PRACTICAL APPLICATION:

Using Hubsim to analyse route choices sensitivity in the context of connected vehicles

Introduction

Context

The objectives of the current practical exercise are to draw some analysis on the impact of the connectivity degree and accuracy of the broadcasted information on the route choices made by drivers. The main assumption lies in the fact that equipped and well-informed drivers have better chances to pick up the optimal route than usual ones. In this practical exercise, we offer to consider the impact of connectivity on traffic with respect to the demand management and the flow distribution over the road network.

Modelling assumptions

We offer to model the challenge to assign the traffic over the network by considering a macroscopic model enabling us to take into consideration the impact of the congestion propagation over the road network.

Modelling connectivity with two extrem cases

The introduction of the connectivity aspects is simplified in the model. For sake of simplicity, we will consider two cases under study:

- **MPR=0%**: the drivers are not connected and do not dispose of information about the current traffic conditions, except the information resulting from their expert knowledge (*i.e.* they know about usual conditions): this is equivalent to a Market Penetration Rate (MPR) set to 0%.
- **MPR=100%**: the drivers dispose of updated traffic information broadcasted online (in real-time or almost) by a Human-Machine-Interface (HMI). It enables the driver to pick up the best option in terms of travel time when he is starting to move. We will assume that all the drivers dispose of information in the same way when information is available. It matches with a Market Penetration Rate of 100% of Connected Vehicles.

Modelling the information degree of the driver

To perform the analysis, we suggest focusing on **two parameters**:

- the **level of travel time sensitivity**: it is assumed that drivers with information and/or expert knowledge of the network will be more sensitive to the broadcasted information and will trend to follow the best option.
- the **level of temporal accuracy/aggregation**: we assume the following assertion: the finest is the time discretization of the information provided to the driver, the smarter and more accurate will be his decision when selecting his itinerary.

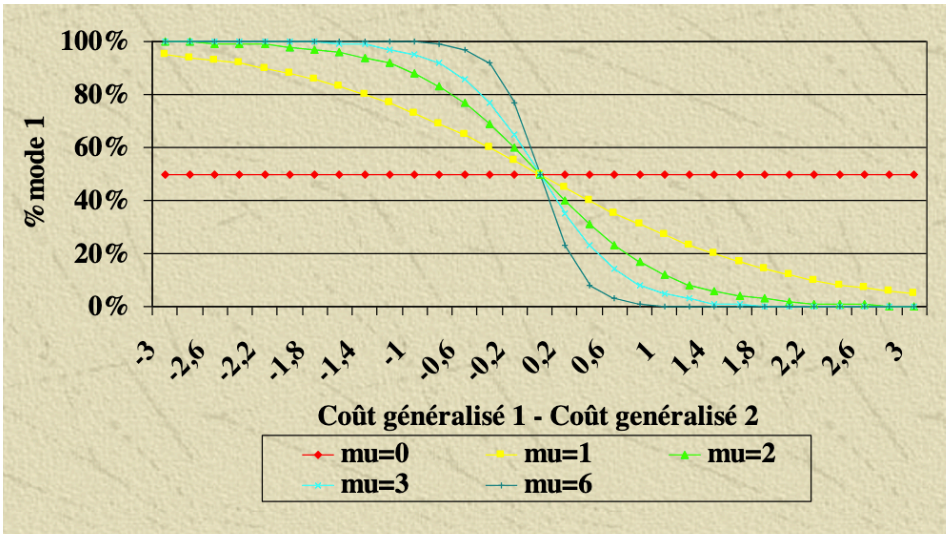
These two parameters makes possible to reproduce the sensitivity of the driver (or a set of drivers) to make an appropriate route choice. The route choice will be accurater if the driver dispose of information about the traffic states and if this information is regularly updated with time. It means that the route choice depends on

- the ability of the driver to follow instructions or to get informed: lets call $\mu (\in [0,1])$ this indicator;
- the ability of the road manager to provide updated information to the drivers: lets call τ this indicator, where τ matches with the elapsed time between two updated information.

Thereafter, the generic formula to model the route choice is assumed to result from a **logit model** with the following features:

$\forall i \in [1;\, K], \quad \forall t \in [0;\, n] \times \tau, \quad p_{route_i}(t) = \frac{e^{-\mu \times TT_i(t)}}{\sum_{k=1}^{K} e^{-\mu \times TT_k(t)}}$, where $p_{route_i}(t)$ is the probability to use the route i among K possible. This probability will change with the value of indicator μ and the refreshment period τ of the Travel Times (TT).

As illustrated by the figure below, the μ parameter of the logit model features the sensitivity of the driver to small differences in Generalised Cost (here: the Travel Time TT).



The main purpose of the subsequent exercise is to play with both indicators in various scenarios, then to assess the impact in terms of traffic efficiency.

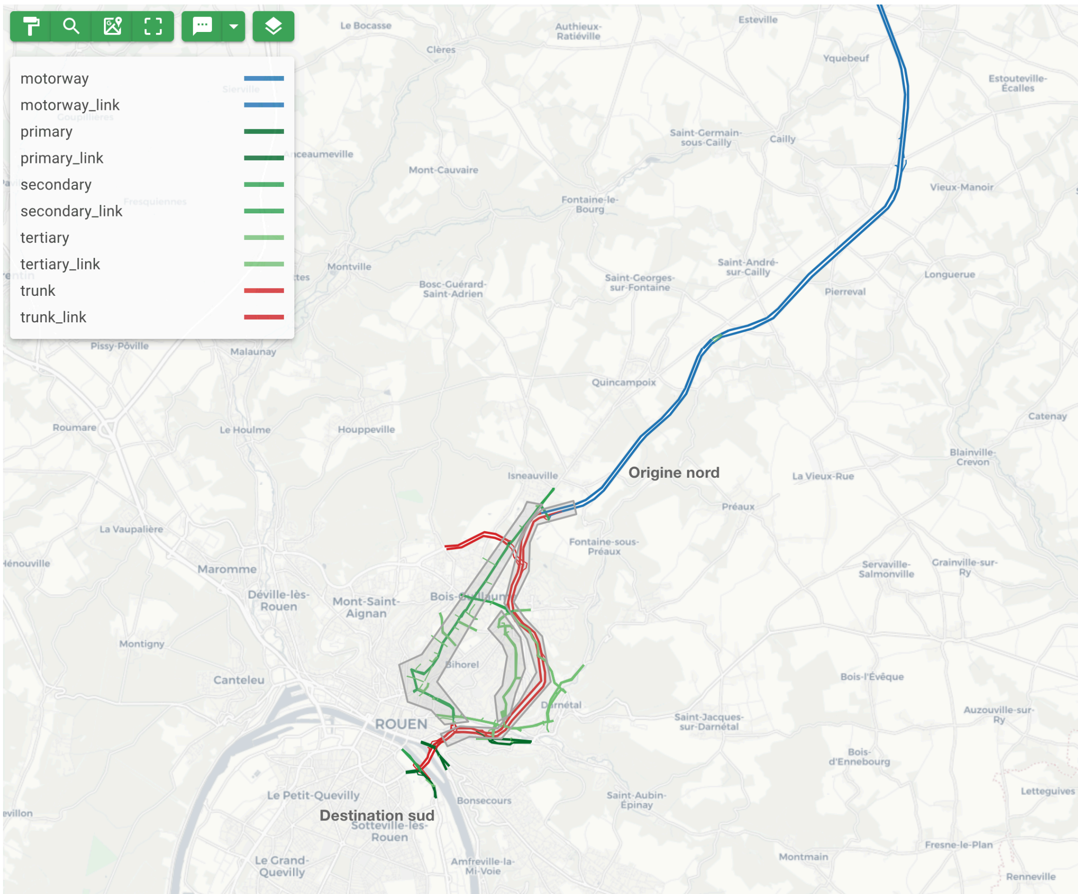
Scenarios under consideration

The various scenarios under consideration are the following:

- **nominal case:** the traffic conditions are the same as usually observed on the network;
- **incident case:** the traffic conditions are affected by an incident located at a specific point and time-period on the network;
- **incident + dynamic speed limit case:** the traffic conditions are affected by an incident located at a specific point and time-period on the network, but some Variable Speed Limit strategies are available thanks to Variable Message Signs (VMS) along the road.

Use case description

We offer to draw the analysis in the vicinity of the Motorway A28 connecting the City of Rouen to the North. The connection to the city of Rouen is made possible by mainly four alternative itineraries or paths. We will focus on the study of such alternative ways.



Getting Acquainted with the simulation tool HUBSIM

HUBSIM is a platform developed by NeoVya corporation. HUBSIM is the host for various traffic simulators from macroscopic to microscopic ones. It includes, among others:

- **MacroVia** for a fast macroscopic simulation of large networks: it is based on LWR model applied to every road link;
- **Stream** for mesoscopic simulation with First In First Out assumption between nodes of the road network (no overtaking maneuvers);
- **SymuVia** for microscopic simulation with a car-following model based on Newell and opportunistic lane-changing models.

HUBSIM comes with full documentation available here or directly from the platform (right-hand panel)

For the current purpose, you will mainly need to interact with three panels of the HUBSIM platform:

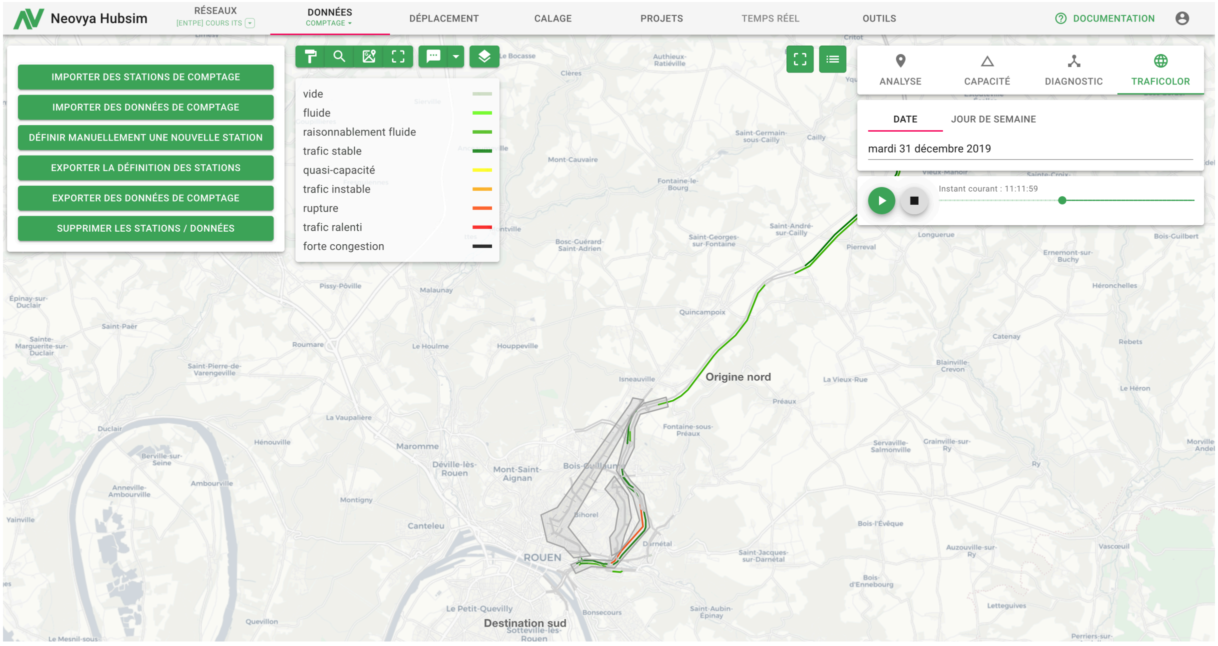
- the panel `données`,
- the panel `calage`,
- the panel `projets`.

Panel données

The purpose of this panel is two-fold:

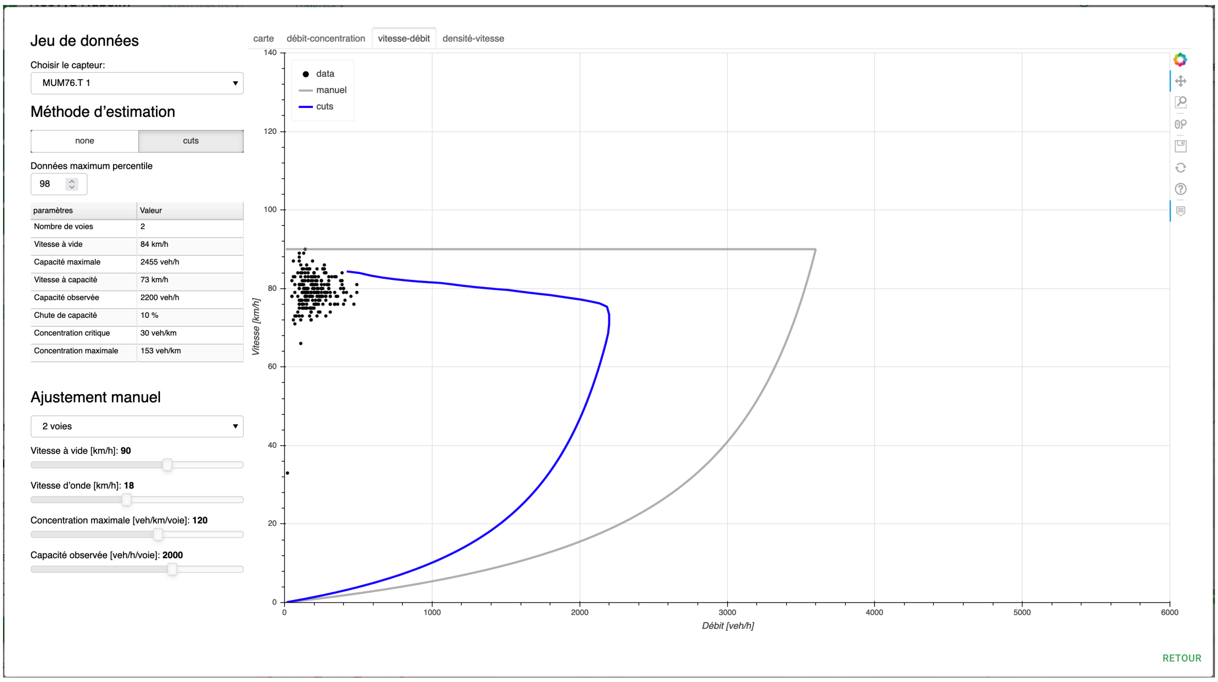
- downloading the data collections required to calibrate the traffic models under consideration;
- drawing some analysis on the downloaded data in order to adjust and set up the macroscopic components of the traffic.

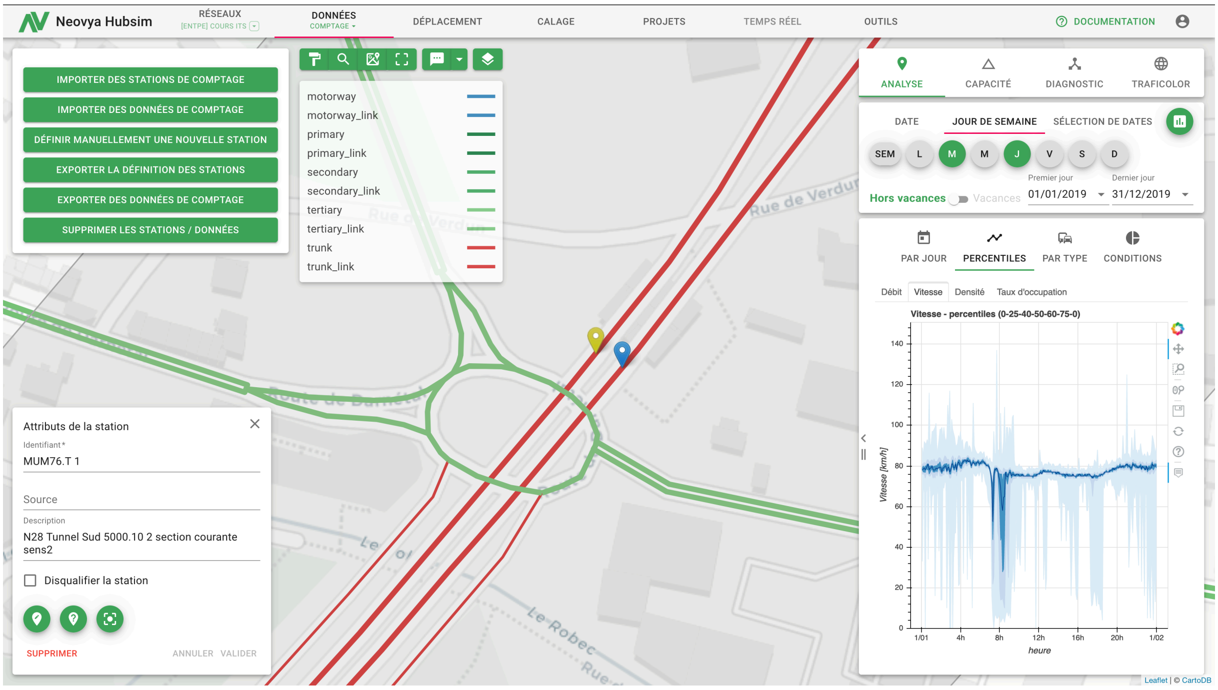
Especially, this panel enables to visualise traficolors with evolution along the time for a specific subset of days or type of days. When multiple days are selected, it proceeds to data agregation in order to display the average trend of traffic states.



Some further punctual analysis might be drawn on real (or virtual) loop sensors using:

- the tab "Capacité", to better feature the local capacity and the capacity drop effects;
- the tab "Analyse", especially the sub-tab "percentile" is useful to highlight the trends in terms of throughput and speed for a typical 24h-period.





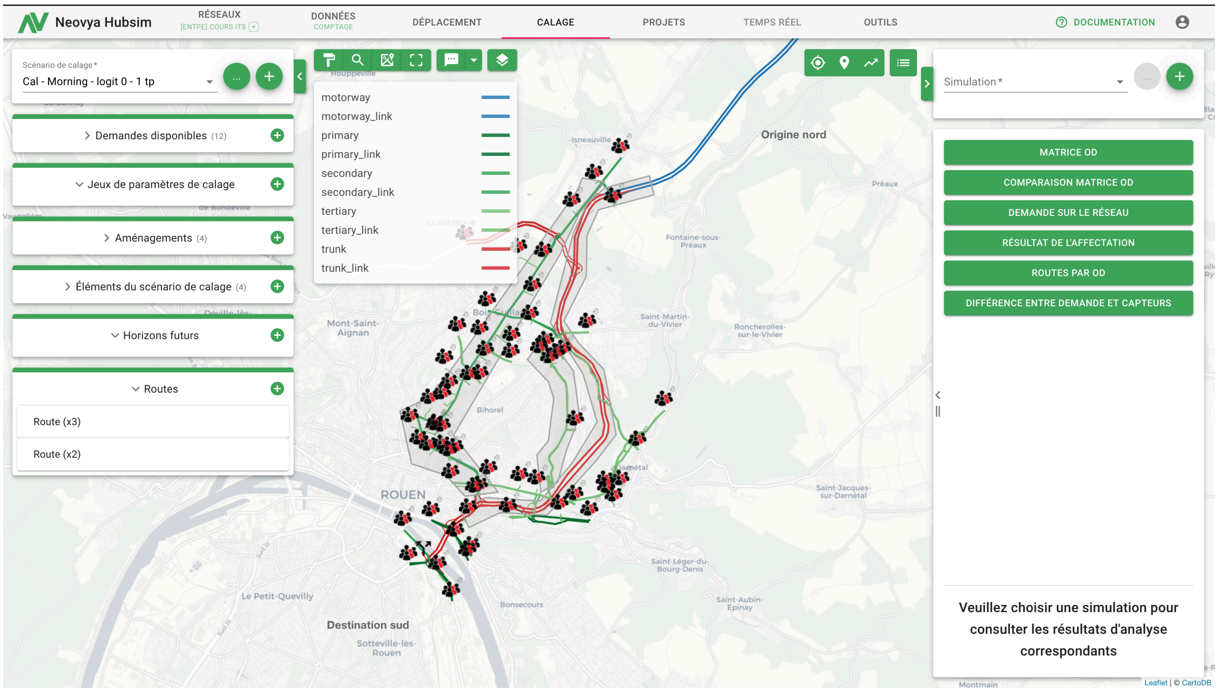
Panel calage

The `calage` panel enables to set up any calibration scenario in the simulation framework. It is used to design the `calage` scenarios, which are used as references. It is to notice that when a `calage` scenario is validated, it automatically launches (or ask for launching) the computations of the results. Then, the results might be compared to real observations (see tab "Difference entre demande et observation") or just assumed as a new reference.

Usually, the objective of a `calage` scenario is:

- to adjust the model parameters in order to finely reproduce field observations;
- to adjust the demand assignment to match with a new specific configuration (new constraint on demand / new supply / etc) and make sure the demand is properly distributed.

The building process for `calage` scenarios mainly requires some manipulations on the left-window of the panel.

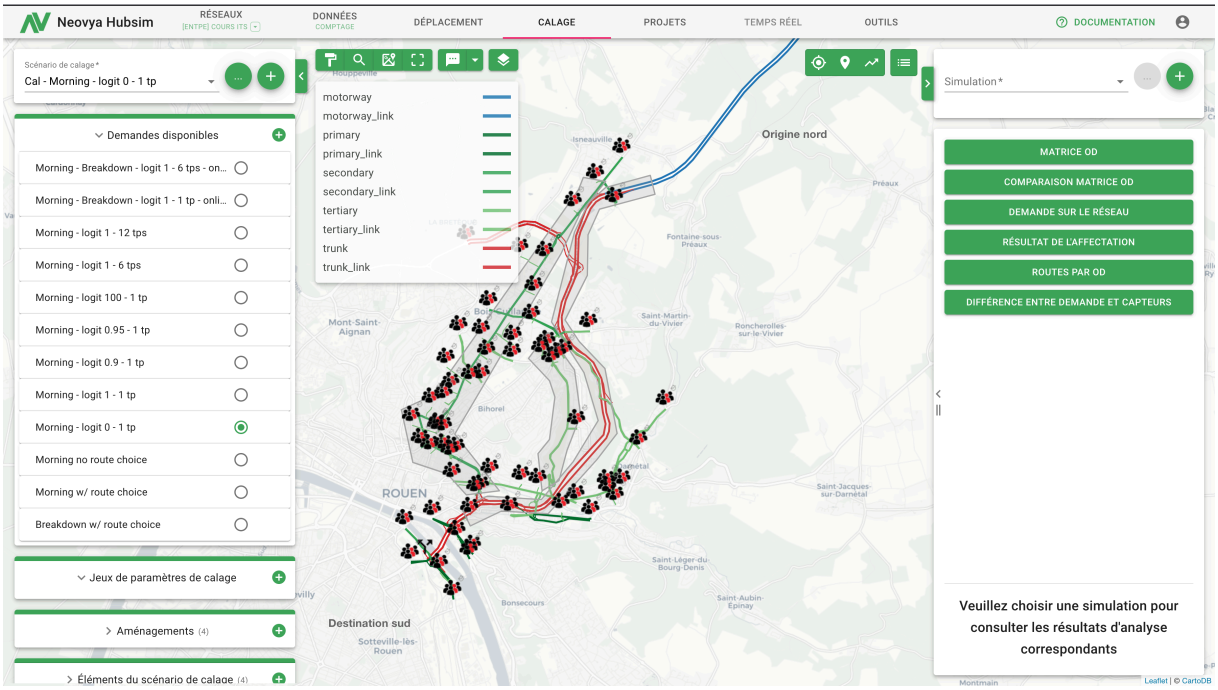


A new `calage` scenario is composed of a new folder called scenario, supporting: a demand profile dispatching the demand per OD over the routes, some supply or demand restrictions and few supplementary parameters.

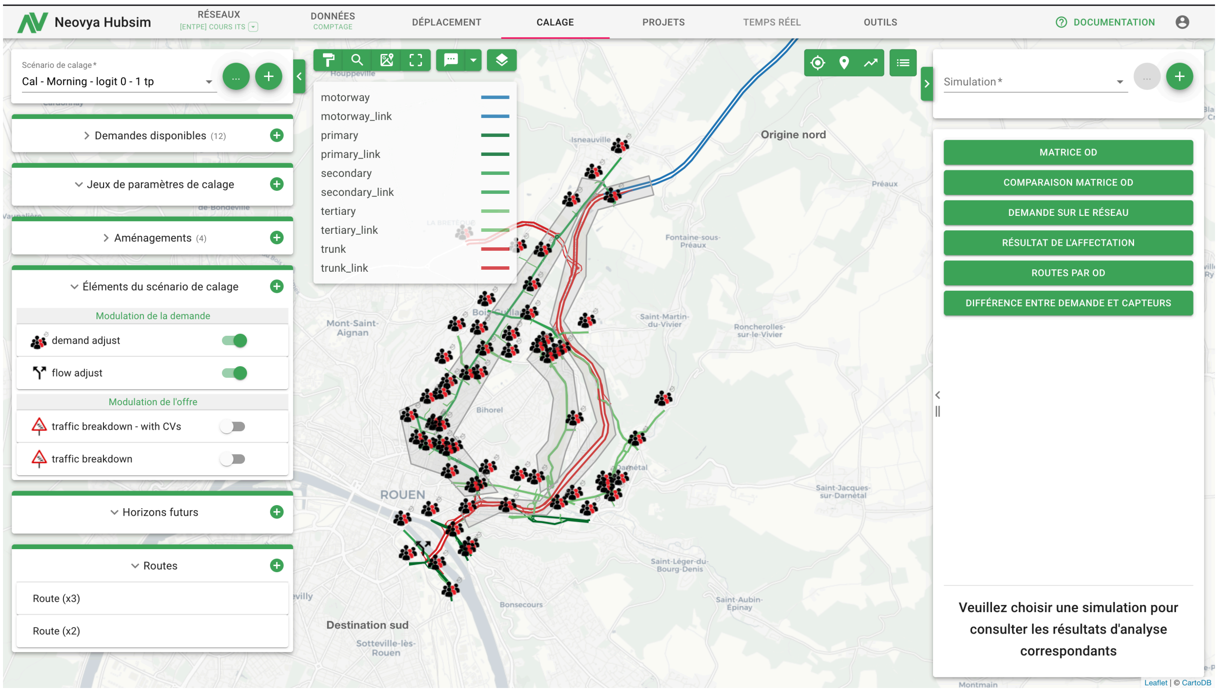
The main process to build a new `calage` scenario is the following one:

- check the "Routes" tab, to select the maximum number of possible routes for a dedicated Origin-Destination: it will be used to dispatch the traffic demand on the O-D over the K possible routes. In teh study, we will consider K=3.
- create a new "Demandes Disponibles". It is recommanded to duplicate one existing demand. The demand is composed of 5 stages depicted with different colours:
    - the days to take into consideration to generate the demand (yellow),
    - the resources at stake to build the demand (blue),
    - the way used to assimilate the field data (purple),
    - the assignment process and its settings (among others the settings of the logit model)
    - the `calage` scenario under consideration to loop over the assignment process while computing the demand distribution per OD over route choice.

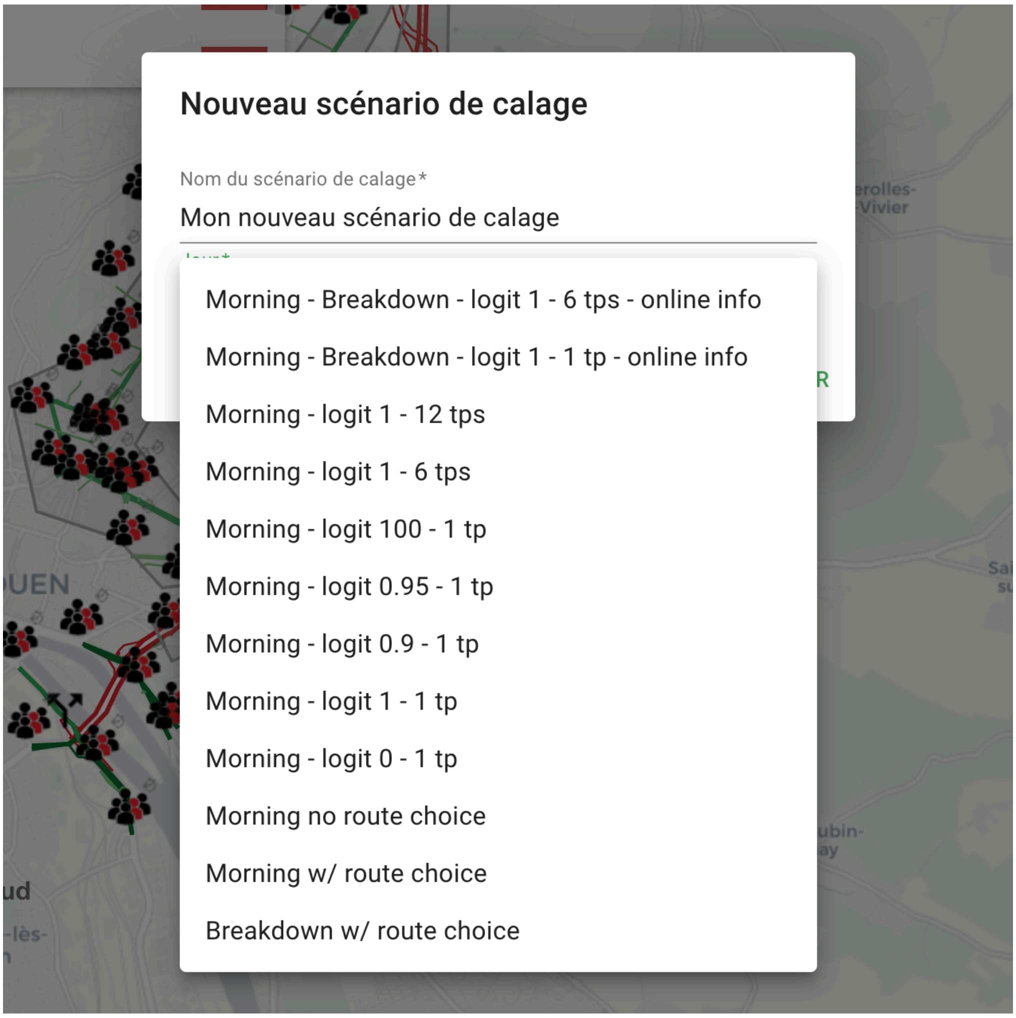
  The validation (saving) of a new demand will automatically trigger the computation of the `calage` scenario (generation of O-D matrices per period, etc).



- before validation of a new demand profile, check for the "Elements du scenario de calage" tab: pay attention to the activated modules and activate the ones required in the current `calage` scenario.



- before validation of a new demand profile, it is usually necessary to build a new `calage` scenario in the upper cell of the left panel. To proceed, the preferred option is to duplicate an existing scenario, but it is possible to create a brand new one directly by clicking on + button. The new `calage` scenario has to point on a specific demand profile: make sure to select the one, you have created.



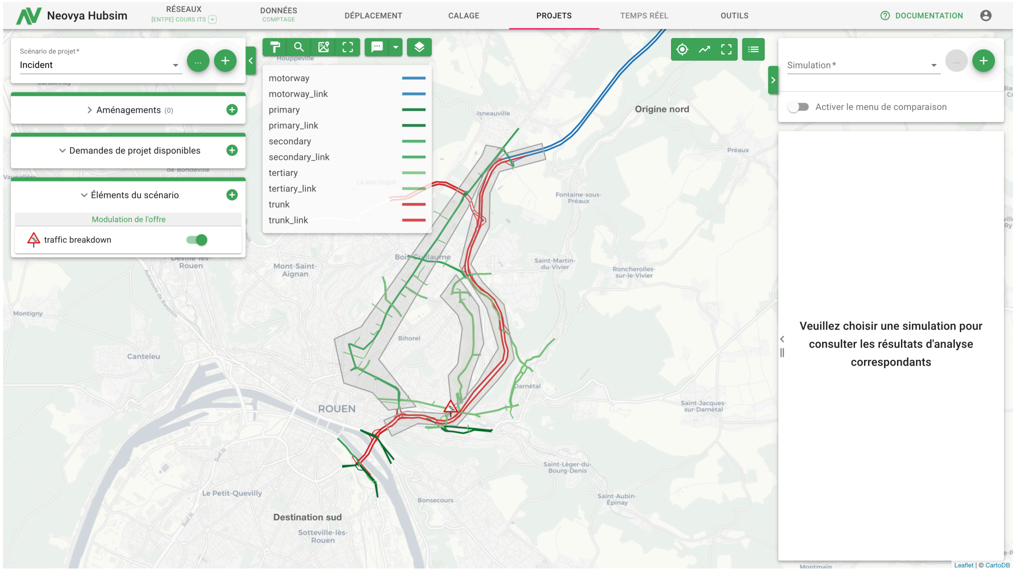
Panel `projets`

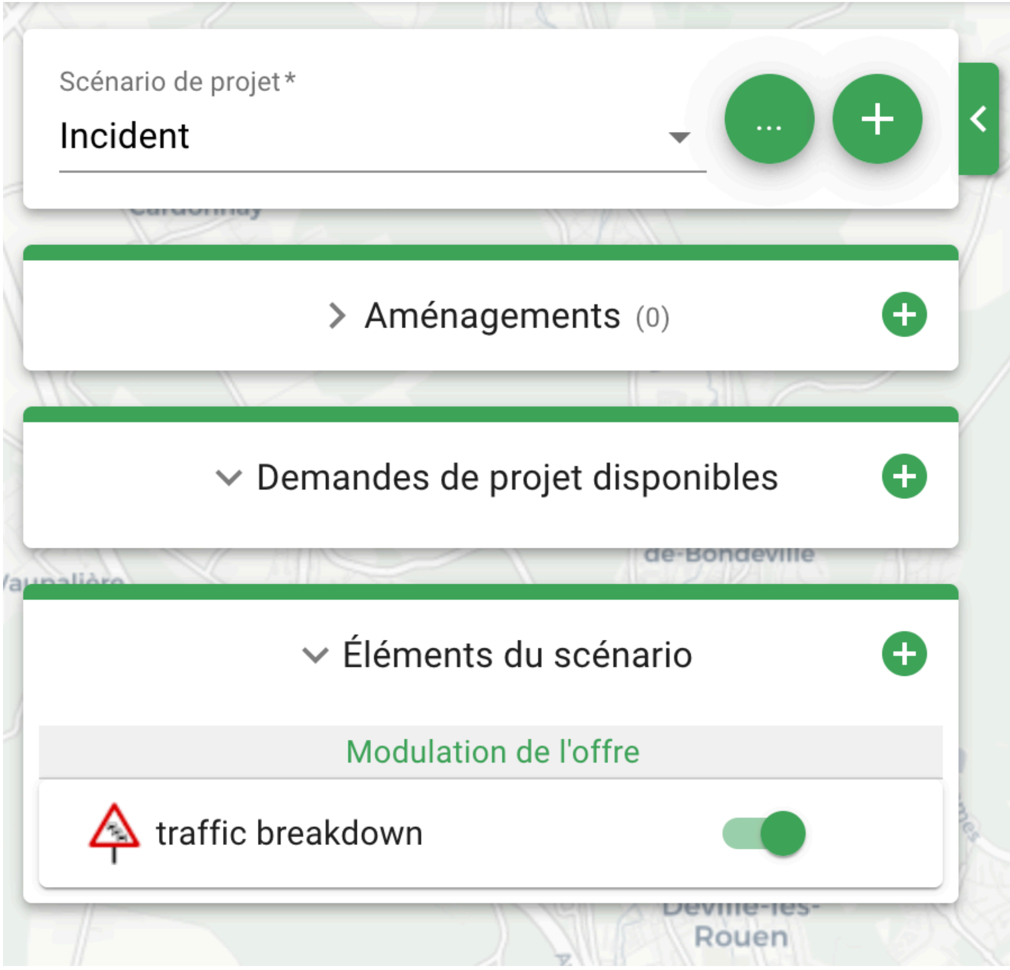
The `projets` panel enables to build some new scenarios including new features or contraints that are not used to calibrated the traffic model. It is useful to test and evaluate some alternatives to a reference assuming similar conditions as the ones of the reference.

Building a `projets` scenario is quite similar to the process used to build `calage` scenarios. only the left side of the screen is used.

A `projets` scenario requires to:

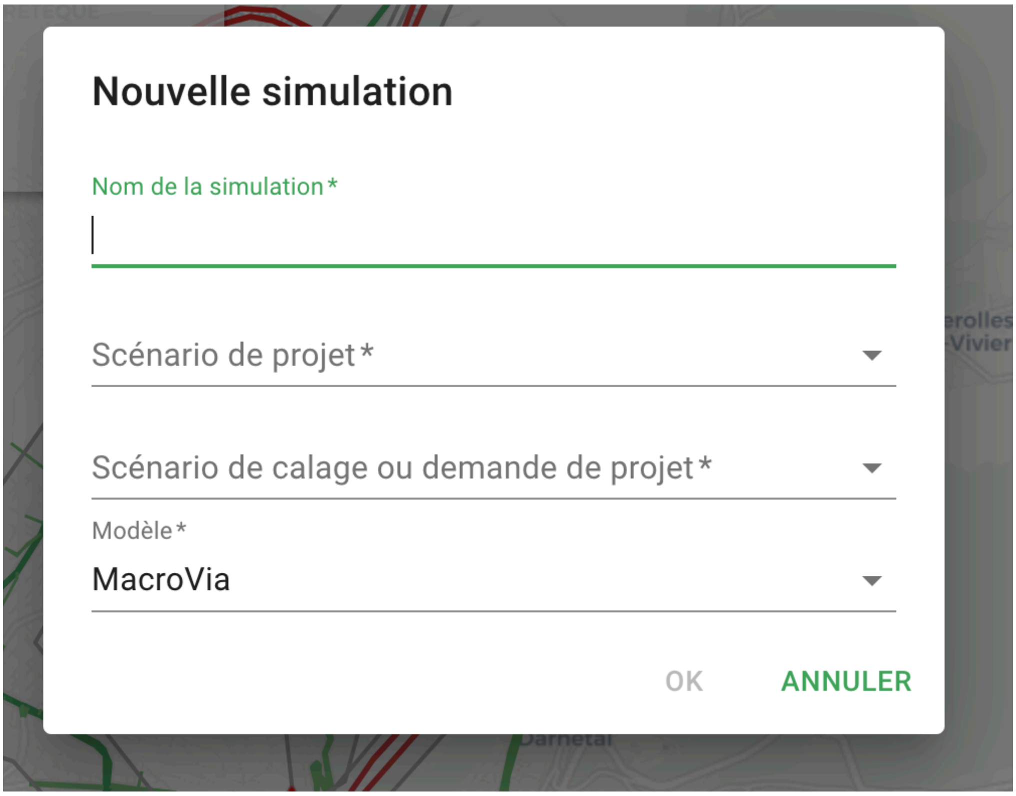
- define a folder, called "scenario de projet", by clicking on + button;
- define the new components to add or remove in terms of demand or supply ("Elements du scénario"), by clicking on the sliding button to activate it or not;
- if required, define some new demand profiles.





Launching a simulation

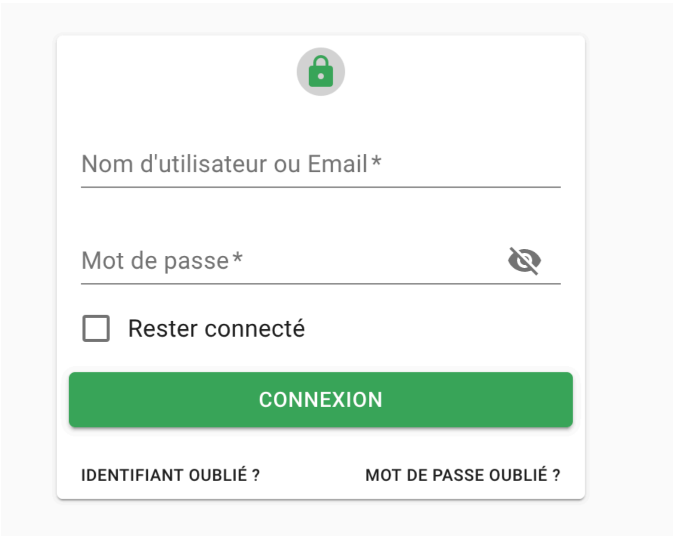
Once a `calage` scenario and a `projets` scenario are defined, it is possible to define a `simulation` (on the right side of the `calage` or `projets` panel). It requires to select the appropriate `calage` and `projets` scenario to be properly defined, then clicking on the computation button will launch the simulation.



Getting started with the use case

Preliminary analysis of the network dynamic

Get connected to the HUBSIM platform with your login and password.



Question 1: Getting acquainted with "données" panel

Draw some analysis on the network under study, in order to highlight the main features of this network

[panel "réseaux"] According to you, what are the main hot point for this network?

Justify it with the design of the road network

[panel "données"] Verify your assumptions about hot points with traffic considerations and graphical analysis.

For instance, you can make use of:

- traficolors, to identify congestion location and time-period;
- capacity analysis, to refine the location of critical point;
- punctual analysis (use the loop sensors already in and/or create new sensors points to draw comparisons at various locations), to draw analysis on the usual profile (use percentiles);
- sectors analysis.

Be careful to pay attention to:

- the selected days, on which you draw the analysis (Should you consider every days? Only Mondays? Only Fridays? Only Tuesdays and Thurdays?)
- the time-period under consideration (All day long? only Morning Peak Period? Only Evening Peak Period?)

Analysis of the nominal use case: Getting acquainted with calibration and route choice models

In this section, we will work on the nominal case without breakdown nor Variable Speed Limit Strategies. The objective is to better understand the impact of the logit model parameters (μ, τ). In the subsequent configuration, these paremeters are assumed as representative of the Market Penetration Rate of Connected Vehicles. It is assumed that Connected Vehicles will dispose of accurater information to make their route choice.

Notice: In the following steps, it is not required to build new scenarios, but we ask you to get started with some available and pre-established `calage` scenarios. Then, simulations scenarios are based on `projet` scenario called 'Base' (nominal case) and the appropriate `calage` scenario.

Question 2: Calibration of the logit model

According to the set of available `calage` scenarios with only 1 time-period (1tp):

- which one is the most suitable to reproduce the current traffic conditions on the area? Therefafter, we will consider this setting of the logit (`logit` parameter) as the one matching with a MPR = 0%.
- Which one is the most suitable to reproduce the choices made by a flow composed of 100% of Connected Vehicles. Thereafter, we will consider this setting of the logit (`logit` parameter) as the one matching with a MPR = 100%.
- What kind of route choice is operated by road users with a logit parameter set to 0?

Justify your analysis with consistent graphical results.

Help:

- **What is the parameter under study (the one that should vary in the analysis)?**
- **Which days are you taking under consideration to draw the analysis?**
- **What is the appropriate tool to check the calibration quality?**

Question 3:

How can you explain the observed differences between the scenarios that you associated to **MPR=0%** vs **MPR=100%**? Which scenario is the best option? Does it make sense? What criterion did you consider (user-based / system-based / both)?

Global Analysis:

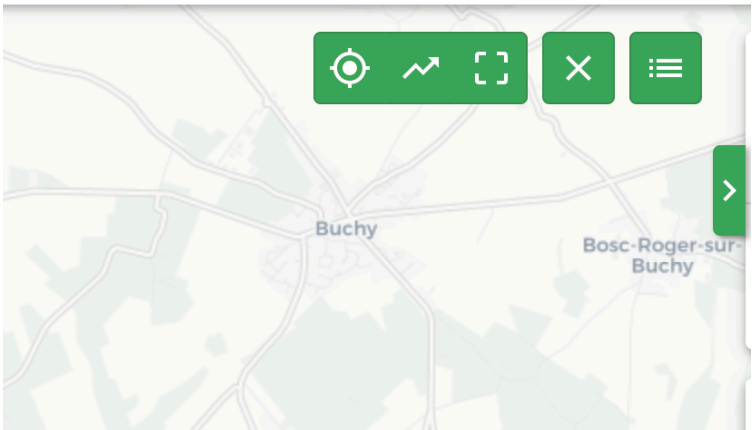
- What is the difference:
  - in terms of Cumulated Queue-Length?
  - in terms of Cumulated Travel Time ?

Refined Analysis:

- by Virtual Sensors:
  - How do the speed and flow demand evolve from one scenario to another?
- by Specific Itineraries:
  - How do the congestion evolve according to one of the four itineraries under consideration?
  - How do evolve the cumulated travel time on the four alternative itineraries?

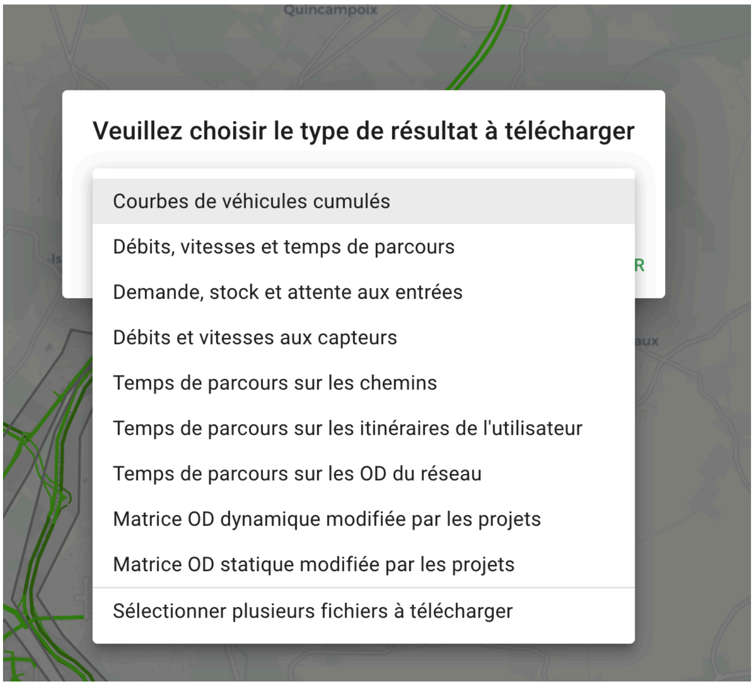
Help:

- **To proceed to refined analysis, you can make use of the pre-selected virtual sensors and itineraries (click on the icon on the right side).**



- **To perform analysis on Cumulated Travel Time, you can export the data related to the simulation scenario under consideration by clicking on the cloud button, then select the data to export.**
  Example: `Temps de parcours sur les itinéraires de l'utilisateur` to get TT on specific itineraries or `Debits, vitesses et temps de parcours` to get global indicators).
  It exports data into csv files, that you can open with excel and save as XLSX. A short

analysis with a `somme()` function enables to get Cumulative indicators according to time-period.



Question 4:

Explore the impact of the refreshment period τ parameter on the global performance of the network. What did you observe? Does it make sense? How can you explain these findings?

To proceed, you can study the scenarios considering a larger number of Time-Periods during the assignment process. Such scenarios are performed with a refined τ value.

- Can you identify the relationship between the number of time-periods (tp=1 / 3 /6 / 12) and the τ value?
- How can you interprete a larger number of Time-Periods with the perspective of Connected Vehicles? What kind of information the driver dispose of? Why?

Analysis of the Breakdown use case

According to the previous findings and to further explore the impact of the τ value on the flow distribution over the network, we will consider in this section a use case involving a breakdown. The breakdown is affecting the main itinerary and generates supplementary congestion propragating along the highway.

Question 5: studying the impact of information reflecting breakdown conditions versus usual conditions

Draw a comparison between 2 appropriate scenarios (with only 1 time-period (tp) for assignment) in order to highlight the effect of aggregated information broadcasted to connected vehicles:

- one scenario should consider the occurence of the breakdown, while the driver make their route choice based on aggregated usual traffic conditions (*i.e.* the driver is not aware of the occurence of a breakdown when he takes his car);
- one scenario should consider the occurence of the breakdown, while the driver make their route choice based on aggregated traffic conditions reflecting the occurence of a breakdown (*i.e.* the driver is aware of the occurence of a breakdown when he takes his car).

Are the results completely intuitive? Why? What could explain such results? Is the main road still congested in the 2nd scenario? Draw a comparative analysis on the 4 alternative itineraries to join the North to the South. How does evolve the Cumulative Travel Time (Cumulative Delay)? How does evolve the Average Delay?

Question 6: studying the impact of the size of time-window during assignment

To further explore, draw the same kind of comparisons with 2 supplementary scenarios:

- one scenario that considers the occurence of the breakdown, while the driver make their route choice based on traffic conditions reflecting the occurence of a breakdown with a refreshment period of 1h (*i.e.* the driver is aware of the occurence of a breakdown when he takes his car and he gets refreshed information every hours).
- one scenario that considers the occurence of the breakdown, while the driver make their route choice based on traffic conditions reflecting the occurence of a breakdown with a refreshment period of 30min (*i.e.* the driver is aware of the occurence of a breakdown when he takes his car and he gets refreshed information every 30 minutes).

What happend? Why? Highlight your findings with visual illustrations and draw some refined analysis.

To proceed, you need to build by yourself these 2 new scenarios, take care about the way you implement the demand. Two steps are really sensitive and/or tricky:

- `Parametres d'affectation`: this panel enables to set up all the parameters related to the logit model (μ, τ) for one iteration of TT estimation;
- `Fonction de coût d'affection`: this panel is dedicated to the definition of the way to re-estimate TT after each iteration of the assignment process (*i.e.* application of logit + flow distribution over the road network per O-D).

Further analysis and discussion:

Analysis of the VSL use case

Complete the previous analysis by considering scenarios with Variable Speed Limit:

- build a (or multiple?) new reference (`calage` scenario) including an incident and a Variable Speed Limit implemented during the Morning Peak Period (7:00am-8:30am) with a speed restricted to 70 km/h.

- build a new `projet` scenario to add a Variable Speed Limit strategy to reference scenarios

Draw some analysis by comparing scenarios involving (or not) Variable Speed Limits:

- What happend when you apply VSL strategies to previous scenarios?
- Does the knowledge of VSL applied at some time-periods affect the route choice? Does it help to improve the traffic conditions ?
- Is the default settings of the Variable Speed Limit (as provided) the best option? What happend when you consider lower speed restrictions? What happend when you consider different periods of application?

LICIT
Laboratoire Ingénierie Circulation Transports
UMR ENTPE – Université Gustave Eiffel
Cité des mobilités - 25, avenue François Mitterrand –
69500 BRON - FRANCE – tel : +33 (0)4 72 14 24 70