Cognitive district: Micromobility fleet planning and management, and its integration to public transport mobility based on data stream mining and big data, at the scale of a suburban district.

Lab: COSYS-GRETTIA

Project: ISite Future/Eiffage E3S

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Context

E3S[1] program is a partnership between University Gustave Eiffel and Eiffage made of 8 research projects on urban innovation. E3S stands for Eco-district Smart, Sure, Sustainable: the project uses the opportunity of a large construction project called LaVallée recently started in Paris's suburb. Its spatial extent is about 500 m x 400 m, part of a larger city called Châtenay-Malabry. The whole district is to be delivered in 2024. We are in the first phase of the project with the first roads being built and the first inhabitants expected by the end of 2021. The figure below illustrates the virtual future look of LaVallée district.

3D digital twin of LaVallée (its CIM): assembling of buildings and roads with BIM360 (Credits : *Atelier M3, Arcadis, SEMOP Châtenay-Malabry - Parc Centrale)*

In its design, the LaVallée district is physically open to the outside and will offer services that will be of interest to other residents or users of the surrounding area. To know the effect of this opening on a potential transit of visitors in the district, as well as the places of interest for the inhabitants, it is necessary to predict the flows of micro-trips within the district in a project situation (ie the eco-district once built).

[1] https://www.programme-e3s.com/en/the-programme/

The work carried out at GRETTIA lab addresses dynamic traffic modeling (road, public transport and active modes) based on travel demand and infrastructure supply. The travel supply is made of the road network and facilities location. We build daily activity planning for a set of agents (a synthetic population), and calculate the temporal evolution of planned trips, that is to say the predicted path of people during a typical day as well as their mode of travel.

Research and development mission of the internship

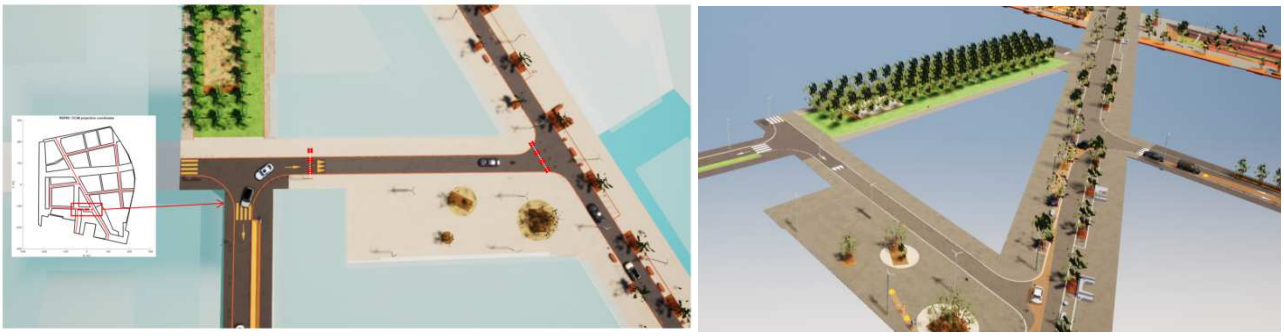
This internship is part of the workshop 8 of E3S: the objective of action 8.1 is to develop methods able to model and predict the potential visitation of the various equipments and public spaces of the district, from which to infer indication of the quality and vitality of public spaces (ie the future hotspots of the district).

Left : Map of the road network (car/walker/bicycle) with parcels and building. Right : activities locations (Home, Work, Leisure, Shopping, Education, Restaurant and Kindergarten) with their access nodes and links to the network.

In order to be able to estimate the validity of the results in a project situation, we want to:

- **Optimize a micromobility fleet made of automated shuttles, ride-hailing services and shared vehicles: number of vehicles, routes and optimal position of pick-up stations and parking spots**
- **Plan and manage the fleet in real-time using data stream mining approach, yet giving the district a cognitive capability related to its mobility management. Subject with a strong link to tactical urbanism.**

Cognitive building is an emerging concept based on digital frameworks and IoT networks, that gives a building the capability of learning from users' behavior and environmental data, to increase users comfort, energy-saving, flexible functionality, high durability, and good maintainability. The concept of cognitive district extend this concept to a larger scale with inputs are not related to physical values (temperature, pollution, wind etc) but real-time traffic data in order to achieve a better residencial mobility. The use of data stream mining -or online training as opposed to a classical approach of a once for all training- is particularly appropriate to give the district a capability to analyse the traffic state inside the district and adapt the management of a micromobility fleet to increase the overall mobility for resident. Data Stream Mining provides a brand new approach to data processing, allowing to create adaptive, incremental models that do not need huge amounts of storage size, as the data is processed as it is received.



Tactial urbanism: some roads of the district can be closed or opened to motorized vehicle.

A diversity of sensing devices densely spread over the infrastructure, vehicles or the travelers' personal devices act as sources of data flows that are eventually fed into software running on automatic devices, actuators or control systems producing. These information flows provide enormous opportunities to improve model development and decision-making.

A cognitive district would have the ability to analyse the current traffic state, making sort-term forecasting on traffic volume (#veh/15min) and A) produce actions on light signals and actuator of road poles to block or open a street to motorized vehicle (tactial urbanism) ; B) adapt and manage the supply of vehicles from a micromobility fleet, in links with public transportation.

Inputs

• Big data: data from mobile device

• data streams: traffic data from fixed sensors such as:

• license plate recognition camera

• vehicle detector station: flow and occupancy from loop detectors

Outputs

• Improve traffic flow and safety by reducing stops

• Tactical urbanism by opening/shutting ways

• Prioritise traffic lights for emergency vehicles and transit

• Reduce greenhouse gas emissions

Methods

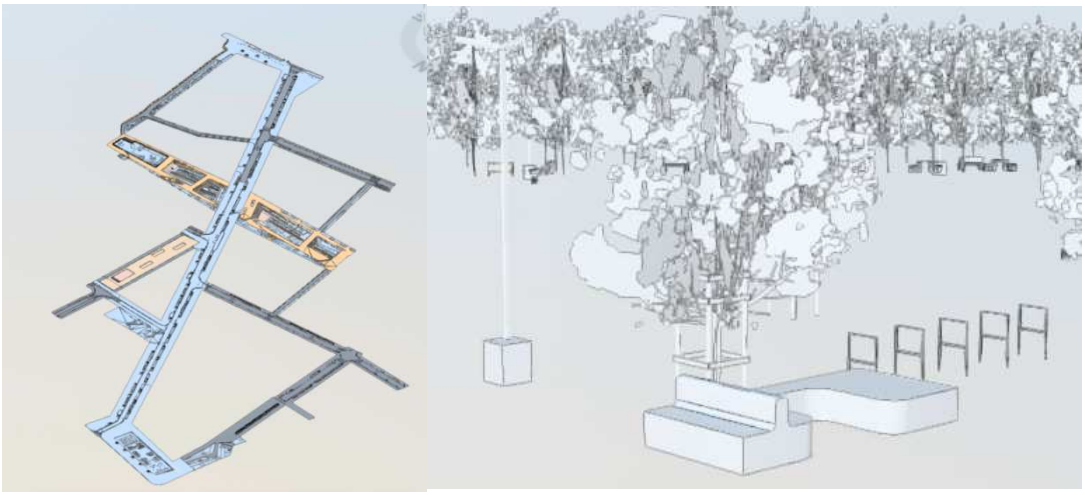
• **data stream mining**

• real-time traffic monitoring

• traffic simulation

• operations: signals, V2I transit priority and emergency pre-emption, traffic rerouting

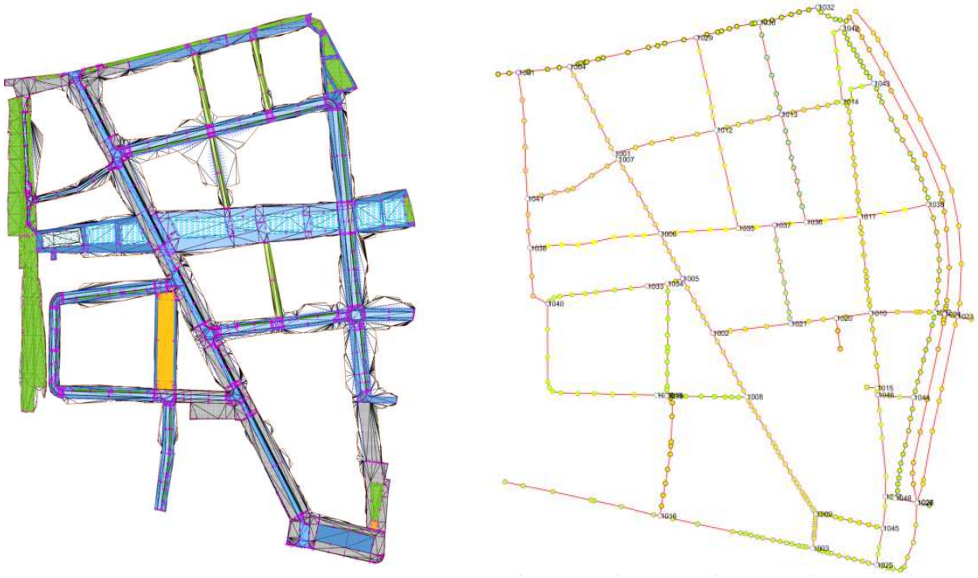
As part of the E3S project, we have access to the CIM of LaVallée (all the BIMs of the works to be carried out including road, gas, water networks, street furnitures, fontains and landscaping). It will give the intern all the necessary information on the infrastructure for all transportation modes (car/walk/bike) including bicycle parking spots or pedestrian ways.



Road network (phase 1) and landscape : urban furnitures et vegetations. Technical caracteristics of the road and pedestrian/bike/e-scooters infrastructure are key inputs in traffic modelling. Credits: *OTCI, Base, Arcadis, SEMOP*

A secondary objective of this internship is to build tools to automatically extract some primitive information from the CIM. The Level Of Detail in LaVallée BIMs objects is LOD=5 (or LOD500 in US) which is a very high accuracy. In our work a LOD=1 or LOD=2 is required, which means a low resolution version of the BIMs : nodes, links for roads, and polygons for buildings. Surprisingly enough, there is no tool to do that without the intervention of a manual operator. For instance, below is a view of the road BIM : a very detailed 3D model made of a mesh of triangles whereas what transportation model require is a wire model (nodes+links). A similar problem occurs with buildings : a lot of applications only requires rough 2.5 models (ie 2D footprint+height), such as CFD for wind flow simulation or thermic analysis, sky vew factor SVF calculation etc. We believe that operation could be done by parsing the IFC files to extract some features such as slabs, floors, roofs and postprocessing them: the intern will use Python or Matlab for this task, with an application to SVF calculation.

It will also be the opportunity to participate in the building of a CIM which is not just a collection of BIMs from various partners and architecture firms, but also the integration of process and data important to decision makers, at the scale of a real district, due 2024. In particular, the BIM of the road (its 3D numerical model, or maquette) is a high level of detail version of the road infrastructure, in which traffic light signals has not yet been included (ie the way to code and decode a traffic light signal diagram into a BIM is not investigated at the industrial level).



Road BIM versus road wire network (nodes, links and intersection) : requires to automatically build the road network

Building KML polygons drawn as 2.5models from footprint plan, displayed with Google Earth Pro

Acquired Skills and tools

Theory: data stream mining, artificial intelligence

Programmation: Python to parse IFC files and for AI tools

Traffic simulation: Java (MATSim platform)

Visualisation 2D: Leaflet (JavaScript) to provide real-time capability to the GIS at
http://137.121.121.18/leaflet_reseau/BuildingsReseauRoutes-v1aFermeUrbainReservee.html

References

Work at University Las Palmas de Gran Canaria:

Lana et al. From Data to Actions in Intelligent Transportation Systems: A Prescription of Functional Requirements for Model Actionability. *Sensors 2021*

Guerra-Montenegro et Sanchez-Medina. Traffic Predictive Analysis Through Data Stream Mining. *Eurocast 2019.*

Sanchez-Medina et al. Data Stream Mining Applied to Maximum Wind Forecasting in the Canary Islands. *Sensors 2019.*

Work at COSYS-GRETTIA:

Delhoum et al. Modeling Activity-Time to Build Realistic Plannings in Population Synthesis in a Suburban Area. *Applied Sciences 2021*

Delhoum et al. Activity-Based Demand Modeling for a Future Urban District. *Sustainability 2020*

https://www.youtube.com/watch?v=UQB0S16a4m4