Smart City Concepts in Curitiba
Innovation for sustainable mobility and energy efficiency

Project NEWSLETTER April 2017
About the cooperation between KTH and the City of Curitiba

In 2013, KTH, the City of Curitiba, universities and the Federation of Industries of the State of Paraná signed a Memorandum of Understanding to develop projects in the areas of mobility, urban planning and environment. Since then, a collaboration has evolved in many fronts. First, a consortium was formed in 2014, including KTH Royal Institute of Technology, VOLVO, COMBITECH, UTFPR (Federal University of Technology – Paraná), URBS (Urbanization of Curitiba S/A) and IPPUC (Urban Planning and Research Institute of Curitiba) to explore the deployment of technologies for improved mobility and energy efficiency in Curitiba, Brazil.

The project Smart City Concepts in Curitiba – innovation for sustainable mobility and energy efficiency has been funded by VINNOVA and consortium partners. This newsletter brings insights into activities performed in the framework of the project, and spill-over activities including new partners from both Brazilian and Swedish sides. The newsletter focuses on the period from November 2016 to March 2017. Click here for more information on the project Smart city concepts in Curitiba.

Curitiba featured in COP 22 in Marrakech

Nordic Countries kept a high profile during COP 22 (Conference of the Parties), which took place in Marrakech (Morocco) during November 2016. Nordic countries shared principles on welfare and sustainable development, and have a long history of cooperation. In an international arena such as the COP, where governments, NGOs, companies and multi-lateral organizations compete for attention, it was sensible to join forces. One important aspect that characterized the COP 22 was the focus on the implementation of climate actions. It is clear that cities are becoming an important focal point for action, being the home of the majority, and also the ground on where much of the global economic value is generated.

Thanks to their proven expertise, the Nordic countries have developed innovative models and best practices that could provide answers to the challenges of sustainable development in many cities of the world. Some of these innovative models were featured in Marrakech. Here, there was also room to show how Sweden is collaborating with other countries to develop smart city concepts. This is how the mobility project in Curitiba came in.

Professor Semida Silveira was invited to speak at the Nordic- Moroccan Forum on Sustainable Cities – challenges and opportunities. The high-level forum was opened by Hakima El Haite, the host Minister in charge of Environment and COP 22; Eva Svedling, Swedish Deputy Prime Minister; and Mohammed Nabil Benabdallah, Minister of Housing and Urban Policy in Morocco. The forum was held in the African pavilion on 12 November, and brought together a large number of officials, companies and various organizations interested in hearing about Nordic solutions for sustainable cities.
Professor Semida Silveira took the chance to speak about projects being developed by the Energy and Climate (ECS) group at KTH in both Stockholm and Curitiba. In addition to present on-going demonstration projects for transport electrification in urban areas, she highlighted the role of energy efficiency in meeting the climate change goals.

**Analysis and demonstrator platform for charging logistics for hybrid buses**

Since August 2016, a plug-in hybrid-electric bus provided by Volvo has been operating in Curitiba (route 285-Juvevê/Água Verde). Route 285 has a charging station installed at the final bus stop in Juvevê. Every completed trip requires re-charging of the battery to operate the hybrid bus in full electric mode through the safe zone (see Fig. 4 for definition of the safe zone in Curitiba).

The project team (UTFPR, Combitech and Volvo, with support from KTH and CISB) is monitoring details around the battery charging process at the charging station of route 285 (Fig. 3). We compare that with experiences reported from other studies. Recent studies indicate that less than 10 minutes are insufficient to re-establish the battery capacity. However, this time is only an estimate and depends on several variables such as type of charging and number of battery packages. In addition, this is quite a long time in most urban situations and needs to be improved.

For that reason, we are currently monitoring the waiting time at the charging stop using data provided by URBS and Setransp (Curitiba Public Transportation Authorities). This will increase our understanding about the required dynamic for charging intervals in route 285. This knowledge can be possibly expanded to other routes and used in simulations in the context of Curitiba.

Fig. 4 shows the safe zone in Curitiba. It corresponds to a central area of approximately 6 km². Within this zone, the plug-in hybrid bus shall operate in electric mode, thus using electrical energy saved in its batteries. The electric mode implies reduced environmental impacts, particularly air pollution and noise.

In addition, the project team is developing a demonstrator for real time planning of the charging process. This includes applications for communication with the bus driver as well as
applications showing the overall metrics of the charging process for all vehicles at the chosen terminal.

![Fig. 4. Central zone in Curitiba aimed for full electric operation (approx. 6 km²).]

To enable real-time analysis and optimization, the simulated data is uploaded to an Internet of Things (IoT) platform developed by Combitech and hosted on the cloud service Microsoft Azure. Both historical and real-time data is exposed through standard representational state transfer (REST) interfaces for application developers. The platform allows analysis and visualization using common tools such as Spark, Hadoop, R and PowerBI. The first version of the app used by the bus driver as well as a dashboard showing real-time information has been developed and is under review.

**2016 IEEE 19th International Conference on Intelligent Transportation Systems**

Three presentations were made by researchers from UTFPR at the conference “2016 IEEE 19th International Conference on Intelligent Transportation Systems” in Rio de Janeiro, Brazil, 1-4 November 2016 (click here). The presentations refer to specific studies carried out in Curitiba aiming at improved mobility based on open data from Curitiba.


The importance of open data for research

Open Data is key to the development of sustainable cities. Not only can Open Data serve as the basis for planning and monitoring urban solutions, but it also provides a starting point for innovation. Using actual data on the city, many instruments and applications can be developed to facilitate traffic and mobility, for example. In addition, energy efficiency and emissions reductions can only be properly addressed and monitored if quality data is provided.

The local public transport and urban development company in Curitiba – URBS (Urbanization of Curitiba S/A) and IPPUC (Planning office) have provided data on bus routes, bus stops and other information through web services or websites. This provides the basis for analysis and development of tools to improve the city environment. URBS does not keep historical data online though that data is available. Since January, UTFPR and UFPR have been providing bus operation raw data and keeping them available to the general public by automatically retrieving and storing URBS data. The data access is available over the servers of the UFPR – Federal University of Paraná (click here).
Other data for Curitiba is available from various open databases. The data can be replicated and automatically updated (click here).

UTFPR is working on a reference model for a WIFI service in the city buses in Curitiba. Two student teams from UTFPR Computer Engineering were awarded a prize at the Embarcados Contest (Contest for embedded systems) in Curitiba in relation to this work. The works are: SmartFare - Ticketing system and public transport data collection (SmartFare – Sistema de bilhetagem eletrônica e coleta de dados de transporte público) won the 2nd prize in the Internet of Things (IoT) Competition NXP 2016 (click here).

‘InfoCidadeCuritiba’ (Sistema Disseminador de Informações), an Information Disseminator System was placed among the top 50 projects and chosen among more than 200 projects (national phase after the regional selection) to be presented in the national competition Intel® Embedded Systems Competition 2016 (click here).

Cost- and Energy-Efficient Backhaul Options for Heterogeneous Mobile Network Deployments

The work of the KTH-ONLab in Curitiba has focused on investigating various deployment options for the Information and Communications Technology (ICT) infrastructure in the city. The objective is to understand the costs of providing broadband connectivity services over a given deployment area. The following two studies have addressed various aspects of the options at hand.

In the first study, Cost- and Energy-Efficient Backhaul Options for Heterogeneous Mobile Network Deployments, a comprehensive methodology was proposed to analyse the total cost of ownership of five backhaul options. Different architectures were considered (see Fig. 5).

As shown in Figures 6 and 7, our overall analyses proves that backhaul architectures based on passive optical networks are very energy-efficient, but they also require a large investment (due to trenching or leasing of the fibre infrastructure).

This leads to high Total Cost of Ownership (TCO) values. This is particularly true when the distance between femto base stations and local exchanges is long (e.g., greater or equal to 1 km). Our results prove that using a fibre to the building infrastructure for backhauling femto base stations and a microwave links for backhauling macro base stations becomes the most cost-efficient solution when it is possible to lease dark fibre already deployed in the area.

![Fig. 5. Backhaul architectures evaluated in Curitiba: (a) Microwave, (b) Fibre to the Node + Microwave, (c) fibre to the Building + Microwave, (d) Fiber to the Home + Microwave, (e) fibre to the Home.](image)

![Fig. 6. Energy consumption cost of the proposed backhaul architectures in a Greenfield scenario as a function of the area traffic demand values from year 2010 until year 2025.](image)
Fig. 7. Energy consumption cost and Total Cost of Ownership values for the proposed backhaul architectures in a Greenfield scenario over a time period $T$ equal to 15 years: (a) energy cost per user per year, (b) TCO assuming trenching, (c) TCO assuming leasing dark fibres.

More details can be found in:

Algorithm to restoration of cloud services in optical networks

The UTFPR team is working on a novel algorithm to restoration of cloud services in optical networks. It leverages the restoration delay tolerance and service degradation SLA (Service Level Agreement) specifications, in a scenario with single fibre link failure. The algorithm is applied to different network loads and classes of service demands. Numerical results show that the algorithm is able to improve the cloud service restoration and reduced the network blocking probability. More information on the analysis will come soon.

Survivable BBU Hotel placement in a C-RAN with an Optical WDM Transport

The second study, Survivable BBU Hotel placement in a C-RAN with an Optical WDM Transport, focused on the survivable Base Band Unit (BBU) Hotel placement problem in Centralized Radio Access Networks (C-RANs) with an optical wavelength division multiplexing (WDM) transport. An algorithm was proposed that jointly decides (i) the placement of a minimum number of BBU Hotels and (ii) solves the Routing and Wavelength Assignment (RWA) problem for the front haul connections, ensuring that each RRU is connected to two different BBU Hotels (i.e., one primary and one backup). A strategy for maximizing the sharing of backup BBU ports among RRUs, was presented, aiming at reducing the total cost of the C-RAN while guaranteeing uninterrupted service provision in case of single BBU Hotel failure. All the results presented in our study demonstrate that the cost of adding resiliency to single BBU Hotel failures in a C- RAN can be contained by encouraging the sharing of both BBU Hotels and BBU ports as much as possible. On the other hand, this requires a WDM transport network with enough wavelength resources to handle the possible bottlenecks that may occur when BBU Hotels are placed quite far (i.e., more than 3 hops) from RRUs. More details can be found in:
New initiative between KTH and Curitiba addresses waste management

A workshop was held 31 October 2016 to discuss opportunities for improved waste management in Curitiba. Since then, three KTH students have joined forces with local universities and the Secretary of Food Supply in the municipality to develop the topic further.

Four universities of Paraná are now involved in the development of opportunities to improve waste management in the city of Curitiba. The city already has a very successful program of low-income food production and a well-organized network of markets generating significant amounts of organic waste. The idea is to identify a good model to move forward, developing an efficient model to utilize the waste and enhance its value. For that, it is important to quantify the amount of biomass resources being generated and identify pathways to organize collection, transformation, use and, most of all, good ways to distribute the benefits of this effort. Three KTH students connected to the Energy and Climate Studies Unit are developing their master’s theses in related topics with support from the Swedish Environmental Protection Agency in Sweden and local universities PUCPR, UFPR, UTFPR and UP.

Understanding the relationship between property development and Bus Rapid Transit: A spatiotemporal analysis of transit oriented development in Curitiba

The city of Curitiba is considered to be the cradle of the Bus Rapid Transit (BRT) system. A master plan approved in the middle of the 1960’s guided development of the city in a Transit Oriented Development (TOD) model with high densities close to five BRT trunk lines, so-called structural axes. A spatiotemporal and statistical analysis to examine the role of the BRT system in property development in Curitiba was carried out by Klara Bergman, KTH student under the supervision of Prof Tatiana Gadda at UTFPR. Spatial data were used in the analysis, including a database of building permits, population densities, social housing locations and cost of land. Three perspectives were explored: Timing of Development, Density of Development and Social Housing Inclusion. The results suggest that areas close to the BRT became popular. However, there were differences depending on the timing of development, surroundings and characteristics of the time periods when the BRT was implemented. High development densities are found in the structural corridors, though high population densities are also found in areas in the South and Southwest parts of Curitiba. The latter coincide with areas of social housing which, surprisingly, have been planned in areas not served by the trunk lines of the BRT system. The study concludes that the BRT system has been a driver for property development, indicating that TOD planning with thoughtful zoning can be a powerful tool to direct property development. In order to counteract urban segregation, strategies for including social housing in the structural axes are recommended. The study has been developed as part of the consortium collaboration. Click here for the master’s thesis of Klara Bergman.
Airborne particles in Curitiba – where do they come from?

Under the framework of the bilateral cooperation between the Environmental Ministries of Brazil and Sweden signed in 2013, a project has been initiated to study the emissions of PM2.5 and BC in Curitiba. The project named ParCur (Particles in Curitiba) is a cooperation between the Swedish Meteorological and Hydrological Institute and the City of Curitiba, local universities and regional authorities in the state of Paraná. The first phase of the project was dedicated to understand the sources to PM2.5 and BC emissions, analyzing measured data and dispersion model results. A second phase, to be carried out during 2017, will assess the effect on air pollution levels of different actions taken in the mobility sector.

During July-August 2016 a monitoring campaign was realized to learn more about present air pollution levels and sources. One objective was to measure how much the traffic exhausts contribute to raised PM2.5 and BC levels inside a “street canyon”, i.e. busy street flanked by buildings on both sides preventing the dilution of the vehicle emissions. We used two monitoring approaches: one with fixed measurements at roof and street levels, the other one with portable monitors on bikes moving along specific routes in the city center (Fig. 9).

The first results of the monitoring campaign are illustrated in Figure 10. Vehicle emissions on a heavy trafficked street contribute with considerable amounts of PM2.5 and BC. But there is a great variation in concentrations at different locations in the Curitiba city centre. These differences are due to traffic intensity and location of bus stops and traffic signals, for example. But they also depend on whether the location constitutes a “street canyon”.

![Fig. 9. The project team cycled around the city to make the measurements.](image-url)

![Fig. 10. Monitored levels of PM2.5, BC and NOx (all in µg/m³) at roof and street level in Marechal Deodoro Street, August 2016. The difference reflects the added contribution of traffic on the street. As a reference, measurements at a similar location in Stockholm reveal the following concentrations (roof / street): BC: 0.4 / 1.4 µg/m³, PM2.5: 4.8 / 5.6 µg/m³, NOx: 17 / 106 µg/m³. WHO guideline for PM2.5 is 10 µg/m³ as an annual average concentration level.](image-url)
For more information on the ParCur project, please, contact:
Lars Gidhagen (lars.gidhagen@smhi.se) Swedish Meteorological and Hydrological Institute, or Patricia Krecl (patriciak@utfpr.edu.br) Federal Technical University of Parana, Londrina.

**Rafael Greca de Macedo – new mayor of Curitiba since 2017**

Following from elections held for mayors in Brazil late in 2016, a new administration was installed in the municipality of Curitiba [click here](#) under the leadership of Rafael Greca de Macedo. Greca, as he is called by the citizens of Curitiba, has a long political history with the city of Curitiba, having also occupied important political positions at national level. He has previously worked in IPPUC (Planning Agency of Curitiba) and as mayor of Curitiba. Greca received 53% of the votes and he is committed to the development of Curitiba as a great city to live in, and a model for other cities in Brazil and the world.

**Photos and impressions**

Inauguration of the plug-in hybrid bus in 2016.

"HibriPlug" – Volvo 7900 Electric Hybrid bus in Curitiba (Photo: SMCS, 2016).


The city of Curitiba.