aalborg East moves on an east-west axis, which makes a north-south movement internally in the area impossible with this type of transportation. Thus, the less mobile population groups can be excluded from activities even close to their homes and can generally become highly segregated.

The separated infrastructure and the distance between the different functions and activities in the district do not encourage multimodal transport, and cars are used for a large part of the trips. However, less than 50% of the residents of Aalborg East have access to a car.

By implementing this driverless bus, increased accessibility aims to help mobilize a number of citizens, as well as enhance both environmental and social sustainability. The project supports the ambition of creating a more cohesive Aalborg East, where increased mobility is counteracting segregation and strengthening social capital. Access possibilities for wheelchairs etc., as well as the fact that the bus will be free of charge, makes the bus an ideal transport option for children, elderly, pedestrians,

Figure 1: Astrupstien (photo: Ditte Bendix Lanng).
wheelchair users and other groups with low car accessibility and mobility.

At the same time, Aalborg East - being the first to implement driverless vehicles in a Danish context - will make the district a first mover on driverless vehicles, using innovative technology as a mean to boost the image of Aalborg East. This is intended to create a positive attention and publicity about the neighbourhood, which in some contexts is associated with insecurity and other social challenges.

The pathway as a new spine for public transport

The Astrupsti connection is today the central connection for north-south movement for cyclists and pedestrians and it can act as the possible missing link between the northern and southern part of Aalborg East for public transport. However, it is not economically viable to implement a standard bus solution on Astrupstien, and therefore this project investigates whether a driverless bus without the cost of chauffeurs is an option that can have several other positive effects.

The test route

As a test route, the pathway from Lejerbo’s apartments at Skallerupvej and Jerupstien in the north to the southern part of the pathway at Torhøjskolen and the newly opened dementia care centre is used. The length of the test route is approx. 2.1 km and there are 10 stops on the route where passengers can get on or off.

On the test route, the busses will be driving on Astrupstien and on Jerupstien on a bus and bicycle track. Both pathways combined are today approx. 6 meters wide along the entire route, where a grass verge divides pedestrians and cyclists. In order to accommodate the buses on Astrupstien, the pathway is expanded from today’s approx. 6 meters to a divided track totalling 6-10 meters.

The busses will be able to pass each other in the bus and bicycle track, but not in the tunnel under Smedegårdsvej and immediately north of this as an expansion of the track is not possible in these areas.

Timing and Legislation

The Danish Parliament passed a change of the Danish Traffic Act that came into force July 1st 2017 allowing for testing of driverless vehicles on SAE-level 3 and 4. A project can apply for a permission for testing driverless vehicles for a maximum of 2 years (with a possibility to re-apply for two more years) on a predefined geographical area. This is the period that is applied for in this project.

The application for this project was sent in the beginning of July 2018, and now follows 3-4 months expected processing time before the test will start in late fall 2018.

Passengers should perceive the bus as safe to use, as there will be an operator or a safety guard present for a start-up period, ensuring a safe ride and providing information to the passengers. Likewise, the busses will act as a safe element in the district, as it will create more life along the pathway.

When the project is fully implemented, it will be driving on SAE-Level 4 without an operator on board. Instead, it will be remotely monitored.

The driverless bus, ARMA

The test route will be serviced with NAVYA ARMA busses, with room for 11 seated passengers. Three electric buses are used, two of which will be in operation at a time while the third will be charging. The busses are designed to drive on a predetermined route and thus not with input from a map or on unplanned areas and roads.

Basically, the bus is built over the principle: If there is anything that it cannot figure out - then it stops.

When the implementation is final, it is expected that the bus will drive with a maximum speed of 23 km/h.

The busses are equipped with a multisensory technology, where the sensors are able to communicate and compare their data to optimize the bus’s decision-making:

- LIDAR sensors: 3D perception. The lidar draws a virtual image of its surroundings and it maps the environment allowing for precise positioning and ensuring that obstacles are detected.
GPS RTK: RTK is a communication between a GPS sensor and a fixed motionless base station on the ground that determines the exact position of the vehicle, which allows navigation with centimetre accuracy.

Odometry: Mechanical measurement of vehicle movement and wheel speed, to determine vehicle speed and confirm its position.

Camera stereovision: Detects obstacles and estimate their position relative to the vehicle.

Evaluation and research
The project will contribute with knowledge about how a driverless bus can become part of an existing urban area. For this reason, Aalborg Municipality has established a collaboration to evaluate the trial with Aalborg University and Nordjylland Trafikselskab (NT). One part of the evaluation deals with the operation, conducted by NT, while the other part primarily will include qualitative evaluations of the integration of city, people and technology. This part is conducted by the Centre for Mobility and Urban Studies (C-MUS) from Aalborg University.

The evaluation conducted by C-MUS aims to create knowledge about the effects of the implementation of the driverless bus. This will examine how the new infrastructure and technology will integrate with the existing urban district, e.g., its physical character and urban life, including how it will be part of everyday life, i.e., how citizens and users will perceive and use the new infrastructure and technology, whether they can decode it and how it is used.

As knowledge about the effects of the new infrastructure is collected, the project will contain a special focus on evaluating sense of security and ownership. Firstly, on users’ and citizens’ sense of security in the district in relation to the driverless bus, as well as their perception of new situations that arise in and around the bus itself, which are relevant to safety. Secondly, on how public ownership of the bus is perceived and created; the extent to which different user groups accept the new infrastructure and technology and their perception of it as a new addition to the service to the local area and everyday life.

Nordjylland Trafikselskab (NT) will conduct an evaluation of operations. This includes documentation and data collection about bus driving, ‘uptime’, timeliness and other events that may occur. This will be supplemented by counting of passengers, cyclists and pedestrians, as well as examination of how the bus is used.

The “bigger picture”: new technology in planning
Though the scope, the purpose and the setting for this trial project is focused and limited, the project is carried out to gain experiences and learning points for further navigation in ‘the bigger picture’ of a driverless future. Hence, the knowledge created in this project will contribute to answering some of the big questions that awaits future decisions on self-driving technology:

Safety and security – How are the sense of security affected by the bus and on the pathway in the area? Can the new technology be used as a reassuring action?

Which effects does the technology have on the physical surroundings? Which effects can driverless technology have on existing urban districts, and to what extent will it change the design of future cities?

How reliable is the technology? Who uses it and what is it used for? How can this technology help mitigate other problems in the future? How can this project be scaled to other contexts and geographies?

"Connecting people with technology" – What happens in the meeting between humans and driverless technology? How does this affect future society, and how will local communities perceive it and, perhaps, want to adapt to it?

In these years, self-driving vehicles is only a small part of technological development that affects our society and mobility. If we are to decide what kind of cities and mobility we aim for in the future and if we want to expand citizens’ possibilities to carry out sustainable mobility (both social, ecological and economical), we need to gain experiences now on how to build future mobility planning. Perhaps this project is can help answering the question of how we can embrace technology in city and traffic planning and make informed decisions when we plan our future cities.
Using machine learning and radar detection to improve efficiency of signal-controlled intersections

This article presents new principles for managing signal-controlled intersections. By using machine learning and radar detection a controller has been developed using the optimization tool UPPAAL Stratego. Using VISSIM, the controller has been tested in four signal-controlled intersections. The simulation shows that in comparison with the existing controller, this controller provides a reduction of between 30% and 50% in average delays, queues and number of stops in all four intersections. Moreover, the fuel consumption and total travel time through the four intersections are reduced by about 20%.

Harry Lahrmann, Advanced Traffic Systems
hsl@at-systems.dk

Mikkel Færgemand Hansen, COWI
MIFM@cowi.com

Kim Guldstrand Larsen, Advanced Traffic Systems
kgl@at-systems.dk

Introduction

One of the biggest problems in the world’s big cities is traffic congestion and many fronts work to reduce congestion, both on the demand side and on the supply side. On the supply side, we can build more roads or execute traffic more efficiently. In case if traffic is to be executed more efficiently, the signal-controlled intersections is the crucial element, as these intersections determine the capacity of urban roads. There is thus a great potential for less congestion if capacity can be improved here.

Traditionally, signal-controlled crossings are time-controlled - first green in one direction and then green in the other direction for some time periods. A variation of these has been the introduction of green waves where contiguous signal systems, for example on an approach route to a city, have been adapted so that road users on the route could drive through a number of intersections without stops by driving at a predetermined speed.

There is also traffic controlled signalised intersections that typically measure arriving vehicles before the stop line and extend the green time if there are still arriving vehicles when a minimum green time is about to expire. Finally, we have signal control systems that measure traffic at points in an entire network and then try to optimize the signal settings – e.g. systems like SCOOT and SCATS.

Common to today’s systems, however, is that they either have no optimization in relation to current traffic or this optimization is very primitive and works with very long delays. In Denmark it is estimated that the annual societal costs of a signal-controlled intersection amount to EUR 650,000 of which delay related costs represent 69% [Vejdirektoratet 2012].

Traditionally, input to traffic control of signal-controlled intersections has been inductive loops that detect passing vehicles, thus giving a spot measurement in the section the loop is located at. However, in recent years traffic radars have been introduced on the market, enabling continuous measurements of position, course and speed of all objects heading towards the intersection. Thus, it is possible to continuously provide an estimated time of arrival (ETA) of the individual vehicle. Such information will allow for completely new and much more effective optimization methods than previous used.

Method

In Advanced Traffic Systems, for the last two years, we have been working on developing optimization algorithms that are able to utilize the numerous additional traffic information that a continuous flow of information about the individual vehicle provides.

The starting point for us have been to use modern optimization techniques to optimize traffic flow in signal-controlled intersections. Others have done this before [Mousavi 2017; Genders 2016; El-Tantawy 2013; Balaji 2010; Sanchez-Medina 2010]. In our solution, we use UPPAAL Stratego for online synthesis of optimal control for a signal-controlled intersection. UPPAAL Stratego is an optimization tool that combines machine learning and model checking techniques to synthesize at run-time.
a near-optimal control strategy for signal management [David, 2015]. Importantly, and in contrast to above-mentioned references, our solution requires no training phase (say for training a Neural Network). In fact, our method will instantaneously adapt to any changes in the pattern of traffic, and will allow online change of optimization criteria. We optimize the signal setting based on reinforcement learning using continues input information about all vehicles within 200 meters of the intersection stop line. UPPAAL Stratego can use several parameters in its optimization, such as queue length, number of stops, delay, vehicle type and fuel consumption; however initially we only optimize so as to minimize the overall delay.

To test our method, we simulated traffic on a road section with four signal-controlled intersections with the VISSIM simulation tool. We have modelled the four intersections with the existing traffic into VISSIM and then simulated traffic flow with the existing controller (exploiting green wave) and our new UPPAAL Stratego controller exploiting continuous data from arriving traffic at a distance of 200 meters from the stop line. For evaluation, we compared the difference between the existing controller and the UPPAAL Stratego based controller.

The route was a section on Hobrovej in Aalborg, Denmark which has an ADT of 20,000-30,000 vehicles. Three of the intersections are today coordinated in a green wave with fixed cycle time, minimum green time, traffic dependent shortening of the green times and phase order. The fourth intersection is independent of the others and is traffic controlled. In the test, we used intersection counts in the morning peak hours from 7:00 to 9:00. Pedestrians and cyclists are not included in this evaluation.

Results

From the VISSIM simulations we discovered that the mean delays were reduced by between 28% and 53% in the all four intersections and that the 95% quantile queue lengths were reduced by between 42% and 64%. In addition to the effect in each intersection, the effect is measured on travel time of the entire route. The travel speed for the south bound traffic was on average increased from 38 km/h to 43 km/h, and for the northbound traffic, the travel speed was increased from 34 km/h to 42 km/h.

Table 1 shows more detailed data about delay for the (busiest) intersection Hobrovej / Ny Kærvej / Vestre Allé and shows improvements on all parameters and from all directions. The simulation results show that the mean delay is reduced from 20 to 9 seconds, corresponding to a reduction of the mean delay by 53%. The greatest impact has been for the traffic from side roads, where the average delay per vehicle for some directions is reduced by half a minute.

Table 1 shows the 95% quantile of queue length with the two controllers. It appears that for the most congested direction, queue length is reduced from about 200 m to 8-20 m. On average, the queue lengths decrease by as much as 64%, equivalent to 45 m. It also appears that the queue lengths in all directions are reduced.

Discussion and conclusion

Today there are many systems for adaptive signal management but the basic algorithms are in almost all systems relatively primitive. Typically, they are based on discrete information in points and can choose between predefined settings - such as extensions, phase order or different coordination programs. [Gautier 2001; Agerholm 2013; Krøyer 2008; Kronborg & Davidsson 2004].

Through microsimulation with VISSIM, we have demonstrated that our controller based on the UPPAAL Stratego optimization algorithm makes traffic significantly

**Table 1: Average delay with existing controller and new controller for Hobrovej/Ny Kærvej/Vestre Allé.**

<table>
<thead>
<tr>
<th>Traffic flow</th>
<th>Average delay (Hobrovej/Ny Kærvej/Vestre Allé)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Existing controller</td>
</tr>
<tr>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>Hobrovej S</td>
<td>Hobrovej N</td>
</tr>
<tr>
<td>Ny Kærvej</td>
<td>Vestre Allé</td>
</tr>
<tr>
<td>Ny Kærvej</td>
<td>Hobrovej S</td>
</tr>
<tr>
<td>Vestre Allé</td>
<td>Ny Kærvej</td>
</tr>
<tr>
<td>Vestre Allé</td>
<td>Hobrovej S</td>
</tr>
<tr>
<td>Vestre Allé</td>
<td>Hobrovej N</td>
</tr>
<tr>
<td>Ny Kærvej</td>
<td>Hobrovej N</td>
</tr>
<tr>
<td>Hobrovej S</td>
<td>Ny Kærvej</td>
</tr>
<tr>
<td>Hobrovej S</td>
<td>Vestre Allé</td>
</tr>
<tr>
<td>Hobrovej N</td>
<td>Ny Kærvej</td>
</tr>
<tr>
<td>Hobrovej N</td>
<td>Vestre Allé</td>
</tr>
<tr>
<td>Hobrovej N</td>
<td>Hobrovej S</td>
</tr>
<tr>
<td>Weighted average</td>
<td>20</td>
</tr>
</tbody>
</table>
more effective than the existing controller as regards average delay, queue length, number of stops, fuel consumption and overall travel time. All parameters were improved in the four intersections and in addition, the total travel time in the previously coordinated route was also significantly improved.

Cyclists and pedestrians have not been included in the current study. It is difficult to estimate how the results would be affected if they had been included, but there is no reason to believe that they could affect the difference between the two simulations significantly.

In summary a great optimization potential appears to exist in signal-controlled intersections using UPPAAL Stratego for the optimization of traffic in a single signal-controlled intersection instead of today's principles based on discrete observations and coordinated signal systems.

The next step will be to demonstrate that the convincing simulation results from this first VISSIM test can be repeated in real traffic. We have an ongoing project with Aarhus Municipality, where our controller will be installed and tested in an intersection in Aarhus, and we expect to be able to present results from this test in the near future.

References

Table 2: Queue lengths (95% quantile) with existing controller and new controller for Hobrovej/Ny Kærvej/Vestre Allé.

<table>
<thead>
<tr>
<th>Traffic flow</th>
<th>Queue length, 95% quantile</th>
<th>Existing controller</th>
<th>UPPAAL Stratego controller</th>
<th>Number</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>From To</td>
<td>[m]</td>
<td>[m]</td>
<td>[veh.]</td>
<td>[m]</td>
<td>[%]</td>
</tr>
<tr>
<td>Hobrovej S</td>
<td>Hobrovej N</td>
<td>87</td>
<td>36</td>
<td>1819</td>
<td>-51</td>
</tr>
<tr>
<td>Ny Kærvej</td>
<td>Vestre Allé</td>
<td>41</td>
<td>25</td>
<td>340</td>
<td>-17</td>
</tr>
<tr>
<td>Ny Kærvej</td>
<td>Hobrovej S</td>
<td>18</td>
<td>14</td>
<td>174</td>
<td>-4</td>
</tr>
<tr>
<td>Vestre Allé</td>
<td>Ny Kærvej</td>
<td>200</td>
<td>31</td>
<td>411</td>
<td>-169</td>
</tr>
<tr>
<td>Vestre Allé</td>
<td>Hobrovej S</td>
<td>193</td>
<td>8</td>
<td>139</td>
<td>-185</td>
</tr>
<tr>
<td>Vestre Allé</td>
<td>Hobrovej N</td>
<td>183</td>
<td>17</td>
<td>147</td>
<td>-166</td>
</tr>
<tr>
<td>Ny Kærvej</td>
<td>Hobrovej N</td>
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<td>20</td>
<td>333</td>
<td>-17</td>
</tr>
<tr>
<td>Hobrovej S</td>
<td>Ny Kærvej</td>
<td>21</td>
<td>8</td>
<td>290</td>
<td>-13</td>
</tr>
<tr>
<td>Hobrovej S</td>
<td>Vestre Allé</td>
<td>11</td>
<td>6</td>
<td>159</td>
<td>-4</td>
</tr>
<tr>
<td>Hobrovej N</td>
<td>Ny Kærvej</td>
<td>18</td>
<td>9</td>
<td>252</td>
<td>-9</td>
</tr>
<tr>
<td>Hobrovej N</td>
<td>Vestre Allé</td>
<td>6</td>
<td>4</td>
<td>95</td>
<td>-2</td>
</tr>
<tr>
<td>Hobrovej N</td>
<td>Hobrovej S</td>
<td>35</td>
<td>23</td>
<td>1,337</td>
<td>-12</td>
</tr>
<tr>
<td>Weighted average</td>
<td></td>
<td>70</td>
<td>25</td>
<td>5,495</td>
<td>-45</td>
</tr>
</tbody>
</table>
Preparing Tomorrow's Innovators

The digital revolution is transforming transportation to serve an increasingly connected world. At Halmstad University, an important part of our mission is to prepare innovators to lead this transformation. Tomorrow’s innovators must wield a broad range of technical and social skills. More importantly, they must be able to pursue new knowledge and expertise when they need it. Here, we describe our approach to preparing tomorrow’s innovators at our School of Information Technology at Halmstad University.

The School of Information Technology offers a range of closely-coordinated degree programs at both undergraduate and graduate levels. These programs make extensive use of five methods that are essential for preparing future innovators:

1. Focus on externally recognized problems, e.g. real-world problems or challenges
2. Co-production with the private and the public sectors
3. Interdisciplinary team work
4. Systems integration
5. Research literacy.

When it comes to learning, how is as important as what. These five methods cultivate the skills needed to manage one’s own focus and time, collaborate with peers with different skills, and function in the context of the complex and rapidly evolving technological landscape.

Teaching For Real

Each degree program involves a series of increasingly larger projects, culminating in a development project and a thesis project. Each year, the results of various projects are presented at a university-wide public exposition, involving partners from the private and public sectors. The development projects exemplify how we put all five methods to work: Students select a problem from among offerings, provided mostly by external partners.

For engineering programs, students work in groups of four, one coming from each program (Computer Engineering, Electrical Engineering, Mechatronics, and Intelligent Systems). Thesis projects are similar, but are done in smaller groups and have more emphasis on scholarship.

Our Development Projects consistently win external competitions in a wide variety of domains. In the transportation sector, two high-profile awards were the Grand Cooperative Driving Challenge (GCDC) and the National Science Foundation Cyber-Physical Systems (NSF CPS) Challenge. GCDC 2016 was an international competition where teams from around Europe participated, and our students built and deployed cooperative driving functions and won first place (figure 1 is a photo of the team).

They were later invited to write articles describing their approach in IEEE journals. The NSF CPS Challenge held in U.S. was another international competition that involved designing, building, and deploying an unmanned aerial rescue vehicle, and our students won second place, but was the top team that competed fully autonomous (figure 2 is a photo of the team). In addition to providing a unique experience for students, participation in such competitions or research projects often leads directly to attractive opportunities for employment or advanced studies.
Finally, we also offer flexible study programs aimed at continued education. These programs allow people working in industry to follow courses on an advanced level to sharpen their skills in our areas of expertise. Our most recent addition here is a program directed at designing digital services around artificial intelligence technologies.

The Research We Do

As the transportation sector continues its current, rapid evolution, a wide range of challenges emerge that can only be addressed through world-class research. These challenges range from global and societal to the individual and microscopic. To address this broad range of challenges in an agile manner, the School of Information Technology at Halmstad University organizes its research into four technology areas:

**Digital Design** (depicted in figure 3) integrates Information Systems and Human Computer Interaction research. The focus of this research area is on understanding the user, and on how value is created for users, organizations and societies through combining, re-combining and integrating resources into digital services. It also addresses the wellbeing of different societal actors. Our core competence areas include innovation process knowledge, digital service and business innovation, digital ethnographic, interaction design and design science. We often use qualitative research methods such as qualitative interviews, focus group and workshop methods (e.g. co-design, participatory design, personas) participant observation, and design ethnography.

**Artificial intelligence** (depicted in figure 4) is about building systems that behave intelligently. Traditionally, human experts define the task to be performed, what data should be collected, how to represent it, and what metrics to use for evaluation. But this means that when the context changes, these systems break. Our goal is systems that can-do lifelong learning and require less supervision and can handle unexpected situations. We focus on creating systems that, as autonomously as possible, construct knowledge from real life streaming data to capture the interaction with the environment.

We collaborate with many industrial partners, especially in the transportation domain. A recent project used our methods to improve transportation system efficiency through better maintenance and monitoring solutions. The research questions we explore include selecting what data to collect and how to find general and robust representations; how to do (semi-)autonomous deviation detection, dealing with concept drift and seasonal variations; how to associate events from different data sources; is it possible to explain why certain things have happened? Because we focus primarily on systems problem, we often build demonstrators to showcase our results and a broad range of tools.

**Cyber-Physical Systems** (depicted in figure 5) is concerned with addressing problems that arise in any system connecting digital and physical subsystems. Our expertise in this area include real-time communications and model-based design methods. This includes 5G and 802.11p technologies as well as methods for specification, implementation, simulation, testing, and verification. Model-based methods can consider a wide range of dynamics and effects, such as continuous and discrete time dynamics, discretization, quantization, non-determinism, and randomness. In the transportation sector, projects have addressed rigorous virtualization of safety testing and the design of real-time communication infrastructure for ITS.

**Smart Electronic Systems** (depicted in figure 6) is concerned with the hardware and physical aspects of computing and communication. Our expertise in this area include massively parallel embedded computing architectures, nano-electronics and photonics, high-frequency electronics, antenna design, radio, radar, electromagnetic interference and compatibility, and building practice for components and systems. In the transportation sector, an example of our efforts is addressing the radar interference problem, which currently prevents any significant fraction of vehicles from using radar due to interference effects.
Providing a Link to mobility’s future

Upgrades to the Storebæltbroen’s road tolling facilities will treble capacity, removing the need for travellers to stop and pay, and reducing congestion and pollution. Norwegian company Q-Free is providing the state-of-the-art video and supporting technologies which will make it all happen.

Q-Free, a Scandinavian Intelligent Transport Systems (ITS) provider, has made its first appearance in the Danish road management sector – and it has done so in a huge way, by gaining a NOK70m (DKK54m/US$8.4m) contract to upgrade and support the tolling system on Denmark’s most prestigious engineering project, the Storebæltsbroen (Great Belt Fixed Link).

Opened in 1998, the Storebæltsbroen is a multi-element construction which crosses the Great Belt strait between the Danish islands of Zealand and Funen. It consists of several structures: a road suspension bridge and a railway tunnel between Zealand and the small island of Sprogø which is located in the middle of the Great Belt; and a box girder bridge for both road and rail traffic between Sprogø and the island of Funen. The 1.6km main span of the Link’s suspension bridge, officially known as the East Bridge, is the world’s third-longest, and the longest outside Asia.

Together with the Øresund Bridge, the Storebæltsbroen is having a transformational effect on road access from Continental Europe to Northern Scandinavia via Denmark. The previous 90-minute ferry crossing has been reduced to a 10 or 15-minute car journey, and this ease of use has had a corresponding effect on volumes of traffic – total numbers of vehicles crossing the Great Belt increased by 127 percent in the first year of operation alone. The average number of vehicles per day using the Link now stands at 30,000, and peaks of 50,000 vehicles per day have been recorded.

This has resulted in a pressing need to upgrade the Link’s current road tolling systems, which have been in operation since 1998.

To date, the Link has used tried-and-tested stop-and-go barrier systems combined with card payment. A small number – 4 out of a total of 24 – of express lanes use transponders based on wireless Dedicated Short-Range Communication (DSRC) technology to enable payments.

Capacity is a problem; with traffic levels continuing to grow, congestion and pollution are increasing issues. The ‘user experience’ at the Link is also affected, both in terms of the time travellers spend queueing to cross, and because of travellers’ confusion over which lanes to use.

Increasing capacity

A/S Storebælt, the Link’s operator, therefore looked for ways to increase the tolling system’s overall capacity and improve traffic flows. A clearly stated ambition was to increase the number of express lanes and treble vehicle throughput. A dialogue with potential bidders was started by A/S Storebælt in August 2017, and a Request for Tenders was issued in September 2017 as a European Bid Project with a pre-qualification phase.

Four companies tendered, and their Full & Final bids were assessed against a total of 230 KPIs. The competing companies were assessed against a series of five main categories. Out of a possible total score of five, we achieved a very good score of 4.79. Our nearest competitor achieved 3.7, so we far outstripped the competition – ours was a clear win, and not one just based on a single factor such as price.

The Q-Free solution is to complement the DSRC transponders with ‘pay by plate’.

Making mobility healthier

Copenhagen, the host city of this year’s ITS World Congress, has a well-earned reputation as one of the best cities in the world for cyclists.

Q-Free has developed and delivers ITS solutions which support and promote cycling as part of efforts to improve mobility’s environmental performance as well as individuals’ health and safety, and at this year’s World Congress, the company will take this a step further.

It will offer visitors to the Congress the opportunity to experience a series of practical ITS solutions which support safety and efficiency in an urban setting. Visitors will use electric bikes and be guided through a city environment with the help of visual and audio information from tablets and wireless earbuds. Participants can choose between a short or a long route (100m or 2km) and will score points depending on their behaviour in traffic. A prize will be awarded each day to an urban cyclist, and wireless earbuds and helmets will be provided free of charge.
which will use video technology to read vehicles’ license registrations. This involved a complete redesign of the Link’s tolling facilities and reflects video’s growing capabilities.

Transponder-based DSRC has long been the class-leading technology for tolling and remains a very viable solution, as does so many things very well – for instance, you can use it to deliver a whole range of value-added services, such as payments for fuel, parking, fast food and so on.

Video doesn’t replace DSRC but for discrete applications such as single-lane tolling its performance level is now coming very close. From a tolling concession’s perspective, it’s very attractive because it’s less expensive in terms of the system itself, and also because the concession doesn’t have to get involved in the logistics of procuring, distributing, servicing and taking back tags at end of life.

Q-Free has been able to take advantage of developments in consumer electronics to produce a solution with the necessary performance for the Storebælt bridge. The sensor technology used in the cameras in smart phones has developed at a tremendous rate over recent years, and will continue to do so. The sensors in typical smart phones are 2µm in size and the image resolutions they can achieve are now of professional quality. In our cameras, we use a 1in-sized sensor array of the same sensitivity to achieve the performance we need.

A/S Storebælt elected to retain barriers as a guarantee of payment. However, vehicles without transponders no longer have to stop. Instead, two licence plate readings are taken – a front plate reading at 25m from the barrier, and a rear plate reading at 15m. With identification established, the barrier then opens.

Removal of the need for stop-and-go payment will allow Link users to pass through at speeds of up to 50kmh. Throughput per lane will be increased to 900 vehicles per hour.

This is a major improvement in terms of performance and user experience, and is supported by a range of payment options. Link users can pre- or post-pay – when they sign up to pay by plate, they download an app through which they submit their bank details. Deductions from their designated accounts can then happen automatically. We’ve also retained two lanes for cash payments and will be installing new payment machines. We’ve therefore completely automated payment in the running lanes and increased safety by removing human operatives.

Q-Free is also supplying the operational back office for this project – again, that represents a fundamental overhaul of how operations will be carried out, as the old system will be completely replaced. We’re also going to be responsible for maintenance.

Delivering a world first

Application of video technology of this type for bridge tolling operations is a first for Q-Free and also a world first.

Systems deliveries started in July 2018. The current technology will be replaced on a lane-by-lane basis, with final works due to be finished by the autumn of 2019. This is being done to ensure that the Link’s operations remain as undisrupted as possible but presents challenges in terms of both operative and traveller safety.

Fortunately, Q-Free has a proven pedigree of replacing in-service systems. Back in 2015, the company completed an upgrade of the City of Oslo’s tolling system with minimal interruptions to service or – crucially for a tolling system – revenue collection.

The work we did in Oslo in 2015 still provides a benchmark for the successful in-operation replacement of a live tolling system. It showed how replacing an existing toll system with a new one can be swift and painless, with the least possible loss of revenue.

We faced severe financial penalties if individual gantries were out of operation beyond a specified period but completed the installation work a month early, and without incurring penalties. More importantly, our great emphasis on health and safety meant that over a period of 10 weeks, with 35 nights of installation work on the road and on average 10 people involved, there were no serious injuries or damage.

The keys to success were proper planning at each site, teams of engineers who were well-drilled and fully aware of each other’s tasks, adequate spares provision, planning to cater for any eventuality, pre-testing and deployment of equipment in advance, and good cooperation with the customer and road authorities.

Regional pride

Another aspect of the project which cannot be dismissed is the involvement of a ‘home’ company in the realisation of such a prestigious project.

The customer places great stock in the fact that a Scandinavian company was successful in winning the business. That’s not based on protectionism or on less-than-positive motives. It’s based on the excellence of the technology proposed and on the levels of commitment Q-Free as a company is willing to bring to bear.

On the back of the Storebælt bridge project we’ve already opened a new office in Denmark, which is sited just 2km from the Link itself. It’s important to us to anchor ourselves with the customer and with sub-suppliers with the right levels of experience. We’ve now got people on board locally who’ve been involved with the Link for 20 years.

Q-Free provides a comprehensive range of ITS solutions which can address all manner of road financing and mobility needs, and delivery of a successful solution here is fully intended to be a springboard into other major projects in the Danish market.
Scale up intelligent traffic solutions; supporting a CO₂ neutral Copenhagen

A sustainable city requires sustainable mobility. In 2013, the City of Copenhagen started working on a new generation of intelligent traffic solutions. The first step was to upgrade the traffic signal controllers. As a second step, the City organized a Public-Private Innovation (PPI), in which it challenged the industry and knowledge institutions to come up with innovative, yet realistic ideas for new intelligent traffic solutions. The third step builds on the successes of the first two steps and includes traffic signal optimization along a set of corridors, introducing a sensor network and a city traffic management system. The main question for the City of Copenhagen after the third step is now: “How to scale up the successful solutions and the use of these solutions in order to create a big impact and contribute significantly to the goal of being CO₂ neutral by 2025?”. This question will be answered in this article.

Mads Gami, City of Copenhagen, The Technical and Environmental Administration, Traffic Unit
FG5Q@tmf.kk.dk

Paul van Koningsbruggen, Technolution, The Netherlands
paul.van.koningsbruggen@technolution.nl

A sustainable city asks for sustainable mobility

As with many growing cities in the world, Copenhagen must cope with a growing population and corresponding growing traffic demand that put pressure on the cleanliness, safety and sustainability of the urban environment. The City of Copenhagen deals with the challenges in two ways. First of all, the city formulated a clear political goal: CO₂ neutral in 2025. Secondly, the city formulated a new political vision titled “Community Copenhagen”.

About the year 2013, the City of Copenhagen started working on a new generation of intelligent traffic solutions. To this end, the City upgraded as a first step its traffic signal controllers through the city. As a second step, the City organized a Public-Private Innovation (PPI) from November 2013 to April 2014. The third step builds on the successes of the first two steps and includes:

- traffic signal optimization along a second set of corridors
- bringing in place sensor network to monitor the traffic conditions in the city and a city traffic management system (CTMS) to conduct network wide traffic management using the sensor network data
- bring a subset of the PPI solutions to technology Readiness Level 9 (‘Actual system proven through successful mission operations’) and implement them on modest scale on the streets of Copenhagen: information service and variable message signs for cyclists, (C-ITS based) ecoDriving for most of all heavy traffic, intelligent street lighting and car parking in a dynamic urban space.

The six solutions are now fully operationalized and tested in 2018. In order to prepare and focus the next steps, two questions should be answered, namely:

- Question 1. “Looking through the delivered solutions, have we been smart in designing and implementing the solutions?” This question is answered in the article Intelligent traffic solutions for a clean safe and sustainable environment in Copenhagen to be found in this issue of Traffic and Roads.
- Question 2. “How to scale up the successful solutions and the usage of these solutions in order to create a big impact and contribute significantly to the goal of being CO₂ neutral by 2025?”. This question will be answered in this article.

The magic themes for scaling up intelligent traffic solutions

Creating a big impact with intelligent traffic solutions and contributing significantly to the policy goals of a city (in this case Copenhagen) asks for:

- multimodality of the ITS solutions
- openness of the ITS solutions so the city can keep on building and including new and promising ideas and technologies
- cost efficient large-scale roll-out and mass adoption by road users
- evidence based continuation.

These magic themes for scaling up intelligent traffic solutions will be elaborated on separately.
Multimodality of the ITS solutions

Ensuring that Copenhagen keeps its place among the cities in the world with the highest quality of life, and remains to be known in the world for its climate and environment initiatives, requires a holistic approach. Increasing green mobility, i.e. cycling, public transport and electric vehicles should be aligned with reducing power consumption and using energy from renewable resources such as wind and water.

Some reflections on the six delivered intelligent traffic solutions:
- The sensor network is obtaining traffic data for cyclists, buses, motorcars and pedestrians in the city.
- Cyclists have their own information service that is used to provide cyclists with dedicated information via variable message signs.
- Road safety for cyclists and pedestrians can now be maintained in a city that lowers the illumination levels of the street lights in the dark hours, by increasing these illumination levels at those moments’ cyclists and/or pedestrians’ approach to cross the intersection.
- Traffic signals are optimized for cyclists, buses or motorized traffic depending on the corridor.
- The first parking places can be shared by cars and the residents of the street, who can use the parking place as extension for their shop, bar or restaurant.
- The C-ITS based ecoDriving technology is provided to trucks (heavy traffic), passenger cars and cyclists.

By making the intelligent traffic solutions ‘multi-modal by design’, the city can bring forward its holistic approach on green mobility the oncoming years.

Openness of the ITS solutions

Scaling up requires openness of the delivered intelligent traffic solutions, simply to prevent that the city is blocked by a vendor lock-in or by the costs that come with scaling up. Openness can be looked upon from a technical, operational or data perspective.

Technical openness of the delivered ITS platform

These intelligent traffic solutions are based on an open architecture. A central point in this architecture is that the CTMS binds a series of data sources and makes it possible to fine-tune the solutions on-the-fly. The architecture is open in the sense that it:
- Is open to work with proprietary interfaces for legacy systems.
- Provides an extended RSMP interface to connect to road side instruments equipped with a similar interface, where RSMP is the open protocol for communication between road side equipment and traffic management system.
- Is compliant to the ETSI driven C-ITS standards, so additional C-ITS service can be introduced over time.
- Provides relevant data to the open data platform of the City of Copenhagen.

As a next step, the relation will be established with the European standardization work on vendor lock-in solutions by CEN TC 278 to strengthen Copenhagen’s positions as an urban ITS mixed vendor environment.

Another step the city is making is introducing new C-ITS services via the European C-Mobile project. This includes:
- Multi modal dynamic speed advice (i.e. bikes, buses, cars, heavy trucks);
- Cooperative traffic lights for pedestrians (vulnerable road users).

Openness of data

With the open data the city provides a stimulus to data-driven innovation. Greater access and use of data do come with a price. It creates a wide array of policy issues, such as privacy and consumer protection, open data access, skills and employment, and measurement to name a few.

Cost-efficient large-scale roll-out and mass adoption by road users

Large scale roll-out of intelligent traffic solutions does not start with a blank canvas. The city has already invested in road side equipment and intelligent solutions. The new solutions should build on this legacy. After all, a continuous development and enhancement is not served via innovation by replacement. An example is that by upgrading and embedding RSMP in both the CTMS and the existing and new road side instruments, the City of Copenhagen is brought into a position where it can configure and coordinate all the road side instruments in the city.

Include what is already there along the streets and avenues

Implementing and deploying a new set of intelligent traffic solutions does not start with a blank canvas. The city has already invested in road side equipment and intelligent solutions. The new solutions should build on this legacy. After all, a continuous development and enhancement is not served via innovation by replacement. An example is that by upgrading and embed-ding RSMP in both the CTMS and the existing and new road side instruments, the City of Copenhagen is brought into a position where it can configure and coordinate all the road side instruments in the city.

Align with what is already used by road users

In order to achieve a high impact in the field it is essential to align with smart services that are well adopted by road users, such as Google and Apple Maps, TomTom, Here and Garmin in such a way, that these smart services are coordinated with the city’s strategic traffic management. It is only through cooperation, we can help road users to make smart choices that fulfill both the road users’ own needs as well as the city’s goals.

Aligning comes with the acceptance that private service providers have a growing influence on the results of traffic management that traditionally has been the domain of public road authorities. After all, by introducing more mobile and in-car services, service providers will increasingly influence the trip, route, lane and speed choices of road users.

A first step in this alignment is the strategic and smart routing in the SOCRATES 2.0 project. Service Providers deliver the “best route” advice for drivers and are using their own Floating Car Data (FCD) to identify the fastest and perhaps most reliable route at a specific time for the requested destination.
Stay Saphe in Traffic

Communication between vehicles and infrastructure is a critical next step for improving road safety. This interaction is often referred to as Cooperative Intelligent Transport Systems (C-ITS). Although the technology is ready today, EU adoption of C-ITS is slow, as neither consumers, nor carmakers have a large incentive to invest.

Evidence based continuation
In the introduction the three steps the City of Copenhagen has made in the direction of smart urban mobility, are briefly described. Instead of rolling out even more technology, the time has now come for evidence-based continuation. This implies a conscientious, explicit and judicious use of current best evidence of the socio-economic value of smart urban mobility for the citizens of Copenhagen in programming the next steps. These steps might include expansion of the current intelligent traffic solutions and/or the introduction of new solutions. It means integrating the evidence that is built up in the City of Copenhagen via both technical, economical and user centric evaluations with the best available external evidence from similar evaluations in comparable cities in Europe.

In this way the adopted “learning-by-doing” cycle is enhanced to a “learning-by-doing & sharing the lessons learned” cycle. The ITS Copenhagen program (the third step) of the City of Copenhagen can only be a success if we compare and combine the evaluation results and lessons-learned with evaluation results and lessons learned from other cities.

However, we have created Saphe, a simple solution using Bluetooth technology and smartphones, that will drive quicker adoption of C-ITS. In Denmark we’ve reached a 20% adoption rate within just 24 months, without government funding. Now we are launching the next generation of our device, Saphe Drive, that will incorporate progressive road safety features such as:

- automatic crash detection, emergency vehicle alerts, wrong-way driver and level crossing warnings, and a live in-car traffic information display.

C-ITS will have significant societal impacts in the future
In many respects today’s drivers are already connected to one another. However, in the future, vehicles will also interact with other vehicles and road infrastructure. Cooperative Intelligent Transport Systems (C-ITS) is the domain which describes this interaction. It will allow traffic managers and road users to share data and use it to coordinate their actions. Such communication between vehicles and infrastructure is a critical next step to improve road safety.

To investigate the benefits, costs and implementation challenges, the EU set up the C-ITS Deployment Platform in 2014. This working group of national authorities, stakeholders and the Commission found the benefits of C-ITS to be clear. The group forecasts a 5% reduction in accidents and an additional 7% reduction in fatalities (EU, 2016). Savings are expected to total €15Bn per year by 2030, which is driven by a reduction in the number of accidents and more efficient traffic flows, meaning less time spent on roads.

To understand the scope of C-ITS it is worth borrowing the official C-ITS Deployment Platform’s framework of services. The framework separates C-ITS services into two priorities: Day 1 services, which should be available in the short term, and Day 1.5 services, which are more long term as specifications are not completely ready. Examples of Day 1 and Day 1.5 services are included below:

Day 1 Services:

- Hazardous location notifications:
- Slow or stationary vehicle(s) & Traffic ahead warning
- Road works warning
- Emergency vehicle approaching
- Signage applications:
- In-vehicle signage
- In-vehicle speed limits
- Intersection safety

Day 1.5 Services:

- Intersection safety
- V2V: Vehicle to Vehicle
- V2I: Vehicle to Infrastructure
- V2P: Vehicle to Pedestrian

Stay Saphe in Traffic

Freddy Sørensen
CEO & Founder @ Saphe
freddy@saphe.dk

Emil Sørensen
Business Development @ Saphe

Cooperative Intelligent Transport Systems (C-ITS) use technologies that allow road vehicles to communicate with other vehicles, traffic signals and roadside infrastructure as well as with other road users. The systems are also known as vehicle-to-vehicle communications, or vehicle-to-infrastructure communications. With alerts generated from the increased information available, these systems have a strong potential to improve road safety and the efficiency of the road transport.

Because of these expected benefits and considering the overall relatively moderated costs linked to deployment, there is a strong interest in enabling a fast move at European scale, that will translate into market production and early deployment.” - C-ITS Platform Report (EU, 2016)

"Writing a single business case for C-ITS deployment would be very difficult" (EU, 2016)

C-ITS adoption is sluggish and relies on network effects

Successful C-ITS adoption must take one of two routes: (1) from a supply-side perspective, carmakers should collaborate to include C-ITS in their vehicles, or (2) from a demand-side perspective, consumers must invest in C-ITS enabled devices. Unfortunately, the road map for C-ITS adoption looks challenging for both supply and demand sides. As the C-ITS Deployment Platform notes, “writing a single business case for C-ITS deployment would be very difficult” (EU, 2016). From the supply-side, C-ITS adoption by carmakers is sluggish and will take many years. This delay is driven by two factors: (1) more pressing issues than C-ITS, including tariff threats and a shift to electric vehicles, and (2) a disagreement over which technology to use for implementing C-ITS (C-V2X vs. ITS-G5).

"Writing a single business case for C-ITS deployment would be very difficult" (EU, 2016)

Cracking the ‘C-ITS’ device consumer business model

Like with any industry, before you can reach a state of disruption you need a business case to finance your growth and R&D. For us at Saphe that business case has been our now 3-year old traffic alarm that warns users about speed traps and upcoming accidents. In late 2015, we launched a Bluetooth device that paired with smartphones to enable users to warn others. This crowdsourced network grew incredibly fast and today, just 3 years later, we’ve sold over 400,000 units, reached #1 in the Danish App Store and won several innovation awards.

We have learned that consumers will not buy a product that only relies on safety features, but instead will buy a product that saves them money or time. Thus, by offering a service such as speed camera warnings, we have seen that consumers are willing use a C-ITS enabled device as it also saves them money. This is the best example of a real-world business case to solve the implementation problem the C-ITS Deployment Platform discussed. Additionally, we observe societal benefits from the speed camera warnings: early signage (a few km before) does a better job of slowing drivers than late signage (a few hundred m before).

We are launching Saphe Drive, a consumer ‘C-ITS’ device

Since the successful launch of our original Saphe traffic alarm, we have been able to build up a strong data-driven engineering team, competencies to become traffic and road experts, and most importantly a...
country-wide network of 300,000 daily active users driving over 20 million km per day. Now, with the launch of Saphe Drive, we are at a point where we can return to our original mission: to make 10x improvements in road safety.

Saphe Drive is a complete redesign of our original traffic alarm. It has the same core features, but now with a heads-up display, more advanced sensors and better wireless technology. Key Saphe Drive technologies are:

- High contrast 1.54” e-paper display with front-light
- Rechargeable battery (2-3 times/yr.)
- Buttons to report incidents
- Alarm speaker

These technologies mean that we have been able to include many road safety features in Saphe Drive that we haven’t been able to include in our previous Saphe device. The in-vehicle signage (display) allows for showing any traffic sign, anywhere at any time. This includes several C-ITS Day 1 and 1.5 features:

- Traffic ahead warnings (slow or stationary traffic)
- Vulnerable road users (children, road workers)
- Road hazards
- Traffic information

On top of the C-ITS features, there are also three core Saphe Drive features we want to highlight:

(1) Crash Detect (e-Call):
The Saphe Drive device can measure when a car is involved in a crash, and with that information it can stop the accident by sending alarms to nearby vehicles. This function is not supported by e-Call. It is also possible to inform the emergency services about the accident and its location.

(2) Traffic Dangers - Wrong-way Drivers and Level Crossing Warnings:
Saphe Drive will alert users about wrong-way drivers. By mapping the highway network and using map-matching algorithms, we are able to give a high alert tone to nearby drivers, when a driver enters the highway in the wrong direction. Additionally, when approaching a level crossing, Saphe Drive will give a warning, if there is a risk of meeting a train. We are able to do so by partnering with national rail services as we have done.

(3) Emergency Vehicle Alerts:
We have partnered with Falck, the largest private provider of emergency services worldwide. With Saphe Drive, you will receive alarms about emergency vehicles before you hear them.

We have a unique position to significantly speed up connected cars adoption

In Denmark:
In Denmark, our network of 400,000 drivers will make the C-ITS features of Saphe Drive valuable from launch. With a Saphe currently in around 20% of private cars on the road, users will see value from alarms immediately. Therefore, we forecast high early adoption of Saphe Drive in Denmark because it has an attractive low price point, it solves users existing pain-points with our original device, and we can market our product to our existing users that have a high brand loyalty.

Outside Denmark:
Outside Denmark, we also strongly believe that Saphe Drive will create value despite the network effects we are up against. This value is driven by three key strengths of Saphe Drive: (1) network spill over effects, (2) intrinsic value, and (3) strong partnerships.

(1) One key way of battling network effects in one space is to your leverage network effect in another. Despite only being available in Denmark, we have seen our network of drivers grow beyond the borders as word of Saphe spreads. As we begin to push marketing in Norway, Sweden and Finland in the coming months, we expect this penetration to increase.

(2) Another way to beat network effects is to create stand-alone or intrinsic value, meaning a device must also be valuable without other users. The textbook example of this is of course Facebook, which drove user adoption by creating the only service that also had value as a stand-alone product; the site initially functioned as an online student directory. Saphe Drive is valuable as a stand-alone device in several ways as it features the most up-to-date database of speed traps in Europe and a heads-up display with additional traffic information.

(3) Finally, another reason we believe that Saphe Drive will increase adoption outside Denmark is because of our strong track record of partnerships that we hope to expand. In Denmark, we have partnered with local municipalities to alert users around school roads during busy times. Other partnerships include those with emergency services providers. We are looking at developing similar partnerships outside Denmark to develop further intrinsic value.

Saphe Drive will make consumer C-ITS features relevant in 2018

C-ITS will have clearly have vast positive societal impacts, with an estimated savings of €15Bn per year and a significant reduction in traffic fatalities. However, if left to the EU and carmakers alone, C-ITS adoption will take far too long. We strongly believe that we can speed up the process of C-ITS adoption with Saphe Drive. The success of our first traffic alarm in Denmark shows we have cracked the business model locally. To achieve the same success implementing C-ITS features outside Denmark, we will be looking to create strong partnerships with international stakeholders.

Figure 2: Saphe Drive traffic alarm.

Figure 3: Wrong way alarm - Crossing Warning – School children.
Taking the temperature of cyclists’ behaviours in a troubled intersection

In a Smart City relying on data-driven decisions it is not enough to merely count traffic in the morning and afternoon peak hours, when evaluating the redesign of a troubled traffic intersection. A new method uses Computer Vision (CV) algorithms on thermographic video to track the heat silhouettes, radiated by people, bikes, and vehicles moving through the intersection. The algorithms yield georeferenced tracks which are analysed and visualised using Geographical Information Systems (GIS).

Søren Zebitz Nielsen,
GIS & Smart City Consultant,
Sweco Denmark
sorenzebitz.nielsen@sweco.dk

Background
To evaluate cyclists’ and pedestrians’ use of a newly redesigned traffic intersection and a new bidirectional cycle path, Gladsaxe municipality north of Copenhagen decided to test a new method of thermographic Computer Vision technology for traffic tracking as opposed to traditional traffic counting and observation. The municipality had previously purchased a thermal camera for other Smart City use cases, and wanted to test the possibilities for also using it to automatically collect high-quality data on traffic behaviours in a troubled traffic intersection.

Recently, Gladsaxe municipality completed of a major renovation of a road bridge, and a part of this project was adding a bidirectional cycle path at the south side on the bridge. Another part was to establish a new one-way cycle path road crossing in an intersection just after the bridge, going from the south to north, parallel to the original pedestrian crossing. The purpose of the bidirectional cycle path was to establish a safe connection both ways between a residential area to the east and a school to the west. The cycle path crossing was established to create a much needed crossing for cyclists, where there had been none before. However, due to general traffic regulations in the type of intersection, cycling could only be allowed in the south to north direction.

After the opening, locals complained about the one-way cycle crossing. They wanted the municipality to make cyclist allowed in both directions. To do so would be very complicated due to the traffic regulations and safety concerns especially in reagrding to right turning motorized traffic.

To evaluate the project the municipality was interested in measuring several parameters for the traffic in the intersection. First they wanted to know how many cyclists used the new cycle paths throughout a day. Secondly, they sought to document the effects of increased safety for school children. Thirdly, they wanted to find out...
how many cyclists disrespected the traffic regulations by crossing in the opposite direction on the one-way cycle path. Traditional traffic counting and observation methods would not be feasible for a whole day survey, and due to surveillance regulations, normal cameras could not be applied without an extensive process to get permissions. Nevertheless, a thermal camera could.

Figure 3: Ground Control Points in the video images. The homography principle is illustrated on the right.

Figure 4: An example of a correctly tracked cyclist crossing in the allowed direction.

Methodology

Thermal video cameras operate independent of daylight, and record infrared radiation. The tracking technique used is non-intrusive and ensures privacy by design, since the identity of individuals cannot be revealed in thermal images. In this project a single state-of-the-art uncooled thermal camera with a resolution of 640x480 pixels (Axis Q1922), a lens with a focal length of 10 mm, a viewing angle of 57°, and 10 fps camera frame rate was used. From this a spatial accuracy of about 25-50 cm can be obtained by CV algorithms. This allows for the analysis of behaviours and attendance at a fine scale.

The thermal camera was installed by the municipality on the crosspiece of a lamp pole next to the intersection in a height of approximately 7 meters over the pavement. Connection of power to the camera was taken from the power supply to street lighting, which for that reason had to remain on for the entire period of 24 hours in which the camera was in operation.

In the Computer Vision algorithms, objects moving in the scene were segmented by subtracting the background of the video image. For each object in motion, the bottom point of the object was identified where it was in contact with the pavement. The closer one object was to the camera, the more accurately it could be tracked. A few different settings were tested to calibrate the Computer Vision algorithms depending on which areas of the video image and what size of objects were desired to be tracked.

To principle of homography was used to transfer between video image and real-world geographic coordinates. In this way the recorded tracks were georeferenced. This enabled calculation of derived parameters for the tracks such as speed, acceleration, heading etc., and allowed for analysis of the tracks in relation to other spatio-temporally referenced data in the area.

For each video image, point data for each tracked object in the scene was given in the form [ID, X, Y, t]. ID identifies each track with a unique number, and X and Y are the geographic coordinates at time, t. The output from the tracking algorithm was stored in a simple text format (.csv) that could be loaded into a PostgreSQL database with the spatial data extension PostGIS. From there, data could be selected based on attributes, geometry and geography, and analyzed in QGIS, which could handle and visualize data directly from the database. The methodology used in the project was based on previous work by [1, 2, and 3].

To undertake the thermal tracking project a triple-helix collaboration was established between Gladsaxe municipality, the Visual Analysis of People Lab (VAP) at Aalborg University (AAU), and road engineers and geodata consultants from Sweco Denmark. The camera setup and data collection were conducted by Gladsaxe municipality, the thermal videos were analysed using algorithms, developed during a research project at VAP AAU, and the georeferenced tracks from the algorithms were analysed and visualised by Sweco.

Acknowledgements:

Sweco will like to thank Chris Holmberg Bahnsen, PhD student at VAP AAU, for undertaking the Computer Vision analysis, and Oskar Wodschou Theilmann Mule, Geographer at Gladsaxe municipality for coordinating the installation of the thermal camera and collection of the data.

Figure 5: All tracks crossing the intersection in both directions coloured according to speed. Green is slowest, red is highest.
Analysis and error sources
The results from the thermographic method were compared with traditional traffic counts in the morning and afternoon peak hours. To distinguish between traffic modes, tracks with speeds below 8 km/h were classified as pedestrians, and tracks on bike paths with speeds greater than 8 km/h were classified as cyclists.

The results showed that in most cases the difference between thermographic and the traditional traffic counting methods were within a range of +/- 3 road users per hour. It was found that the thermographic analysis in the morning period slightly overestimated the number of cyclists in the east-west directions on the southern bidirectional cycle path, and underestimated the numbers on the south-north crossing. In the afternoon, the thermography overestimated slightly in east-west directions, but was in accordance with the traditional counts on the south-north crossing.

A manual review of video recordings revealed a few persistent error sources in the automatic tracking of road users. A typical error resulted from occlusions when several people moving close together are perceived as one individual by the algorithm, and therefore only assigned a single track. Another well-known error was that tracks sometimes jumped between objects, for example between pedestrians and cyclists when these passed each other closely.

Over the whole day, the thermographic method identified 120 cyclists cycling illegally southward in the crossing. Despite some uncertainty on this number, it was still quite a bit larger than expected when extrapolating from the isolated traditional counts done in the morning and afternoon peak hours. To mitigate the number of cyclists taking this route, an alternative legal route of similar length close by was identified. This route was recommended to be sign-posted to lead the southbound cycle traffic along this route instead.

Since the thermal camera tracked the movement of all objects in the scene, it was also possible to get additional statistics from the dataset, such as traffic counts and speed distribution for the motorized vehicles in the different directions through the intersection. Results from this were in

Figure 6: East-west cycle traffic on the double-track cycle path in the morning rush hour. The majority of the red westbound tracks are children on their way to school. A route that was not possible before the cycle path was established.

Figure 7: Speed distribution for all tracks of motorised vehicles travelling towards the east. Notice the slow speeds for the right turning traffic.
accordance with previous vehicle counts in the area some years back, when adjusted for a known overall traffic growth in the municipality of 20%.

Furthermore, the dataset allowed for calculation of the fraction of vehicles speeding at different times of the day, which were interesting data for the municipality in relation to traffic safety with regards to the school children commuting through the area. It was found that 18% of the 6400 vehicles are driving more than the allowed 50 km/h in the eastward direction. In the westward direction it is 28% of the 6900 vehicles. Around 5% of all vehicles over the course of the day are speeding at more than 60 km/h. Deriving these numbers only demanded an additional query of the geospatial tracks in the database since all tracks for all road users where recorded anyway.

**Conclusion and perspectives**

The thermographic method showed promising results in tracking the overall traffic flows and behaviours of roads users quite well. With Computer Vision algorithms improving quite rapidly these years, better accuracy and completeness of the tracking could be expected in the near future.

However, if the thermographic method is to be used for speed investigations on an equal footing with existing methods such as coils and laser measurements, it should be benchmarked against these to verify the accuracy of the method in relation to the recognized standards in the field.

In perspective the thermographic method might also prove useful to understand flows in other places where the soft modes of traffic in terms of pedestrians and cyclist are dominant, such as at stations, bus terminals, and urban plazas.

**References**


Intelligent traffic solutions for a clean, safe and sustainable environment in Copenhagen – a special focus on traffic management and signal optimization

In November 2015, the City of Copenhagen kicked off six well-defined intelligent traffic solutions that are operationalized and tested in 2017 and 2018. In this paper, we look at two of the six ITS solutions: “City Traffic Management System” and “Signal Optimizations” and ask ourselves the basic question: “Have we been smart in designing and implementing these solutions?”

Mads Gaml, City of Copenhagen,  
The Technical and Environmental Administration, Traffic Unit  
F05Q@tmf.kk.dk

Paul van Koningsbruggen,  
Technolution, The Netherlands  
paul.van.koningsbruggen@technolution.nl

A sustainable city asks for sustainable mobility

As with many growing cities in the world, Copenhagen must cope with a growing population and corresponding growing traffic demand that put pressure on the cleanliness, safety and sustainability of the urban environment. What is the Copenhagen way to deal with the challenges? A simple question that comes with two answers. The first answer is laid out in a clear political goal (CO₂ neutral in 2025). The second answer is formulated in a new political vision, called “Community Copenhagen”.

The answers set the scene and the conditions for the way any intelligent solution need to be shaped, formed and operationalized within Copenhagen. This includes solutions that enhance smartness in mobility.

City Traffic Management System and a corresponding Sensor Network

The first step is to monitor the status of the road network and the traffic conditions. For the road network data from the existing system, such as the winter system and environmental system, will be used, as well as manual input from traffic operators. For the traffic conditions, we will start with a layer of real-time floating car data for motorized traffic, GPS data from busses and cyclists and operational data from traffic light controllers.

This provides traffic operators with an overview of speed and travel times as realized at that very moment on the road network in Copenhagen. On top of that, we will use a set of radar sensors to measure on essential locations, volumes and speed of motorcars and heavy traffic. Additionally, a set of video-based sensors will be applied to measure volumes of cyclists on essential locations.

Now, traffic conditions on the city’s network should not only be monitored, but should also be evaluated in relation to political decided service goals as defined in the city’s traffic management strategy. Given the on-going evaluation, traffic management scenarios can be (de)activated in the City Traffic Management System (CTMS) to tune the settings and configurations of the road side instruments (traffic lights controllers, variable message signs) to the evolving traffic situation. Thereby getting the maximum out of the road network.

Traffic Signal Optimization

The quality of the resulting traffic flow is in the traffic management strategy expressed in travel times. By optimizing the traffic signals along some of the major corridors, the waiting time at controlled intersections is prevented or shortened. As such, cyclists, public transport bus passengers, pedestri-
ans and motorist can be provided with service goals. Service goals that give cyclists and public transport a competitive edge over the motorcar in the city.

Have we designed solutions in an open way, inclusive for multiple actors in the domain?

Implementing the intelligent traffic solutions is not an objective by itself. They are a step in the process to achieve a cleaner, safer and more sustainable urban environment. As such, it should be possible for the city to keep on building on these solutions and to work with the right professionals in delivering services, enabled by the solutions.

The CTMS can grow in the future, given the solutions are based on an open architecture (figure 1). A central point in this architecture is that the CTMS binds a series of data sources and makes it possible to fine-tune the solutions on-the-fly. From a technical perspective, the architecture is open in the sense that it: (i) is open to work with proprietary interfaces for legacy systems; (ii) provides an extended RSMP interface to connect to road side instruments equipped with a similar interface; (iii) provides relevant data to the open data platform of the City of Copenhagen, ready to be used by public and private service providers.

From a process perspective, the architecture is open in the sense that the City of Copenhagen can link new RSMP-compliant road side instruments to the CTMS, provide dedicated data to C-ITS service providers, and open data to other service providers. The city can also configure and fine-tune the solutions itself or select freely the appropriate professionals to support the city here.

During the ITS Copenhagen project, the RSMP protocol has been upgraded to a protocol that enables not only on-the-fly selection of signal plans, but also fine-tuning of parameter settings of the selected signal plan on-the-fly. This creates the basis for a much faster and more effective way of doing signal optimization.

The Road Side Message Protocol (RSMP) is an open, modern, lightweight and flexible protocol for real-time communication between traffic lights and other road side equipment, and traffic management systems.

Are we making use of what was already there, and have we created new traffic solutions by adding new elements instead of ‘innovating by replacement’?

ITS stands for a continuous development that seeks to use modern technologies to enhance people’s daily life through smart mobility solutions, putting the user and their specific needs at the centre of the mobility system and safeguard them from infringements on their privacy and (data related) security. A continuous development is not furthered by innovation by replacement. A city should be able to keep on building on a solid foundation, which is exemplified in the previous section. Furthermore, a city should be able to make use of everything that is already there.

By upgrading and embedding RSMP in both the CTMS and the existing and new road side instruments, the City of Copenhagen is in a position where it can configure and coordinate all the road side instruments in the city.

The CTMS itself is modified off-the-shelf and builds on a MobiMaestro suite that is shared with other cities and provinces and allows for upgrades, jointly initiated by these road operators.

Are we using smart data and are we using this data in a smart way?

The smartness in the data is, in our opinion, threefold. First of all, we use data from existing systems in the city and the public transport company and bring this rich set of data into the context of a common sensor network. Secondly, we use commercially provided floating car data services - data that is already available and for which the data providers have their own model for enhancing the data year by year. Thirdly, we apply road side sensors on carefully selected locations for three reasons: (i) count volumes of cyclists, passenger cars and heavy traffic, and (ii) detect whether there are vehicles and/or cyclist approaching a controlled intersection and feed this information to the adaptive signal program, and (iii) detect approaching cyclists and pedestrians on intersections with intelligent street lighting.

Bringing all this data into one common sensor network, the data can be used for various reasons. The full set of data is used by the CTMS to express the current traffic situation on the road, to trigger the (de)activation of scenarios and to monitor the service levels over time (hour, day, week, month, year). A selection of the data is made available as open data for public and private service providers. And the data can be used in other tasks within the City of Copenhagen, amongst others the other traffic, traffic management and traffic information related tasks.

Have we designed and implemented the solutions in an economical viable, “get what you need” manner, and are these solutions scalable and maintainable?

This is not an easy question to answer. We can explain how we have interpreted these non-functional requirements and leave it to the opinion of the reader to see whether we have been successful.

Economical viable solutions are to us solutions that contribute to an improved road safety in Copenhagen as well as improved mobility, especially for cyclists, pedestrians, and bus passengers. Solutions that make it even more attractive to drop the car to and from work, in favour of cycling, walking or travelling by public transport. This is simply because it is the most efficient way to improve mobility in Copenhagen, create a city with cleaner air, less noise, and reduced CO2-emissions. Coming from this perspective, technology is deployed as an enabler for the solutions, not as a means by itself.

The “get what you need” based designs, together with the budget limitations in the project, have led to solutions that are cost-efficient. If the evaluations show the solutions are effective too, it is straightforward for the city to scale them up.

Last but not least, all solutions have been designed and developed for 24/7 operations and life cycle management. The solutions are in production and are far beyond the phase of an experiment. The experiment is on the factual use of the solution in day-to-day practice. Managing the changes and using the solutions are the obvious next steps for the city. Technical development and implementation are one level of engagement. An even deeper level of engagement is exploiting the solutions to the maximum.
Smart (sustainable) mobility in Copenhagen is a journey that has only just started. A journey that is anchored in political ambitions of a steady growing metropole region, and where every intelligent traffic solution is challenged in its design and added value; Challenged from a human perspective of the citizens. Challenged form a sustainability perspective, where each solution is designed so it can be scaled up, once proven to be successful and appreciated. And challenged for openness, so new solutions and private contributions can be added that support the city’s vision to be CO₂ neutral in 2025 and beyond.

Through the solutions that have been operationalized, we have picked up these challenges. With the results from the ongoing evaluations, we can see where adjustments and/or additions are needed.

Figure 1: CTMS architecture in City of Copenhagen.
Visual City – ÅF’s smart integrated planning process with visual simulations and synergy analysis

Visual City concept is about planning ahead and making smart choices for the future, based on knowledge of consequences and synergy effects.

Cecilia Windh, ÅF, Sweden
Cecilia.windh@afconsult.com

Paoli Marco, ÅF, Denmark
Paoli.marco@afconsult.com

New Planning Tools Ahead
Building a city is often based on old ideas and historical information. The thoughts and solutions we come up with in 2018 will be outdated by the time a project comes to life, several years from now. The industry and markets are evolving so quickly that construction with the latest technology is challenging, since new innovations are launched each day. Many of us still use the same tools as our grandparents did – pen, paper and 2D maps. Outside of the traditional municipal planning process of today, rapid development occurs. So why not let it penetrate every project and plan? New planning tools can assist us in planning the future in a better way.

The integrated planning processes
We live in a digital world as much as in a physical one, and there is an obvious advantage in combining the two to get important knowledge and improve the quality of urban life. The purpose of a Visual City process is to systematically experiment and analyze solutions for a sustainable city. Rather than producing one memo for traffic, one for air and one for noise, Visual City combines them all and evaluates the total impact. The strength is the connections between different issues and a chain of dependences. It is all about people, their habits, needs and demands.

Building the model
Visual City is based on GIS data. (see figure 1) creating buildings and environment in several types of smart modelling software.

Figure 1: Simple cityscape in Esri CityEngine.

Figure 2: Houses pre-programmed with data in Esri CityEngine.

Figure 3: Traffic simulations in InfraWorks.
Mastering different fields, such as urban planning, landscape architecture, transport planning, ITS, noise, vibration, wind and pollution, we can combine planning processes, which are usually separate, into one model. Within the model we can illustrate the consequences of urban planning ideas.

**Merging different planning tools**

Visual City uses an array of software and data to answer the important questions of planning for the future: Traffic analysis tools, noise evaluation, wind, pollution, and so on.

Using various traffic analysis tools, we can model the impact of increased traffic movements. In the example shown in Figure 3, the current crossing will create more congestion and tailbacks. When cars are idling, they release more pollution, and in this case it’s right next to a kindergarten.

Figure 4 shows an alternative solution. The traffic flow is better and the kindergarten less subjected to pollution from idling cars. If the planners decide that this is the best solution, we can continue, and make more detailed sketches and road plans. Or we can try a different approach and evaluate the scenarios.

Noise and sound pollution are key to unlocking land for development. Areas affected by sound pollution cannot meet the high requirements for quiet living areas stipulated by law in Sweden. In a Visual City model, we put traffic noise and housing in direct relation, so we can clearly show how sustainable mobility solutions create new opportunities for housing, schools and public areas.

Figure 6 shows a before-and-after image of winds accumulating between buildings. The left image shows a yellow field with strong winds, creating an unpleasant environment not suitable for outdoor seating or lengthy social interactions. The right image shows the same area, but planted with trees in strategic locations. Suddenly, the corner of the building is a much more qualitative space for people, suited for restaurants or benches.

The combination of analyses is key to a better understanding of the consequences of urban planning. The public spaces, streets and connections in the urban form have great impact on where people move, live and spend their time and money.

Figure 7 shows a Space syntax analysis in a GIS model to find locations, strong links and populated streets in a city. A red line indicates a street with many connections and heavy pedestrian traffic. A blue link indicates that the street is isolated and has few connections. A red area could be a good location for shops, services or public transport hubs. A green/ blue area indicates a less frequented place.

Stay interconnected!

Technology is entering our streets and cities and the transport solutions of tomorrow are smart and interconnected, drawing on the advantages that synergy effects can give. Visual City is a perfect tool to evaluate these solutions, and illustrate their effects, not only from a transport perspective, but with regard to other social aspects of urban planning.

Follow our presentation at the ITS World Congress to learn more about this process.
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